A PLANT ECOLOGICAL STUDY OF THE FARM "VAALPUTS", BUSHMANLAND, WITH SPECIAL REFERENCE TO EDAPHIC FACTORS

by

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ABSTRACT

The vegetation mosaic present in the False Succulent Karoo (Acocks 1975, Veld Type 29) on the farm "Vaalputs", Bushmanland, is classified using the Braun-Blanquet method, and is mapped on a scale of 1:10 000. The vegetation data are ordinated using detrended correspondence analysis (DCA), and related to various edaphic factors. Classification and ordination are used complementarily in interpreting the ecological relationships between the plant communities and their habitat.

Eleven plant communities are recognized, varying physiognomically from dwarf/low semi-open shrublands, with a high degree of succulence and spinescence on saline and calcareous soils, to low open grasslands on deeper, strongly acid aeolian sands. Three of the communities are associated with calcrete and calcareous soils; three communities with saline soils; two communities on shallow soils overlying basement or dorbank; two communities on soil mixed with aeolian sand; and one community is associated with deeper, strongly acid aeolian sand. The environmental gradients are complex, with more than one factor apparently influencing the vegetation trends.

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TABLE 7.1 loose in back pocket

CHAPTER 1 INTRODUCTION

In February 1983 Vaalputs was purchased as a site for the storage / disposal of low- and intermediate- level radioactive waste in South Africa, at which time this study was initiated. It forms part of a detailed site investigation programme involving many other disciplines such as geology, geophysics, geochemistry, chemistry and hydrology.

The primary motivation for the investigation was twofold :

a) to provide a base - line study for a long - term vegetation monitoring programme, as well as to provide a record of the vegetation present before trenching and associated operations began; and

b) to investigate the possible causes of the vegetation mosaic evident on the site.

Bushmanland, in general, is badly overgrazed and is not a well - studied area ecologically. Vaalputs is well situated in a transition zone (climatically, topographically and geologically) and the relatively diverse vegetation is representative of a fairly wide area. It also lies on the boundary between Namaqualand and Bushmanland (Fig. 1.1). This area is, therefore, of potential value in serving as a reference point for future studies in Bushmanland.

The major objectives of the study were :

a) to prepare a vegetation map of the study area;

b) to analyse the plant communities in terms of structure, composition and distribution;

c) to investigate the possible causes of the vegetation pattern present in the area by relating the plant communities to their habitats; and

d) to provide a basis for a long - term vegetation monitoring programme.

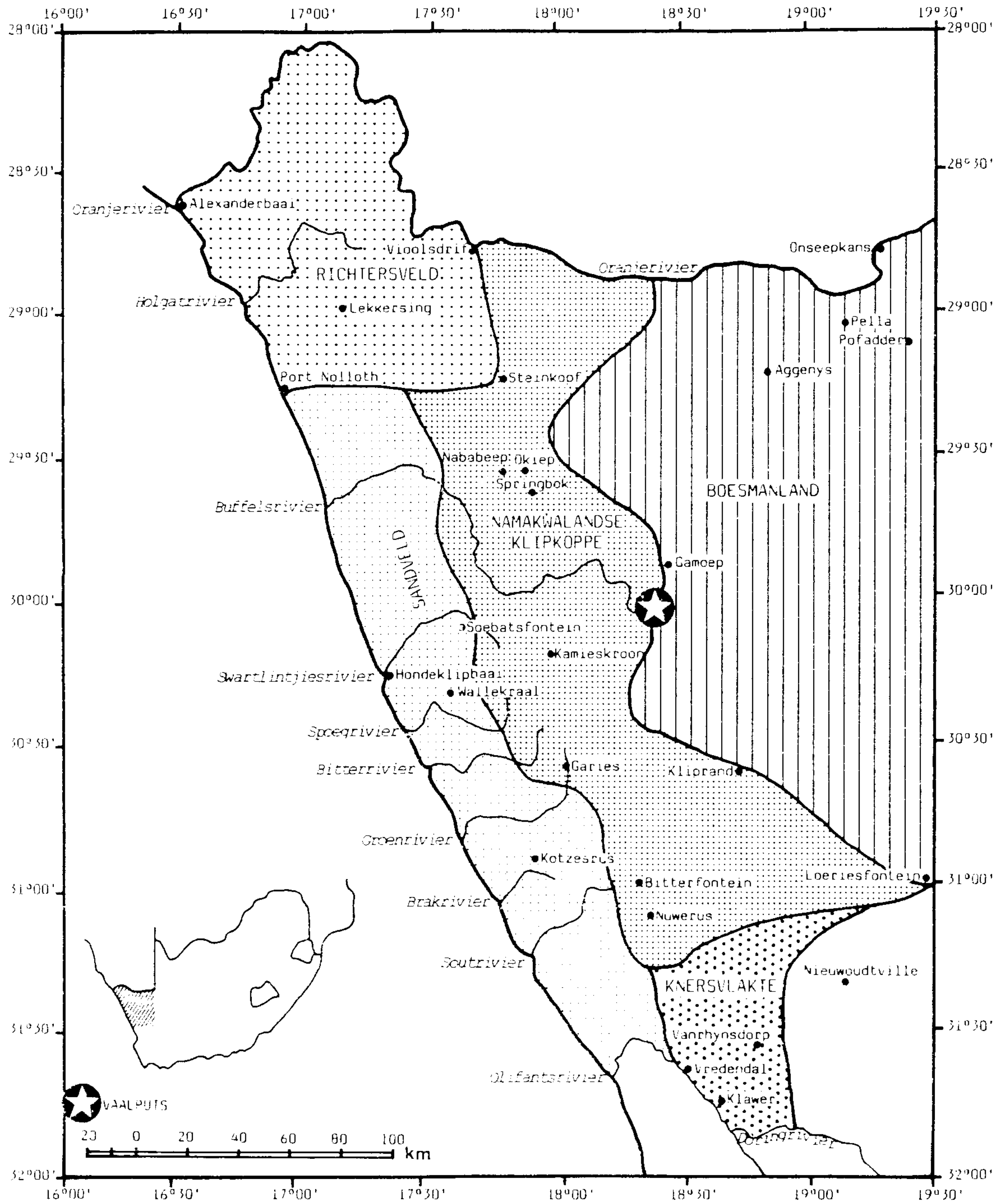


FIGURE 1.1 The location of Vaalputs and the geographical subdivisions of the Northwestern Cape Province (after Le Roux 1984).

CHAPTER 2 GEOGRAPHY AND GENERAL DESCRIPTION

2.1. LOCATION AND GEOGRAPHICAL SITUATION

Following the boundaries and the five broad geographical subdivisions of the Northwestern Cape Province as defined by Le Roux (1984) (Fig. 1.1), the Vaalputs radioactive waste disposal site lies on the border between Bushmanland and the Namaqualand rocky hills ("Namakwalandse klipkoppe" *sensu* Le Roux 1984).

Le Roux (1984) defines the northwestern Cape, consisting of Namaqualand and Bushmanland, as that area bounded by the Orange River in the north, the Olifants River in the south, the Atlantic Ocean in the west, and in the east by an imaginary line running slightly to the east of Onseepkans and Pofadder, southwards to Loeriesfontein and then west of the Bokkeveld Mountains to the Doring River. Bushmanland may, however, be extended further eastwards into the Central Cape Province possibly as far as Carnarvon and slightly west of Prieska.

The geographical subdivisions of the northwestern Cape described by Le Roux (1984) include the Richtersveld, the Sandveld, the Namaqualand rocky hills, the Knersvlakte, and Bushmanland (Fig. 1.1).

Vaalputs is situated between Gamoep and Platbakkies on the western edge of the Bushmanland Plateau, and extends some way into the Kamiesberg which form part of the Namaqualand rocky hills (Fig. 2.1). It is situated about 100 km SSE of Springbok and 60 km N of Kliprand. The study area lies between 30^{o} 04' 30" S and 30^{o} 10' 50" S latitude, and 18^{o} 29' 50" E and 18^{o} 36' 55" E longitude, falling within the grids 3018 BA 11; 12; 13; 16; and 17.

2.2. FARMS AND SIZE OF THE STUDY AREA

The farms purchased by the Nuclear Development Corporation (hereafter referred to as NUCOR), Vaalputs 369 (Garing and Geelpan subdivisions) and Bok - Puts 380 (Stofkloof subdivision) cover an area of 10 000 ha (100 km^{2}). The study area is, however, restricted to the sections of the farms on the Bushmanland Plateau (Fig. 2.2) and bounded on the west by the Springbok - Kliprand road, covering an area of 7 787.5 ha ($77.875\ km^2$).

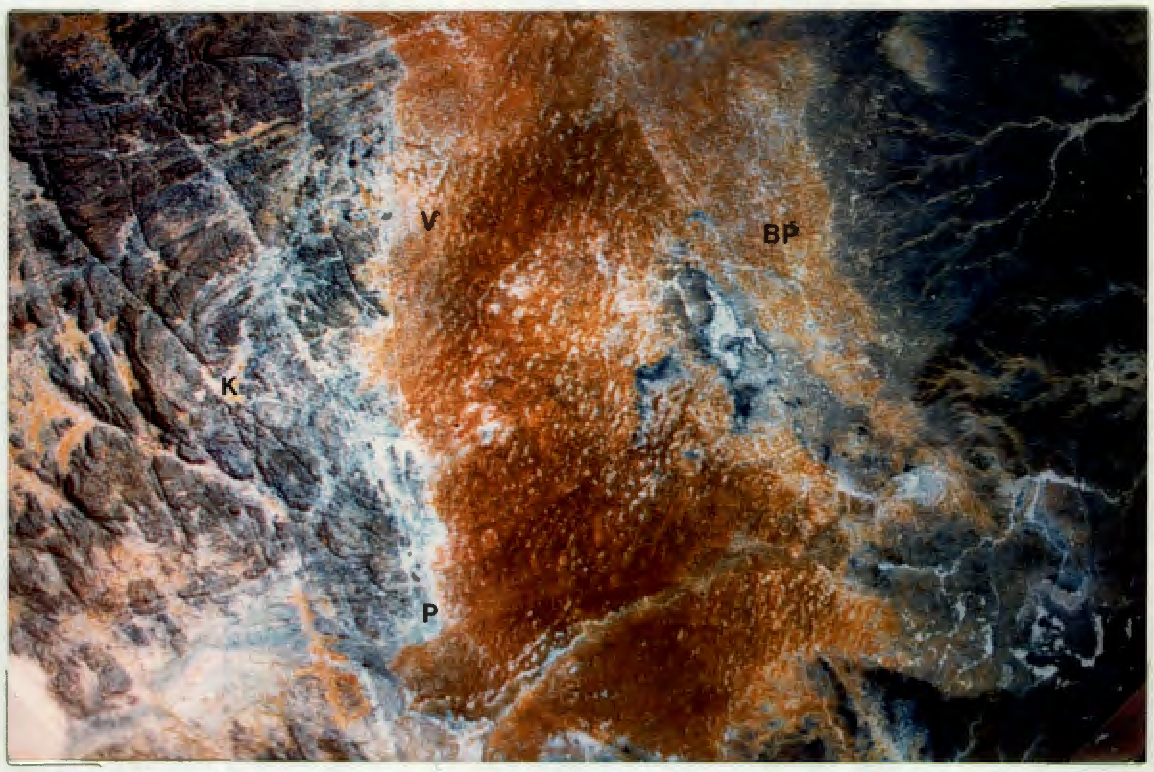


FIGURE 2.1 A LANDSAT image of the study area (V) in the sand-covered section on the Bushmanland Plateau (BP), to the east of the Kamiesberg (K) and north of Platbakkies (P).

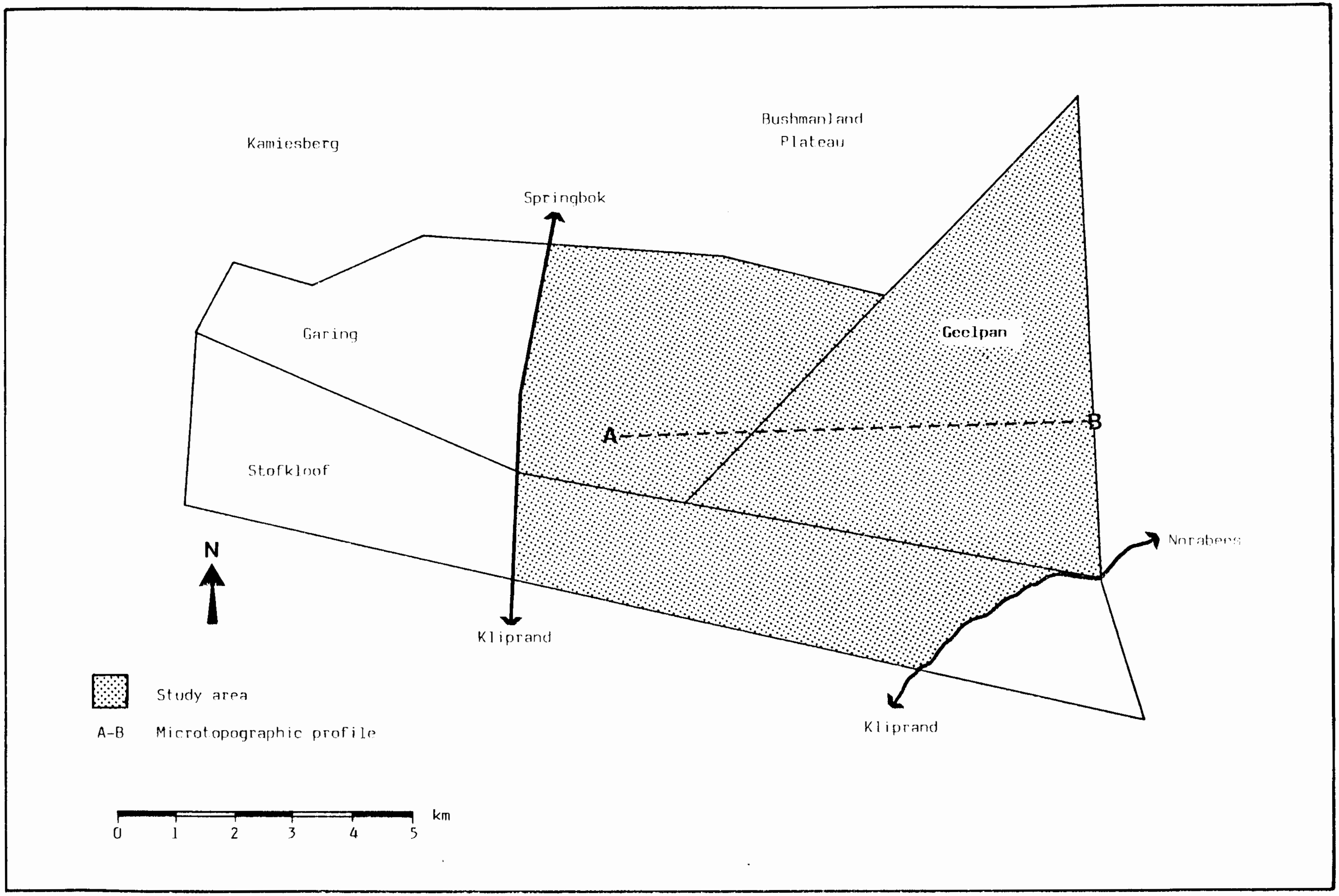


FIGURE 2.2 The boundaries of the study area including Geelpan and Garing sections of the farm Vaalputs 369 and Stofkloof portion of Bok-Puts 380, on the Bushmanland Plateau. The line A-B represents the baseline along which the microtopographic profile of Fig. 3.1 is drawn.

CHAPTER 3 ENVIRONMENTAL FACTORS

3.1. PHYSIOGRAPHY

3.1.a) TOPOGRAPHY AND GEOMORPHOLOGY

In considering the erosion surfaces and their ages, Mabbutt (1955) proposed the term "Namaqua Highland" for the surface at 1 200 m, and the "Bushmanland" surface at 1 000 m. These two erosion surfaces were formerly known as "Little Namaqualand", south of the Orange River. The Bushmanland surface is correlated with the Great Namaqualand surface to the north of the Orange River. This is indicated by their comparable altitudes and by their similar relationships to the major knickpoints of the Orange River system. Mabbutt (1955) hypothesised that the Great Namaqualand, Bushmanland and Kalahari limestone surfaces all relate to a common cycle of erosion.

Vaalputs is located on the western edge of the flat Bushmanland Plateau at the eastern edge of the escarpment. The study area consists of a gently undulating landscape which is fairly flat with an altitudinal variation of 33 m from the east to the west of the site. The vertically exaggerated microtopographic profile along the baseline illustrates the east-west altitudinal variation across the study area (Fig. 3.1). There is a greater topographic variation in the extreme eastern portion of the site.

Land facets which are present on Vaalputs are convex crests, rolling plains, drainage lines, swales, waxing slopes, flat summits and concavo-convex slopes (Fig. 6.1).

No active drainage occurs in the area, but ill-defined drainage lines follow the interdune valleys which are probably palaeodrainage distributary channels of an alluvial fan radiating eastwards from the Kamiesberg to the south of the area (Levin & Raubenheimer 1983). Vaalputs lies at the junction of a number of catchment basins including the Buffels, Groen, Olifants, and an area of internal (endoreic) drainage to the northeast (Heydorn & Tinley 1980).

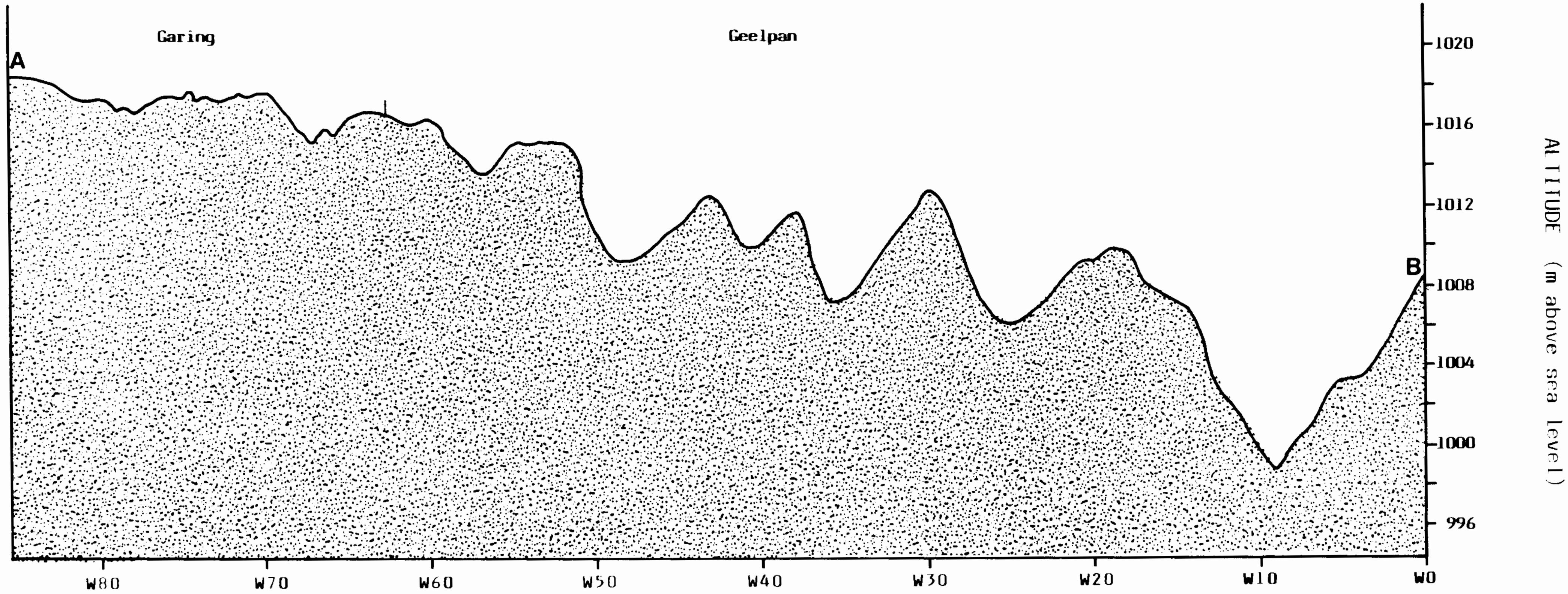


FIGURE 3.1 A microtopographic profile from A-B along the baseline.

3.1.b) GEOLOGY

(i) Introduction

The geology-soil-vegetation relationships are very important in arid and semi-arid areas. The soils develop in response to various factors, and their characteristics aid the interpretation of relationships which exist between the various plant communities and their habitat.

Geology, topography, climate, biological activity and time are possibly the most important factors determining the development of the soil profile and soil catena on Vaalputs.

The mineral composition, structure and weathering susceptibility of the geological parent material influences the type of soil to develop from a particular rock type as well as its nutrient value. This is possibly the most important factor, together with climate, affecting the vegetation distribution in this area.

The type of soil form developed depends on topography, the position on a slope and position relative to the water table influencing run-off and the degree of weathering and subsequent leaching of the soil.

Climate influences the intensity of weathering conditions as well as the degree of leaching of the soil forming minerals. One would expect to find low leaching where the rainfall is low, such as in Bushmanland, and for this reason the soils developed on Vaalputs are generally eutrophic. One would not expect to find a highly leached soil in Bushmanland.

One of the very noticeable features on Vaalputs is the presence of a soil catena effect with corresponding vegetation associations. A catena is defined by MacVicar, Loxton, Lambrechts, Le Roux, De Villiers, Verster, Merryweather, Van Rooyen & Harmse (1977) as a "sequence of soils of about the same age, derived from similar parent material, and occurring under similar macroclimatic conditions, but having different characteristics due to variation in relief and drainage."

The effect is particularly noticeable in the eastern section of Vaalputs where there is a repetitive sequence of deeper aeolian sand on the east and southeastern aspect of the ridges (Fig. 3.2).

(ii) Geological succession

The geological succession is generally granite-gneiss basement overlain by kaolinite, sandy and gritty clay, calcrete and silcrete, and covered by surficial sand (Fig. 3.3). Towards the east of the site the Dwyka Formation is present as remnant fillings of pre-Karoo depressions, and there is at least one clay-filled pipe present (Andersen, Raubenheimer & Levin 1983).

(iii) Basement

The metamorphic basement, which forms part of the Namaqua-Natal mobile belt, underlying the site is composed of metasediments, pink gneisses and the Norabees granite (Evans 1983).

The Concordia-type granite basement, which is flat-lying and has a sill-like form, belongs to the Spektakel Suite, and has been named the Norabees granite where it outcrops in the Vaalputs area (Andersen *et al* 1983).

This leucocratic granite is a fine- to medium- grained quartz-microcline gneissose aplogranite which is characterized by having a very low biotite content; has microcline-microperthite as the most abundant feldspar constituent with plagioclase occurring as irregular grains of oligoclase (SACS 1980). The mineral lineation is well developed and is due to elongated grains and aggregates of quartz and feldspar. Foliation is generally poor to indistinct (SACS 1980).

The basement rocks have undergone several phases of folding and deformation, the F2, F3 and F4 phases of folding (Joubert 1971) being recognized (Andersen *et al* 1983).

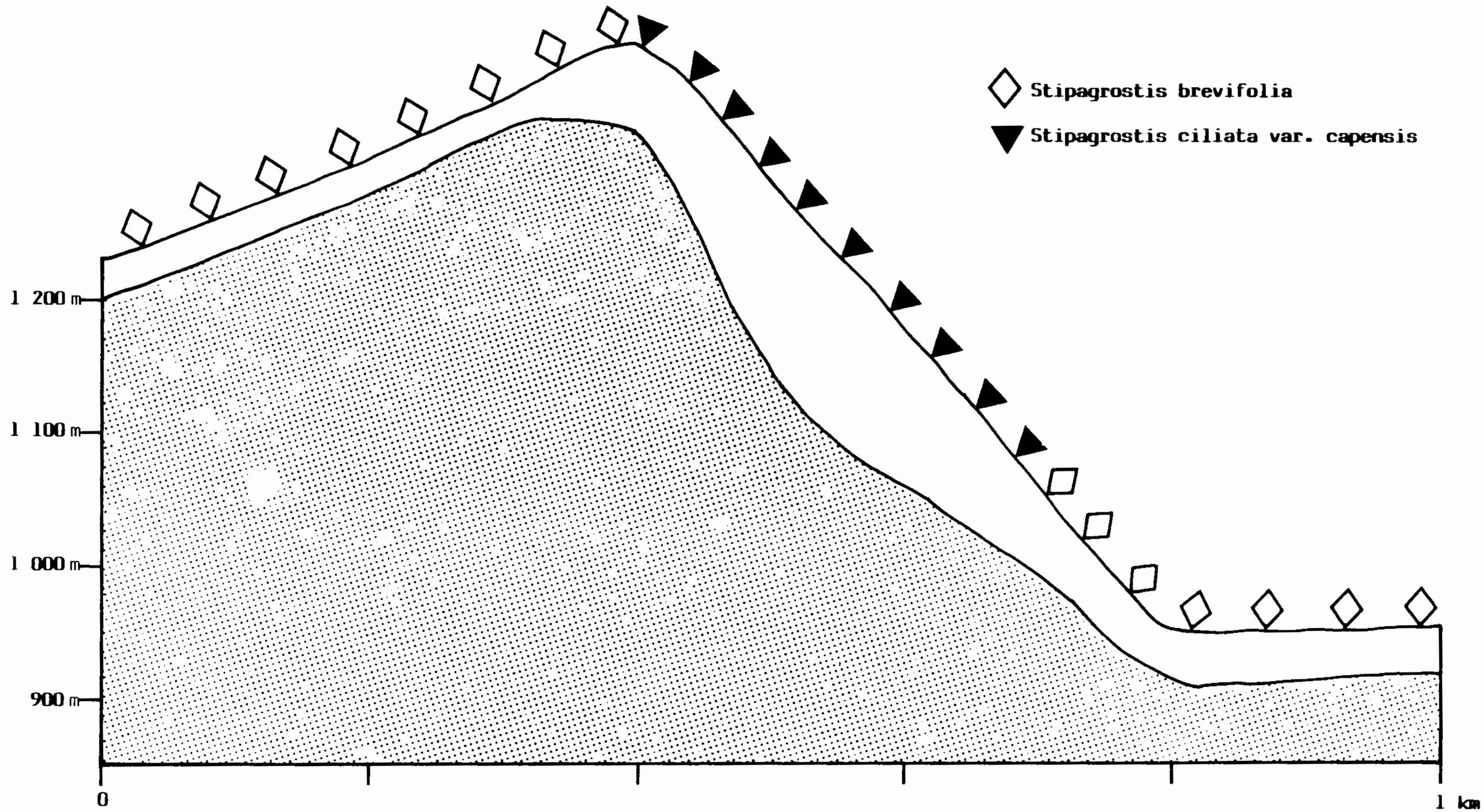


FIGURE 3.2 A schematic cross section through one of the "dunes" on the eastern section of Vaalputs showing the relatively deeper sand on the eastern side and the change in vegetation over this deeper sand.

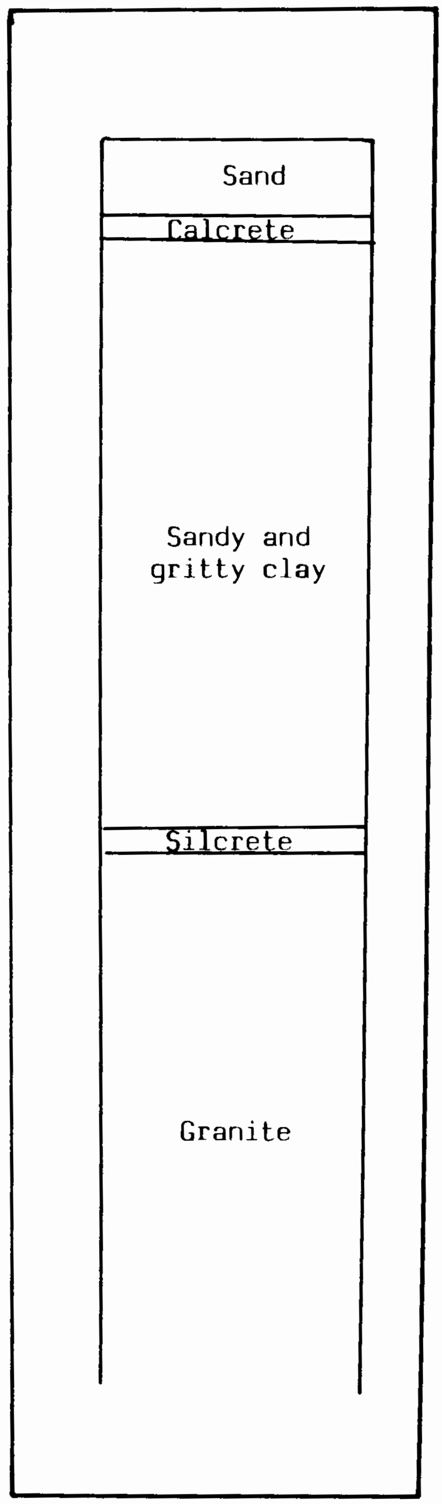


FIGURE 3.3 A schematic section showing the geological succession on Vaalputs.

(iv) Dwyka tillite and shales

Most of the Dwyka covering, which previously extended further west than its present position, with the exception of small remnants, has been removed by erosion. There is a general increase in the size of pebbles and boulders towards the east which indicates that this area is at the western limit of the melting of the Dwyka-ice and the deposition of the coarse material that was transported in the ice (Reuning 1931).

Andersen et al (1983) have inferred Dwyka suboutcrop from two areas where Dwyka float was noticed on Bokseputs. Dwyka shales have also been intersected in a borehole from a depth of 14 m on Bokseputs. This interpretation is consistent with the western limit of the Karoo Sequence (Dwyka Formation) as illustrated in SACS (1980) [Fig. 3.4].

Reuning (1931) indicates that most of the Dwyka in the vicinity of the edge of the Bushmanland Plateau is a remnant infilling of pre-Karoo valleys and depressions on the old granite and gneiss land surface, which was a gently undulating peneplain.

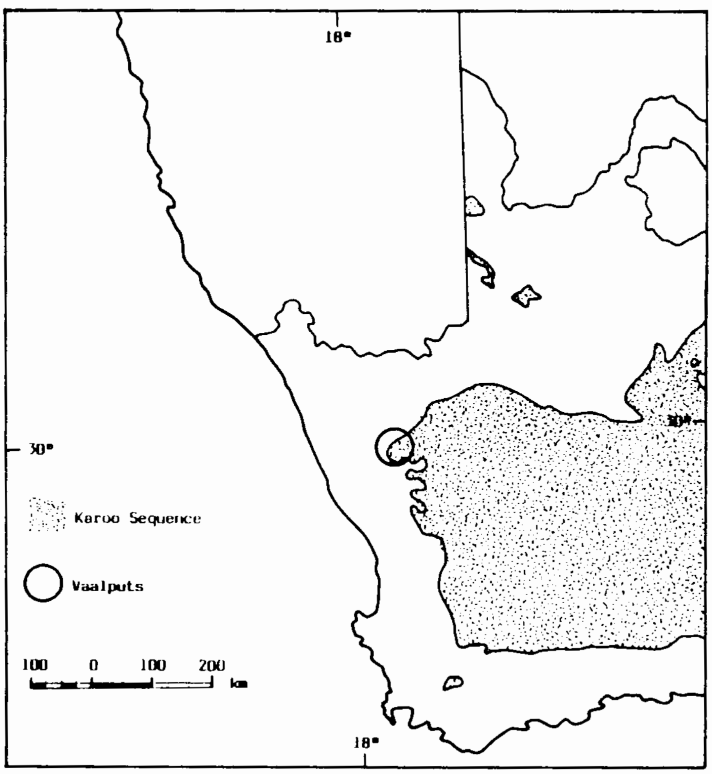


FIGURE 3.4 A map showing the western limit of the Karoo Sequence in relation to the position of Vaalputs (after SACS 1980).

(v) Kimberlites

Rogers (1911) and Reuning (1931) indicate that a relatively large number of kimberlite and related (melilite-basalt and nepheline-melilite basalt) pipes occur in the Gamoep and Platbakkies area. Drilling into one such pipe on Vaalputs has shown it to be clay-filled to a depth of 117 m (Andersen *et al* 1983). Reuning (1931) suggests that the clay constituents may have been partly derived from the Dwyka shales.

(vi) Younger surficial deposits

Andersen *et al* (1983) proposed the name Vaalputs Clay Formation for the succession of calcrete, silcrete, and sandy and gritty clay overlying the kaolin deposits derived from the granitic basement. The alluvium and sand overlying the Vaalputs Clay Formation is correlated with the Gordonia Sand Formation (SACS 1980), both of which form part of the Kalahari Group in this area (Andersen *et al* 1983).

Alluvium & sand	-	Gordonia Sand Formation	Kalahari Group
Calcrete, silcrete, sandy and gritty clay	-	Vaalputs Clay Formation	

Calcrete and silcrete:

Both calcrete and minor amounts of silcrete, with a thickness of up to 10 m, are present on Vaalputs, the calcrete outcrops being elongated in the strike direction of the dunes and seem to be associated with the sides and crests of the dunes rather than with the interdune valleys.

Watts (1980) states that "the distribution of vegetation in southern Africa, although related to climate, aspect and drainage, is particularly sensitive to host sediment type and has enabled differentiation of calcrete areas from aerial photography (e.g. Mountain 1967)." This is also very evident on Vaalputs where there are some ridges and small remnant patches of calcrete which have survived the erosion which removed the calcrete formerly surrounding such patches.

Goudie's (1973) definition of calcretes as stated by Watts (1980) is that "pedogenic calcretes are terrestrial materials composed dominantly, but not exclusively, of $CaCO_3$, which occur in stages ranging from nodular and powdery to highly indurated and result mainly from the displacive and / or replacive introduction of vadose carbonate into greater or lesser quantities of soil, rock or sediment within a soil profile."

Calcretes, such as those found on Vaalputs, are of some significance in providing evidence for palaeoclimatic interpretations and environmental changes which may have occurred with time, if one considers the factors which are important in calcrete formation. These factors are geomorphological position, climate, host materials, carbonate source, time, organic influences, sedimentation (or erosion) rate, and various localized conditions, all of which may influence the form, type and thickness of the calcrete produced (Watts 1980). The calcretes were produced during the Cenozoic when drier, more arid conditions prevailed.

Dorbank:

Ellis & Schloms (1980) define dorbank as a hardened subsurface horizon with reddish brown colours and variable thickness (10-120 cm) which occurs widely in the arid and semi-arid regions of the Cape Province, and is also found on Vaalputs.

The dorbank soils all appear to have the following common properties (Ellis & Schloms 1980):

a) the material above the dorbank (apedal A and B horizons) is non-calcareous and reddish-brown in colour;
b) free calcium carbonate ($CaCO_3$) may be present or absent in the dorbank layer which is red to red - brown in colour;
c) the material below the dorbank is either rock or weakly structured

calcareous material or contains gypsum;

d) where dorbank is associated with highly calcareous soils (e.g. calcareous Hutton soil forms), the dorbank is always on the oldest topographic position in the landscape.

The Bushmanland and Namaqualand dorbank (Ellis & Schloms 1980):

a) is massive, structurally;
b) has a thickness of 10-40 cm;
c) occurs in areas with a mean annual rainfall $<$ 100 mm ;
d) the dorbank layer is most often found at depths of between three and 15 cm from the surface;
e) parent material is granite - gneiss or old, red - brown deflation sands.

Genesis of the dorbank occurs when there is hardening of the subsurface horizon which is apparently caused by silica, accompanied occasionally by cementing agents such as calcium carbonate and iron oxides. For genesis of dorbank the ground must be dry or seasonally dry, and the soluble silica must be able to wash deeper into, but not out of, the profile. In the arid areas where soluble cations are abundant, the pH will be relatively high (alkaline to very alkaline). The solubility and resulting mobility of silica will be relatively high which means that it can move in the groundwater in a closed system, to a certain depth where it gives rise to cementation (Ellis & Schloms 1980).

Sands of the Gordonia Sand Formation:

Three different sand types were recognized and mapped on approximately 1:16 000 aerial photographs, and later onto a scale of 1:10 000. They are light brown sands, red-brown aeolian sands and sands intermediate between these two both in texture and colour (Fig. 3.5).

- Light brown sand

These sands occur closer to the areas of outcrop and are possibly formed *in situ*. They are not as well sorted as the red-brown aeolian

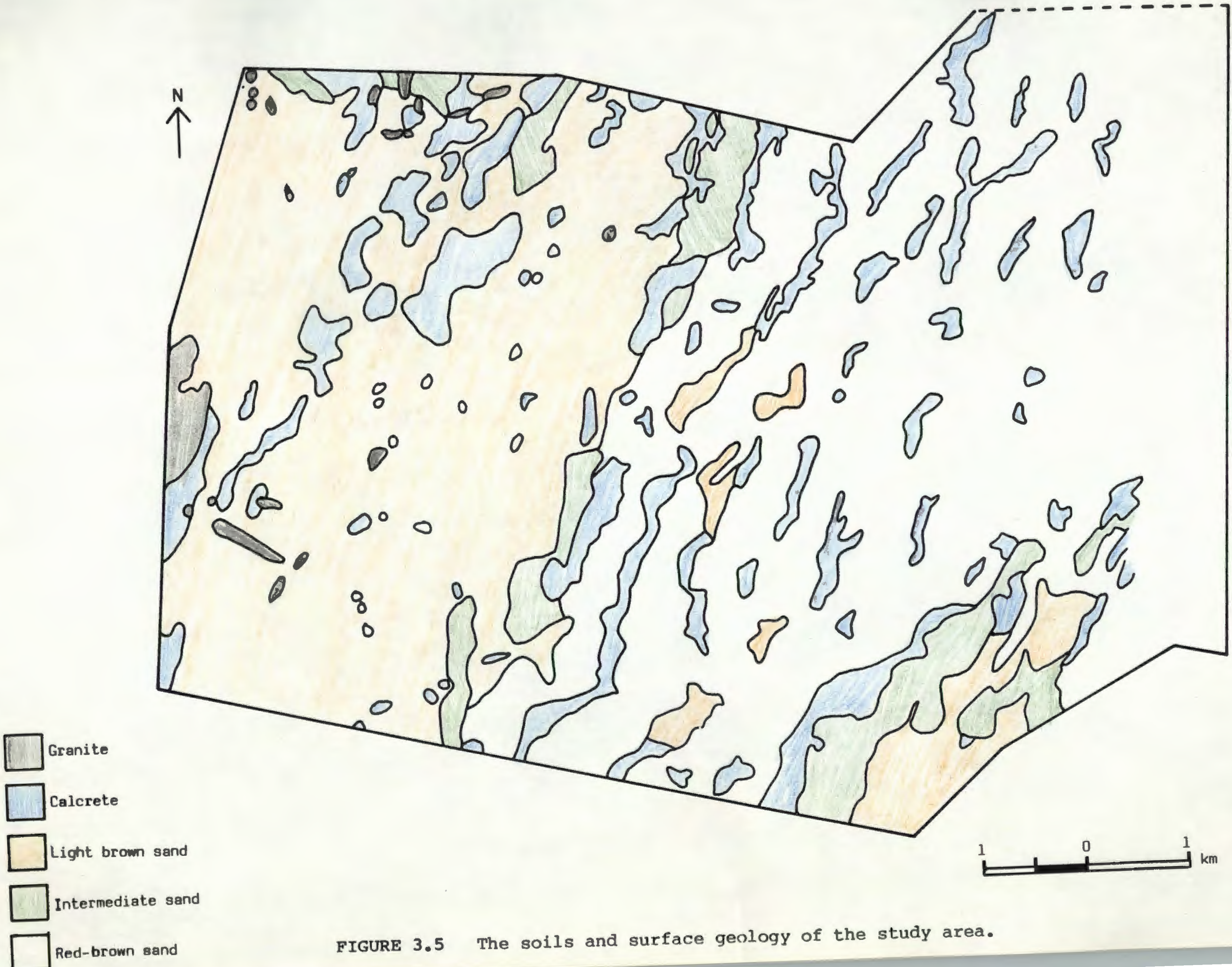


FIGURE 3.5 The soils and surface geology of the study area.

sands and contain quartz, feldspar and some limonitic fragments.

- Red-brown aeolian sand

This sand is found associated with the eastern and southeastern aspects of the dunes on Vaalputs. It consists predominantly of quartz grains and is fairly well sorted.

Adamson (1938) referred to " the loose and often mobile" soils which are common in the driest parts of the country. These "Kalahari sands" are more or less consolidated terrestrial sands (Haughton 1969) which are aeolian (Du Toit 1954, Haughton 1969) deposits reflecting a period of arid conditions during the Pleistocene (Haughton 1969) when the surface of the terrain was unstable (Gill 1961). Du Toit (1954) gives evidence, in the form of artefacts which were found below the Kalahari sands around the margin of the Kalahari, which suggests a Lower- to Middle- Pleistocene age for the sands at those localities. But, as Truswell (1977) indicates, it is difficult to give ages as there are several stages of sand movement.

The sands are reddish in colour due to haematitic (iron oxide) and limonitic coatings around the individual detrital grains (Rogers & Du Toit 1909, Van der Merwe 1941, Baillieul 1975, Watts 1980). The iron is derived from <u>in situ</u> weathering of ferromagnesian minerals such as biotite, hornblende and hypersthene, the released iron migrating to the grain boundaries (Rogers & Du Toit 1909, Watts 1980). The sands which have been wet at some time, such as in pans and river beds, have had this film of iron oxide removed, and the grains are greyish or whitish in colour (Rogers & Du Toit 1909, Van der Merwe 1941 and Baillieul 1975).

- Intermediate sands

This sand occurs in the transition zone between the light brown and red-brown sands, but is better developed north and south of Vaalputs and is virtually absent on the study area. In colour and texture it lies between the previously mentioned sands.

3.1.c) SOILS

(i) General

According to the schematic soil map of southern Africa (Harmse 1978), lithosols and weakly developed shallow soils of arid regions are represented in this area.

The lithosols are shallow soils which do not have a well-differentiated profile, and contain coarse fragments and solid rock at depths of 30 cm and less. The dominant soil-forming factor is topography, and the rate of removal of the weathered material exceeds the rate of formation (Harmse 1978).

The weakly developed shallow to moderately shallow soils of arid regions are predominantly reddish brown to greyish brown sandy loams and loams, overlying reddish brown to yellow - brown sandy loams and clays. These soils may or may not have B-horizons, their properties and characteristics depend largely on the composition of the parent material, and they often contain free lime ($CaCO_3$). They are usually derived from granite, gneiss or metamorphosed siliceous rocks but include calcareous sands and loams mainly overlying calcrete, as well as other calcareous soils. There are often large reserves of weatherable material and the base saturation and cation exchange capacity are usually high (Harmse 1978).

Compact red sandy loam overlying dorbank (desert ferricrete), saline and alkaline soils (Heydorn & Tinley 1980), and Kalahari sand of aeolian origin (Van der Merwe 1941) also occur in the Vaalputs area.

(ii) Characteristics of desert and semi - arid region soils

The soils from Vaalputs display many characteristics of semi - arid region soils as described below. These characteristics aid the interpretation of relationships which exist between the plant communities and their habitat.

Vertical differentiation of the soil profile into distinctive horizons is not well developed i.e. profiles are weak or stunted (Nikiforoff 1937, Van der Merwe 1941, Van der Merwe & Heystek 1955, Harmse 1978).

Chemical properties of the soil are essentially those of the parent material. The parent material is only altered to a limited extent by soil forming processes and chemical decomposition plays a secondary role in the soil formation (Van der Merwe 1941).

The accumulation of calcium carbonate ($CaCO_3$) in the B - horizon (Nikiforoff 1937) is as a result of the low rainfall and high evaporation rate which are not conducive to chemical decomposition of the parent material and leaching of the soluble constituents from the profile (Van der Merwe & Heystek 1955).

The calcium carbonate ($CaCO_3$) which is often leached from the surface and accumulates in the B - horizon is either powdery, hard lumps, or well - cemented.

The soils contain an accumulation of clays, iron oxides and soluble salts which may have been eluviated from the upper horizons or brought up from below by means of capillary action. Soils analysed by Van der Merwe & Heystek (1955) had an average clay content of just less than 20 %. This was also the case with the silt content. All these soils fell into the sandy loam class.

Van der Merwe & Heystek (1955) maintain that a high potassium content is indicative of the presence of fairly large amounts of hydrous mica clay minerals in the colloids, and the deficient leaching of the soils.

The salt content may be high in local, poorly drained areas.

The sparse vegetation contributes to the deficiency of organic matter in these soils (Van der Merwe 1941, Van der Merwe & Heystek 1955). The soils do not accumulate or contain any humus, which is prevented from forming when the production of ephemeral green plants in spring is followed by a hot period which results in rapid decomposition (Nikiforoff 1937).

The soils are residual but have been influenced in their formation by windblown material (Van der Merwe & Heystek 1955).

There are a great diversity of soils in these regions (Van der Merwe & Heystek 1955), however, soils of the Hutton and Mispah soil forms (MacVicar et al 1977) are most dominant.

3.1.d) LANDTYPES

A number of different landtype units are represented on Vaalputs (Fig. 3.6) (F. Ellis, pers. comm.). The most important units occurring within the study area are LJ3a and LJ13a, with LJ9a occurring in the rocky western parts.

Unit LJ13a occurs on undifferentiated granite and gneiss which is covered by Tertiary to Recent sand. It is comprised of three terrain units with convex or straight slopes varying between 0-2 %. The depth-limiting material is bedrock, calcrete or dorbank. Soil forms and series (MacVicar et al 1977) occurring within this landtype unit include: Ms22 (Kalkbank) and Ms24 (Vredendal) at depth between 15-30 cm; Hu32 (Moriah) and Hu35 (Portsmouth) with a clay content of 4-10 % in the B-horizon, and occurring at depths of between 20-35 cm; Hu42 (Quaggafontein) and Hu45 (Vergenoeg) with a clay content of 4-10 % in the B-horizon, and occurring at depths of between 20-35 cm.

Landtype unit LJ3a occurs on gneissic granites covered with Early Tertiary to Recent deposits of older sand. It is comprised of five terrain units with convex or straight slopes varying between 0-6 %. The depth-limiting material is calcrete, dorbank or bedrock. Soil forms and series (MacVicar et al 1977) occurring within this landtype unit include: Ms20 (Muden) which is calcareous in the A-horizon and is underlain by hard rock; Ms14 (Winchester) which is non-calcareous in the A-horizon; Hu32 (Moriah) and Hu31 (Gaudam) which are developed on the higher slopes, are found at a depth of 20-30 cm, and have a clay content of 0-6 % in the B-horizon; Hu35 (Portsmouth) and Hu34 (Zwartfontein) which are found at approximately mid-slope at depth between 80-120 cm, and have a clay content of between 6-15 % in the B-horizon; Hu36 (Shorrocks) which is found at depths greater than 1 200 cm, and has a clay content of 15-35 % in the B-horizon. All these soils, with the exception of Ms20 and Ms14, are non-calcareous in the B-horizon, are eutrophic in the B-horizon with an S-value generally >15 which indicates that there has been little or no leaching, have a high base status, and are coarse sands.

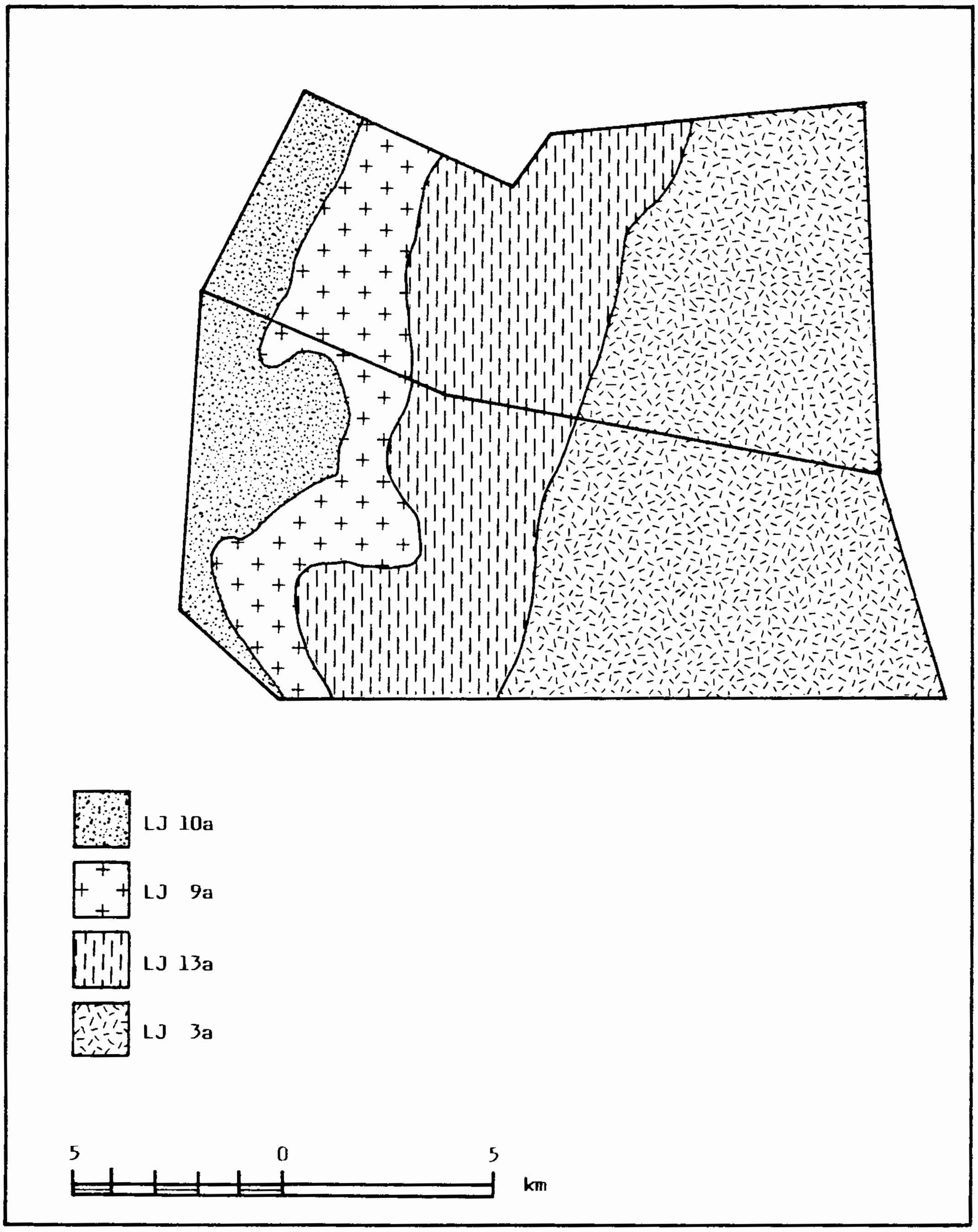


FIGURE 3.6 The three major landtype units present on Vaalputs (F. Ellis, pers. comm.).

3.1.e) EVIDENCE FOR PALAEOCLIMATIC CHANGES

Cooke (1975) proposed a relationship between climatic (and tectonic) events and sedimentary processes and their deposits. The types of sedimentary deposits present on Vaalputs serve as supporting evidence for interpretations of palaeoclimatic changes which have taken place over the last 65 million years, since the beginning of the Cenozoic.

Interpretations are based on knowledge of the genesis of deposits such as calcrete and silcrete, calcrete being correlated with semi - arid episodes (Cooke 1975), whereas silcrete formation and dune migration are correlated with arid periods (Watts 1980). The conditions under which such deposits are known to form, as well as their ages, enable comparison of present - day climates with palaeoclimates (Table 3.1). The presence of erosion surfaces and palaeobotanical evidence may also be useful in supporting, or providing evidence for, the palaeoclimatic interpretations as well as for putting age limits on deposits or events.

It appears that from the Early- to Middle- Tertiary there was a climatic change, globally and regionally, from warm and humid to cool and dry, and that from the Miocene onward, and possibly even earlier, world climates became cooler and more seasonal (Laporte & Zihlman 1983). Laporte & Zihlman (1983) attribute this significant cooling of the Earth's high and middle latitudes during the Cenozoic to the final breakup of the northern (Laurasia) and southern (Gondwana) supercontinents which resulted in increased equator - to - pole temperature gradients in the oceans with the development of the circum - Antarctic currents. There were presumably also increased equator - to - pole temperature gradients on land (Savin 1977). These increases in global temperature gradients resulted in greater seasonality of climate, especially temperature and rainfall, in the middle latitudes during the Miocene and in widespread glaciation in high latitudes during the Plio - Pleistocene. The contraction of the Tethys Sea, when Africa converged with Europe, and India collided against Asia, during the Miocene, reinforced regional and global increases in climatic seasonality (Laporte & Zihlman 1983).

"Geological and palaeobotanical evidence, which tends to suggest that arid conditions were only fully developed in the Late Tertiary, culminating in the Lower Pleistocene, and that, during the Early- to Mid- Miocene, the climate of the west coast of southern Africa was probably somewhat warmer and wetter than it is today" (Lancaster 1979).

Vaalputs lies on the Bushmanland erosion surface (plateau), at the edge of the "Namaqua Highland". Planation of the Bushmanland Plateau, when the climate was wetter than present (Table 3.1), and the beginning of regional aridity, occurred in the Early- to Mid-Tertiary, following evidence presented by Mabbutt (1955), and not during the end - Cretaceous, as was previously thought. The evidence is in the form of the flora and fauna of the Banke clays on the Bushmanland Plateau near Vaalputs which have been broadly dated as Tertiary (Reuning 1931). An upper limit of this cycle is set by the occurrence of the early Pliocene horse, Notohipparion namaquense, to the east of Springbok (Haughton 1932). The widespread glaciation during the Plio - Pleistocene is of significance because a drop in sea level (whatever the cause) would have sharply lowered water tables and also promoted aridity (Laporte & Zihlman 1983).

Surface limestone (calcrete) is extensive on the Bushmanland Plateau, and when the age of the Plateau is considered, the beginning of calcification could not have started later than early Pliocene, on the faunal grounds presented above. Ward, Seely & Lancaster (1983) suggest that there was a period of geomorphic stability at the end of the Miocene which resulted in widespread calcrete formation. This, they suggest, may have occurred in a semi - arid climate with summer rainfall.

This arid or semi - arid period during which calcification took place was followed by a later period, or periods, of greater rainfall during which there was erosion of the present valleys into the limestones. The calcrete surface on Vaalputs is an eroded surface which is consistent with this interpretation. This can be correlated with the known climatic changes of the Pleistocene (Mabbutt 1955).

The Bushmanland Plateau later became covered with a flat surface cover of red sand which, according to Mabbutt (1955), is characteristic of the Plateau. The true dunes are limited to depressions such as the Koa Valley which is a restriction implying later redistribution such as is known to have occurred in the southern Kalahari and along its borders (Mabbutt 1955).

Haughton (1969) states that during the Quaternary there were periods of more intense rainfall over the inland regions, during which time the major rivers and their tributaries eroded their valleys, leaving remnants of earlier fluvial deposits on their sides. These fluvial periods alternated with drier periods during which calcretes, silcretes and ferricretes were formed. The calcification and laterization of river sands occurred under these semi - arid conditions (Haughton 1969). There were even more arid periods during which the Kalahari - type sands were spread over a large part of southern Africa by wind. There appears to be evidence substantiating much of this on Vaalputs.

Table 3.1 Evidence from Little Namaqualand for palaeoclimatic changes from the Cretaceous to present (table modified after Mabbutt 1955)

CLIMATE COMPARED WITH PRESENT	AGE	LITTLE NAMAQUALAND
Drier to present	Middle Pleistocene and later	Major rejuvenation forming gorges below knickpoints
Wetter	Upper Tertiary - Lower Pleistocene	Rejuvenation in two sub - stages (780 m and 600 m)*
		UPLIFT
Drier	Upper Tertiary	Red sands
	? Early Pliocene	Calcification
Wetter	Early - Middle Tertiary	Bushmanland surface
Drier	End - Cretaceous or early Tertiary	Valley infilling
		Kaolinisation
		Kangnas Valley stage
Wetter	Cretaceous	Namaqua Highland surface

(* 780 m = 2 600' ; 600 m = 2 000')

3.2. CLIMATE

3.2.a) INTRODUCTION

Vaalputs is situated in the transitional zone between the winter rainfall area of Namaqualand, which experiences cyclonic and orographic rainfall, and the summer rainfall area of Bushmanland (Fig. 3.8), which experiences convective rainfall. The nature and intensity of the rainfall of these respective areas is therefore different and determines the type of vegetation which occurs in each area.

Coastal lows and cold fronts periodically pass over Vaalputs bringing little or no precipitation as a result of the orographic influences of the Kamiesberg, and the rain which does fall on Vaalputs is usually from the convective storms which occasionally occur in summer (Redding 1983).

The sparse population of Bushmanland has resulted in a paucity of weather stations. Often only rainfall data are collected at the few weather stations which do exist (Fig. 3.7). The two rainfall stations closest to Vaalputs are Gamoep, which has sporadic data, and Burdensput, which has only been collecting data for five years.

Redding (1983) indicates that "the aridity of the area classifies it as similar to stations to the east of the Kamiesberg and so the first order station of Upington and others with continuous data, such as Pella, are cited as typical of the area under consideration." The general climate of Vaalputs has been described in this section using data from the stations mentioned above and from maps available for various climatic variables (Weather Bureau 1974, Werger 1978).

Although an automatic weather recording station has been erected on Vaalputs and data are available from November 1983, there is not sufficient information over a long enough period of time to be able to make any generalisations.

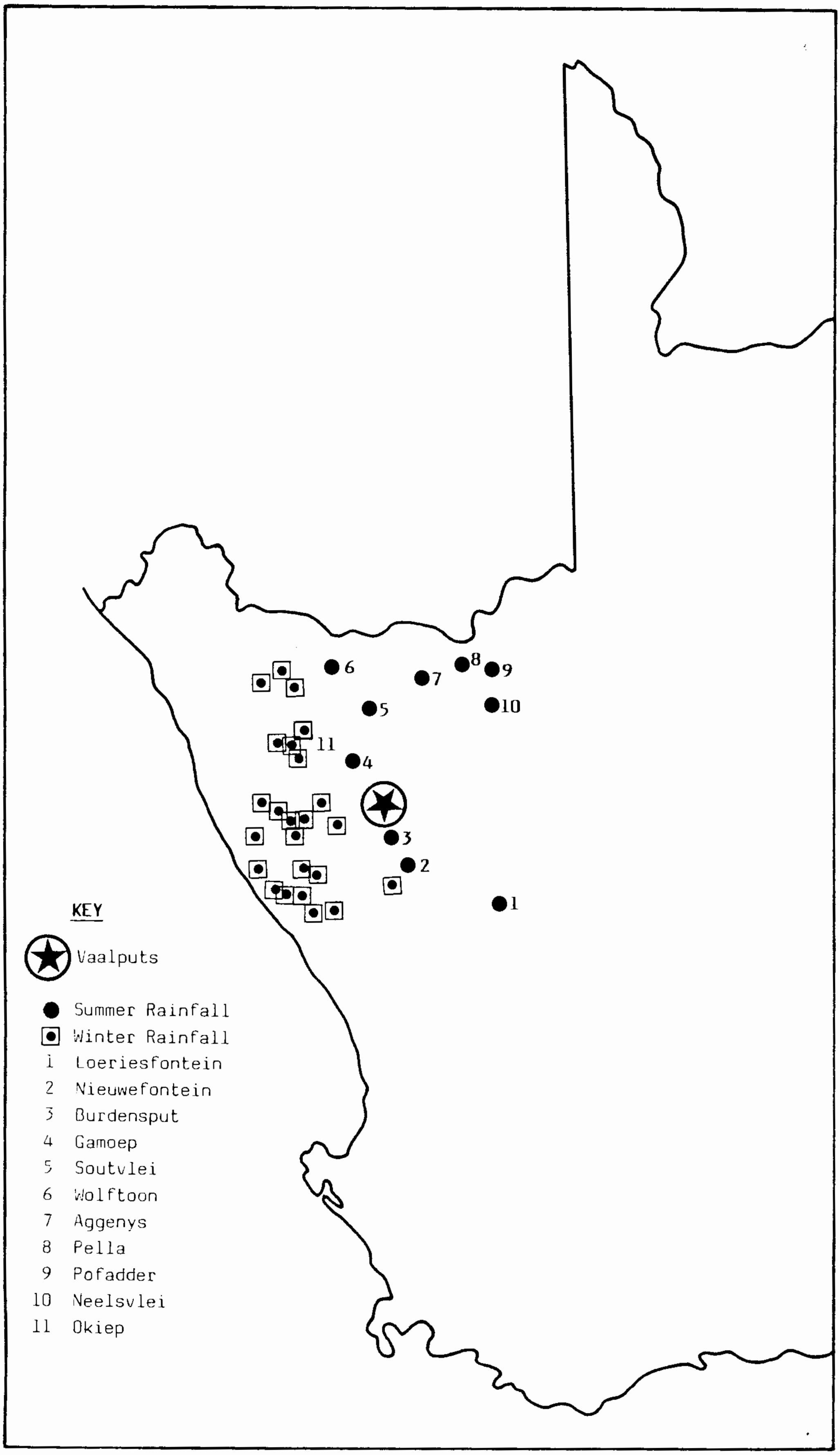


FIGURE 3.7 Vaalputs in relation to the surrounding summer- and winter- rainfall stations (after Redding 1983).

3.2.b) CLIMATIC CLASSIFICATION

According to the simplified climatic classification of Köppen (Schulze & McGee 1978), Vaalputs falls within the BWk climatic region. BWk stands for an arid zone (B) with a desert climate (W) which is dry - hot, and has a mean annual temperature below 18 ^{o}C (k) [Köppen & Geiger (1936) in Schulze & McGee (1978)].

3.2.c) PRECIPITATION

(i) Rainfall

The rainfall in this area is generally erratic and unreliable. Precipitation is mainly due to convectional showers in summer and autumn occurring on about two days per month. Single very rare heavy showers can account for as much as the annual precipitation (Weather Bureau 1974). The mean January (summer) as well as the mean July (winter) precipitation is estimated at between 0 - 10 mm [Jackson (1961) in Schulze & McGee (1978)], with a mean annual rainfall greater than 100-150 mm (South Africa 1:250 000 sheet 3018 Loeriesfontein 1966).

(ii) Mist and fog

There is more often mist over Vaalputs, as a result of the influence of the cold Benguela Current on the west coast of South Africa, than fog which is experienced along the coast and west of the Kamiesberg. This mist (Fig. 3.8) may be a very important source of moisture for the perennial shrubs in this area during times of drought.

(iii) Dew

Dew occurs in this area and may be an important source of moisture for certain plants.

(iv) Frost

Frost is common during the winter (Weather Bureau 1974).

FIGURE 3.8 Mist near the Garing and Geelpan boundary fence at the edge of the Stipagrostis brevifolia - Lycium spp. short open grassy shrubland community.

(v) Hail and snow

Both hail and snow are rarely recorded in this area (Weather Bureau 1974).

3.2.d) TEMPERATURE

There are fairly large variations in both seasonal and diurnal temperatures. For the Vaalputs area the summer (January) mean daily temperature is approximately 19.5 ^{o}C, as opposed to the winter (July) mean daily temperature of approximately 8 ^{o}C. The summer (January) mean daily maximum temperature is 31 ^{o}C as opposed to the winter (July) mean daily minimum temperature of 5 ^{o}C. The mean annual temperature for Vaalputs is 16 ^{o}C, and the mean annual range of temperature is 12 ^{o}C.

3.2.e) WIND

Wind is an important environmental factor in both Namaqualand and Bushmanland, but as Redding (1983) indicates, there is a general lack of representative wind data for Bushmanland. Local data collection has commenced with the erection of the automatic weather recording station on Vaalputs, as was mentioned previously. The prevailing wind directions are southeast and northwest (Weather Bureau 1974).

During the hot summer days whirlwinds may develop due to strong convection (Weather Bureau 1974).

3.2.f) RADIATION

The amount of solar radiation received at any particular location is influenced by factors such as altitude, topography (slope and aspect), sunshine duration (season), moisture in the atmosphere, cloud cover and dust content. The average annual duration of bright sunshine (percentage of possible) is approximately 80 % (Weather Bureau 1974).

Topographic variations in radiation are of little significance on Vaalputs due to the low relief of the area. The radiant flux densities over the Vaalputs area vary from between 130×10^5 $J/m^2/day$ during winter and 290×10^5 $J/m^2/day$ during summer (Schulze & McGee 1978).

3.2.g) RELATIVE HUMIDITY

The mean annual relative humidity (RH) at 14h00 S.A.S.T. is approximately 40 %, with a mean annual range of RH at 14h00 S.A.S.T. of 15 % (Weather Bureau 1974).

3.3. BIOTIC FACTORS

3.3.a) ANIMALS

As the land use practices on Vaalputs have changed, the intensity and nature of the disturbances, historically, have also changed. This may have resulted in variations in the vegetation besides those natural ones resulting from variations in the soil. Patterns of individual species and populations, as well as vegetation structure, may have changed possibly by differential tolerance to the changing physical environment or by competitive displacement (Pickett 1982).

In considering the Karoo vegetation dynamics it is evident that biotic influences, such as the grazing intensity, have played a large part in changing the structure, and accelerating the degeneration, of the karoo vegetation by an increase in the number of unpalatable shrubs (Acocks 1953, 1975).

Historically, utilization of the veld has changed from grazing and browsing by migratory herds of springbok and a variety of other animals (Talbot 1961), to farming which has changed from cattle to sheep and goats since 1943, and from intense periodic grazing after rain followed by periods of rest at the time of the "Trekboers", to a period of more seasonal, selective grazing since 1916. According to Acocks (1975) the areas from which the perennial grasses and better karoo bushes have practically disappeared are the areas which have come to be regarded as useful only for goats and karakul sheep.

The most palatable grazing plants in the Karoo are grasses (Acocks 1975), the three most important perennial grasses grazed in Bushmanland being Stipagrostis brevifolia, S. obtusa and S. ciliata, all of which occur on Vaalputs (Fig. 3.9). The Karoo bushes are valuable only as reserves for winter and droughts when the grasses can no longer be utilized, and many of the unpalatable Karoo bushes are on the increase as a result of selective grazing (Acocks 1975).

Van der Walt (1971) investigated the effect that grazing at various times of the year had on the basal cover of S. ciliata and S. obtusa, which can be regarded as the natural climax in the Arid Karoo of the northwestern Cape (Van der Walt 1971). The results of this investigation could be implemented in veld management in this area.

It appears that the effect of summer grazing (November, December and January) on the combined (total) grass cover was to depress the basal cover by 0.0297 % per year, and to depress the basal cover of S. ciliata and S. obtusa by 0.1434 % and 0.2917 % per year, respectively. Winter grazing (May, June and July), however, had no significant effect on S. obtusa, but increased the basal cover of S. ciliata by 0.1390 % per year (Van der Walt 1971).

Results of a recent survey of the grazing conditions in Bushmanland (Barnard & Louw 1984) following the prolonged drought, indicate that the average vegetation cover is 30.1 %, but that the true perennial cover is lower than this if the ephemeral component is subtracted. S. brevifolia covers an average of 10.6 % of the surface area, S. ciliata covers an average of 3.3 % and S. obtusa an average of 3.9 % (Barnard & Louw 1984).

Indications are that sufficient seed reserves of both S. ciliata and S. obtusa exist, with most grass tufts having established during 1984 by means of seed after rain had fallen. This is significant as it indicates conditions which possibly exist for the revegetation programme on Vaalputs. S. brevifolia does not establish as fast as S. ciliata and S. obtusa which stresses the need for more controlled grazing in areas where S. brevifolia occurs (Barnard & Louw 1984).

Barnard & Louw (1984) advocate keeping animals off the veld for as long as possible, but at least a period of two months, after sufficient rainfall, to give the grasses and shrubs which have survived the drought an opportunity to develop their root systems as fully as possible before grazing commences. This would also give the new seedlings a chance to establish and replace the dead grass tufts and shrubs. Provided grazing is properly controlled, the natural vegetation in Bushmanland has a good chance of recovery following rainfall (Barnard & Louw 1984).

The carrying capacity on Vaalputs was 9 ha per sheep in 1983, at which time (1 July 1983) the sheep were removed from the study site, with the exception of one camp. Since 1983 grazing has been limited to the relatively low number of buck which occur naturally in the area.

The vegetation changes which may occur on the site as a result of the grazing pressure being removed, may be reflected in the long-term monitoring of selected plots on the site. One might predict an increase in the grass cover as well as an associated increase in the small mammal populations.

Some of the animals which occur on the site include steenbok (*Raphicerus campestris*), which are both grazers and browsers. They generally occur in open grassland or in lightly wooded grassland on flat or gently undulating terrain.

3.3.b) HUMAN INFLUENCES

Human influences which have caused disturbance of some sort to the naturally occurring plant communities on the site include the network of boreholes and access roads to them (Fig. 3.10); the windpumps and cement dams which previously served as watering points for the sheep on the farm; the buildings of the field camp, living quarters and offices; the weather station and access roads; the airstrip and access roads; and the buildings, trenches and fences around the area where the low- and intermediate- level radioactive waste is to be buried.

FIGURE 3.9 The grasses Stipagrostis ciliata var. capensis and S. brevifolia which were heavily grazed on Vaalputs.

FIGURE 3.10 Human influences, such as fencing and roads, on Vaalputs.

CHAPTER 4 HISTORICAL BACKGROUND

4.1. LAND USE

The land use practices in the Vaalputs area have changed with time, particularly the nature and intensity of grazing. The farmers in the Kamiesberg were used to "trekking" (moving from one place to another with their flocks and herds) rather than being bound to one homestead. They always "trekked" in the direction from which reports of good rains came. This was often from the Kamiesberg to Bushmanland, and then to other parts of the district. The best pasture would be grazed at one place before they moved off in another direction. "The seasonal movements of the domestic animals of the Europeans were similar, if not parallel, to those of the blesbok, springbok, wildebeest and other game" (Talbot 1961). There are accounts of the vast herds of springbok which at one time swept through these areas (Talbot 1961), as well as records of ostriches and gemsbok roaming in Bushmanland (Van der Merwe 1941).

Because they were used to "trekking", the farmers were reluctant to possess their own piece of land when farms were first given out in the Kamiesberg in 1843 (Kotzé 1943). In 1915, Gamoep, Kammiebees, Alwynsfontein and Dooddrink were given out. It was only after 1916 that the Crown land farms in the vicinity of the study area, including Bokseputs and Vaalputs were given out, and by 1938 all the land in this area was in the possession of private people.

As from February 1983, NUCOR began negotiations and purchased the farms Vaalputs A (Garing portion), Vaalputs B (Geelpan portion) and the Stofkloof portion of Bokseputs, to use as a low- and intermediate-level nuclear radioactive waste disposal/storage site.

The scanty rainfall during the summer months makes Bushmanland unsuitable for grain-farming, which means it is only really suitable for stock- farming. Land use practices on Vaalputs have therefore changed from erratic, but intense periodic grazing for relatively short periods of time by the "Trekboers", to a period of more intense, regular grazing over the last 70 years, since 1916, when the farms were given out. Most farmers in this area have farms in both the winter and summer rainfall areas, which effectively means that there is seasonal grazing on the farms. The fairly prolonged (seven-year) drought in Bushmanland prior to this investigation, and the continued grazing on the farms has contributed to the relatively poor condition of the veld. Kotzé (1943) records that this area was previously known (prior to 1943) to be suitable for cattle farming, but that the herds of large stock (cattle) vanished quickly as a result of continuous droughts. By 1943 there was virtually only small stock (sheep and goats) farmed in the area.

The land use of Vaalputs has changed fairly drastically since its purchase by NUCOR as a radioactive waste repository. Sections of the site will be used to this end, whereas other sections, particularly the section in the Kamiesberg, will, for the time being, be left as it is with no further influence by domestic animals.

CHAPTER 5 VEGETATION OF THE NORTHWESTERN CAPE

5.1. VELD TYPES

According to Acocks (1975) map, Vaalputs falls into the False Succulent Karoo (Acocks 1953, 1975, Veld Type 39) (Fig.5.1). However, from the descriptions of the various veld types, it appears that there are elements of Arid Karoo (Veld Type 29) and False Desert Grassveld (Veld Type 33) present together with the False Succulent Karoo, forming a mosaic in the study area, and that there are elements of the typical form of Namaqualand Broken Veld (Veld Type 33) present in the areas of rocky outcrop on the western part of Vaalputs.

5.1.a) FALSE SUCCULENT KAROO (VELD TYPE 39)

Vaalputs falls into the area mapped by Acocks (1975) as False Succulent Karoo (Fig. 5.1). According to Acocks (1975) it consists of species belonging to the Mesembryanthemaceae as well as relics of the Arid Karoo, such as *Salsola tuberculata*, *Stipagrostis obtusa*, *S. brevifolia* and *S. ciliata*. He further indicates that its development is as a result of excessive grazing pressure and that the species which are of value for grazing are the ones which will not be found in this veld type.

To the east of the Kamiesberg, on the western edge of the Bushmanland Plateau, in the transitional zone between the summer and winter rainfall areas, the vegetation belonging to the False Succulent Karoo also shows a transitional character from the succulent dwarf shrub and shrub vegetation of the Western Cape Domain to the narrow - leaved dwarf shrub vegetation of the Karoo Domain (Werger 1978). Werger (1978) indicates that in this veld type many species of *Ruschia* are still important, particularly *Ruschia robusta* (Acocks 1975, Werger 1978) (Fig. 5.2), as well as other Mesembryanthemaceae, but towards the east species of the Asteraceae gain more importance.

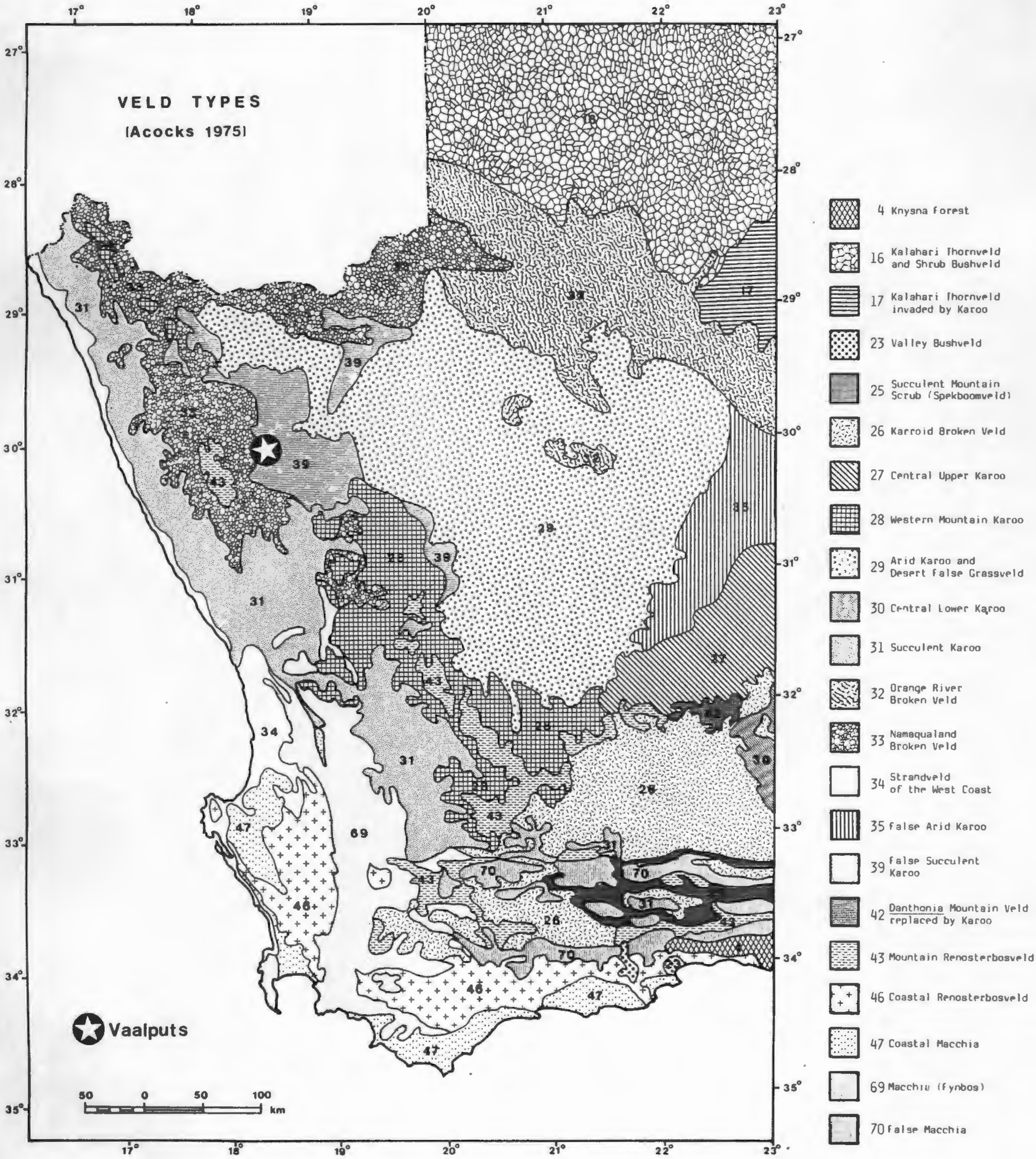


FIGURE 5.1 A map showing the position of Vaalputs in relation to Acocks (1975) Veld Types.

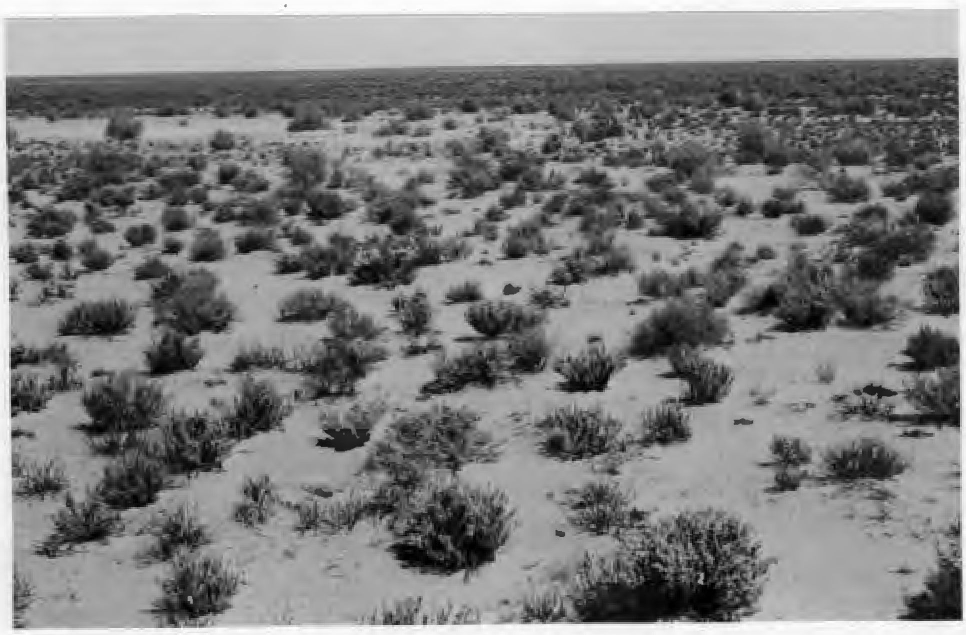


FIGURE 5.2 Ruschia robusta in the False Succulent Karoo.

Some of the species from this veld type listed by Acocks (1975) include : Ruschia robusta; R. muricata; R. leucanthera; R. leucosperma; R. kakamasensis; R. uncinella; Brownanthus ciliatus; Eberlanzia ferox; Psilocaulon absimile; P. arenosum; Sphalmanthus suffusus; S. tetragonus; Aridaria cf. A. noctiflora; Hereroa fimbriata; Drosanthemum framesii and Augea capensis.

5.1.b) ARID KAROO (VELD TYPE 29)

The Arid Karoo lies on the western edge of the Bushmanland Plateau on calcrete and sandy patches at an altitude of between 900 and 1 200 m. The annual rainfall of 50-200 mm falls mainly in late summer and autumn. The vegetation of the calcrete is generally open to fairly dense dwarf shrub and grass formations, whereas the sandy patches consist predominantly of grasses, although annuals and geophytes can be abundant after rain.

Some of the annuals and geophytes include Radyera urens, Aizoon canariense, Dimorphotheca polyptera, Galenia sarcophylla, Heliophila trifurca, Sutera tristis and Zygophyllum simplex.

There are three main variations of the Arid Karoo, namely Blomkoolganna Veld of calcrete along the northern edge of the plateau; Driedoring Veld of gravelly and stony soil; and the semi-succulent Karoo of stony soil in the southern part, south of the Carnarvon-Calvinia main road (Acocks 1975).

The calcrete is characterized by Salsola tuberculata, Stipagrostis obtusa and S. ciliata. Some of the grasses are Enneapogon desvauxii, Eragrostis nindensis, Sporobolus lampranthus and Oropetium capense, with Stipagrostis brevifolia being commonly found on the sandy patches. Some of the other common species which are present in this veld type include : Galenia sarcophylla; Zygophyllum microphyllum; Z. gilfillani; Aptosimum depressum; Eberlanzia ferox; Pteronia mucronata; Hermannia spinosa; Salsola zeyheri; Rosenia humilis; Osteospermum armatum; Leysera tenella; Gazania lichtensteinii and Mesembryanthemum annuum (Werger 1978).

The Blomkoolganna Veld (Salsola tuberculata community) (Fig. 5.3) is thought to be the climax community of the whole of the Arid Karoo (Acocks 1975), and is what is found occurring to a limited extent on Vaalputs. Two dwarf shrub species which tend to invade this community are Pentzia spinescens and Eriocephalus spinescens (Werger 1978).

Werger (1973a) lists the following families amongst those being of importance in Veld Type 29 : Asteraceae; Poaceae; Aizoaceae; Liliaceae; Scrophulariaceae; Fabaceae; Chenopodiaceae; Asclepiadaceae; Sterculiaceae; Euphorbiaceae; Zygophyllaceae and Polygalaceae.

FIGURE 5.3 Salsola tuberculata which has been heavily grazed, on calcrete.

5.1.c) NAMAQUALAND BROKEN VELD (VELD TYPE 33)

According to Acocks (1975), this veld type has three variations, namely the typical form of Namaqualand Broken Veld on the more mountainous granite domes, gneisses and quartzite hills; the Rhigozum trichotomum Veld of the gravelly sandy loam on the plains between the ridges; and the False Desert Grassveld which results from a grazing out of the karoo bushes in the more open parts of the Rhigozum trichotomum Veld (Acocks 1975).

The typical form of Namaqualand Broken Veld is represented on Vaalputs together with elements of the False Desert Grassveld. The typical form is characterized by Aloe dichotoma and has many succulent species, many of which are unpalatable. The vegetation consists of small trees, shrubs and dwarf shrubs, with few grasses.

On the higher lying slopes, aspect is important, with the southern slopes being more like Western Mountain Karoo (Veld Type 28) with less succulent vegetation. The vegetation on southern aspects, at higher altitudes, is less succulent and taller, forming a scrub which is dominated by Pteronia leptospermoides, P. undulata, P. divaricata, Salvia dentata, Rhus horrida, Eriocephalus africanus and Indigofera pungens (Acocks 1975). The Namaqualand Broken Veld occurs in the winter rainfall area at altitudes of between 300 and 1 350 m.

Examples of the small trees and shrubs which occur in this veld type are Aloe dichotoma, Euclea undulata, E. tomentosa, Rhus undulata, Ficus cordata (Le Roux 1984), Pappea capensis and Boscia albitrunca. Some of the smaller shrubs and dwarf shrubs include Othonna arbuscula, Euphorbia mauritanica, Pteronia incana, Ruschia spp., Montinia caryophyllaceae, Galenia africana, Zygophyllum morgsana, Dyerophytum africanum, Lebeckia sericea, Didelta spinosa, Eriocephalus ericoides, Berkheya spinosa, Thesium lineatum, Crassula spp. and Pelargonium spp. (Acocks 1975, Werger 1978).

The False Desert Grassveld in its extreme form is a pure grassveld consisting of Stipagrostis brevifolia, S. obtusa and S. ciliata, such as are found on the eastern section of Vaalputs.

5.2. KAROO VEGETATION CHANGES

Variations in the veld may be due to variations in the soil as well as to variations in grazing intensity (Acocks 1975), and it is necessary to separate the natural variations from the man-made ones.

Acocks (1975) indicates that the two distinct floras of South Africa, the winter rainfall area Fynbos and forest, and the summer rainfall area tropical forest, savanna and grassveld have interacted to produce the distinct Karoo vegetation type with all its variations.

In considering vegetation changes, Acocks (1975) illustrated how rapidly the Fynbos and Karoo are moving eastwards and northwards. The Karoo has a strong Fynbos affinity, especially the Upper Karoo and the Western Mountain Karoo. When the Tropical grassveld and scrub is disturbed by man, it is the Fynbos - derived elements of the Karoo which play a leading part in the invasion. Some of the genera in the Karoo which are well represented in the Fynbos include Chrysocoma, Hermannia, Pteronia, Eriocephalus, Selago, Pentzia and Lightfootia.

Examination of Acocks' (1975) maps showing vegetation changes since AD 1400, and his predicted changes up until 2050 unless the veld is managed properly, shows the changes in the Vaalputs area as follows :

AD	
1400	Karoo, including Karroid Bushveld
1950	Succulent Karoo
1975	False Succulent Karoo
2050	Desert

The Succulent Karoo is thought to be invading the Arid Karoo and Western Mountain Karoo. According to Acocks (1975) this movement is relatively small so far, because the Succulent Karoo belongs to the winter rainfall area and is not that well adapted to the summer rainfall areas which it is invading. This results in a very poor, weedy type of Succulent Karoo which advances eastwards and can hardly be distinguished from desert. There are no sharp boundaries to these internal Karoo changes, the Karoo tending to become a general mixture of all types, with the pioneers of the Succulent Karoo and Arid Karoo already penetrating almost as far as the False Karoo boundary in the east (Acocks 1975).

According to Acocks (1975) by 2050 the present Karoo and False Karoo will largely have degenerated into near - desert False Succulent Karoo, except in some of the more mountainous areas and in areas of deep sand. Under correct management, the False Succulent Karoo could be pushed back to where it belongs in the winter rainfall area, and the False Karoo could be reclaimed to sweet grassveld.

CHAPTER 6 METHODS

6.1. VEGETATION

6.1.a) THE BRAUN-BLANQUET METHOD OF CLASSIFICATION

(i) Introduction

The Braun-Blanquet method as described by Braun-Blanquet (1932), Poore (1955), Becking (1957) and Werger (1974) is employed in this investigation.

(ii) Plot size

The minimal sample size for relevés are determined by using the nested plots technique and constructing species-area curves. This is achieved by doubling the previous sample area and recording the new species present. The area is increased until there are few or no new species. The number of species is plotted against the size of the sample area and the minimal sample size is found by taking the value at which the curve flattens. A point is taken at which a 10 % increase in the sample area results in a 10 % increase in species. This point is joined to the origin and the point at which a line parallel to this touches the species-area curve tangentially, is taken as the x-value which defines the minimal sample area. The size of relevés used on Vaalputs was 4 m x 4 m (16 m^2).

(iii) Plot selection

The Braun - Blanquet method (Werger 1974) requires subjective selection of representative samples of communities, structurally and floristically. In this survey, plots are placed in subjectively selected homogeneous areas which appear to represent the vegetation units present. An area is considered to be homogeneous where the vegetation is structurally and floristically uniform and where there are no marked changes in the habitat (Shimwell 1971, Westhoff & Van der Maarel 1973, Jooste 1980).

After a reconnaissance of the area, plots were initially selected along an east - west transect which cuts across the maximum number of vegetation units. This transect is along the "baseline", an arbitrary line on a grid system extending north - south and east - west of trig. beacon number 56, which serves as the zero coordinate. A second line of plots was placed approximately north - south, and the rest were put out subjectively so as to have a sufficient number of plots representing each recognizably different vegetation unit. Because the vegetation units are very localized, the sample distribution is uneven.

(iv) Number of relevès

An area of 7 787.5 ha (or 77.875 km^2) is sampled by means of 178 relevès, of which 13 are repeat samplings of permanent plots. The communities are each represented by between six and 37 relevès.

(v) Floristic lists

All the plant species occurring in each relevè, including lichens, are recorded and given a cover-abundance rating according to the following Braun-Blanquet cover-abundance scale:

R very rare with negligible cover
+ present but not abundant, and with a small cover value (less than 1 % of the quadrat area)
1 numerous but covering less than 1 % of the quadrat area, or not so abundant but covering between >1 % and 5 % of the quadrat area
2m very numerous and covering less than 5 % of the quadrat
2a covering between >5 % and 12 % of the quadrat area, independent of abundance
2b covering between >12 % and 25 % of the quadrat area, independent of abundance
3 covering between >25 % and 50 % of the quadrat area, independent

of abundance

4 covering between >50 % and 75 % of the quadrat area, independent of abundance

5 covering between >75 % and 100 % of the quadrat area, independent of abundance

0 rare, but present just outside the quadrat

On the Braun-Blanquet table (Table 7.1) only 2a is represented and has thus been indicated as 2.

(vi) Physiognomy

Only perennial species which are visible at all times of the year are used in the physiognomic classification.

The structural classification used primarily follows that proposed by Edwards (1983). A modification of the height classes proposed by Edwards (1983) is an extension of the "low" shrub, grass and herb class into two classes using the terminology of Campbell et al (1981) and conforming to that adopted by Le Roux (1984). The "low" height class of Edwards (1983) becomes the low class from >0.25-0.50 m and the dwarf class from 0.00-0.25 m.

Terminology adopted for height classes:

>2.00-3.00 m	high
>1.00-2.00 m	tall
>0.50-1.00 m	short
>0.25-0.50 m	low
0.00-0.25 m	dwarf

(vii) Synthesis

Tabulation:

The field data are entered into a two - way matrix in which rows represent species and the columns represent relevés. A raw table is then constructed and examined for positive and negative species associations, the positively associated species being grouped together. The general (companion) and infrequent species which do not show clear discriminant floristic associations are listed in the lower part of the table. The rows (species) and columns (relevés) in the matrix are then reshuffled until clear species - relevé groups are obtained. The table has been shuffled using permanently visible perennial species only, however, the ephemeral species and geophytes in the corresponding relevés are indicated in part B of Table 7.1.

The computer program TABSORT (of the Botanical Research Unit, Stellenbosch) was used as a tool in compiling the final table from the raw table. This computer program facilitated more rapid, efficient sorting of species - relevé data.

Within each nodum (species - relevé group), the species are placed in order of presence and the relevés can be arranged in sequence according to decreasing total number of species, any environmental gradient observed, or any other varying character of the vegetation or habitat observed (Braun - Blanquet 1964 from Werger 1974). In this case the relevés within each species-relevé group are arranged according to increasing relevé number rather than any vegetation or habitat characters.

In the past there has been some contention as regards the inclusion or exclusion of unrepresentative relevés from the phytosociological table. Werger (1974) considers that " the retention of relevés that are atypical of a nodum has definite advantages in initial studies of undescribed areas, since these relevés may well prove valuable data for the later recognition of previously unrecognised and undersampled syntaxa." Westhoff & Den Held (1969 from Werger 1974) argue that the transitional relevés give information on the habitat of the transitional stands, once a proper syntaxonomical system is available. "The transitional habitat is a mixture of the habitat requirements of the communities that constitute the transitional stand. The relative importance of the various habitat factors is in direct correspondence with that of the constituent communities. Therefore relevés should not be rejected on prejudice " (Werger 1974). A relevé should only be ommitted from the table when it appears to be clearly heterogeneous. No relevés have been omitted from the Vaalputs phytosociological table.

Character species, differential species and synthetic characters:

It is necessary to distinguish between dominant and constant species. Constant species occur constantly over the entire table, whereas differential species are limited to one, or a number, of communities thereby distinguishing these communities from floristically related communities. The differential species need not have a high presence value within the community for which it is preferential, and may be equally well, if not better represented in still other communities. A special type of differential species is a character species which is restricted to one community or occurs optimally in one community compared to others, i.e. it may be exclusive, selective or preferential. In this study no attempt has been made to distinguish character and differential species following reasons supplied by Leistner & Werger (1973), that character species only represent a special type of differential species, and that a valid decision on whether species typifying associations in this area are to be regarded as character or differential species can only be made when more data are available from the Karoo - Namib floral Region. No formal syntaxonomical classification is attempted, and the species-relevé groups are termed communities (Robinson 1976) which, in this study, are distinguished by differential species combinations. Character and differential species have a smaller ecological amplitude than companion species (Werger 1974).

Companion species or accompanying species do not differentiate between communities, and they may be constant as well as rare. Companion species have the widest ecological amplitude compared to character and differential species.

There are various synthetic characters, such as the average number of species in the relevès of a community, the community structure and fidelity, which is the faithfulness of a species to a community or certain communities, based on presence, cover - abundance, sociability and vitality (Werger 1974). In this study, the average number of permanently visible perennial species is indicated in addition to the average number of species in the relevès of a community.

Ecological confirmation of the table pattern:

The community - type is correlated with specific habitat conditions, and the ecological amplitude of all taxa is considered (Werger 1974). Further correlation between the plant communities and habitat characteristics is provided by means of ordination techniques and resulting scatter diagrams.

Summary table:

The presence of every species within each community is rated on a six - point scale and the range of its cover - abundance value is noted.

+ species present in < 5 % of the relevès of a community
1 species present in 5 - 20 % of the relevès of a community
2 species present in 21 - 40 % of the relevès of a community
3 species present in 41 - 60 % of the relevès of a community
4 species present in 61 - 80 % of the relevès of a community
5 species present in 81 - 100 % of the relevès of a community

Each community is thus reduced to a single column in the summary table, so that it is easy to assess which species are faithful to the various communities.

Nomenclature:

Each community name is composed of three parts, the first representing the diagnostic differential species and most prominent differential species or prominent companion species, in some cases, which would make the community more easily recognizable in the field; the second part being the structural classification (Edwards 1983) and the third part a term conveying something about the habitat of the particular community.

Homotoneity and affinities between syntaxa:

The average number of species in the relevés of a community is a standard for judging the relative floristic agreement between the relevés and the communities to which they belong because it is based on the total number of species in each relevé. However, in a semi-arid area such as this there can be considerable variation in the number of species in each relevé from season to season and from year to year, because of the strong geophyte and ephemeral components. For this reason it would be better to compare the average number of permanently visible perennial species in the relevés of each community, even if these averages are not a true indication of the relative floristic richness of the communities. For example, repeat samplings of some of the same relevés in the Stipagrostis ciliata var. capensis - Asthenatherum glaucum community yielded the lowest number of species (1 species) of all the communities during most of the year, and the highest number of species (38 species) of all the communities during spring after sufficient rainfall, during 1983.

One has a homogeneous community - table if the total number of species in each relevé is similar for all relevés within one community. Table homogeneity is equivalent to homotoneity. The absolute values of homotoneity are unimportant, what is important is the deviation of the value for each relevé from the average, in that it indicates the extent to which each relevé is floristically representative of the entire community. If the permanently visible perennial species are considered in the classification, there is not too much deviation of the relevés from the average. This is, however, not so if all the species are considered, for reasons mentioned above. Robinson (1976) encountered the same problem when dealing with the vegetation of the Namib Desert Park.

6.1.b) DISCUSSION OF THE METHODS OF VEGETATION ANALYSIS

(i) Classification or ordination ?

Introduction

There are two seemingly dichotomous views as regards the nature of vegetation:

- the community-unit theory, which regards vegetation as comprising distinct units which are present in the structure of natural communities, and which are in contact with each other along narrow boundaries. This implies discontinuity between units. "The units can be combined to form abstract classes or types reflective of natural entities" (McIntosh 1967);

- the continuum concept which regards vegetation as undifferentiated and continuously changing along different gradients. There is continuity between communities.

The community-unit theory is consistent with the Classificatory School of Thought, whereas the continuum concept is consistent with the Individualistic School of Thought, as regards the nature of vegetation.

The community-unit theory

The community-unit theory "postulates that vegetation consists of natural entities usually in contact with each other along narrow boundaries" (Werger 1974). This applies to a natural situation in the sense that there has been no influence or disturbance of the community by man. In environments where conditions such as climate, soil, animal influences, and time are comparable, similar, recurring plant assemblages occur. Their tolerance ranges are similar. These concrete units can be combined to form abstract classes, each of which have distinguishing characteristics (Daubenmire 1966).

The Zürich-Montpellier or Braun-Blanquet approach to vegetation survey is consistent with the community-unit theory. This is the method chosen to classify the vegetation of Vaalputs.

The continuum concept

The continuum concept of Gleason (McIntosh 1967) states that no two concrete units (or stands, of Cain & Castro 1959) in the vegetation of an area are floristically the same, and that there is a continuous gradient in the variation of the floristic composition of one stand to another which can be correlated with a gradient in environmental conditions (Greig-Smith 1964, Lambert & Dale 1964, McIntosh 1967, Morris 1969, Louw 1970, Bredenkamp 1982).

In considering whether or not the community-unit theory and continuum concept conflict, one need only view the difference between the two hypotheses as one of degree. There are situations where there are discontinuities between community-types due, perhaps, to change in habitat, historical treatment, or chance (Greig-Smith 1964, McIntosh 1967). There are also situations where gradations occur possibly as a result of disturbance of the vegetation. The community-unit theory and continuum concept do not necessarily conflict.

It appears that the method of analysing the vegetation and the organization of the results can determine whether the vegetation consists of units or continua. This was demonstrated by Daubenmire (1966) for the Steppe vegetation, Washington. By ignoring population structure and dynamics, and by focussing attention on floristics and relative abundance with all species treated as having the same ecological significance wherever they occur, a floristic continuum can be demonstrated. This continuum approach denies recognition of competition which is an imortant factor.

One of the major areas of contention between proponents of each theory is the choice of sample area. The community-unit theory is said to be biased as a result of sample area selection being subjective. The results would therefore tend to support the theory of discrete units. The continuum concept has vegetation selected objectively, but it is argued that this gives the appearance of continuity by the use of mixed, unstable, or rare species groupings (Daubenmire 1966).

The community-unit theory would seem to be the more practical method to use for classifying results, and for its predictive value. The continuum concept may, however, be useful in interpreting results and illustrating the dissimilarities between community-types. Ordination methods are often used in this case, but not necessarily so. The continuum concept is also useful in interpretation of changes in communities along environmental gradients. The two theories should be used in conjunction with each other, as has been done in this study.

Both methods are also complementary in their treatment of sample data. Stands sampled for a classification can be subjected to ordination (as has been done here), while stands sampled for an ordination can be classified, provided they are floristically complete enough (Mueller-Dombois & Ellenberg 1974).

A classification aims at grouping individual stands into categories and it emphasizes the similarity between stands. In contrast, an ordination aims at portraying the individuality of each stand; it emphasizes the dissimilarity of all stands to one another in the form of geometric models.

Ordination is used so as to interpret the results of the Vaalputs vegetation obtained by means of the Braun-Blanquet survey method.

(ii) The Braun-Blanquet method of classification

Introduction

The basic unit of classification is the association (Whittaker 1962). This is an abstract unit which can be grouped into higher units on the basis of floristic composition rather than on the basis of physiognomy. These higher units are successively larger, more heterogeneous groups that reflect successively lower degrees of similarity. The community - unit theory is a floristic - sociological approach to vegetation survey.

The association consists of character - species which are species restricted to, and characteristic of, a particular community. They may be minor species (not prominent) in the community, but diagnostic of it and its environment. In this study the term community is used rather than the term association.

The Braun - Blanquet method, as summarized from Werger (1974), requires subjective selection of representative samples of communities. The most efficient way of finding units or associations which are abstracted from actually occurring stands, is to subjectively select those stands which are representative of the vegetation, structurally and floristically. Each plot represents only one community. This will give the maximum information for description of a community - type.

The plots must be of a minimum size so that the community can be sampled most efficiently and also that it can be adequately represented. Homogeneity of vegetation structure and habitat is important in the community - unit theory approach, because the information from the sample should come from one community only, and not from mixtures of communities.

Sampling should be done so that each plot adequately represents the structure of the surrounding vegetation. The strata in a stratified community can not be considered as separate, independent ecological units except in the case of crustal lichen communities on trees and in the case of aquatic communities (Werger 1974).

A floristic list is made and the relative importance of each species in a quadrat is rated on a cover - abundance scale. The vegetational units or associations are obtained after the samples are shuffled on phytosociological tables. These can then be interpreted ecologically, and classified.

A certain degree of continuity or gradualness in transitions between community - types is recognised, i.e. some boundaries are more sharp than others (Whittaker 1973).

The Braun - Blanquet method is useful in the sense that it classifies vegetation on the basis of associations, and from this predictions can be made, as roughly the same combination of species occur together. The units have a large amount of practical value. The community - unit theory (Braun - Blanquet method) centres on subjectively chosen community - types which makes it difficult to see the relationships existing between vegetation types that are dissimilar, which is possibly one of its disadvantages. The "community - unit theory is essentially one of correlation and similarity in vegetation study" (McIntosh 1967).

Plot size

It is essential, for economic reasons, to sample vegetation efficiently, so as to obtain the maximum information with the minimum of time and effort. The sampling procedure must, therefore, be adequate and consistent with the information required as all conclusions derived will depend on the sampling.

Goodall (1952) and Werger (1972) trace the development of the concept of minimal area fairly thoroughly. Jooste (1980) gives the Zürich - Montpellier school's definition of minimal area as "that area at which the species area curve becomes approximately horizontal ", and that of the Uppsala school as " the area at which the constancy - area curve becomes approximately horizontal, where a constant is a species which has a frequency of not less than 90 percent " (Hopkins 1957). Mueller - Dombois & Ellenberg (1974) define minimal area as " the smallest area on which the species composition of the community in question is adequately represented."

Werger (1972) is of the opinion that the community or association should be known prior to determining the minimal area, therefore it is impossible to define minimal area objectively, and optimal plot size should rather be used.

The scale of the survey being undertaken is also important in determining the type of method used to calculate the optimal sample size. On a scale of survey encompassing a number of communities, the optimal plot size may be determined by using regression equations based on a logarithmic series. The two equations which may be used are those of Gleason (1925) and Fisher, Corbet & Williams (1943), cited in Werger (1972):

$$y = a + b \log x \qquad \text{(Gleason 1925)}$$

where y is the expected number of species on area x, and a and b are constants derived from observed data, and

$$S = a \log (1 + N/a) \qquad \text{(Fisher } \underline{\text{et}}\ \underline{\text{al}} \text{ 1943)}$$

where S is the number of species observed, N is the number of individuals, and a is a constant.

Most uniform populations or plant communities should manifest themselves within an area of one hectare, which can be regarded as the maximum (100 %) level of information (Williams 1943). The plot size can therefore be calculated depending on what level (%) of information is required per plot.

According to Werger (1972), Scheepers (1968), in attempting to determine the most efficient plot size in a survey of the Highveld, using time measurements and increase in species per area, concluded that time depends on too many other variables, amongst others, wind, rain, temperature, and the human element, and is thus not suitable as a measurement.

A species - area curve is another method of determining the minimal sample size of a relatively homogeneous (uniform habitat and plant cover) community. In constructing the species - area curve, the nested plot technique is used, in which the sample area is increased by doubling the previous area and recording the new species present. The area is increased until there are few or no new species. The number of species is plotted against the size of the sample area. The minimal sample size is found by taking the value at which the curve flattens.

The scale of the axes selected in plotting the species - area curve will influence the minimal sample area because the rate of flattening of the curve will change with change in y - axis relative to x - axis (Goodall 1952, Cain & Castro 1959). For this reason it is better to use a slightly larger sample area than that determined from the curve.

Cain (1938) suggests that this may be eliminated by taking a point at which a 10 % increase in the total sample area results in a 10 % increase in species. This point is joined to the origin and the point at which a line parallel to this touches the species - area curve tangentially, is taken as the x - value which defines the minimal sample area. Goodall (1952) indicated that this method depends on the largest area surveyed; the larger the area, the larger will be the minimal area.

The largest minimal area obtained for several plots within the same community should be the minimal sample size for a relevé. Three areas were determined for each community on Vaalputs, using the species-area curve and nested plots technique. Random nested plots may also be used in constructing the species - area curve, but this is not as practical as the nested plots technique as the chances of missing out rare species are increased.

Mueller - Dombois & Ellenberg (1974) advocate the species - area curve to be the best way of determining minimal sample area for species diversity, but not suitable for determining the sample area needed for the number of individuals per species, cover or frequency.

Plot selection

The Braun - Blanquet method (Werger 1974) requires subjective selection of representative samples of communities, structurally and floristically. In the survey of Vaalputs, plots were placed in subjectively selected homogeneous areas which appeared to represent the vegetation units present. An area was considered to be homogeneous where the vegetation was structurally and floristically uniform and where there were no marked changes in the habitat (Shimwell 1971, Westhoff & Van der Maarel 1973, Jooste 1980).

The recognition of units or subdividing of the vegetation cover is always subjective (Mueller - Dombois & Ellenberg 1974). However, the subsequent selection of sample plots within these units may be either subjective or objective.

Plots were not selected systematically or randomly, as this objective approach essentially means sampling according to chance (Mueller - Dombois & Ellenberg 1974). The vegetation patterns were clear enough so as to be able to recognize initial units. Objective selection of plots would have eliminated any further choice in locating samples within these units and would, therefore, have been too inflexible an approach. Subjective plot selection is a more efficient method of data collection and utilization, provided that statistics are not needed to back up any conclusions which are made. Jooste (1980) gives sufficient justification for using subjectively selected plots, among other reasons, that an objective approach would increase the chances of ecotones being sampled sufficiently to be extracted as community - types in the phytosociological tables, and besides being time-consuming, a large number of plots would also be needed to sufficiently sample all the smaller variations. This is well illustrated by Goodall's (1953) method - study of objectively dividing an Eucalyptus stand into four subassociations. This operation took five days whereas the application of Braun - Blanquet's relevè method would have clarified the four entities in four hours through floristic comparison (Mueller - Dombois & Ellenberg 1974).

Werger (1974) advocates an even distribution of relevès over the entire study area to ensure that the total variety in the area is reflected adequately. This was not done on Vaalputs as the plant communities were very localised, which resulted in an uneven sample distribution so that an adequate number of plots could be put out in each recognizably different unit.

The plots on Vaalputs were not all marked permanently, but were all given a set of coordinates (Appendix IV). The 4 m x 4 m plots were all square in shape.

Number of relevès

Mueller - Dombois & Ellenberg (1974) suggest that several sample stands (a minimum of between five and ten) should be established particularly in what has been recognized as similar recurring plant combinations. This will permit an assessment of whether these recombinations, which seem useful for classifying into types, really are similar. This is what Poore (1962) calls sampling of noda.

The number of plots required depends on the scale of the survey, the degree of accuracy required, as well as the heterogeneity of the area. Leistner & Werger (1973) and Jooste (1980) made relatively fewer relevès in the vegetation units which were relatively homogeneous and covered large parts of the study area. The same approach was adopted on Vaalputs.

Floristic lists

A list of all the plant species occurring in each plot was drawn up, including lichens which were present. The plants were identified as far as was possible under the circumstances, bearing in mind that many of the plants in this area are drought deciduous.

The classification requires complete species lists from each plot (Poore 1955, Becking 1957, Shimwell 1971, Werger 1973 and Robinson 1976), however, in arid and semi - arid areas such as this, it is not always possible to draw up a complete species list unless each plot is visited a number of times, at various times of the year, over a period of years. Table 7.1 illustrates how additional species were recognized in the repeat plots at different times of the year, and after rain had fallen on Vaalputs.

The irregular rainfall and associated temperatures mean that some geophytes and annuals may not be visible every year or at any particular time of the year (Werger & Leistner 1973 in Werger 1974, Robinson 1976). Robinson (1976) gives the example of the Sesuvium sesuvioides - Stipagrostis obtusa community in the Namib Desert Park where geophytes, which were numerous following rains in 1972, were absent from the same sites in 1973. Similarly, Le Roux (1984) illustrates how the ephemeral component differs between two successive years (1975 and 1976) for the same sites on the Hester Malan Nature Reserve in Namaqualand. For these reasons only the permanently visible perennial species, which constitute the more permanent component of the vegetation, were considered in the classification, although the geophytes and ephemeral species which were recorded for 1983 are also included in the descriptions. All species recorded are considered in the ordination.

Where it is not possible to visit plots more regularly over a period of time, one has to use perennial (permanently recognizable) species (Werger, Kruger & Taylor 1972, Werger 1973a, 1973b), which are generally better indicators of specific habitat factors than ephemeral species in arid regions (Batanouny & Abu El - Souod 1972 in Werger 1974). This was confirmed by Leistner & Werger (1973) in the southern Kalahari (Werger 1974). Werger (1974) refers to other workers, such as Grunow (1965), Ayyad & Ammar (1973) and Zohary (1973), who found that annuals play a relatively unimportant role in vegetation classification in dry regions.

In contrast to this, however, Garcia - Moya (1972) found annuals to be very useful in a phytosociological classification of arid vegetation of Arizona (Werger 1974).

(iii) Ordination

Introduction

The ordination of vegetation stems from the continuum concept of Gleason (McIntosh 1967 cited in Bredenkamp 1982).

Ordination is a method of analysing field observations for the purpose of recognizing those factors which are likely to be most important in determining the distribution of plants and vegetation (Gittins 1969). The data used consists of estimates of the composition of a number of vegetation samples in terms of cover and abundance of species represented. In this study data was collected using the Braun-Blanquet method (Werger 1974). The stands and species are ordinated so that the associations or arrangement of the entities provide some insight into the ecological processes which may have caused the observations (Gittins 1969). According to Bredenkamp (1982), ordination is often a multistatistical analysis of vegetation data (Gittins 1965) or habitat data (Tracey 1969, Jeglum, Wehrhahn & Swan 1971) in an attempt to gain an objective insight into the composition and structure of the stands in relation to environmental factors (Gittins 1965).

Gittins (1969) views the name "ordination" as embracing a group of methods rather than a single technique. A large variety of ordination techniques exist and much has been written on the subject by many authors, amongst others, Bray & Curtis (1957), Seal (1964), Bannister (1968), Anderson (1971), Gauch & Whittaker (1972), Noy-Meier & Whittaker (1977), Cottam, Goff & Whittaker (1978), Noy-Meier & Whittaker (1978), Orlóci (1978), Whittaker & Gauch (1978), Bredenkamp (1982) and Gauch (1982).

An attempt has been made, using the vegetation data for Vaalputs, to realise the three objectives of ordination as set out by Van der Maarel (1979), namely summarization, ordering and trend seeking. This was done by attempting to reduce the dimensionality of the data in order to find trends which would clarify and aid the interpretation of the results.

Detrended Correspondence Analysis

DECORANA, which is a FORTRAN program for detrended correspondence analysis (DCA) and reciprocal averaging (RA) (Hill 1979) was the ordination method used on the vegetation data from Vaalputs. Although the author is not familiar with all the multivariate techniques available, DCA was chosen as it has been used successfully in vegetation ecology by Westfall, Van Rooyen & Theron (1983); Theron, Morris & Van Rooyen (1984) and Slack & Glime (1985).

The Ecology and Systematics section at Cornell University, New York, claim that their "tests indicate that DECORANA is the best general purpose ordination, superior to RA and multidimensional scaling, and far superior to principal components analysis" (Hill 1979).

In evaluating DCA against some of the other ordination methods, particularly RA and PCA, using some of the criteria of Whittaker & Gauch (1978), its two greatest advantages are its relatively weaker distortion by elimination of the arch effect, and its correction for compression of the axis ends.

Reciprocal averaging, principal components analysis and non-parametric multidimensional scaling all have the problem of the "arch" effect (Kendall 1971) which is produced by the quadratic dependency of the second axis on the first axis. There is often also some relationship between the first and higher axes. DCA avoids this effect by having no correlation and no systematic relation of any kind between the first and higher axes, i.e. it represents an independent direction of variation on axis 2 (Hill & Gauch 1980). This is done by calculating the first axis by reciprocal averaging, and detrending axes subsequent to the first. The method of doing this is explained by Hill (1979).

Hill (1979) and Hill & Gauch (1980) indicate that DCA, although avoiding the arch effect, still retains an analogous, though far weaker distortion, by replacing the spurious quadratic axis by a spurious cubic axis (applying to the third and higher axes).

Hill & Gauch (1980) cite examples of the field data on which DCA has been tested. They concluded that there was consistently greater ease in interpretation of results compared to other techniques. This they attributed to the more efficient relationship of the axes to environmental gradients, and the interpretation of the scaling in terms of species turn-over along gradients. So, there is greater clarity of the ecological meaning of the results, which may, or may not, also be related to heuristic function (success in revealing new insights in the relationships between plant communities and their environments) (Whittaker & Gauch 1978).

DCA presents greater clarity of the ecological meaning of results in that the resulting ordinations have species appearing and disappearing at a roughly constant rate along the gradient, and the within-sample standard deviation is approximately 1 (Hill 1979). The unit of distance along the gradient [beta-diversity in the sense of Whittaker (1960)] is termed a "standard deviation" (sd).

6.1.c) Vegetation Map

The initial vegetation mapping was done onto a 3x enlargement of a 1:50 000 aerial photograph i.e. at a scale of approximately 1:16 600. The final vegetation map (Appendix I) was drawn at a scale of 1:10 000 with the aid of orthophoto maps. Many of the plant communities were present as small scattered patches, which made it difficult to map them individually. In these cases they have been indicated as mosaics of plant communities.

6.2. HABITAT CHARACTERISTICS

6.2.a) ALTITUDE: The altitude for each plot was determined from a 1 m contour survey map (from NUCOR) on a scale of 1:10 000 which is far more detailed than the existing 1:50 000 topographic maps.

6.2.b) LAND FACETS: The land facets were determined from the scheme illustrated on Fig. 6.1 (McDonald 1983).

6.2.c) SURFACE ROCK COVER: The percentage surface rock cover was estimated visually.

6.3. SOILS

6.3.a) Sampling procedure and sample preparation

A sample of approximately 1 kg was taken just outside the first 100 relevés, and thereafter from every second relevé as the time and costs involved limited the number of soil samples analysed. Certain parameters such as soil depth were, however, recorded for each relevé. Sampling was done by digging a pit down the profile using a spade, as far as the dorbank layer, any other hard layer, or the basement. The top two centimetres of soil were scraped away, and the sample was taken down the profile to a point where there was a change in horizon. As the soils in this area are weakly developed there was often only one horizon to sample.

The soil sample preparation was done in accordance with the procedures set out by the Fertilizer Society of South Africa (F.S.S.A. 1974). The soil was air-dried and crushed to pass through a 2 mm sieve.

6.3.b) Soil classification

For each profile the soil form and soil series were determined, as far as possible without chemical analyses, using the binomial system of classification of MacVicar *et al* 1977.

LAND FACETS

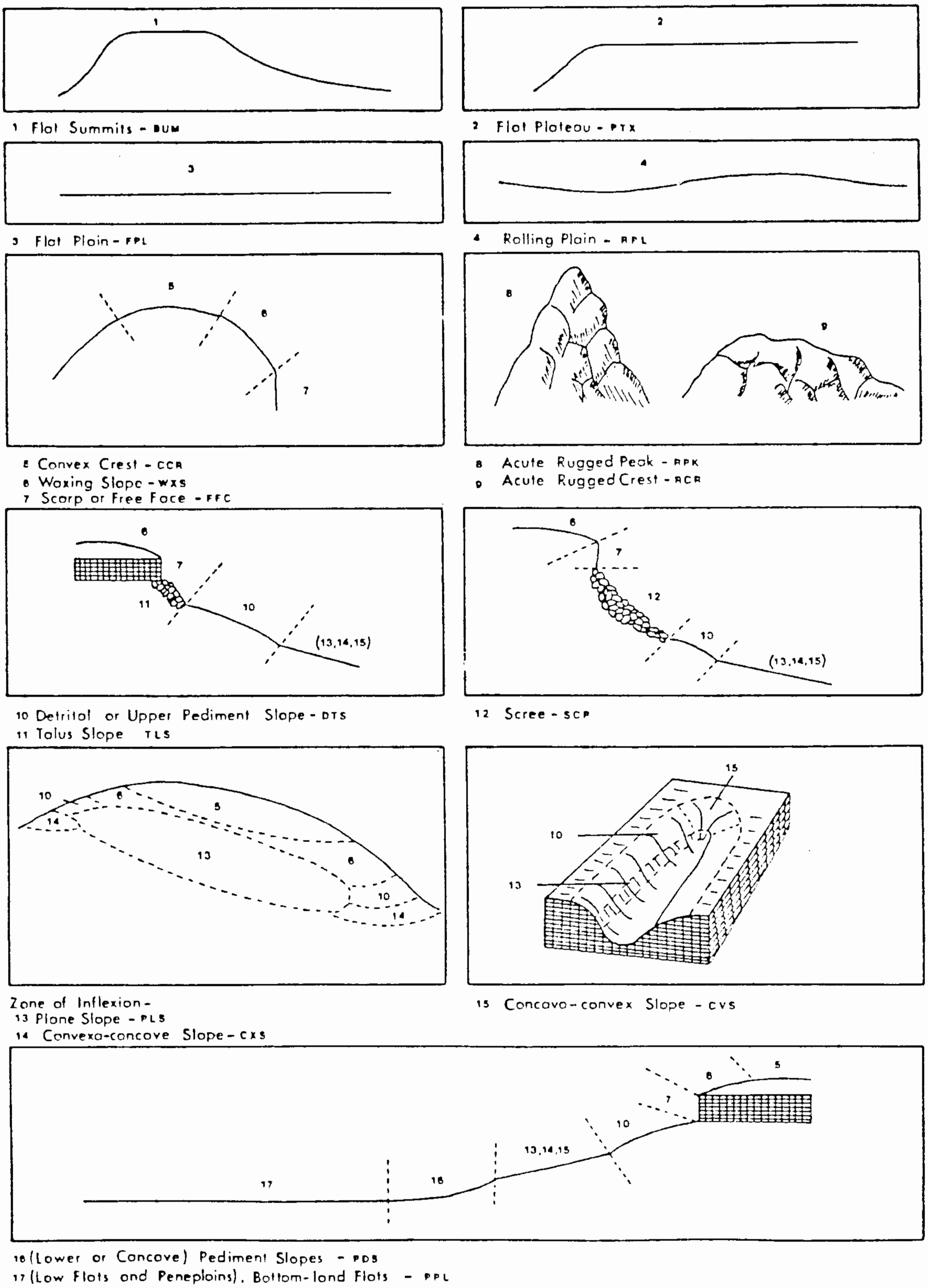
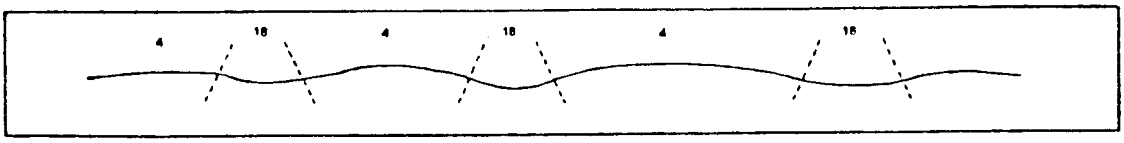
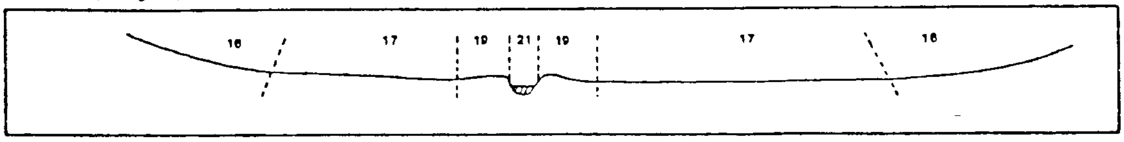


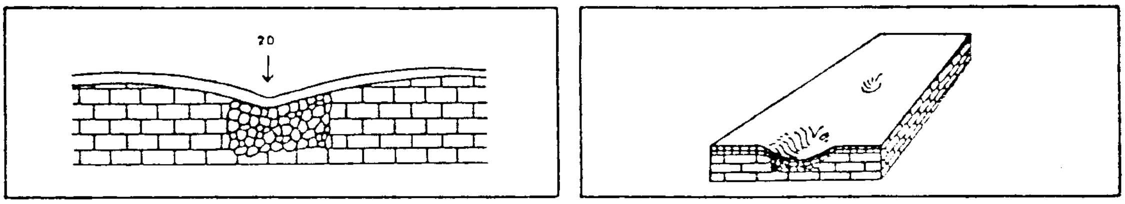
FIGURE 6.1 Land facets (McDonald 1983)



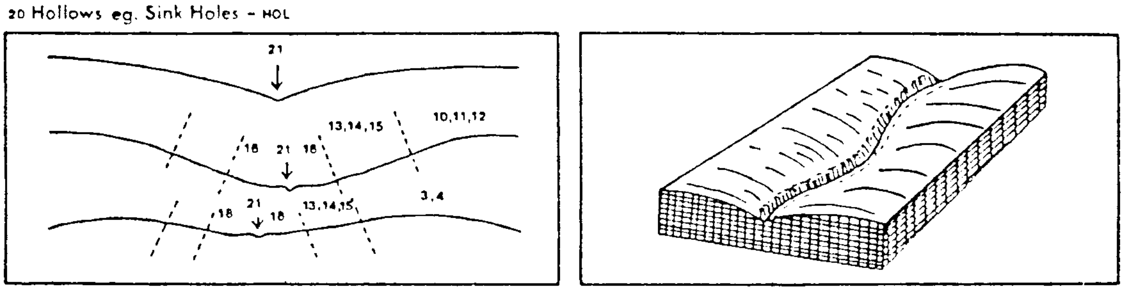
18 Swales ('Leegtes') - SWL



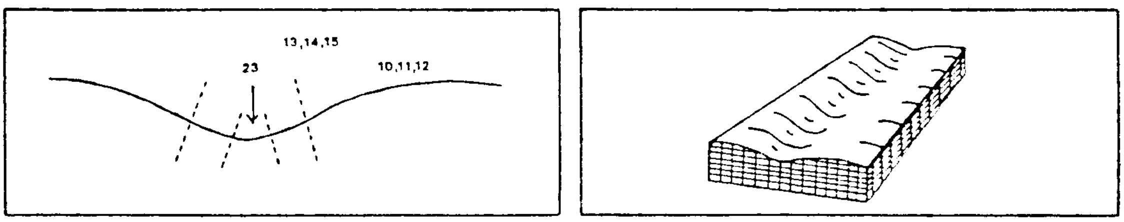
19 Levees (and Bottom-land Convexities) - LEV



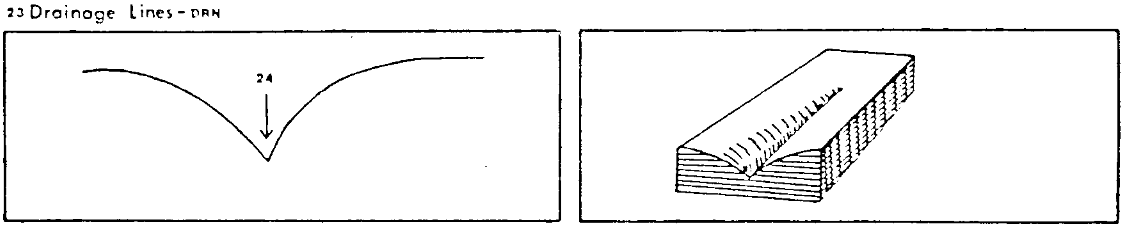
20 Hollows eg. Sink Holes - HOL



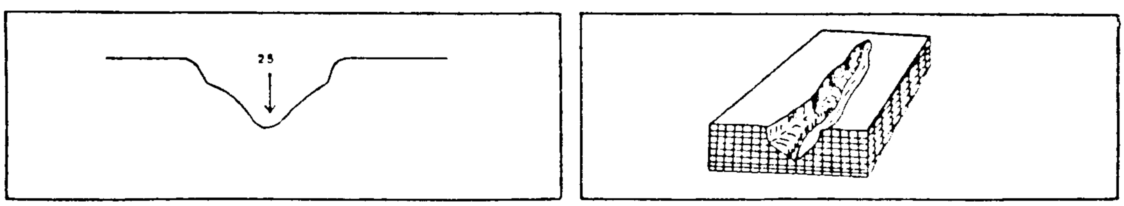
21 Water Courses - RIV 22 Estuaries - EST



23 Drainage Lines - DRN



24 Ravines and Kloofs - RAV



25 Dongas and Gullies - GUL

FIGURE 6.1 (continued)

6.3.c) Soil Colour

The colour of the A and B master horizons (MacVicar *et al* 1977) were determined using the Munsell soil colour chart. The abbreviations for soil colour used in the tables are as follows:

yr = yellowish red
yb = yellowish brown
rb = reddish brown
r = red
lrb = light reddish brown

6.3.d) Soil depth

The soil depth to the basement rock or hard subsurface layers (calcrete, silcrete or dorbank) was determined by digging a pit just outside each relevé. This was considered to be the effective depth which is ecologically more meaningful in that these hard layers limit the penetration of roots and water infiltration.

6.3.e) Soil sample analyses

(i) Physical properties

Structure

The soil grade in this area is structureless or weak. Structureless soils have no observable aggregation of grains and weakly structured soils have poorly formed indistinct peds, or crumbs, which are barely observable *in situ*.

Texture

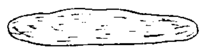
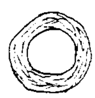
The soil textural classes were determined using the rough field procedure (modified from the method originally described by Loxton

1963, cited in F.S.S.A. 1974) set out below:

FIELD KEY TO SOIL TEXTURAL CLASSES (no stones, gravel or roots)

1(a)	soil consists of lumps or aggregates	2
(b)	no lumps; soil is loose; only sand grains can be seen & felt	SAND
2(a)	lumps or aggregates are not disrupted by slight pressure	4
(b)	aggregates are easily disrupted after slight pressure	3
3(a)	wet to moist soil cannot be made to a little thin roll (worm) by fingers and hand; sand can be felt easily	LOAMY SAND
(b)	soil can be made to a little thin roll, which is not firm and breaks easily when bowed	SANDY LOAM
4(a)	wet to moist soil made to a roll of 3-5 mm diameter is firm	5
(b)	soil roll (3-5 mm) is not firm, sand can be felt easily	LOAM
5(a)	wet roll adheres to fingers	6
(b)	wet roll does not adhere, is plastic and can easily be deformed	SILT LOAM
6(a)	no sand is felt in the roll	7
(b)	sand grains can be felt	SANDY CLAY LOAM
7(a)	roll can be deformed, but gives some resistance when deformed with fingers	CLAY LOAM
(b)	roll is very stable, flexible and can be bowed without breaking; roll adheres to fingers and more pressure is needed to deform the wet soil	CLAY

A rough estimate of the percentage clay present in each of the soil textural classes is presented below (Loxton 1963 in F.S.S.A. 1974):

	TEXTURE	% CLAY
—	SAND	0-10
	LOAMY SAND	>10-15
	SANDY LOAM	>15-20
	SANDY CLAY LOAM	>20-35
	SANDY CLAY	>35-55
	CLAY	>55

The grain size distribution of the sand fraction of 84 soil samples was determined by settling tube analysis. The abbreviations used in the tables of results are as follows:

mSa	medium sand
cSa	coarse sand
gSa	gravelly sand
gmSa	gravelly muddy sand
sl gmSa	slightly gravelly muddy sand
sl gSa	slightly gravelly sand

Abbreviations used for sorting, skewness and kurtosis, respectively include:

mod	moderately sorted
poor	poorly sorted

v.well	very well sorted
n symm	nearly symmetrical
positive	positively skewed
v.positive	very positively skewed
meso	mesokurtic
platy	platykurtic
lepto	leptokurtic

Field capacity (soil water retention)

A 100 g sample of sieved (< 2 mm) oven-dried soil was weighed out and placed in a filter funnel plugged with cotton wool previously soaked in alcohol. Water was dripped from a burette onto the centre of the soil and the quantity of water added was recorded before the first drainage drop appeared through the filter funnel.

Bulk density

To determine the bulk density, 200 ml of sieved (< 2 mm) air-dried soil was measured out into a measuring cylinder. The sample was accurately weighed and the weight per ml was calculated.

Organic matter

The organic matter content was determined by weighing out 20 g of soil sample into a crucible and placing it in an oven for 5 hours. It was cooled in a desiccator and reweighed to determine the soil dry weight. The crucibles were placed in a furnace and ignited at 400 ^{o}C for 12 hours. The sample was then cooled in a desiccator and reweighed to determine the organic matter content.

Free carbonate

The presence (+) or absence (-) of free carbonate in the soil samples was determined by dripping a few drops of dilute HCl onto a small amount of the soil sample and recording the degree of effervescence as follows:

A = absent

W = weak

M = moderate

S = strong

(ii) Chemical properties

Soil pH

Soil pH was initially tested in the field at intervals down the profile, particularly in areas of deeper sand. This rough test was performed by wetting the soil sample with distilled water and measuring the pH with Universal indicator paper. As there did not appear to be any marked change in pH down the profile, accurate pH determinations were only made on the soil sample taken from the B-horizon at each relevé. These samples were considered to be the most important as they were taken from the plant root zone.

The soil pH was determined in the laboratory following the procedures set out in the manual of the F.S.S.A (1974). A mass of 20 g of soil was mixed with 50 ml of 1N KCl solution and the pH was determined by measuring this 1:2.5 soil/1N KCl suspension using a pH meter fitted with a glass electrode.

The soil reaction, measured by its pH, has been divided (after MacVicar et al 1977) as follows:

pH 7.5 - 8.4	moderately alkaline
pH 6.6 - 7.4	neutral
pH 5.5 - 6.5	moderately acid
pH < 5.5	strongly acid

Resistance

The resistance of the soil, which is proportional to the concentration of soluble salts in the soil, was determined using a 1:1 soil:distilled water suspension and measuring the resistance by means of a Wheatstone Bridge.

Cation exchange capacity (CEC)

The cation exchange capacity was determined using the procedures of the F.S.S.A. (1974).

Exchangeable cations (Ca, Mg, Na, K)

The exchangeable cations were determined using the procedures set out by the F.S.S.A. (1974). A modification of this was the use of NH_4Cl extracting solution for samples with a pH $\leq$ 6.0, and $CH_3COONH4$ extracting solution for samples with a pH > 6.0. This probably gives a more realistic value for the exchangeable cations at higher pH values (G. Thompson, pers. comm.).

Base saturation

The base saturation was calculated as the ratio of S-value to cation exchange capacity (MacVicar *et al* 1977).

S-Value (total cations)

This is the sum of the exchangeable, rather than soluble, Ca, Mg, Na and K (MacVicar *et al* 1977).

Phosphorus

The phosphorus was determined using the Bray No 2 method (F.S.S.A. 1974). This method gives a value to the "plant available" phosphorus.

The failing of this acid extraction method is that more phosphorus may be extracted than is actually "plant available". There may also be a seasonal change in values which was not taken into account in this investigation.

CHAPTER 7 DESCRIPTION OF THE VEGETATION AND PLANT COMMUNITIES OF VAALPUTS

7.1. INTRODUCTION

Eleven plant communities, based on perennial species permanently visible above ground, are recognized from the Braun-Blanquet phytosociological table (Table 7.1). Three of the communities are associated with calcrete and calcareous soils; three communities with saline soils; two communities on shallow soils overlying basement or dorbank; two communities on soils mixed with some aeolian sand; and one community is associated with deeper, strongly acid aeolian sand.

The structure of the plant communities vary from low/dwarf semi-open shrublands, with a higher degree of succulence and spinescence, over calcrete and saline soils to low/short open grassy shrublands in areas of soil mixed with some aeolian sand, to low open grasslands in the areas of deeper, strongly acid aeolian sand.

The distribution of the plant communities is indicated on Appendix I. The succulent communities and calcrete communities tend to be better represented on the western portion of the study area, whereas the grasslands are confined to the eastern portion of the study area. The central portion consisting of grassy shrublands is a transitional area between the succulent dwarf shrublands and grasslands. The most common shrubs which appear to be invading the grasslands in this transition are _Ruschia robusta_, _Lycium_ spp. and _Euphorbia decussata_. It is not always possible to map the individual vegetation units on this scale as many are represented as isolated scattered patches, particularly on the west and southwestern sections of the site. In these areas, the communities are indicated as mosaics of two or more plant communities.

7.2. THE PLANT COMMUNITIES

The eleven plant communities recognized are:

A. THE APTOSIMUM DEPRESSUM COMMUNITIES ON CALCAREOUS AND SALINE SOILS

- 1.1 The Aptosimum depressum - Salsola tuberculata dwarf/low open shrubland community
- 1.2(a) The A. depressum - Ruschia muricata - Zygophyllum retrofractum low semi-open shrubland community
- 1.2(b) The A. depressum - Ruschia muricata low semi-open//moderately closed shrubland community
- 1.3(a) The A. depressum - Psilocaulon ciliatum dwarf semi-open shrubland community
- 1.3(b) The A. depressum - P. ciliatum - Ruschia cf. R. levynsiae dwarf semi-open shrubland community
- 1.4 The A. depressum - Psilocaulon planisepalum - Salsola zeyheri low semi-open shrubland community

B. THE EBERLANZIA ARMATA COMMUNITIES ON SHALLOW SOILS

- 2.1 The Eberlanzia armata low open//semi-open shrubland community
- 2.2 The E. armata - Ruschia robusta low open//semi-open shrubland community

C. THE STIPAGROSTIS BREVIFOLIA COMMUNITIES ON SOILS MIXED WITH AEOLIAN SAND

- 3.1 The Stipagrostis brevifolia - Ruschia robusta low/short open grassy shrubland community
- 3.2 The S. brevifolia - Lycium spp. complex short open grassy shrubland community

D. THE STIPAGROSTIS CILIATA VAR. CAPENSIS COMMUNITY ON DEEPER, STRONGLY ACID AEOLIAN SAND

- 4.0 The Stipagrostis ciliata var. capensis - Asthenatherum glaucum low open grassland community

THE APTOSIMUM DEPRESSUM - SALSOLA TUBERCULATA DWARF/LOW OPEN SHRUBLAND COMMUNITY ON CALCRETE OUTCROPS

Community number: 1.1

Symbol: ◆

CLASSIFICATION (Table 7.1)

Community: *Aptosimum depressum* - *Salsola tuberculata*

Veld Type (Acocks 1975): Relics of Arid Karoo within the False Succulent Karoo

Edwards (1983) structural class: Dwarf/Low Open Shrubland

RELEVES

Total number: 12

List: 71, 77, 78, 85, 89, 90, 133, 134, 135, 136, 155, and 156

Grid location: 3018 BA 11;12

RELEVE HABITAT DETAILS (Tables 7.1, 7.2 & 7.3)

Land-facets: Convex crests (12 relevés)

Altitudinal range: 1 010-1 030 m

Aspect: variable

Slope: $1^{o}-4^{o}$ (average 2.6 %)

Rock cover: 70-90 % (average 80.7 %)

Geology: Surficial deposit - Qc (calcrete)

Substrate: Calcrete nodules with a little sand and stones in places

Soil series: Ms22 (Kalkbank) (12 relevés)

Soil depth: 1-24 cm (average 14.5 cm)

Soil moisture: well-drained

Soil colour: yellowish red

Soil analyses:

Soil pH: 6.7-8.3 (average 7.8)

Bray 2 P: 0.71-79.97 ppm (average 38.556 ppm)

Base saturation: 66.74-565.72 % (average 307.806 %)

Resistance: 330-3 600 Ω (average 1 712.8 Ω)

Cation exchange capacity: 3.77-6.82 me% (average 5.067 me%)

S-value: 6.25-46.67 me% (average 27.11 me%)

Exchangeable Na: 0.16-1.27 me% (average 0.66 me%)

Exchangeable K: 0.58-0.86 me% (average 0.727 me%)

Exchangeable Ca: 3.22-43.50 me% (average 24.433 me%)

Exchangeable Mg: 0.94-1.93 me% (average 1.29 me%)

Free carbonate: present (weak to strong reaction with HCl)

Organic content: 1.10-3.16 % (average 1.716 %)

Field capacity: 116.09-138.98 (average 127.857) gH_2O/100g soil

Bulk density: 1.20-1.60 g/ml (average 1.387 g/ml)

RELEVE VEGETATION DETAILS (Table 7.1)

Projected cover: 8-13 % (average 10.8 %)

Total number of species: 4-22 (average 14)

Number of permanently visible perennial species: 4-12 (average 8)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: *Aptosimum depressum*, *Zygophyllum retrofractum*, *Z. gilfillani*, *Hirpicium alienatum*, *Euphorbia* cf. *E. gentilis*, *Salsola tuberculata*, *Psilocaulon articulatum*, *Titanopsis schwantesii* and *Chrysocoma tenuifolia*.

Conspicuous species: *Zygophyllum retrofractum*, *Z. gilfillani* and *Salsola tuberculata* are the conspicuous differential species.

Companion species: *Xanthoria marlothii*, a lichen, is associated with the woody shrubs in this community.

Physiognomic structure: Overgrazed stubbly fruticose chamaephytes predominate, forming the highest layer between 0.18 and 0.30 m. The lower layer consists of leaf succulent chamaephytes.

IDENTIFICATION

This community is distinguished from the Aptosimum depressum - Ruschia muricata - Zygophyllum retrofractum community by the absence of Ruschia muricata and the less prominent occurrence of Psilocaulon planisepalum.

GEOPHYTES AND EPHEMERALS (for 1983) (Table 7.1)

Associated species: Pentzia pilulifera, Gazania lichtensteinii, Mesembryanthemum karrooense, JWL132, Felicia australis and Dregeochloa pumila.

Companion species: Leysera tenella, Schismus barbatus, Heliophila variabilis, Galenia papulosa and Dimorphotheca Polyptera.

NOTES: Titanopsis schwantesii blends in very well with the calcrete, looking much like a calcrete nodule.

PHOTOGRAPH (Fig. 7.1)

FIGURE 7.1 The Aptosimum depressum - Salsola tuberculata (St) dwarf/low open shrubland community on calcrete.

Table 7.2 Soil depth together with some chemical and physical properties of the soils from the <u>Aptosimum depressum</u> - <u>Salsola tuberculata</u> dwarf/low open shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %) Na	K	Ca	Mg	FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
71	24	7.9	20.71	565.72	600	5.28	29.87	1.27	0.83	26.50	1.27	S +	1.60	129.52	1.39
77	7	6.7	24.28	165.78	3600	3.77	6.25	0.29	0.81	3.22	1.93	W +	1.10	116.09	1.60
78	24	8.0	43.55	306.29	2700	4.45	13.63	0.16	0.58	11.95	0.94	M +	1.65	123.55	1.51
89	9	7.6	67.83	66.74	3200	3.96	32.35	0.17	0.61	30.50	1.07	S +	1.35	129.66	1.38
134	12	8.0	32.84	444.00	1100	6.75	29.97	0.59	0.63	27.52	1.23	S +	1.85	-	1.37
135	14	8.1	79.97	454.98	460	6.82	31.03	0.88	0.86	27.84	1.45	S +	1.30	129.34	1.26
155	24	8.3	0.71	151.13	330	4.44	46.67	1.26	0.77	43.50	1.14	S +	3.16	138.98	1.20

Table 7.3 Soil colour, soil texture and a statistical summary of textural analyses of the sand size fraction of some soils from the Aptosimum depressum - Salsola tuberculata dwarf/low open shrubland community

RELEVE NO.	TEXTURE (sand fraction)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemming 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL >2 mm (%)	SILT & CLAY < 63 μm (%)	SAND/ SILT & CLAY RATIO	MEAN	STD SORTING	SKEWNESS	KURTOSIS	MEDIAN	SOIL COLOUR CODE (Munsell chart)	SOIL COLOUR
71	mSa	sl gmSa	mod	well	n symm	platy	3.24	21.67	3.47	1.07	0.89	0.29	2.60	1.09	5YR5/6	yr
77	mSa	sl gmSa	mod	well	n symm	meso	2.44	13.79	6.07	1.18	0.92	0.25	2.98	1.21	5YR5/6	yr
78	mSa	sl gmSa	mod	well	n symm	meso	2.20	12.92	6.57	1.42	0.84	0.27	2.96	1.43	5YR5/6	yr

THE APTOSIMUM DEPRESSUM - RUSCHIA MURICATA - ZYGOPHYLLUM RETROFRACTUM LOW SEMI-OPEN SHRUBLAND COMMUNITY ON CALCRETE AND CALCAREOUS SOILS

Community number: 1.2(a)

Symbol: O

CLASSIFICATION (Table 7.1)

Community: Aptosimum depressum - Ruschia muricata - Zygophyllum retrofractum

Veld Type (Acocks 1975): False Succulent Karoo

Edwards (1983) structural class: Low Semi-Open Shrubland

RELEVES

Total number: 15

List: 3, 18, 27, 42, 47, 58, 73, 82, 88, 110, 111, 124, 125, 165 and 166

Repeat relevé: 88=3

Grid location: 3018 BA 11;12;17

RELEVE HABITAT DETAILS (Tables 7.1, 7.4 & 7.5)

Land-facets: Rolling plains (8 relevés), convex crests (5 relevés), drainage lines (1 relevé) and swales (1 relevé)

Altitudinal range: 1 005-1 030 m

Aspect: variable

Slope: 0^{o}-4^{o} (average 1.7^{o})

Rock cover: 0-90 % (average 25.2 %)

Geology: Surficial deposits - Qc (calcrete) and Q2 (sandy soil)

Substrate: Calcrete nodules and calcareous sandy soil

Soil series: Hu45 (Vergenoeg) (7 relevés) Hu32 (Moriah) (3 relevés); Ms22 (Kalkbank) (3 relevés) and Ms10 (Mispah) (2 relevés)

Soil depth: 5-60 cm (average 30.7 cm)

Soil moisture: well-drained

Soil colour: yellowish red

Soil analyses:

Soil pH: 5.7-8.3 (average 7.7)

Bray 2 P: 7.85-84.25 ppm (average 42.835 ppm)

Base saturation: 80.63-811.44 % (average 284.333 %)

Resistance: 800-3 700 Ω (average 1 973.3 Ω)

Cation exchange capacity: 4.76-15.52 me% (average 7.188 me%)

S-value: 4.29-51.77 me% (average 18.592 me%)

Exchangeable Na: 0.17-3.21 me% (average 0.866 me%)

Exchangeable K: 0.52-1.56 me% (average 0.824 me%)

Exchangeable Ca: 1.90-24.70 me% (average 13.662 me%)

Exchangeable Mg: 0.61-2.87 me% (average 1.546 me%)

Free carbonate: present (moderate to strong reaction with HCl)

Organic content: 0.70-1.82 % (average 1.331 %)

Field capacity: 115.41-141.30 (average 124.095) gH_2O/100g soil

Bulk density: 1.42-1.67 g/ml (average 1.518 g/ml)

RELEVE VEGETATION DETAILS (Table 7.1)

Projected cover: 10-32 % (average 20.3 %)

Total number of species: 4-24 (average 12)

Number of permanently visible perennial species: 4-14 (average 7)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: Aptosimum depressum, Psilocaulon planisepalum, Ruschia muricata, Zygophyllum retrofractum, Z. gilfillani, Hirpicium alienatum and Euphorbia cf. E. gentilis.

Conspicuous species: Zygophyllum retrofractum, Ruschia muricata and Psilocaulon planisepalum are conspicuous differential species, with Pteronia scariosa, Salsola zeyheri and Aridaria noctiflora being prominent companion species.

Companion species: Salsola zeyheri, Pteronia scariosa, Aridaria noctiflora, Stipagrostis obtusa and Xanthoria marlothii are the more common companion species.

Physiognomic structure: Overgrazed stubbly fruticose chamaephytes and leaf succulent chamaephytes predominate forming the highest layer between 0.18 and 0.30 m.

IDENTIFICATION

This community is distinguished from the *Aptosimum depressum* - *Salsola tuberculata* community by the absence of the *Salsola tuberculata* species group, the prominence of *Psilocaulon planisepalum*, and the presence of *Ruschia muricata*. It is distinguished from the *A. depressum* - *Ruschia muricata* community by the presence of the *Zygophyllum retrofractum* species group.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: *Pentzia pilulifera*, *Helichrysum herniarioides*, JWL132.

Companion species: *Galenia papulosa*, *Leysera tenella*, *Schismus barbatus*, *Heliophila variabilis* and *Dimorphotheca polyptera*.

PHOTOGRAPH (Fig. 7.2)

FIGURE 7.2 The Aptosimum depressum - Ruschia muricata (Rm) - Zygophyllum retrofractum (Zr) low semi-open shrubland community on calcrete and calcareous soils.

Table 7.4 Soil depth together with some chemical and physical properties of the soils from the _Aptosimum depressum_ - _Ruschia muricata_ - _Zygophyllum retrofractum_ low semi-open shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %) Na	K	Ca	Mg	FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
3	17	7.8	17.85	121.24	1840	6.12	7.42	0.97	0.95	3.42	2.08	A -	1.34	119.57	1.42
18	20	5.7	7.85	125.07	1300	3.43	4.29	0.40	0.56	1.90	1.43	M +	0.70	115.41	1.67
27	40	8.3	37.13	94.14	1800	15.52	14.61	2.30	0.52	10.48	1.31	M +	-	123.40	1.59
42	50	8.0	65.69	104.24	2000	13.20	13.76	0.30	0.90	16.08	1.48	S +	1.40	124.89	1.53
47	5	7.7	32.80	427.13	2400	6.34	27.08	0.17	0.59	24.50	1.80	S +	1.25	124.68	1.53
58	32	7.7	23.56	515.09	2600	5.17	26.63	0.28	0.84	23.50	2.01	S +	1.50	123.52	1.56
73	25	8.0	71.40	376.67	800	8.40	31.64	3.21	1.56	24.00	2.87	S +	1.85	122.47	1.45
82	18	8.3	37.84	241.18	1700	4.76	11.48	0.36	0.87	8.98	1.27	M +	1.35	123.76	1.54
110	11	7.6	36.41	80.63	3100	6.04	4.87	0.25	0.82	2.45	1.35	S +	-	141.30	1.47
124	60	7.8	62.83	132.72	900	4.66	6.45	1.22	1.16	2.43	1.64	S +	1.02	122.26	1.50
165	60	8.0	84.25	811.44	1540	6.38	51.77	0.56	0.59	24.70	0.61	S +	1.37	124.34	1.48
166	35	7.5	36.41	382.45	3700	6.04	23.10	0.37	0.53	21.50	0.70	S +	1.53	123.54	1.48

Table 7.5 Soil colour, soil texture and a statistical summary of textural analyses of the sand size fraction of some soils from the Aptosimum depressum - Ruschia muricata - Zygophyllum retrofractum low semi-open shrubland community

REL-EVE NO.	TEX-TURE (sand frac-tion)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemm-ing 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL > 2 mm (%)	SILT & CLAY < 63 µm (%)	SAND/ SILT & CLAY RATIO	MEAN	STD SORT-ING	SKEW-NESS	KURT-OSIS	MED-IAN	SOIL COLOUR CODE (Munsell chart)	SOIL COL-OUR
3	mSa	sl gmSa	mod	well	n symm	meso	2.92	19.93	3.87	1.10	0.98	0.50	3.02	1.08	5YR5/6	yr
18	cSa	sl gmSa	mod	well	positive	meso	2.40	14.22	5.87	0.82	0.95	0.72	3.45	0.73	5YR5/6	yr
27	mSa	sl gmSa	mod	well	positive	meso	1.28	11.65	7.48	1.23	1.02	0.69	3.53	1.12	5YR5/6	yr
42	mSa	sl gmSa	poor	well	n symm	meso	3.92	10.81	7.90	1.25	1.12	0.54	2.84	1.19	5YR5.5/5	yr
47	mSa	gmSa	poor	well	n symm	meso	5.64	13.98	5.75	1.57	1.02	0.32	2.64	1.54	5YR6/4	lrb
58	mSa	sl gmSa	mod	well	n symm	meso	3.28	13.42	6.21	1.12	0.83	0.30	2.96	1.10	5YR5/6	yr
73	cSa	sl gmSa	mod	well	positive	lepto	2.19	30.89	2.17	0.98	0.93	0.93	3.63	0.84	5YR5/6	yr
82	mSa	sl gmSa	mod	well	n symm	lepto	3.38	13.22	6.31	1.14	0.92	0.60	3.46	1.09	5YR5/6	yr

THE *APTOSIMUM DEPRESSUM* - *RUSCHIA MURICATA* LOW SEMI-OPEN//MODERATELY CLOSED SHRUBLAND COMMUNITY OF CALCAREOUS SOILS

Community number: 1.2(b)

Symbol: ●

CLASSIFICATION (Table 7.1)

Community: *Aptosimum depressum* - *Ruschia muricata*

Veld Type (Acocks 1975): False Succulent Karoo

Edwards (1983) structural class: Low Semi-Open//Moderately Closed Shrubland

RELEVES

Total number: 9

List: 16, 19, 23, 25, 44, 52, 59, 112 and 120

Grid location: 3018 BA 11,12,16

RELEVE HABITAT DETAILS (Tables 7.1, 7.6 & 7.7)

Land-facets: Rolling plains (4 relevés), convex crests (3 relevés), flat plateaux (1 relevé) and swales (1 relevé)

Altitudinal range: 1 016-1 030 m

Aspect: variable

Slope: 0°-3° (average 1.7°)

Rock cover: 0-80 % (average 10.9 %)

Geology: Surficial deposit - Q2 (sandy soil)

Substrate: Calcareous sandy soil with some calcrete nodules

Soil series: Hu45 (Vergenoeg) (9 relevés)

Soil depth: 1-50 cm (average 20.1 cm)

Soil moisture: well-drained

Soil colour: yellowish red

Soil analyses:

- Soil pH: 7.3-8.3 (average 7.67)
- Bray 2 P: 7.14-371.28 ppm (average 91.951 ppm)

Base saturation: 106.34-311.00 % (average 187.904 %)

Resistance: 66-3 500 Ω (average 2 060.8 Ω)

Cation exchange capacity: 4.19-15.61 me% (average 10.034 me%)

S-value: 5.16-26.49 me% (average 17.901 me%)

Exchangeable Na: 0.24-2.68 me% (average 0.934 me%)

Exchangeable K: 0.70-3.89 me% (average 1.968 me%)

Exchangeable Ca: 2.78-22.25 me% (average 13.357 me%)

Exchangeable Mg: 1.34-3.11 me% (average 2.32 me%)

Free carbonate: present (moderate to strong reaction with HCl)

Organic content: 0.50-2.15 % (average 1.323 %)

Field capacity: 116.44-125.03 (average 120.591) gH_2O/100g soil

Bulk density: 1.33-1.62 g/ml (average 1.53 g/ml)

RELEVE VEGETATION DETAILS (Table 7.1)

Projected cover: 12-38 % (average 25.2 %)

Total number of species: 5-15 (average 9)

Number of permanently visible perennial species: 4-7 (average 6)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: *Aptosimum depressum*, *Psilocaulon planisepalum*, *Ruschia muricata*.

Conspicuous species: *Ruschia muricata* and *Psilocaulon planisepalum* are conspicuous differential species. *Salsola zeyheri* and *Sphalmanthus tetragonus* are prominent companion species.

Companion species: *Salsola zeyheri*, *Sphalmanthus tetragonus* and *Stipagrostis obtusa*.

Physiognomic structure: Leaf succulent chamaephytes predominate, forming a layer at approximately 0.26 m.

IDENTIFICATION

This community is distinguished from the Aptosimum depressum - Ruschia muricata - Zygophyllum retrofractum community by the absence of the Z. retrofractum species group, and the prominence of Psilocaulon planisepalum and Sphalmanthus tetragonus. It is distinguished from the Aptosimum depressum - Psilocaulon planisepalum - Salsola zeyheri community by the presence of Ruschia muricata.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: Helichrysum herniarioides and Pentzia pilulifera.

Companion species: Galenia papulosa and Schismus barbatus.

PHOTOGRAPH (Fig. 7.3)

FIGURE 7.3 The Aptosimum depressum - Ruschia muricata low semi-open//moderately closed shrubland community with R. muricata (Rm) and Psilocaulon planisepalum (Pp).

Table 7.6 Soil depth together with some chemical and physical properties of the soils from the Aptosimum depressum - Ruschia muricata low semi-open//moderately closed shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %) Na	K	Ca	Mg	FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
16	20	7.3	7.14	123.15	2580	4.19	5.16	0.34	0.70	2.78	1.34	A -	0.50	116.44	1.58
19	50	7.5	39.27	106.34	1800	15.61	16.60	1.92	1.26	11.08	2.34	M +	1.10	125.03	1.60
23	15	7.4	40.70	109.73	3000	14.08	15.45	0.31	3.89	12.73	1.52	S +	1.45	120.67	1.58
25	18	7.4	142.09	177.07	3500	14.96	26.49	0.52	1.25	22.25	1.97	S +	1.55	118.18	1.55
44	15	7.5	43.55	145.06	-	8.30	12.04	1.10	1.58	6.25	3.11	M +	1.75	120.31	1.62
52	20	7.6	15.71	176.18	1900	8.06	14.20	0.82	1.23	9.65	2.50	S +	2.15	119.33	1.58
59	12	7.8	85.00	256.77	2300	9.16	23.52	0.24	1.40	18.85	3.03	S +	0.75	119.66	1.60
112	1	8.2	371.28	311.00	66	8.18	25.44	2.68	1.24	18.92	2.60	S +	1.45	122.46	1.33
120	30	8.3	82.82	285.84	1340	7.77	22.21	0.48	1.56	17.70	2.47	S +	1.21	123.24	1.33

Table 7.7 Soil colour, soil texture and a statistical summary of textural analyses of the sand size fraction of some soils from the Aptosimum depressum - Ruschia muricata low semi-open//moderately closed shrubland community

RELEVE NO.	TEXTURE (sand fraction)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemming 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL > 2 mm (%)	SILT & CLAY < 63 μm (%)	SAND/SILT & CLAY RATIO	MEAN	STD SORTING	SKEWNESS	KURTOSIS	MEDIAN	SOIL COLOUR CODE (Munsell chart)	SOIL COLOUR
16	mSa	sl gmSa	mod	well	positive	meso	3.84	12.46	6.73	1.08	1.02	0.92	4.31	0.97	5YR5/6	yr
19	mSa	gmSa	poor	well	positive	meso	5.01	15.06	5.31	1.15	1.05	0.61	3.09	1.05	5YR5/6	yr
23	mSa	sl gmSa	poor	well	positive	meso	3.30	14.24	5.81	1.29	1.08	0.70	3.26	1.23	5YR5.5/5	yr
25	mSa	gmSa	mod	well	n symm	meso	8.30	15.47	4.93	1.09	0.95	0.49	3.11	1.07	5YR5.5/5	yr
44	mSa	sl gmSa	mod	well	n symm	lepto	3.04	19.18	4.05	1.33	0.96	0.32	3.17	1.39	5YR5/6	yr
52	mSa	sl gmSa	poor	well	positive	meso	3.28	17.06	4.67	1.32	1.08	0.42	2.63	1.26	5YR5/6	yr
59	mSa	sl gmSa	mod	well	n symm	meso	2.07	18.56	4.28	1.07	0.86	0.49	3.08	1.03	5YR5/6	yr

THE *APTOSIMUM DEPRESSUM* - *PSILOCAULON CILIATUM* DWARF SEMI-OPEN SHRUBLAND COMMUNITY ON SALINE SOIL

Community number: 1.3(a)

Symbol: □

CLASSIFICATION (Table 7.1)

Community: *Aptosimum depressum* - *Psilocaulon ciliatum*

Veld Type (Acocks 1975): False Succulent Karoo

Edwards (1983) structural class: Dwarf Semi-Open Shrubland

RELEVES

Total number: 11

List: 4, 15, 56, 69, 86, 137, 138, 139, 140, 141 and 142

Repeat relevė: 86=4

Grid location: 3018 BA 11

RELEVE HABITAT DETAILS (Tables 7.1, 7.8 & 7.9)

Land-facets: Rolling plains (6 relevės), flat plateaux (4 relevės) and swales (1 relevė)

Altitudinal range: 1 016-1 018 m

Aspect: Variable

Slope: 0^{o} - 2^{o} (average 1^{o})

Rock cover: 0 %

Geology: Surficial deposit - Q2 (sandy soil)

Substrate: Shallow sandy loam

Soil series: Hu32 (Moriah) (10 relevės), Hu45 (Vergenoeg) (1 relevė)

Soil depth: 6-35 cm (average 15.3 cm)

Soil moisture: temporary free water (7 relevės), well-drained (4 relevės)

Soil colour: yellowish red

Soil analyses:

Soil pH: 5.9-8.4 (average 7.46)

Bray 2 P: 6.43-18.56 ppm (average 11.73 ppm)

Base saturation: 97.29-351.55 % (average 164.191 %)

Resistance: 140-2 100 Ω (average 1 030 Ω)

Cation exchange capacity: 5.16-9.57 me% (average 7.073 me%)

S-value: 7.94-18.14 me% (average 10.853 me%)

Exchangeable Na: 0.87-2.81 me% (average 1.784 me%)

Exchangeable K: 0.71-1.32 me% (average 1.051 me%)

Exchangeable Ca: 3.63-12.08 me% (average 5.587 me%)

Exchangeable Mg: 1.24-4.06 me% (average 2.287 me%)

Free carbonate: absent to moderate reaction with HCl

Organic content: 0.80-1.70 % (average 1.339 %)

Field capacity: 114.96-126.47 (average 120.086) gH_2O/100g soil

Bulk density: 1.32-1.65 g/ml (average 1.517 g/ml)

RELEVE VEGETATION DETAILS (Table 7.1)

Projected cover: 10-28 (average 16.2 %)

Total number of species: 4-21 (average 15)

Number of permanently visible perennial species: 4-11 (average 8)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: *Aptosimum depressum*, *Psilocaulon planisepalum*, *P. ciliatum* and *Galenia crystallina*.

Conspicuous species: *Psilocaulon ciliatum* and *P. planisepalum* are the conspicuous differential species with *Salsola zeyheri* and *Aridaria noctiflora* being the prominent companion species.

Companion species: *Salsola zeyheri*, *Sphalmanthus tetragonus*, *Xanthoria marlothii*, *Aridaria noctiflora* and *Drosanthemum schoenlandianum*.

Physiognomic structure: Leaf succulent chamaephytes predominate with some chamaephytes having woolly leaves. The highest stratum of vegetation consists of Salsola zeyheri and Aridaria noctiflora at 30 cm, with a 10 cm stratum consisting of Psilocaulon ciliatum and P. planisepalum.

IDENTIFICATION

This community is distinguished from the Aptosimum depressum - Psilocaulon planisepalum - Salsola zeyheri community by the presence of Psilocaulon ciliatum, and from the A. depressum - P. ciliatum - Ruschia cf. R. levynsiae community by the absence of Ruschia cf. R. levynsiae.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: Pentzia pilulifera, Helichrysum herniarioides, Gazania lichtensteinii, Felicia brevifolia, JWL132 and Felicia australis.

Companion species: Leysera tenella, Galenia papulosa, Schismus barbatus, Heliophila variabilis and Pentaschistis cf. P. patula.

PHOTOGRAPH (Fig. 7.4)

FIGURE 7.4 The Aptosimum depressum - Psilocaulon ciliatum (Pc) dwarf semi-open shrubland community with Salsola zeyheri (Sz) on saline soils.

Table 7.8 Soil depth together with some chemical and physical properties of the soils from the <u>Aptosimum depressum</u> - <u>Psilocaulon ciliatum</u> dwarf semi-open shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %)				FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
								Na	K	Ca	Mg				
4	35	8.0	18.56	150.44	1120	5.67	8.53	1.19	0.78	5.32	1.24	A -	1.16	121.67	1.54
15	20	6.8	6.43	97.29	2100	9.57	9.33	1.61	1.20	3.90	2.62	W +	1.70	119.48	1.60
56	10	7.9	12.14	351.55	1900	5.16	18.14	0.87	1.13	12.08	4.06	M +	1.15	114.96	1.55
69	10	8.4	11.42	146.25	1300	6.40	9.36	2.81	1.32	3.63	1.60	M +	0.80	117.83	1.65
138	14	5.9	8.57	121.08	170	9.25	11.20	2.23	0.71	5.77	2.49	A -	1.69	126.47	1.32
140	9	8.4	12.14	121.78	140	6.52	7.94	0.97	1.01	3.93	2.03	W +	1.20	117.63	1.50
141	10	6.8	12.85	160.95	480	6.94	11.47	2.81	1.21	4.48	1.97	A -	1.67	122.56	1.46

Table 7.9 Soil colour, soil texture and a statistical summary of textural analyses of the sand size fraction of some soils from the Aptosimum depressum - Psilocaulon ciliatum dwarf semi-open shrubland community

RELEVE NO.	TEXTURE (sand fraction)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemming 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL >2 mm (%)	SILT & CLAY < 63 μm (%)	SAND/ SILT & CLAY RATIO	MEAN	STD SORTING	SKEWNESS	KURTOSIS	MEDIAN	SOIL COLOUR CODE (Munsell chart)	SOIL COLOUR
4	cSa	gSa	mod	v.well	positive	platy	6.10	8.65	9.86	0.76	0.87	0.79	3.66	0.66	5YR5/6	yr
15	mSa	gmSa	poor	well	n symm	meso	7.22	19.71	3.71	1.15	1.08	0.61	3.07	1.09	5YR5/6	yr
56	mSa	sl gmSa	mod	well	positive	meso	2.64	28.41	2.43	1.16	0.95	0.45	2.76	1.10	5YR5/6	yr
69	mSa	sl gmSa	mod	well	n symm	meso	2.20	19.46	4.03	1.07	0.81	0.41	3.11	1.05	5YR5/6	yr

THE APTOSIMUM DEPRESSUM - PSILOCAULON CILIATUM - RUSCHIA CF. R. LEVYNSIAE DWARF SEMI-OPEN SHRUBLAND COMMUNITY ON SALINE SOILS

Community number: 1.3(b)

Symbol: X

CLASSIFICATION (Table 7.1)

Community: Aptosimum depressum - Psilocaulon ciliatum - Ruschia cf. R. levynsiae

Veld Type (Acocks 1975): False Succulent Karoo

Edwards (1983) structural class: Dwarf Semi-Open Shrubland

RELEVES

Total number: 14

List: 93, 94, 99, 100, 104, 105, 106, 107, 113, 114, 121, 157, 158 and 167

Grid location: 3018 BA 11;16;17

RELEVE HABITAT DETAILS (Tables 7.1, 7.10)

Land-facets: Rolling plains (10 relevés), swales (2 relevés) and flat plateaux (2 relevés)

Altitudinal range: 1 006-1 030 m

Aspect: Variable

Slope: 0^{o} - 2^{o} (average 0.8^{o})

Rock cover: 0-1 % (average 0.3 %)

Geology: Surficial deposit - Q2 (sandy soil)

Substrate: Shallow saline sandy loam with a relatively high organic content

Soil series: Hu32 (Moriah) (11 relevés), Ms14 (Winchester) (3 relevés)

Soil depth: 4-23 cm (average 11.6 cm)

Soil moisture: temporary free water

Soil colour: yellowish red

Soil analyses:

Soil pH: 7.1-8.3 (average 7.76)

Bray 2 P: 14.28-85.68 ppm (average 50.337 ppm)

Base saturation: 124.36-553.68 % (average 302.856 %)

Resistance: 35-2 000 Ω (average 601.4 Ω)

Cation exchange capacity: 5.05-9.20 me% (average 7.276 me%)

S-value: 6.28-40.64 me% (average 22.546 me%)

Exchangeable Na: 1.32-8.32 me% (average 4.535 me%)

Exchangeable K: 0.27-1.88 me% (average 1.298 me%)

Exchangeable Ca: 2.47-32.28 me% (average 13.935 me%)

Exchangeable Mg: 1.42-3.77 me% (average 2.774 me%)

Free carbonate: absent to strong reaction with HCl

Organic content: 0.65-2.20 % (average 1.591 %)

Field capacity: 118.54-134.23 (average 123.308 gH_2O/100g soil

Bulk density: 1.11-1.51 g/ml (average 1.384 g/ml)

<u>RELEVE VEGETATION DETAILS</u> (Table 7.1)

Projected cover: 6-15 % (average 11.3 %)

Total number of species: 7-15 (average 11)

Number of permanently visible perennial species: 3-10 (average 6)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: *Aptosimum depressum*, *Psilocaulon ciliatum* and *Ruschia* cf. *R. levynsiae*.

Conspicuous species: *Ruschia* cf. *R. levynsiae* and *Psilocaulon ciliatum* are the conspicuous differential species with *Salsola zeyheri* and *Drosanthemum schoenlandianum* being the prominent companion species.

Companion species: *Salsola zeyheri*, *Drosanthemum schoenlandianum*, *Sphalmanthus quartziticus* and *S. tetragonus*.

Physiognomic structure: Leaf succulent chamaephytes predominate with some chamaephytes also having woolly leaves. The highest vegetation stratum consists of Salsola zeyheri at 30 cm, with Ruschia cf. R. levynsiae and Psilocaulon ciliatum forming a lower stratum at 10 cm.

IDENTIFICATION

This community is distinguished from the A. depressum - Psilocaulon ciliatum community by the presence of Ruschia cf. R. levynsiae and less prominent occurrence of P. ciliatum, A. depressum and P. planisepalum.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: Pentzia pilulifera, Gazania lichtensteinii and Helichrysum herniarioides.

Companion species: Leysera tenella, Heliophila variabilis, Galenia papulosa and Schismus barbatus.

PHOTOGRAPH (Fig. 7.5)

FIGURE 7.5 The Aptosimum depressum - Psilocaulon ciliatum - Ruschia cf. R. levynsiae (Rl) dwarf semi-open shrubland community on saline soils.

Table 7.10 Soil depth together with some chemical and physical properties of the soils from the *Aptosimum depressum* - *Psilocaulon ciliatum* - *Ruschia* cf. *R. levynsiae* dwarf semi-open shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %)				FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
								Na	K	Ca	Mg				
93	4	7.8	57.12	301.56	2000	5.78	17.47	1.32	1.88	11.28	2.95	M +	2.10	123.57	1.44
99	10	7.8	85.68	401.41	1200	9.20	36.93	3.17	1.74	28.25	3.77	S +	1.75	124.74	1.46
104	6	7.8	37.13	358.45	500	7.10	25.45	6.04	0.27	16.03	3.11	M +	2.20	122.13	1.51
106	30	7.3	15.71	232.89	35	7.54	17.56	8.32	1.18	5.29	2.77	A -	1.28	122.43	1.38
113	16	7.1	14.28	124.36	900	5.05	6.28	1.32	1.07	2.47	1.42	A -	0.65	119.70	1.46
121	15	7.8	58.55	203.18	46	9.12	18.53	6.03	0.96	8.02	3.52	A -	1.27	121.12	1.31
158	9	8.3	41.41	247.32	65	7.08	17.51	6.06	1.75	7.86	1.84	W +	1.80	118.54	1.40
167	12	8.2	92.82	553.68	65	7.34	40.64	4.02	1.53	32.28	2.81	S +	1.68	134.23	1.11

THE APTOSIMUM DEPRESSUM - PSILOCAULON PLANISEPALUM - SALSOLA ZEYHERI LOW SEMI-OPEN SHRUBLAND COMMUNITY ON NEUTRAL TO SLIGHTLY SALINE SOILS

Community number: 1.4

Symbol: ◇

CLASSIFICATION (Table 7.1)

Community: Aptosimum depressum - Psilocaulon planisepalum - Salsola zeyheri

Veld Type (Acocks 1975): False Succulent Karoo

Edwards (1983) structural class: Low Semi-Open Shrubland

RELEVES

Total number: 6

List: 20, 43, 53, 66, 70 and 72

Grid location: 3018 BA 11

RELEVE HABITAT DETAILS (Tables 7.1, 7.11 & 7.12)

Land-facets: Rolling plains (3 relevés), waxing slopes (1 relevé), swales (1 relevé) and convex crests (1 relevé)

Altitudinal range: 1 011-1 018 m

Aspect: Variable

Slope: $0^{\circ} - 4^{\circ}$ (average 1.8°)

Rock cover: 0 %

Geology: Surficial deposit - Q2 (sandy soil)

Substrate: shallow sandy loam which has a relatively high organic content

Soil series: Hu32 (Moriah) (5 relevés), Hu45 (Vergenoeg) (1 relevé)

Soil depth: 12-45 cm (average 23 cm)

Soil moisture: well-drained

Soil colour: yellowish red

Soil analyses:

Soil pH: 7.0-8.0 (average 7.22)

Bray 2 P: 5.71-59.26 ppm (average 16.538 ppm)

Base saturation: 78.10-386.99 % (average 182.668 %)

Resistance: 510-3 300 Ω (average 2 582 Ω)

Cation exchange capacity: 3.32-7.74 me% (6.29 me%)

S-value: 5.74-22.60 me% (average 10.957 me%)

Exchangeable Na: 0.37-3.98 me% (average 1.278 me%)

Exchangeable K: 0.41-1.78 me% (average 1.142 me%)

Exchangeable Ca: 2.85-18.55 me% (average 6.733 me%)

Exchangeable Mg: 1.02-2.34 me% (average 1.803 me%)

Free carbonate: present in most samples (absent to moderate reaction with HCl)

Organic content: 0.80-2.50 % (average 1.50 %)

Field capacity: 117.69-126.69 (average 121.377) gH_2O/100g soil

Bulk density: 1.35-1.66 g/ml (average 1.545 g/ml)

RELEVE VEGETATION DETAILS (Table 7.1)

Projected cover: 9-22 % (average 14.5 %)

Total number of species: 4-14 (average 8)

Number of permanently visible perennial species: 3-7 (average 5)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: *Aptosimum depressum* and *Psilocaulon planisepalum*.

Conspicuous species: *Psilocaulon planisepalum* is the conspicuous differential species with *Salsola zeyheri* and *Sphalmanthus tetragonus* being the prominent companion species.

Companion species: *Salsola zeyheri* and *Sphalmanthus tetragonus*.

Physiognomic structure: Leaf succulent chamaephytes predominate, forming a layer between 0.2 and 0.3 m high.

IDENTIFICATION

This community is distinguished from the Aptosimum depressum - Ruschia muricata community by the absence of Ruschia muricata, and from the A. depressum - Psilocaulon ciliatum community by the absence of P. ciliatum.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: Helichrysum herniarioides.

Companion species: Galenia papulosa.

PHOTOGRAPH (Fig. 7.6)

FIGURE 7.6 The Aptosimum depressum - Psilocaulon planisepalum (Pp) - Salsola zeyheri (Sz) low semi-open shrubland community on neutral to slightly saline soils.

Table 7.11 Soil depth together with some chemical and physical properties of the soils from the _Aptosimum depressum_ - _Psilocaulon planisepalum_ - _Salsola zeyheri_ low semi-open shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %)				FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
								Na	K	Ca	Mg				
20	28	7.2	11.42	130.88	3300	7.74	10.13	1.40	1.65	5.40	1.68	W +	1.65	123.62	1.54
43	20	7.1	5.71	119.46	-	6.02	7.19	0.86	0.41	4.90	1.02	W +	1.25	126.69	1.35
53	45	8.0	59.26	386.99	2600	5.84	22.60	0.37	1.34	18.55	2.34	A -	1.25	117.69	1.66
66	12	7.7	4.28	201.20	4100	3.32	6.68	0.54	0.94	3.15	2.05	M +	0.80	118.36	1.60
70	13	6.3	10.71	78.10	2400	7.35	5.74	0.52	0.73	2.85	1.64	W +	1.55	118.97	1.63
72	20	7.0	7.85	179.38	510	7.47	13.40	3.98	1.78	5.55	2.09	M +	2.50	122.93	1.49

Table 7.12 Soil colour, soil texture and a statistical summary of textural analyses of the sand size fraction of some soils from the Aptosimum depressum - Psilocaulon planisepalum - Salsola zeyheri low semi-open shrubland community

RELEVE NO.	TEXTURE (sand fraction)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemming 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL > 2 mm (%)	SILT & CLAY < 63 μm (%)	SAND/SILT & CLAY RATIO	MEAN	STD SORTING	SKEWNESS	KURTOSIS	MEDIAN	SOIL COLOUR CODE (Munsell chart)	SOIL COLOUR
20	mSa	gmSa	mod	well	n symm	platy	5.62	22.85	3.13	1.03	0.98	0.53	2.93	0.98	5YR5/6	yr
43	mSa	sl gmSa	poor	well	positive	meso	4.48	11.55	7.29	1.01	1.05	0.81	3.69	0.92	5YR5/6	yr
53	mSa	sl gmSa	mod	well	positive	meso	2.60	17.41	4.60	1.11	0.92	0.66	3.21	1.04	5YR5/6	yr
66	cSa	gmSa	mod	v.well	n symm	meso	20.40	15.93	4.00	0.96	0.91	0.65	3.46	0.91	5YR5/6	yr
70	mSa	sl gmSa	mod	well	n symm	meso	3.29	18.93	4.11	1.23	0.87	0.18	2.79	1.25	5YR5/6	yr
72	mSa	sl gmSa	mod	well	n symm	meso	3.27	22.29	3.34	1.24	0.96	0.14	3.49	1.22	5YR5/6	yr

THE *EBERLANZIA ARMATA* LOW OPEN//SEMI-OPEN SHRUBLAND COMMUNITY ON SHALLOW SOILS

Community number: 2.1

Symbol: ▲

CLASSIFICATION (Table 7.1)

Community: *Eberlanzia armata*

Veld Type (Acocks 1975): False Succulent Karoo

Edwards (1983) structural class: Low Open//Semi-Open Shrubland

RELEVES

Total number: 20

List: 5, 6, 41, 45, 54, 91, 92, 102, 103, 108, 109, 117, 118, 119, 122, 123, 132, 147, 168 and 170

Repeat relevés: 168=5; 170=6

Grid location: 3018 BA 11;16;17

RELEVE HABITAT DETAILS (Tables 7.1, 7.13 & 7.14)

Land-facets: Swales (17 relevés), convex crests (2 relevés) and rolling plains (1 relevé)

Altitudinal range: 1 016-1 030 m

Aspect: Variable

Slope: 0° - 3° (average 0.9°)

Rock cover: 0-10 % (average 0.7 %)

Geology: Surficial deposit - Q2 (sandy soil)

Substrate: Shallow sandy loam

Soil series: Hu32 (Moriah) (15 relevés), Ms14 (Winchester) (5 relevés)

Soil depth: 1-15 cm (average 8.9 cm)

Soil moisture: Temporary free water

Soil colour: yellowish red

Soil analyses:

Soil pH: 5.4-6.6 (average 5.83)

Bray 2 P: 5.00-19.28 ppm (average 11.281 ppm)

Base saturation: 65.16-180.65 % (average 116.769 %)

Resistance: 530-7 200 Ω (average 3 602.0 Ω)

Cation exchange capacity: 1.86-5.05 me% (average 3.307 me%)

S-value: 2.50-6.72 me% (average 3.755 me%)

Exchangeable Na: 0.21-1.49 me% (average 0.596 me%)

Exchangeable K: 0.31-1.15 me% (average 0.597 me%)

Exchangeable Ca: 0.88-2.40 me% (average 1.331 me%)

Exchangeable Mg: 0.90-3.11 me% (average 1.239 me%)

Free carbonate: absent to moderate reaction with HCl

Organic content: 0.40-1.01 % (average 0.705 %)

Field capacity: 114.26-119.56 (average 117.014) gH_2O/100g soil

Bulk density: 1.46-1.71 g/ml (average 1.574 g/ml)

<u>RELEVE VEGETATION DETAILS</u> (Table 7.1)

Projected cover: 7-17 % (average 11.85 %)

Total number of species: 4-18 (average 9)

Number of permanently visible perennial species: 1-9 (average 4)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: <u>Eberlanzia armata</u>, <u>Osteospermum sinuatum</u> and <u>Eriocephalus ericoides</u>.

Conspicuous species: <u>Eberlanzia armata</u> is the prominent differential species.

Companion species: <u>Aridaria noctiflora</u>, <u>Drosanthemum schoenlandianum</u>, <u>Sphalmanthus quartziticus</u> and <u>Xanthoria marlothii</u>.

Physiognomic structure: Leaf succulent chamaephytes are most prominent with some fruticose chamaephytes also present, at a height of between 0.2 and 0.3 m.

IDENTIFICATION

This community is distinguished from the Eberlanzia armata - Ruschia robusta community by the absence of Ruschia robusta and Euphorbia decussata.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: Pentzia pilulifera, Gazania lichtensteinii, Helichrysum herniarioides, Moraea serpentina, Dimorphotheca sinuata and Sutera sp.(368).

Companion species: Leysera tenella, Galenia papulosa, Schismus barbatus and Heliophila variabilis.

PHOTOGRAPH (Fig. 7.7)

FIGURE 7.7 The Eberlanzia armata (Ea) low open//semi-open shrubland community on shallow soil overlying dorbank (d).

Table 7.13 Soil depth together with some chemical and physical properties of the soils from the *Eberlanzia armata* low open//semi-open shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %) Na	K	Ca	Mg	FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
5	14	5.4	13.57	118.48	7200	2.11	2.50	0.29	0.31	0.97	0.93	A -	0.85	119.56	1.55
6	12	5.4	7.85	114.79	530	2.84	3.26	0.32	0.39	1.27	1.28	A -	0.65	115.48	1.56
41	15	6.2	11.42	97.82	2600	5.05	4.94	0.50	0.56	2.40	1.48	M +	1.00	117.43	1.67
45	9	6.2	5.00	102.22	4500	2.70	2.76	0.21	0.32	1.25	0.98	M +	0.70	116.09	1.71
54	15	6.6	11.42	114.92	2300	4.96	5.70	1.16	0.67	2.23	1.64	M +	0.40	116.34	1.62
91	4	5.9	11.42	65.16	6000	4.22	2.75	0.34	0.51	1.00	0.90	W +	-	117.75	1.61
102	5	5.7	8.57	127.60	4700	2.79	3.56	0.53	0.86	1.15	1.02	W +	0.80	116.68	1.53
108	8	5.7	10.71	136.33	4000	3.11	4.24	0.78	1.15	1.30	1.01	A -	0.65	114.26	1.49
117	1	5.7	7.14	100.30	1100	3.31	3.23	0.99	0.59	0.88	0.90	W +	0.50	-	-
119	11	5.9	16.42	104.66	2120	3.86	4.04	0.92	0.68	1.27	1.17	A -	0.60	115.70	1.46
122	11	5.6	19.28	97.22	4300	3.60	3.50	0.58	0.97	0.93	1.02	W +	0.71	118.84	1.55
132	9	6.2	10.71	180.65	6200	1.86	3.36	0.22	0.55	1.65	0.94	A -	0.50	117.52	1.61
147	9	6.2	14.28	158.12	750	4.25	6.72	1.49	0.69	1.43	3.11	A -	1.01	117.50	1.46
168	14	5.4	13.57	118.48	7200	2.11	2.50	0.29	0.31	0.97	0.93	A -	0.85	119.56	1.55
170	12	5.4	7.85	114.79	530	2.84	3.26	0.32	0.39	1.27	1.28	A -	0.65	115.48	1.56

Table 7.14 Soil colour, soil texture and a statistical summary of the textural analyses of the sand size fraction of some soils from the Eberlanzia armata low open//semi-open shrubland community

RELEVE NO.	TEXTURE (sand fraction)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemming 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL > 2 mm (%)	SILT & CLAY < 63 μm (%)	SAND/ SILT & CLAY RATIO	MEAN	STD SORTING	SKEWNESS	KURTOSIS	MEDIAN	SOIL COLOUR CODE (Munsell chart)	SOIL COLOUR
5	mSa	sl gmSa	mod	well	n symm	meso	3.61	11.33	7.51	1.06	0.90	0.62	3.42	1.00	5YR5/6	yr
6	cSa	gmSa	mod	v.well	positive	meso	5.30	12.60	6.52	0.81	0.84	0.95	4.05	0.72	5YR5/6	yr
41	cSa	sl gmSa	mod	well	n symm	meso	3.60	13.16	6.33	0.99	0.85	0.65	3.41	0.94	5YR5/6	yr
45	cSa	sl gSa	mod	well	positive	meso	4.60	9.53	9.03	0.99	0.95	1.18	4.64	0.84	5YR5/6	yr
54	mSa	sl gmSa	mod	v.well	n symm	meso	2.62	16.41	4.93	1.08	0.78	0.50	3.31	1.07	5YR5/6	yr

THE <u>EBERLANZIA ARMATA</u> - <u>RUSCHIA ROBUSTA</u> LOW OPEN//SEMI-OPEN SHRUBLAND COMMUNITY ON VERY SHALLOW SOILS

Community number: 2.2

Symbol: △

<u>CLASSIFICATION</u> (Table 7.1)

Community: *Eberlanzia armata - Ruschia robusta*

Veld Type (Acocks 1975): False Succulent Karoo

Edwards (1983) structural class: Low Open//Semi-Open Shrubland

<u>RELEVES</u>

Total number: 16

List: 33, 48, 51, 95, 96, 97, 98, 101, 126, 143, 144, 145, 146, 148, 149 and 150

Grid location: 3018 BA 11;12;16

<u>RELEVE HABITAT DETAILS</u> (Tables 7.1, 7.15 & 7.16)

Land-facets: Rolling plains (9 relevés), swales (6 relevés) and waxing slope (1 relevé)

Altitudinal range: 1 014-1 028 m

Aspect: variable

Slope: $1^{\circ} - 3^{\circ}$ (average 1.4°)

Rock cover: 0-10 % (average 0.6 %)

Geology: Surficial deposit - Q2 (sandy soil) and Q1 (sand)

Substrate: loamy sand

Soil series: Hu32 (Moriah) (12 relevés), Hu35 (Portsmouth) (3 relevés), Ms10 (Mispah) (1 relevé)

Soil depth: 3-20 cm (average 9.1 cm)

Soil moisture: Well-drained

Soil colour: Yellowish red

Soil analyses:

Soil pH: 5.0-7.3 (average 6.37)

Bray 2 P: 1.43-37.13 ppm (average 16.208 ppm)

Base saturation: 101.33-137.71 % (average 118.814 %)

Resistance: 500-7 700 Ω (average 2 851.5 Ω)

Cation exchange capacity: 2.57-9.94 me% (average 4.726 me%)

S-value: 3.04-11.22 me% (average 5.622 me%)

Exchangeable Na: 0.23-3.16 me% (average 1.044 me%)

Exchangeable K: 0.40-0.95 me% (average 0.653 me%)

Exchangeable Ca: 1.25-3.96 me% (average 2.262 me%)

Exchangeable Mg: 1.02-3.51 me% (average 1.654 me%)

Free carbonate: absent to weak reaction with HCl

Organic content: 0.20-2.35 % (average 0.846 %)

Field capacity: 114.62-120.42 (average 117.958) gH_2O/100g soil

Bulk density: 1.37-1.69 g/ml (average 1.526 g/ml)

RELEVE VEGETATION DETAILS (Table 7.1)

Projected cover: 9-18 % (average 12.6 %)

Total number of species: 9-20 (average 14)

Number of permanently visible perennial species: 2-12 (average 6)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: Eberlanzia armata, Osteospermum sinuatum, Eriocephalus ericoides, Ruschia robusta and Euphorbia decussata.

Conspicuous species: Eberlanzia armata and Ruschia robusta are the prominent differential species.

Companion species: Aridaria noctiflora, Xanthoria marlothii, Salsola zeyheri and Sphalmanthus quartziticus.

Physiognomic structure: Leaf succulent chamaephytes are prominent, some of which have spines. The highest stratum is 0.4-0.5 m high, with a lower stratum between 0.2 and 0.25 m high.

IDENTIFICATION

This community is distinguished from the *E. armata* community by the presence of *Ruschia robusta* and *Euphorbia decussata*, and from the *Stipagrostis brevifolia* - *Ruschia robusta* community by the presence of *E. armata*.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: *Pentzia pilulifera*, *Gazania lichtensteinii*, *Helichrysum herniarioides*, *Felicia brevifolia*, *Mesembryanthemum karrooense*, *Moraea serpentina*, *Sutera* sp.(368) and *Dimorphotheca sinuata*.

Companion species: *Leysera tenella*, *Galenia papulosa*, *Schismus barbatus*, *Heliophila variabilis*, *Cotula* sp.(233) and *Senecio arenarius*.

PHOTOGRAPH (Fig. 7.8)

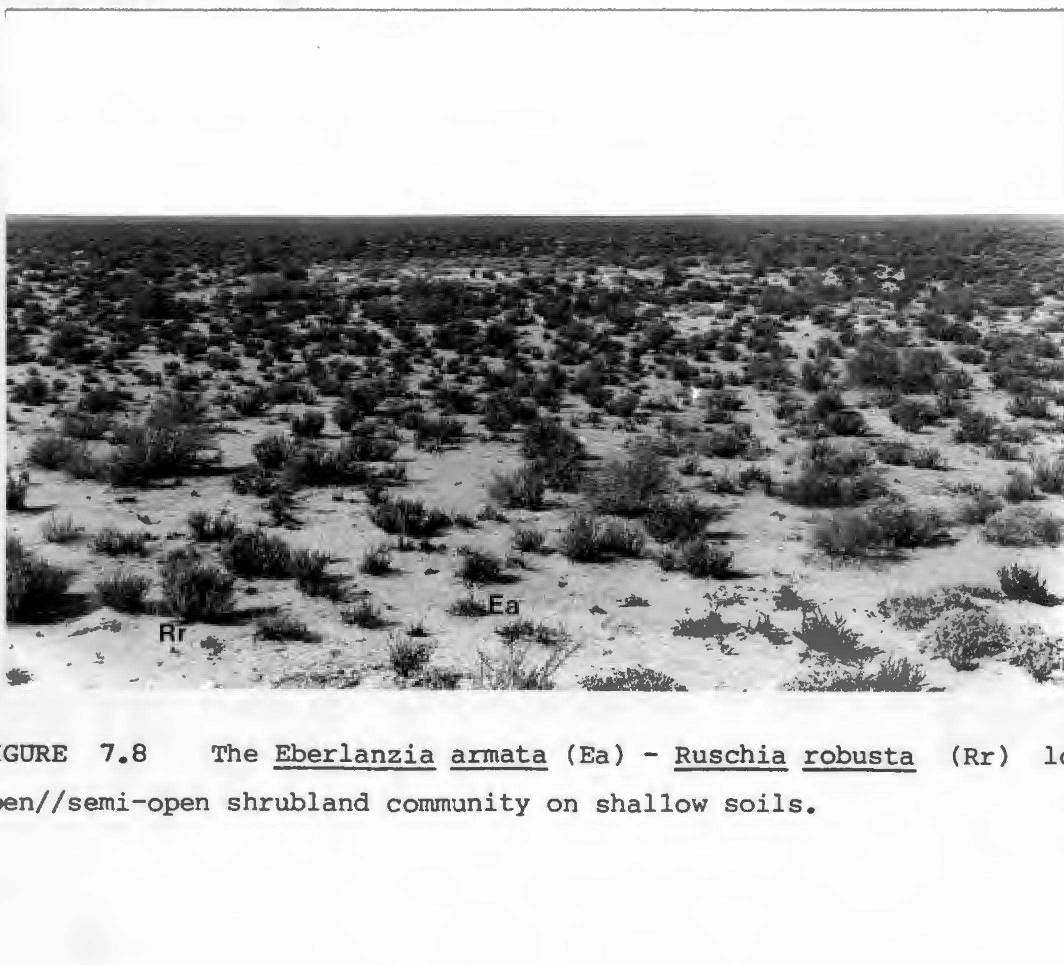


FIGURE 7.8 The *Eberlanzia armata* (Ea) - *Ruschia robusta* (Rr) low open//semi-open shrubland community on shallow soils.

Table 7.16 Soil colour, soil texture and a statistical summary of the textural analyses of the sand size fraction of some soils from the Eberlanzia armata - Ruschia robusta low open//semi-open shrubland community

RELEVE NO.	TEXTURE (sand fraction)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemming 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL > 2 mm (%)	SILT & CLAY < 63 μm (%)	SAND/ SILT & CLAY RATIO	MEAN	STD SORTING	SKEWNESS	KURTOSIS	MEDIAN	SOIL COLOUR CODE (Munsell chart)	SOIL COLOUR
33	mSa	sl gmSa	mod	well	n symm	meso	4.27	10.98	7.72	1.18	0.96	0.54	3.12	1.18	10R4/6	r
48	mSa	sl gmSa	mod	well	positive	meso	2.15	10.91	7.97	1.08	0.88	0.80	3.72	0.97	5YR5/6	yr
51	mSa	sl gmSa	mod	well	positive	meso	2.80	12.02	7.09	1.02	0.92	0.75	3.35	0.89	5YR5/6	yr

Table 7.15 Soil depth together with some chemical and physical properties of the soils from the Eberlanzia armata - Ruschia robusta low open//semi-open shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %)				FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY ($gH_2O/100$ g soil)	BULK DENSITY (g/ml)
								Na	K	Ca	Mg				
33	50	5.0	1.43	113.04	7700	2.76	3.12	0.35	0.41	1.25	1.11	A -	0.50	120.27	1.59
48	20	6.5	7.85	121.17	4100	3.59	4.35	0.23	0.43	1.85	1.84	W +	0.75	118.02	1.68
51	18	6.3	2.14	101.33	5300	3.00	3.04	0.27	0.40	1.36	1.02	W +	0.20	116.66	1.69
95	5	5.9	12.14	133.07	3500	2.57	3.42	0.45	0.51	1.33	1.13	A -	0.30	118.64	1.57
97	3	6.3	14.28	106.78	600	4.57	4.88	1.73	0.78	1.31	1.06	A -	1.00	114.62	1.58
101	5	6.7	30.70	133.38	500	6.62	8.83	3.16	0.92	2.29	2.36	A -	1.20	115.65	1.40
126	3	7.0	37.13	112.88	245	9.94	11.22	1.86	0.95	4.90	3.51	A -	2.35	120.42	1.37
143	10	6.6	20.71	114.64	2920	5.67	6.50	0.82	0.73	2.94	2.01	A -	0.71	118.74	1.44
145	10	7.3	14.99	137.71	2800	4.72	6.50	0.47	0.73	3.96	1.34	A -	0.65	119.24	1.51
149	15	6.1	20.71	114.14	850	3.82	4.36	1.10	0.67	1.43	1.16	A -	0.80	117.32	1.43

THE STIPAGROSTIS BREVIFOLIA - RUSCHIA ROBUSTA LOW/SHORT OPEN GRASSY SHRUBLAND COMMUNITY ON MODERATELY ACID SOILS MIXED WITH AEOLIAN SAND

Community number: 3.1

Symbol: ●

CLASSIFICATION (Table 7.1)

Community: Stipagrostis brevifolia - Ruschia robusta

Veld Type (Acocks 1975): False Succulent Karoo with elements of Arid Karoo and False Desert Grassveld (such as Stipagrostis brevifolia and S. obtusa)

Edwards (1983) structural class: Low/Short Open Grassy Shrubland

RELEVES

Total number: 37

List: 2, 7, 8, 9, 17, 21, 22, 24, 26, 29, 31, 46, 49, 50, 55, 57, 60, 64, 67, 68, 80, 84, 87, 127, 128, 129, 130, 131, 151, 152, 153, 154, 163, 171, 172, 173 and 177

Repeat relevės: 87=2; 171=7; 172=8; 173=9

Grid location: 3018 BA 11;12;16;17

RELEVE HABITAT DETAILS (Tables 7.1, 7.17 & 7.18)

Land-facets: Rolling plains (14 relevės), convex crests (7 relevės), drainage lines (6 relevės), waxing slopes (5 relevės), swales (3 relevės), flat summits (1 relevė) and concavo - convex slopes (1 relevė)

Altitudinal range: 1 007-1 028 m

Aspect: West and east

Slope: 0^{o}-4^{o} (average 2^{o})

Rock cover: 0-1 % (average 0.1 %)

Geology: Surficial deposits - Q1 (sand), Q2 (sandy soil)

Substrate: slightly loamy sand

Soil series: Hu35 (Portsmouth) (32 relevės), Hu32 (Moriah) (5 relevés)

Soil depth: 3-45 cm (average 21.9 cm)

Soil moisture: well-drained

Soil colour: yellowish red to red predominates

Soil analyses:

Soil pH: 4.6-7.8 (average 6.117)

Bray 2 P: 0.71-35.70 ppm (average 9.473 ppm)

Base saturation: 72.92-219.38 % (average 118.884 %)

Resistance: 1 000-8 500 Ω (average 4 325 Ω)

Cation exchange capacity: 1.84-7.85 me% (average 3.745 me%)

S-value: 1.85-17.55 me% (average 4.543 me%)

Exchangeable Na: 0.16-0.80 me% (average 0.368 me%)

Exchangeable K: 0.26-1.01 me% (average 0.57 me%)

Exchangeable Ca: 0.35-14.13 me% (average 2.292 me%)

Exchangeable Mg: 0.53-2.08 me% (average 1.313 me%)

Free carbonate: absent to moderate reaction with HCl

Organic content: 0.10-2.75 % (average 0.812 %)

Field capacity: 114.78-124.92 (average 118.91) gH_2O/100g soil

Bulk density: 1.50-1.69 g/ml (average 1.589 g/ml)

RELEVE VEGETATION DETAILS (Table 7.1)

Projected cover: 9-36 % (average 16.4 %)

Total number of species: 5-18 (average 10)

Number of permanently visible perennial species: 3-9 (average 6)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: *Stipagrostis brevifolia*, *Lycium* spp. complex, *Sarcocaulon salmoniflorum*, *Osteospermum sinuatum*, *Eriocephalus ericoides*, *Ruschia robusta* and *Euphorbia decussata*.

Conspicuous species: *Stipagrostis brevifolia*, *Ruschia robusta*, *Euphorbia decussata* and *Lycium* spp. complex are the prominent differential species.

Companion species: Salsola zeyheri, Stipagrostis obtusa, Sphalmanthus tetragonus and Aridaria noctiflora.

Physiognomic structure: The upper 1-1.5 m stratum consists predominantly of caespitose nanophanerophytes (Lycium spp.), and the lower 25-50 cm stratum consists primarily of grass and leaf and stem succulents. The most prominent life forms are caespitose hemicryptophytes, stem succulent chamaephytes, and caespitose nanophanerophytes. After sufficient rain has fallen and the temperature conditions are suitable for germination, geophytes and therophytes may also form part of the life form structure.

IDENTIFICATION

This community is distinguished from the Eberlanzia armata - Ruschia robusta community by the absence of E. armata and the relative dominance of S. brevifolia. It is distinguished from the S. brevifolia - Lycium spp. complex community by the presence of Ruschia robusta, Euphorbia decussata, Osteospermum sinuatum and Eriocephalus ericoides.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: Pentzia pilulifera, Gazania lichtensteinii, Helichrysum herniarioides, Felicia brevifolia, Mesembryanthemum karrooense, Dimorphotheca sinuata, Moraea serpentina, Sutera sp.(368) and Helichrysum dunense.

Companion species: Leysera tenella, Galenia papulosa, Schismus barbatus, Heliophila variabilis, Senecio arenarius and Dimorphotheca polyptera.

PHOTOGRAPH (Fig. 7.9)

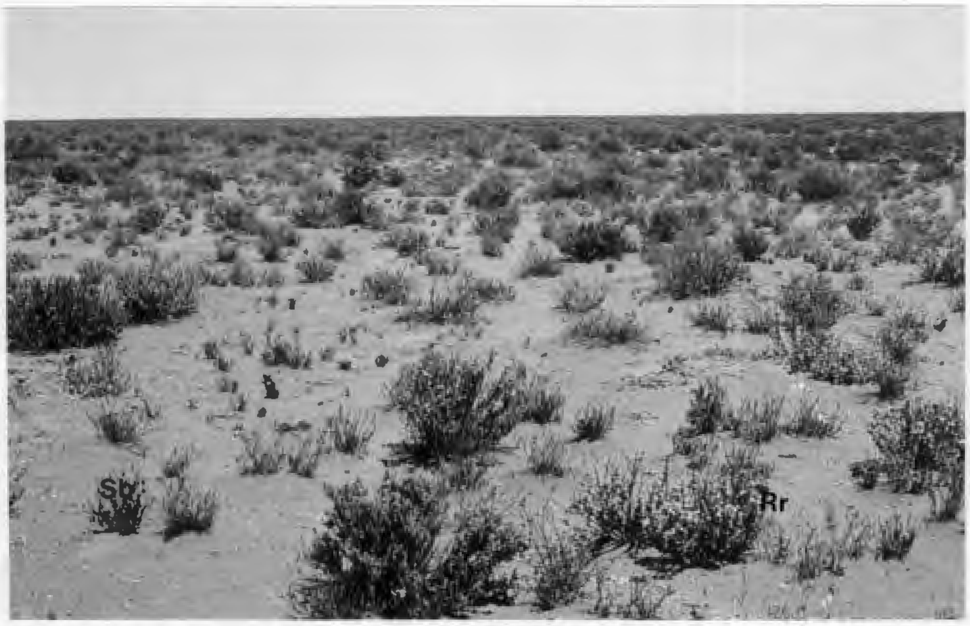


FIGURE 7.9 The Stipagrostis brevifolia (Sb) - Ruschia robusta (Rr) low/short open grassy shrubland community.

Table 7.17 Soil depth together with some chemical and physical properties of the soils from the Stipagrostis brevifolia - Ruschia robusta low/short open grassy shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %) Na	K	Ca	Mg	FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
2	15	6.6	6.43	124.54	3200	3.30	4.11	0.76	0.57	1.59	1.19	A -	0.35	117.06	1.60
7	15	7.8	7.85	101.00	3300	5.00	5.05	0.32	0.57	2.08	2.08	A -	0.65	117.21	1.52
8	25	4.6	6.43	113.04	7800	1.84	2.08	0.20	0.26	0.80	0.82	A -	0.40	119.60	1.55
9	15	6.7	13.57	110.14	2600	6.61	7.28	0.32	0.71	4.51	1.74	A -	1.05	121.70	1.50
17	25	7.3	8.57	117.45	2600	7.85	9.22	0.48	1.01	6.30	1.43	A -	-	124.92	1.52
21	24	5.9	4.28	130.50	2400	4.00	5.22	0.50	0.54	2.50	1.68	W +	0.70	116.11	1.65
22	25	5.5	7.85	115.84	2700	6.44	7.46	0.80	0.93	3.68	2.05	W +	2.50	121.61	1.57
24	15	5.4	13.57	128.06	4200	3.92	5.02	0.52	0.70	2.08	1.72	W +	0.90	117.80	1.66
26	35	5.5	5.00	142.13	8200	2.16	3.07	0.37	0.37	1.43	0.90	W +	0.40	115.91	1.65
29	20	5.0	12.14	128.50	7700	2.14	2.75	0.37	0.41	1.15	0.82	A -	0.40	116.29	1.62
31	45	4.7	1.43	126.64	8000	2.29	2.90	0.35	0.40	1.33	0.82	W +	0.50	120.06	1.63
46	15	6.7	2.86	99.57	2700	4.63	4.61	0.44	0.59	1.90	1.68	W +	0.85	120.88	1.60
49	15	6.0	2.86	100.00	4700	2.80	2.80	0.21	0.36	1.26	0.98	W +	0.10	114.94	1.67
50	28	5.5	4.28	98.70	5800	3.08	3.04	0.27	0.42	1.33	1.02	M +	0.60	116.59	1.63
55	20	5.6	6.43	121.21	3750	1.98	2.40	0.24	0.29	1.03	0.84	A -	0.50	117.83	1.61
57	25	6.3	8.57	161.49	3800	2.96	4.78	0.49	0.45	2.59	1.25	A -	0.35	117.97	1.60
60	10	6.5	9.28	104.91	2700	3.46	3.63	0.37	0.49	1.50	1.27	W +	0.45	114.78	1.66
64	40	4.8	0.71	84.16	5100	2.21	1.86	0.30	0.45	0.58	0.53	A -	1.23	120.15	1.55
67	11	6.2	5.71	116.46	1400	3.28	3.82	0.54	0.64	1.45	1.19	M +	0.65	116.46	1.60
68	30	6.9	35.70	219.38	1000	8.00	17.55	0.42	0.99	14.13	2.01	M +	2.75	123.72	1.51
80	35	7.0	21.42	72.92	2600	4.32	3.15	0.22	0.82	0.35	1.76	W +	1.05	122.10	1.57
84	40	6.5	12.85	144.44	4200	2.17	4.29	0.16	0.77	2.38	0.98	A -	0.85	120.61	1.61
128	16	5.9	8.57	88.52	8500	2.09	1.85	0.29	0.33	0.70	0.53	A -	-	-	-
130	14	5.8	11.42	97.73	4700	3.09	3.02	0.38	0.65	1.25	0.74	A -	0.65	118.28	1.56
151	10	6.3	13.57	159.06	3800	2.98	4.74	0.32	0.57	1.88	1.97	A -	0.96	118.63	1.60
153	30	6.4	3.57	163.03	6000	1.98	3.03	0.35	0.45	1.25	0.98	A -	0.75	116.58	1.69
171	15	7.8	7.85	101.00	3300	5.00	5.05	0.32	0.57	2.08	2.08	A -	0.65	117.21	1.52
172	25	4.6	6.43	113.04	7800	1.84	2.08	0.20	0.26	0.80	0.82	A -	0.40	119.60	1.55
173	15	6.7	13.57	110.14	2600	6.61	7.28	0.32	0.71	4.51	1.74	A -	1.05	121.70	1.50
177	35	7.0	21.42	72.92	2600	4.32	3.15	0.22	0.82	0.35	1.76	W +	1.05	122.10	1.57

Table 7.18 Soil colour, soil texture and a statistical summary of the textural analyses of the sand size fraction of some soils from the Stipagrostis brevifolia - Ruschia robusta low/short open grassy shrubland community

RELEVE NO.	TEXTURE (sand fraction)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemming 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL > 2 mm (%)	SILT & CLAY < 63μm (%)	SAND/SILT & CLAY RATIO	MEAN	STD SORTING	SKEWNESS	KURTOSIS	MEDIAN	SOIL COLOUR CODE (Munsell chart)	SOIL COLOUR
2	cSa	sl gmSa	mod	v.well	positive	meso	3.93	12.77	6.52	0.84	0.96	0.80	3.79	0.71	10YP5.5/5	yb
7	mSa	sl gmSa	mod	well	n symm	meso	2.56	15.06	5.47	1.05	0.87	0.69	3.72	1.01	10YR5/4	yb
8	cSa	sl gmSa	mod	well	positive	meso	1.87	9.99	8.83	0.94	0.92	0.94	4.06	0.81	10R4/6	r
9	mSa	gmSa	mod	well	n symm	meso	5.88	11.86	6.94	1.09	0.87	0.71	3.84	1.06	5YR4.5/5	rb
17	mSa	sl gmSa	poor	well	n symm	meso	2.45	14.16	5.90	1.29	1.04	0.52	2.92	1.26	5YR5/6	yr
21	cSa	sl gmSa	mod	well	positive	meso	4.39	10.79	7.86	0.93	0.90	0.57	3.02	0.87	5YR5/6	yr
22	mSa	sl gmSa	poor	well	positive	meso	2.78	14.40	5.76	1.03	1.04	0.92	3.70	0.90	5YR5/6	yr
24	mSa	sl gmSa	mod	well	n symm	meso	3.26	14.13	5.85	1.01	0.90	0.37	3.18	1.06	10R4/6	r
26	cSa	sl gSa	mod	v.well	n symm	platy	4.04	6.43	13.92	0.80	0.78	0.88	4.65	0.72	10R4/6	r
29	cSa	sl gSa	mod	v.well	positive	meso	1.82	9.21	9.66	0.80	0.93	1.18	4.67	0.62	10R4/6	r
31	cSa	sl gSa	mod	v.well	positive	platy	2.50	8.26	10.81	0.74	0.99	0.75	3.20	0.58	10R4/6	r
46	mSa	sl gmSa	mod	well	positive	meso	3.32	13.45	6.19	1.05	0.98	0.68	3.44	0.97	10R4/6	r
49	mSa	sl gmSa	mod	well	n symm	meso	2.70	11.67	7.34	1.08	0.92	0.56	3.15	1.03	5YR5/6	yr
50	mSa	sl gmSa	mod	well	n symm	meso	2.93	11.84	7.20	1.14	0.88	0.60	3.14	1.09	5YR5/6	yr
55	cSa	sl gmSa	mod	well	n symm	meso	4.02	10.82	7.87	0.97	0.91	0.44	3.00	0.94	5YR5/6	yr
57	mSa	sl gmSa	mod	v.well	positive	meso	1.32	13.36	6.39	1.03	0.79	0.67	3.45	0.96	5YR5/6	yr
60	mSa	sl gmSa	mod	well	n symm	meso	2.03	12.65	6.75	1.10	0.88	0.52	3.10	1.08	5YR5/6	yr
64	mSa	sl gmSa	mod	well	positive	meso	2.02	10.91	7.98	1.01	0.97	0.43	2.85	0.93	10R4/6	r
67	mSa	sl gmSa	mod	well	n symm	meso	2.98	16.48	4.89	1.21	0.90	0.35	2.83	1.19	5YR5/6	yr
68	mSa	sl gmSa	mod	well	n symm	meso	3.81	19.54	3.92	1.40	0.94	0.04	2.62	1.47	5YR5/6	yr
80	cSa	sl gmSa	mod	well	positive	meso	3.16	12.64	6.66	0.98	0.91	0.78	3.34	0.86	5YR5/6	yr
84	cSa	sl gmSa	mod	well	n symm	meso	1.81	10.03	8.79	0.98	0.90	0.68	3.52	0.92	10R4/6	r

THE STIPAGROSTIS BREVIFOLIA - LYCIUM SPP. COMPLEX SHORT OPEN GRASSY SHRUBLAND COMMUNITY ON MODERATELY ACID SOILS MIXED WITH AEOLIAN SAND

Community number: 3.2

Symbol: ▽

CLASSIFICATION (Table 7.1)

Community: Stipagrostis brevifolia - Lycium spp. complex

Veld Type (Acocks 1975): False Succulent Karoo with elements of Arid Karoo and False Desert Grassveld (such as Stipagrostis brevifolia)

Edwards (1983) structural class: Short Open Grassy Shrubland

RELEVES

Total number: 19

List: 1, 11, 12, 13, 14, 34, 35, 36, 39, 40, 62, 65, 74, 75, 76, 81, 169, 175 and 176

Repeat relevés: 169=1; 175=11; 176=12

Grid location: 3018 BA 11;12;13;17

RELEVE HABITAT DETAILS (Tables 7.1, 7.19 & 7.20)

Land-facets: Waxing slopes (9 relevés), rolling plains (3 relevés), convex crests (2 relevés), concavo - convex slopes (2 relevés), swales (2 relevés) and flat plateaux (1 relevé)

Altitudinal range: 1 000-1 015 m

Aspect: Variable

Slope: 1^{o} - 6^{o} (average 3.9^{o})

Rock cover: 0-1 % (average 0.2 %)

Geology: Surficial deposits - Q1 (sand) and Q2 (sandy soil)

Substrate: slightly loamy sand

Soil series: Hu35 (Portsmouth) (16 relevés), Hu45 (Vergenoeg) (2 relevés), Hu32 (Moriah) (1 relevé)

Soil depth: 14-45 cm

Soil moisture: well-drained

Soil colour: red and yellowish red predominate

Soil analyses:

- Soil pH: 4.8-7.8 (average 6.08)
- Bray 2 P: 0.71-37.84 ppm (average 8.606 ppm)
- Base saturation: 53.89-151.74 % (average 106.456 %)
- Resistance: 600-9 200 Ω (average 4 075.8 Ω)
- Cation exchange capacity: 1.72-15.20 me% (average 4.492 me%)
- S-value: 1.92-20.64 me% (average 4.905 me%)
- Exchangeable Na: 0.14-3.24 me% (average 0.443 me%)
- Exchangeable K: 0.26-1.64 me% (average 0.619 me%)
- Exchangeable Ca: 0.50-16.63 me% (average 2.695 me%)
- Exchangeable Mg: 0.57-2.58 me% (average 1.214 me%)
- Free carbonate: absent to weak reaction with HCl
- Organic content: 0.20-2.15 % (average 0.655 %)
- Field capacity: 115.53-123.99 (average 119.797) gH_2O/100g soil
- Bulk density: 1.48-1.70 g/ml (average 1.59 g/ml)

RELEVE VEGETATION DETAILS (Table 7.1)

Projected cover: 5-38 % (average 17.4 %)

Total number of species: 2-9 (average 6)

Number of permanently visible perennial species: 2-5 (average 3)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: *Stipagrostis brevifolia*, *Lycium* spp. complex and *Sarcocaulon salmoniflorum*.

Prominent species: *S. brevifolia* and *Lycium* spp. complex are the prominent differential species.

Companion species: *Salsola zeyheri*, *Sphalmanthus tetragonus*, *Protasparagus capensis* and *Osteospermum armatum*.

Physiognomic structure: The nanophanerophytes (*Lycium* spp.) form the upper 1-1.5 m stratum over a 50 cm high grass stratum. The prominent life forms are caespitose nanophanerophytes and caespitose hemicryptophytes. Geophytes and therophytes form part of the life form structure after sufficient rainfall and under favourable temperature conditions.

IDENTIFICATION

This community is distinguished from the S. brevifolia - Ruschia robusta community by the absence of R. robusta, Euphorbia decussata, Osteospermum sinuatum and Eriocephalus ericoides, and is distinguished from the Stipagrostis ciliata var. capensis - Asthenatherum glaucum community by the absence of these two species.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: Mesembryanthemum karrooense, Pentzia pilulifera and Helichrysum herniarioides.

Companion species: Galenia papulosa, Schismus barbatus and Leysera tenella.

NOTES: The ecotone between this and adjacent communities is fairly sharp, over a distance of about 1 m. The ecotone with the Stipagrostis ciliata var. capensis - Asthenatherum glaucum community is often marked by a strip of Osteospermum armatum shrubs.

PHOTOGRAPHS (Figs 7.10 & 7.11)

FIGURE 7.10 The Stipagrostis brevifolia (Sb) - Lycium spp. (L) complex short open grassy shrubland community on soils mixed with aeolian sand.

FIGURE 7.11 The Stipagrostis brevifolia - Lycium spp. complex short open grassy shrubland community with an annual grass covering of Schismus barbatus (S).

Table 7.19 Soil depth together with some chemical and physical properties of the soils from the <u>Stipagrostis</u> <u>brevifolia</u> - <u>Lycium</u> spp. complex short open grassy shrubland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %)				FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
								Na	K	Ca	Mg				
1	20	6.3	7.14	99.10	4300	3.34	3.31	0.20	0.38	1.49	1.24	A -	0.40	116.96	1.62
11	40	4.8	1.43	128.41	5980	1.76	2.26	0.19	0.26	1.09	0.72	A -	0.25	120.10	1.52
12	20	6.4	10.00	101.87	3700	4.28	4.36	0.20	0.50	2.50	1.16	A -	0.55	121.32	1.59
13	38	7.6	37.13	118.11	1800	10.27	12.13	3.24	1.26	5.05	2.58	W +	2.15	123.99	1.52
14	14	6.3	6.43	85.51	4800	4.97	4.25	0.37	0.53	2.08	1.27	W +	0.35	116.77	1.67
34	40	4.9	0.71	91.50	5000	2.00	1.83	0.25	0.55	0.50	0.53	A -	0.45	119.81	1.63
35	45	4.8	1.43	70.36	8300	2.80	1.97	0.26	0.42	0.63	0.66	W +	0.20	118.66	1.63
36	30	5.5	3.57	106.44	3500	4.19	4.46	0.24	0.47	2.54	1.21	A -	0.40	123.20	1.48
39	35	5.1	4.28	88.89	9200	2.16	1.92	0.24	0.36	0.75	0.57	W +	0.50	117.70	1.67
40	15	7.6	37.84	135.79	600	15.20	20.64	0.61	1.64	16.63	1.76	S +	1.80	123.96	1.53
62	20	6.1	2.14	53.89	2200	5.79	3.12	0.14	0.35	1.20	1.43	A -	0.40	120.00	1.59
65	20	5.9	6.43	92.20	2200	2.95	2.72	0.37	0.45	1.08	1.82	W +	0.40	115.53	1.66
74	20	6.1	7.14	127.74	2800	3.10	3.96	0.27	0.50	1.88	1.31	W +	0.75	118.69	1.70
75	30	6.9	6.43	101.61	1980	6.83	6.94	0.43	1.13	3.64	1.74	A -	1.50	121.56	1.48
76	20	6.0	5.00	140.12	5000	1.72	2.41	0.21	0.32	1.10	0.78	W +	0.80	116.67	1.66
81	30	7.8	7.85	151.74	2100	4.60	6.98	0.60	1.13	3.98	1.27	A -	0.65	122.84	1.56
169	20	6.3	7.14	99.10	4300	3.34	3.31	0.20	0.38	1.49	1.24	A -	0.40	116.96	1.62
175	40	4.8	1.43	128.41	5980	1.76	2.26	0.19	0.26	1.09	0.72	A -	0.25	120.10	1.52
176	20	6.4	10.00	101.87	3700	4.28	4.36	0.20	0.50	2.50	1.16	A -	0.55	121.32	1.59

Table 7.20 Soil colour, soil texture and a statistical summary of the textural analyses of the sand size fraction of some soils from the Stipagrostis brevifolia - Lycium spp. complex short open grassy shrubland community

RELEVE NO.	TEXTURE (sand fraction)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemming 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL > 2 mm (%)	SILT & CLAY < 63μm (%)	SAND/SILT & CLAY RATIO	MEAN	STD SORTING	SKEWNESS	KURTOSIS	MEDIAN	SOIL COLOUR CODE (Munsell chart)	SOIL COLOUR
1	mSa	sl gmSa	mod	well	n symm	meso	3.53	11.12	7.68	1.20	0.90	0.26	2.98	1.21	5YR5/6	yr
11	mSa	sl gSa	mod	well	n symm	meso	2.87	8.45	10.51	1.01	1.01	0.70	3.71	1.00	10R4/6	r
12	mSa	sl gmSa	poor	well	positive	lepto	1.77	14.74	5.69	1.07	1.09	1.12	4.22	0.90	5YR5/6	yr
13	cSa	sl gmSa	mod	v.well	positive	meso	4.43	22.07	3.33	0.82	0.94	0.88	3.97	0.72	5YR5/6	yr
14	cSa	gmSa	mod	v.well	positive	meso	5.32	12.43	6.62	0.07	0.92	0.78	3.67	0.80	5YR5.5/6	yr
34	cSa	sl gSa	mod	v.well	v.positive	meso	2.28	6.25	14.63	0.75	0.97	1.06	3.90	0.53	10R4/6	r
35	mSa	sl gSa	mod	well	n symm	meso	2.01	8.54	10.49	1.07	0.98	0.72	3.94	1.06	10R4/6	r
36	mSa	sl gSa	mod	well	n symm	meso	2.05	9.71	9.09	1.21	0.99	0.57	3.23	1.19	10R4/6	r
39	mSa	sl gSa	mod	well	n symm	meso	2.16	7.03	12.93	1.15	0.98	0.55	3.08	1.13	10R4/6	r
40	mSa	gmSa	poor	well	n symm	meso	9.08	11.10	7.21	1.35	1.09	0.28	2.74	1.44	5YR6/4	lrb
62	mSa	sl gmSa	mod	well	positive	meso	1.69	10.44	8.42	1.13	0.90	0.54	3.02	1.05	10R4/6	r
65	cSa	sl gmSa	mod	well	positive	platy	2.69	12.55	6.75	0.95	0.92	0.50	2.53	0.81	5YR5/6	yr
74	mSa	sl gmSa	mod	well	n symm	platy	2.55	12.97	6.51	1.11	0.93	0.28	2.48	1.10	5YR5/6	yr
75	mSa	sl gmSa	poor	well	positive	meso	3.28	19.23	4.03	1.27	1.17	0.85	3.02	1.06	5YR5/6	yr
76	mSa	sl gSa	mod	well	positive	meso	2.43	9.55	9.21	1.18	0.91	0.72	3.15	1.09	10R4/6	r
81	mSa	sl gmSa	mod	well	positive	meso	1.27	10.80	8.14	1.12	0.94	0.65	3.02	1.01	10R4/6	r

THE STIPAGROSTIS CILIATA VAR. CAPENSIS - ASTHENATHERUM GLAUCUM LOW OPEN GRASSLAND COMMUNITY OF RELATIVELY DEEP ACID AEOLIAN SANDS

Community number: 4

Symbol: ■

CLASSIFICATION (Table 7.1)

Community: *Stipagrostis ciliata* var. *capensis* - *Asthenatherum glaucum*

Veld Type (Acocks 1975): False Succulent Karoo with elements of Arid Karoo and False Desert Grassveld (such as *Stipagrostis brevifolia* and *S. ciliata* var. *capensis*).

Edwards (1983) structural class: Low Open Grassland

RELEVES

Total number: 19

List: 10, 28, 30, 32, 37, 38, 61, 63, 79, 83, 115, 116, 159, 160, 161, 162, 164, 174 and 178

Repeat relevés: 174 and 178=10

Grid location: 3018 BA 12;17

RELEVE HABITAT DETAILS (Tables 7.1, 7.21 & 7.22)

Land-facets: Waxing slope (17 relevés), swale (1 relevé) and concavo-convex slope (1 relevé)

Altitudinal range: 999-1 021 m

Aspect: East and southeast

Slope: $2^{o}-6^{o}$

Rock cover: 0 %

Geology: Surficial deposits - Q1 (sand)

Substrate: Aeolian sand

Soil series: Hu35 (Portsmouth) (18 relevés), Ms14 (Winchester) (1 relevé)

Soil depth: 45-150 cm (average 97.1 cm)

Soil moisture: very well-drained

Soil colour: red

Soil analyses:

Soil pH: 4.3-6.2 (average 5.05)

Bray 2 P: 0.00-7.85 ppm (average 2.746 ppm)

Base saturation: 66.09-119.39 % (average 102.481 %)

Resistance: 995-10 180 Ω (average 6 271.2 Ω)

Cation exchange capacity: 0.98-6.27 me% (average 2.277 me%)

S-value: 1.40-6.51 me% (average 2.288 me%)

Exchangeable Na: 0.13-0.34 me% (average 2.288 me%)

Exchangeable K: 0.11-0.50 me% (average 0.374 me%)

Exchangeable Ca: 0.53-3.00 me% (average 1.035 me%)

Exchangeable Mg: 0.33-1.84 me% (average 0.658 me%)

Free carbonate: absent to weak reaction with HCl

Organic content: 0.20-1.30 % (average 0.53 %)

Field capacity: 117.25-124.93 (average 119.365) gH_2O/100g soil

Bulk density: 1.50-1.67 g/ml (average 1.593 g/ml)

<u>RELEVE VEGETATION DETAILS</u> (Table 7.1)

Projected cover: 2-25 % (average 11.3 %)

Total number of species: 1-32 (average 13)

Number of permanently visible perennial species: 1-5 (average 3)

PERENNIAL SPECIES (excluding geophytes and ephemeral species) (Table 7.1)

Differential species: <u>Stipagrostis ciliata</u> var. <u>capensis</u> and <u>Asthenatherum glaucum</u>.

Prominent species: <u>Stipagrostis ciliata</u> var. <u>capensis</u> and <u>Asthenatherum glaucum</u>.

Companion species: <u>Protasparagus capensis</u>, <u>Osteospermum armatum</u> and <u>Pteronia scariosa</u>.

Physiognomic structure: During spring after sufficient rainfall there are two strata, the lower consisting of geophytes and ephemeral species, and the upper layer of grasses. The grazed basal grass tufts reach a height of 40 cm, but the grasses may reach a height of 80 cm when flowering and not grazed. The prominent life forms are caespitose hemicryptophytes, therophytes and bulbous geophytes.

IDENTIFICATION

This community is distinguished from the *Stipagrostis brevifolia* - *Lycium* spp. complex community by the presence of *S. ciliata* var. *capensis* and *Asthenatherum glaucum*.

GEOPHYTES AND EPHEMERAL SPECIES (for 1983) (Table 7.1)

Associated species: *Helichrysum dunense*, *Pharnaceum* sp.(360), *Herrea blanda*, *Ehrharta pusilla* , *Dorotheanthus flos-solis*, *Hebenstreitia parviflora*, *Wahlenbergia prostrata*, *Pelargonium* sp.(356), *Sutera tristis*, *Nemesia versicolor*, *N. azurea*, *Heliophila trifurca*, *Polycarena collina*, *Lachenalia unicolor*, *Silene* sp.(448), *Rumex lativalvis*, *Hermannia cuneifolia*, *Lachenalia mutabilis*, *Ferraria divaricata*, *Gethyllis* sp.(258), *Wahlenbergia arenarius*, *Arctotis fastuosa*, *Lotononis brachyloba* and *Grielum humifusum*.

Companion species: *Leysera tenella*, *Galenia papulosa*, *Senecio arenarius*, *Dimorphotheca polyptera*, *Schismus barbatus*, *Heliophila variabilis*, *Pentaschistis* cf. *patula* and *Cotula* sp.(233).

NOTES: The ecotone between this and adjacent communities is marked by the presence of a grouping of shrubs, predominantly *Osteospermum armatum*. The ecotone is not sharp, but transitional over a distance of approximately 1-3 m.

PHOTOGRAPHS (Figs 7.12, 7.13, 7.14 & 7.15)

FIGURE 7.12 The Stipagrostis ciliata var. capensis (Sc) - Asthenatherum glaucum low open grassland community on relatively deep, strongly acid aeolian sand.

FIGURE 7.13 Herrea blanda in the S. ciliata var. capensis - Asthenatherum glaucum low open grassland community.

FIGURE 7.14 The geophyte and ephemeral component of the S. ciliata var. capensis - Asthenatherum glaucum low open grassland community with Herrea blanda, Nemesia azurea and Nemesia versicolor.

FIGURE 7.15 Arctotis fastuosa and Nemesia azurea in the S. ciliata var. capensis - Asthenatherum glaucum low open grassland community.

Table 7.21 Soil depth together with some chemical and physical properties of the soils from the *Stipagrostis ciliata* var. *capensis* - *Asthenatherum glaucum* low open grassland community

RELEVE NO.	SOIL DEPTH (cm)	SOIL pH	BRAY 2 P (ppm)	BASE SATURATION (%)	RESISTANCE (Ω)	CEC (me %)	S-VALUE (me %)	EXCHANGEABLE CATIONS (me %) Na	K	Ca	Mg	FREE CARBONATE	ORGANIC CONTENT (%)	FIELD CAPACITY (gH_2O/100 g soil)	BULK DENSITY (g/ml)
10	150	4.3	1.43	119.39	5250	0.98	1.17	0.20	0.11	0.53	0.33	A -	0.40	117.25	1.61
28	120	6.1	2.86	85.60	6800	2.57	2.20	0.17	0.33	1.13	0.57	A -	0.20	118.15	1.65
30	80	4.5	2.14	115.76	7200	2.22	2.57	0.28	0.37	1.08	0.74	A -	0.65	120.13	1.67
32	45	4.7	7.14	116.48	8400	2.69	3.11	0.34	0.50	1.33	0.94	A -	0.40	120.95	1.61
37	65	6.0	0.00	66.09	7400	2.89	1.91	0.13	0.34	0.83	0.61	W +	0.55	119.59	1.60
38	50	5.8	5.00	103.83	2600	6.27	6.51	0.30	1.37	3.00	1.84	W +	1.30	124.93	1.50
61	130	6.2	2.14	111.93	995	3.27	3.66	0.26	0.43	1.95	1.02	A -	0.50	119.61	1.56
63	70	5.3	0.71	90.95	8100	2.10	1.91	0.29	0.47	0.58	0.57	W +	0.85	118.07	1.60
79	55	4.9	2.14	101.45	6000	1.38	1.40	0.17	0.20	0.73	0.50	A -	0.39	119.76	1.55
83	80	4.8	7.85	88.57	8100	1.75	1.55	0.24	0.35	0.58	0.37	W +	0.45	119.09	1.61
115	120	4.5	1.43	93.42	10180	1.52	1.42	0.18	0.17	0.66	0.41	A -	0.40	119.71	1.53
174	150	4.3	1.43	119.39	5250	0.98	1.17	0.20	0.11	0.53	0.33	A -	0.40	117.25	1.61
178	150	4.3	1.43	119.39	5250	0.98	1.17	0.20	0.11	0.53	0.33	A -	0.40	117.25	1.61

Table 7.22 Soil colour, soil texture and a statistical summary of the textural analyses of the sand size fraction of some soils from the Stipagrostis ciliata var. capensis - Asthenatherum glaucum low open grassland community

RELEVE NO.	TEXTURE (sand fraction)	IN A TOTAL SEDIMENT CLASSIFIED AS A .... (Folk 1968)	SORTING (Folk & Ward 1957)	SORTING (Flemming 1977)	SKEWNESS (Folk & Ward 1957)	KURTOSIS (Folk & Ward 1957) -kurtic	GRAVEL > 2 mm (%)	SILT & CLAY < 63 μm (%)	SAND/ SILT & CLAY RATIO	MEAN	STD SORTING	SKEWNESS	KURTOSIS	MEDIAN	SOIL COLOUR CODE (Munsell chart)	SOIL COLOUR
10	cSa	sl gSa	mod	v.well	n symm	meso	3.54	4.11	22.47	0.90	0.81	0.61	3.62	0.86	10R4/6	r
28	mSa	sl gSa	mod	well	n symm	meso	2.51	5.78	15.86	1.07	0.93	0.57	2.96	1.03	10R4/6	r
30	mSa	sl gSa	poor	well	positive	meso	4.98	7.52	11.70	1.03	1.08	0.95	3.86	0.88	10R4/6	r
32	cSa	sl gSa	mod	v.well	positive	meso	3.36	4.29	21.55	0.85	0.88	0.86	4.13	0.75	10R4/6	r
37	cSa	gSa	mod	v.well	positive	platy	6.53	7.58	11.34	0.70	0.98	0.72	3.31	0.57	10R4/6	r
38	mSa	sl gmSa	poor	well	positive	meso	2.57	11.42	7.53	1.04	1.05	0.62	2.86	0.93	5YR5/6	yr
61	mSa	sl gSa	mod	well	n symm	meso	3.20	9.52	9.17	1.07	0.93	0.48	2.85	1.01	10R4/6	r
63	mSa	sl gSa	mod	well	n symm	meso	3.14	8.08	10.99	1.15	0.93	0.34	2.61	1.10	10R4/6	r
79	mSa	sl gSa	mod	well	n symm	meso	1.35	8.67	10.38	1.08	0.87	0.50	3.00	1.03	10R4/6	r
83	mSa	sl gSa	mod	well	positive	meso	1.51	7.83	11.58	1.12	0.89	0.58	3.08	1.04	10R4/6	r

7.3. SUMMARY OF THE EDAPHIC FACTORS AND PLANT COMMUNITIES

A statistical summary of the edaphic factors for each of the eleven plant communities is presented in Appendix V.

The median, lower quartile, upper quartile, interquartile range, range, strays (●) and outliers (□) of each edaphic factor for the eleven plant communities are illustrated on Figs 7.16-7.30, which reduces the data and enables a comparison of data between the communities.

The salient features are the relatively high S-value (Fig. 7.19), high exchangeable Ca (Fig. 7.22) and high field capacity (Fig. 7.29) of the soils of community 1.1, the Aptosimum depressum - Salsola tuberculata community; the relatively high exchangeable Na (Fig. 7.23), high exchangeable Mg (Fig. 7.20) and low resistance (Fig. 7.25) of the soils of community 1.3(b), the A. depressum - Psilocaulon ciliatum - Ruschia cf. R. levynsiae community; the relatively deep sand (Fig. 7.17), higher sand/silt & clay ratio (Fig. 7.30), higher resistance (Fig. 7.25), low soil pH (Fig. 7.16), low cation exchange capacity (Fig. 7.18), low S-value (Fig. 7.19), low exchangeable Mg (Fig. 7.20), low exchangeable K (Fig. 7.21), low exchangeable Ca (Fig. 7.22), low exchangeable Na (Fig. 7.23), low "available" phosphorus (Fig. 7.24) and low organic matter content (Fig. 7.27) of the soils of community 4.0, the Stipagrostis ciliata var. capensis - Asthenatherum glaucum community.

The soils of communities 1.1 to 1.4 generally have higher pH values (neutral to moderately alkaline) (Fig. 7.16), higher organic contents (Fig. 7.27), more "available" phosphorus (Fig. 7.24), higher exchangeable Ca (Fig. 7.22), higher S-values (Fig. 7.19), higher cation exchange capacities (Fig. 7.18) and lower resistance (Fig. 7.25) than the soils of the communities 2.1 to 4.0.

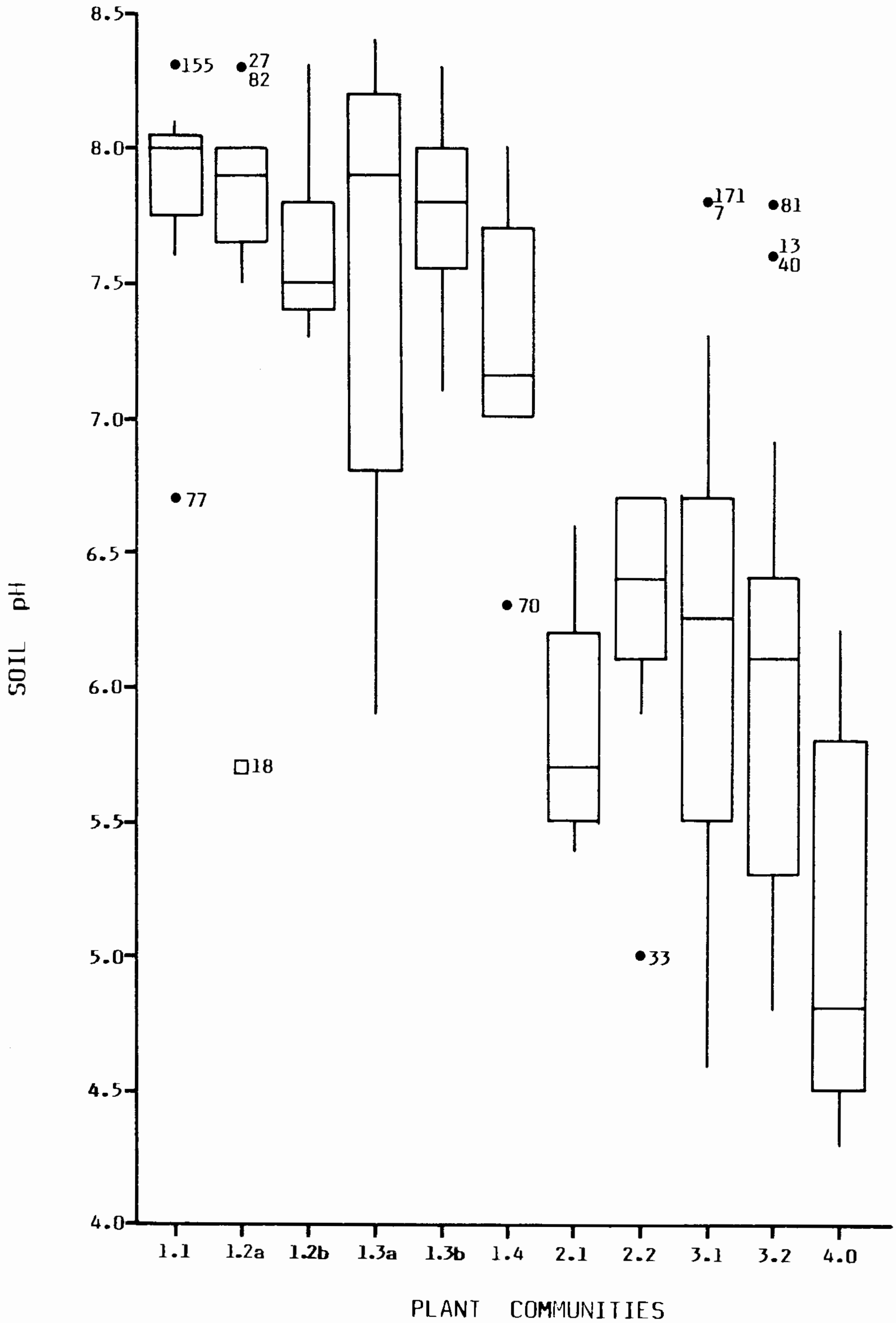


FIGURE 7.16 The location and spread of soil pH data from each of the plant communities on Vaalputs.

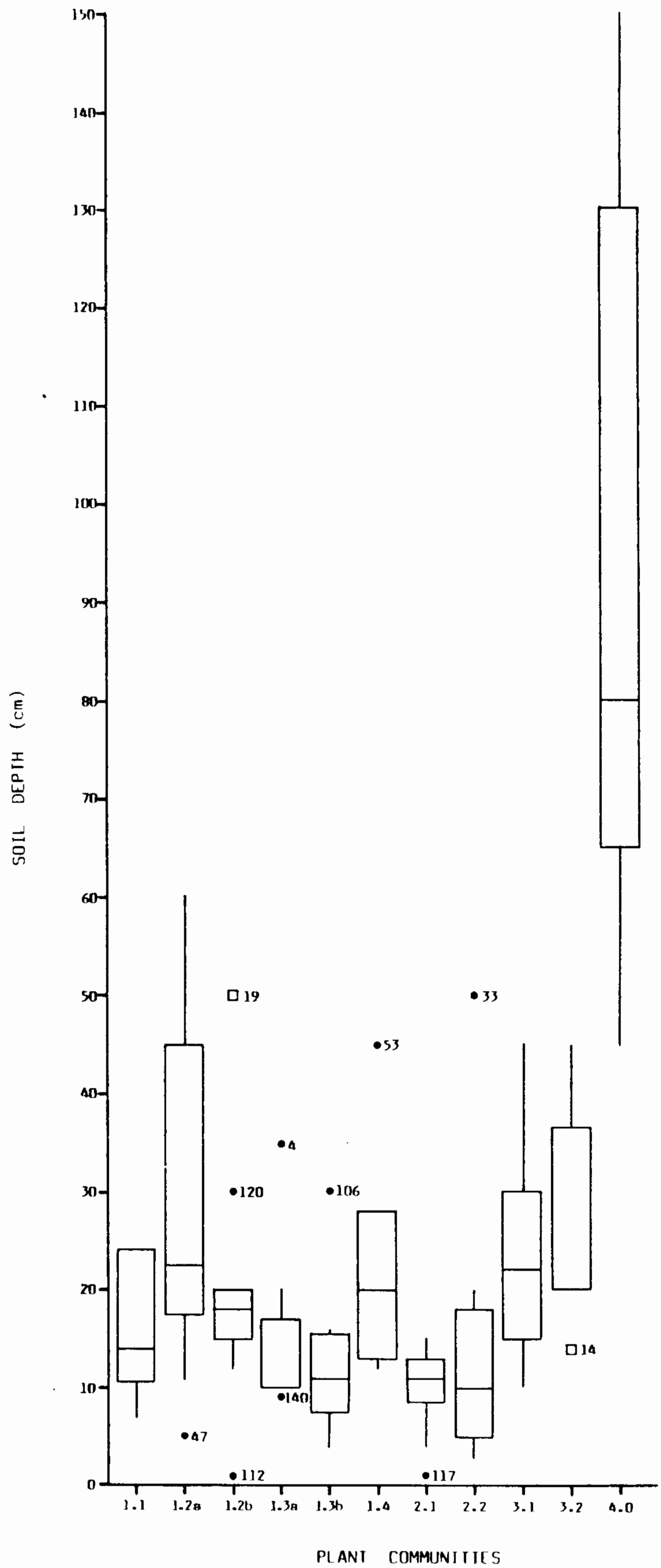


FIGURE 7.17 The location and spread of soil depth data from each of the plant communities on Vaalputs.

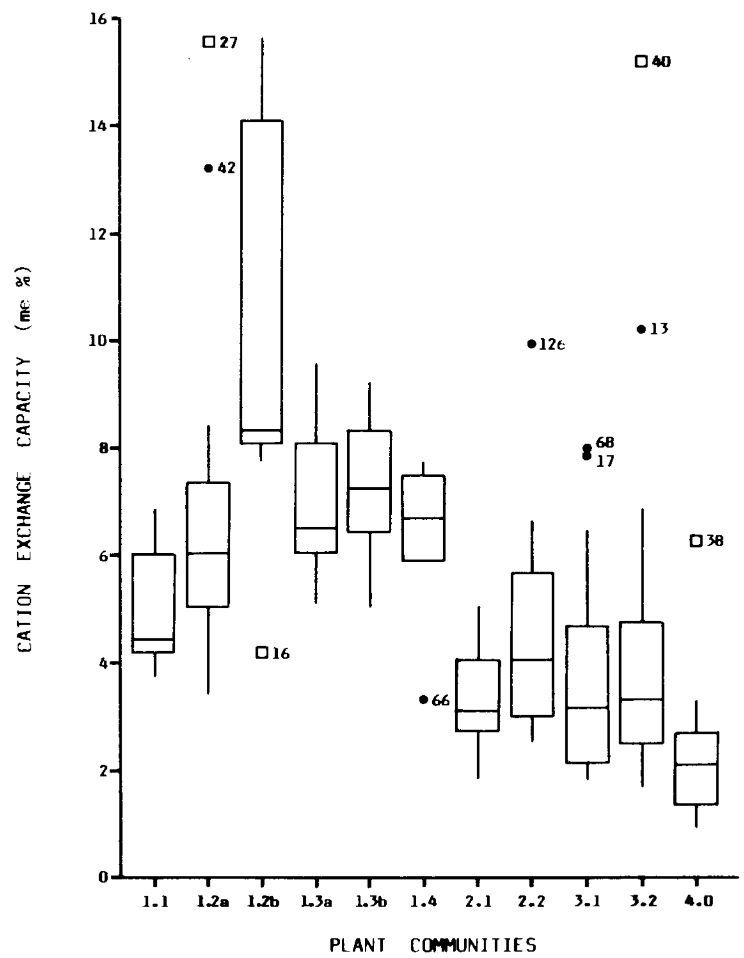


FIGURE 7.18 The location and spread of soil cation exchange capacity data from each of the plant communities on Vaalputs.

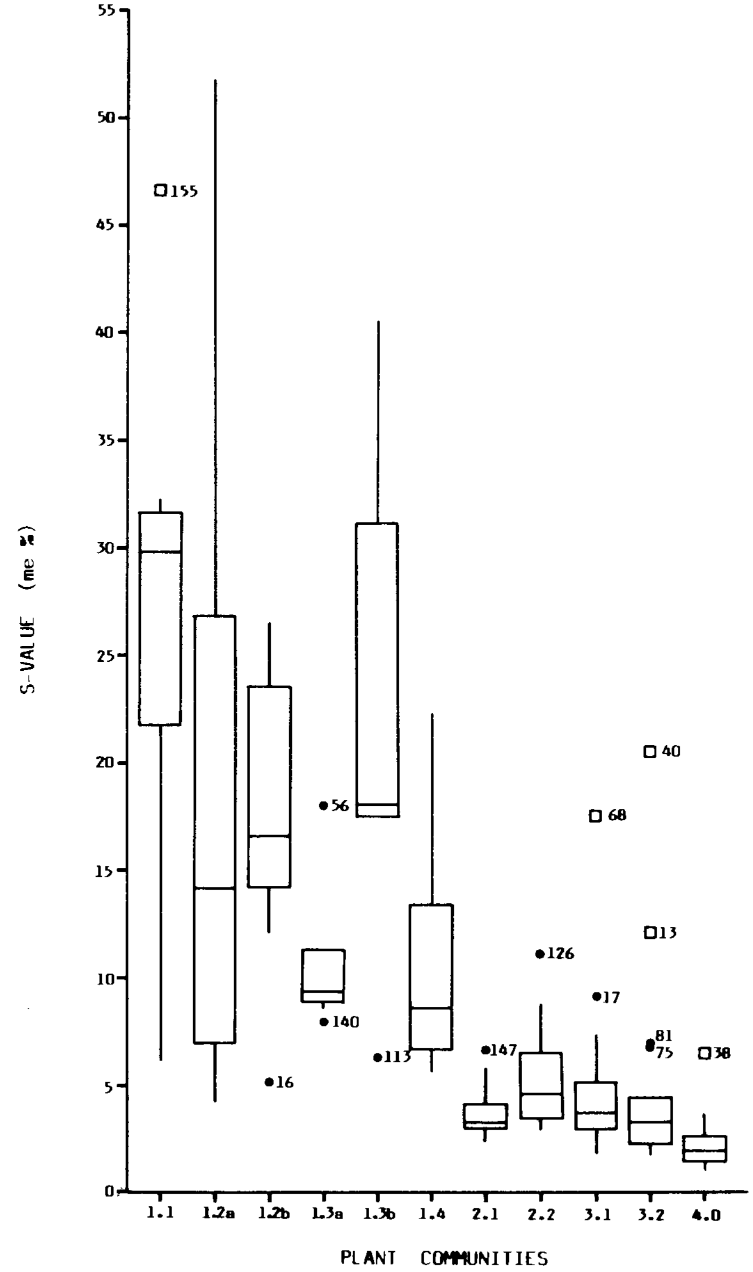


FIGURE 7.19 The location and spread of soil S-value data from each of the plant communities on Vaalputs.

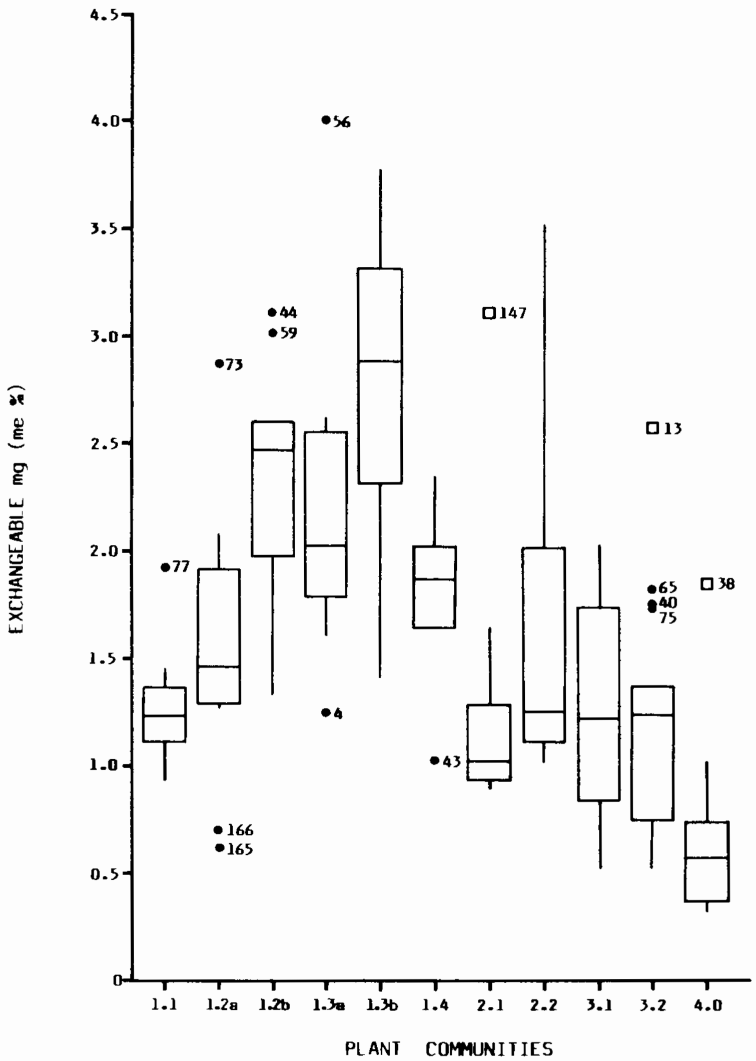


FIGURE 7.20 The location and spread of soil exchangeable Mg data from each of the plant communities on Vaalputs.

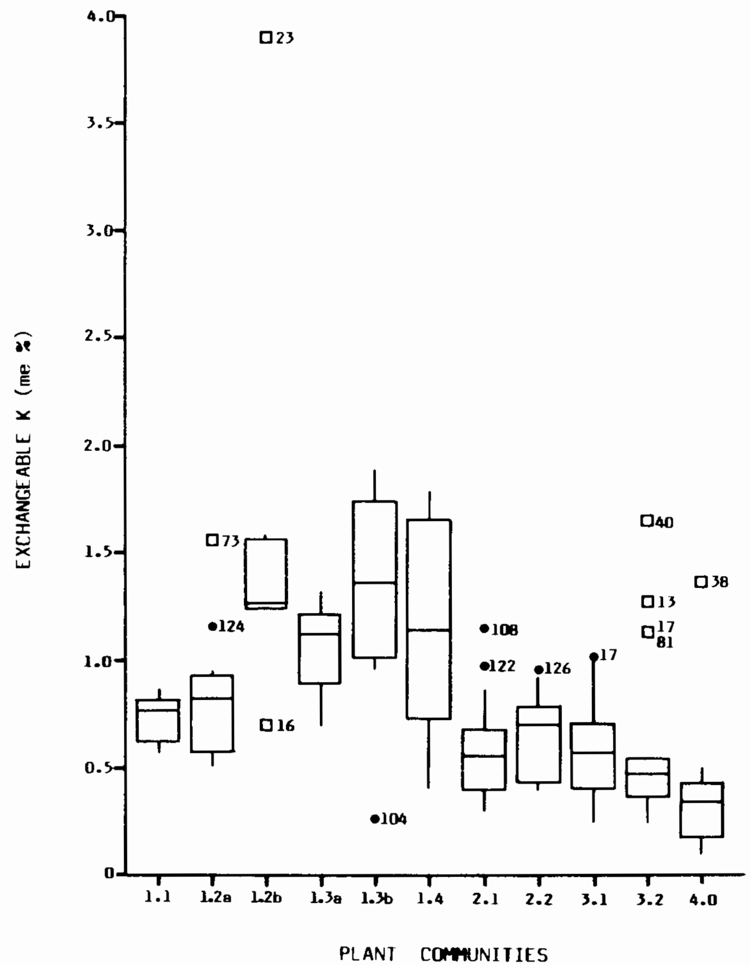


FIGURE 7.21 The location and spread of soil exchangeable K data from each of the plant communities on Vaalputs.

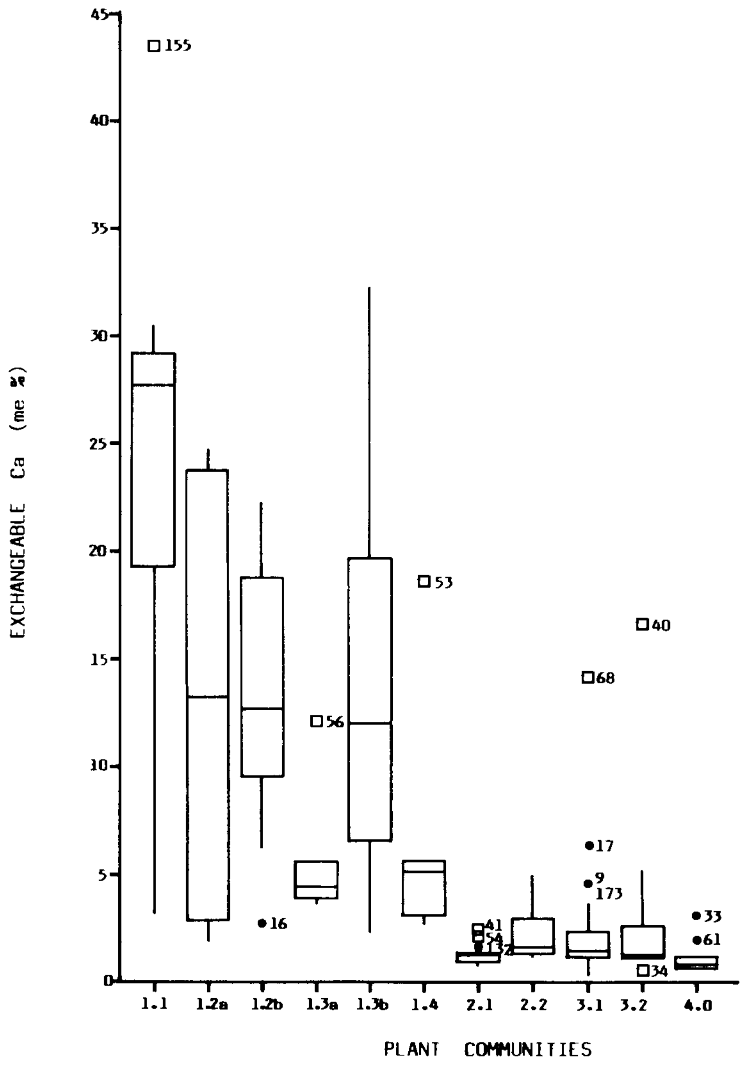


FIGURE 7.22 The location and spread of soil exchangeable Ca data from each of the plant communities on Vaalputs.

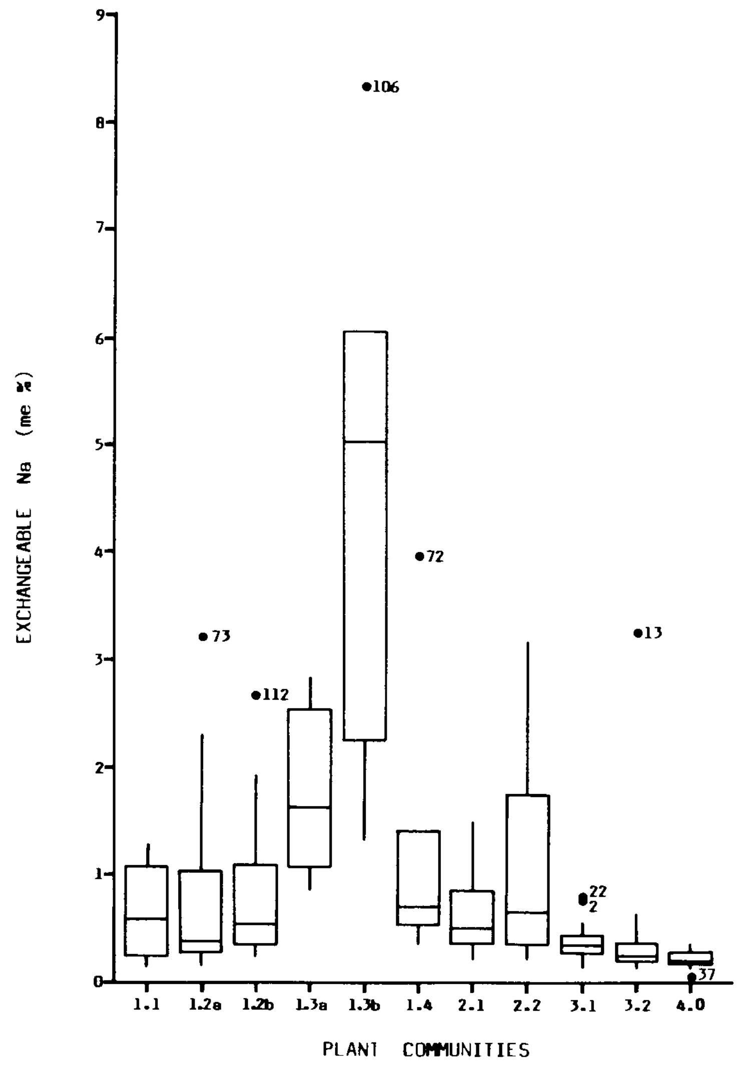


FIGURE 7.23 The location and spread of soil exchangeable Na data from each of the plant communities on Vaalputs.

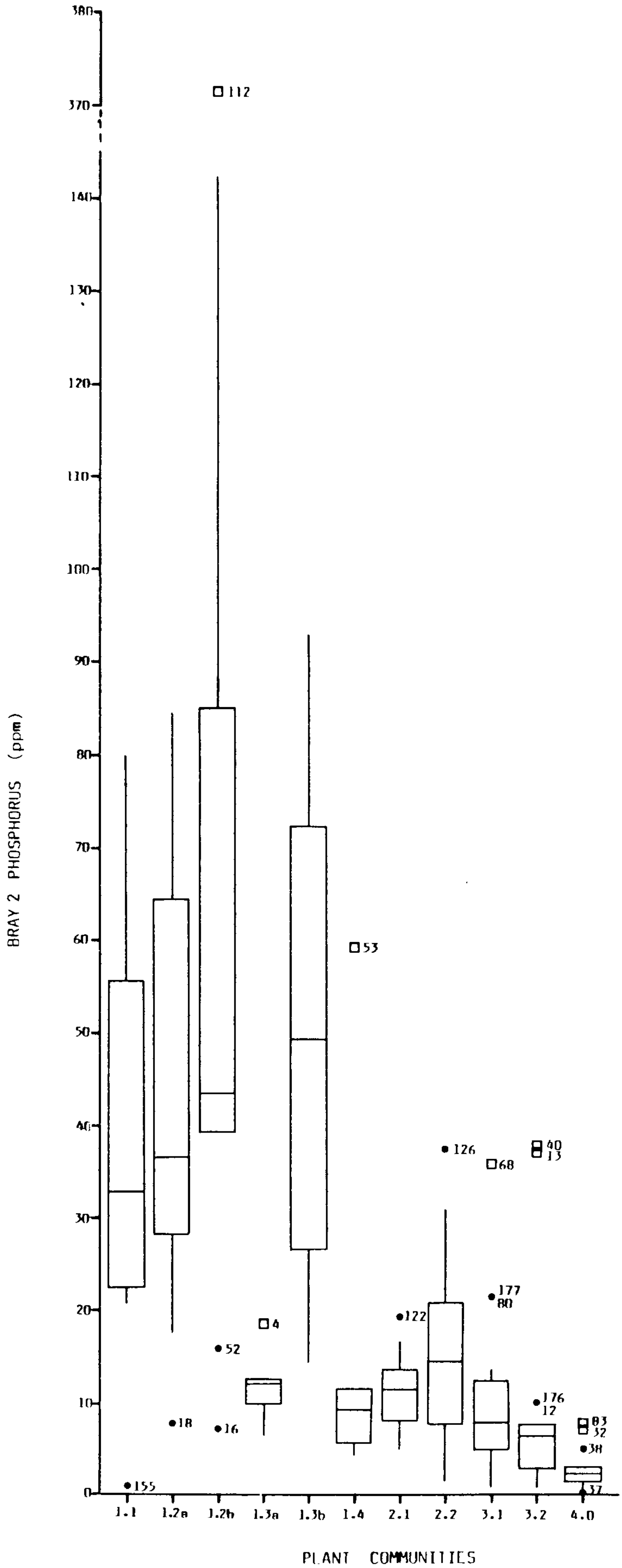


FIGURE 7.24 The location and spread of soil phosphorus data from each of the plant communities on Vaalputs.

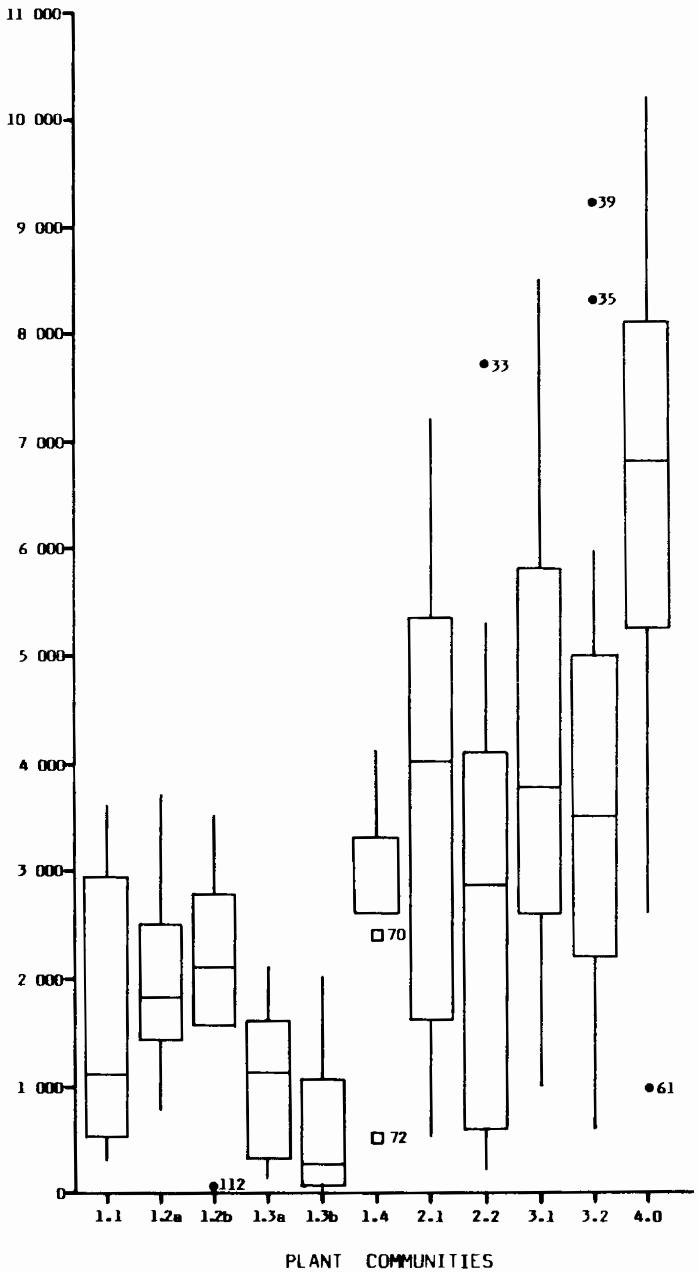


FIGURE 7.25 The location and spread of soil resistance data from each of the plant communities on Vaalputs.

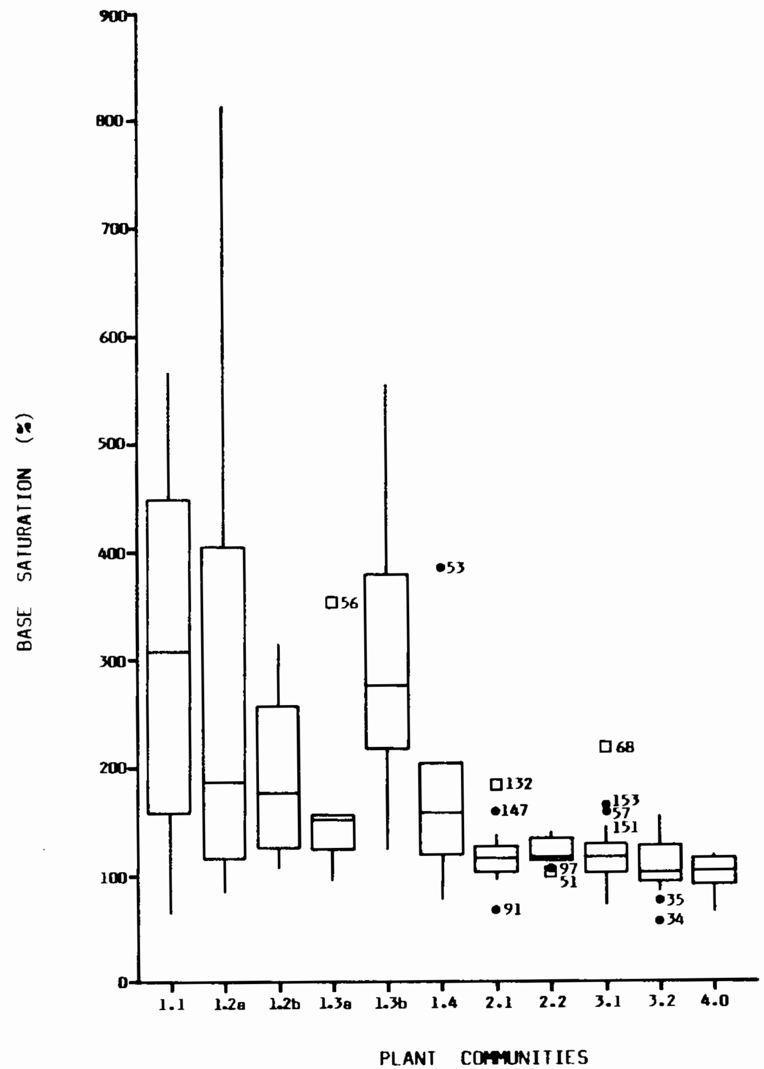


FIGURE 7.26 The location and spread of soil base saturation data from each of the plant communities on Vaalputs.

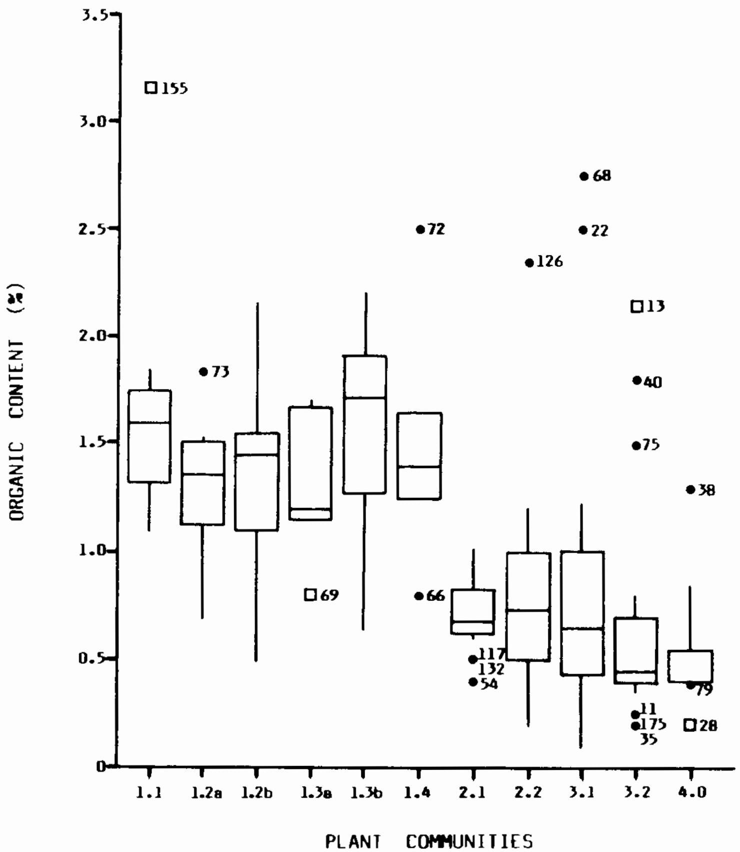


FIGURE 7.27 The location and spread of soil organic content data from each of the plant communities on Vaalputs.

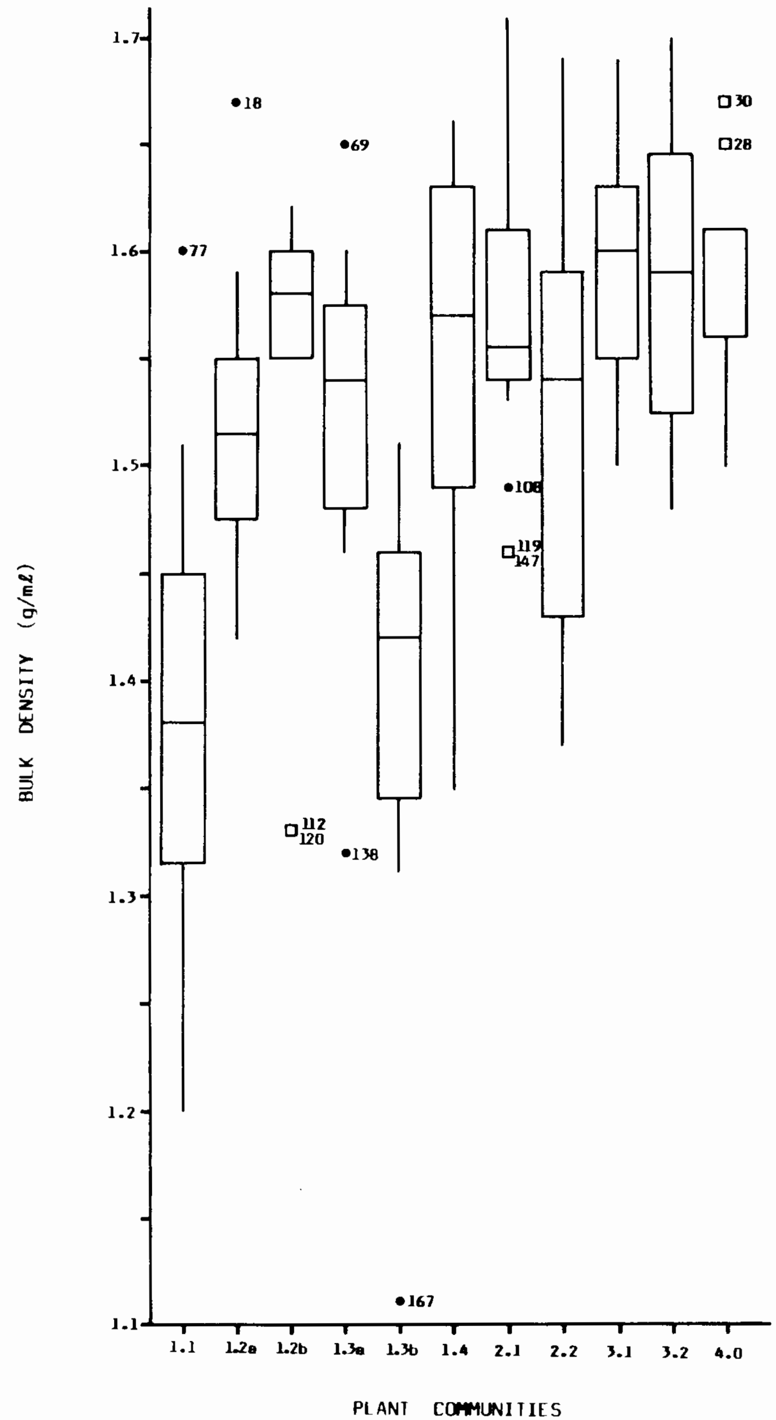


FIGURE 7.28 The location and spread of soil bulk density data from each of the plant communities on Vaalputs.

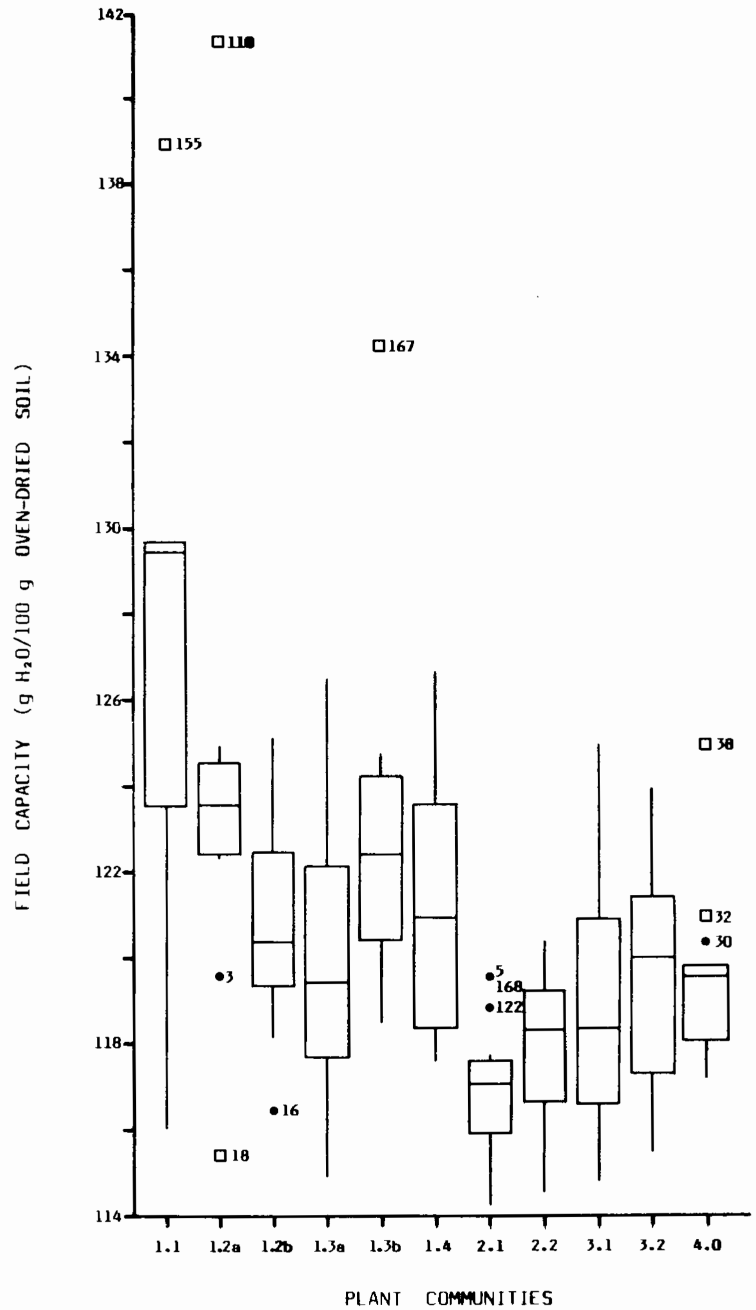


FIGURE 7.29 The location and spread of soil field capacity data from each of the plant communities on Vaalputs.

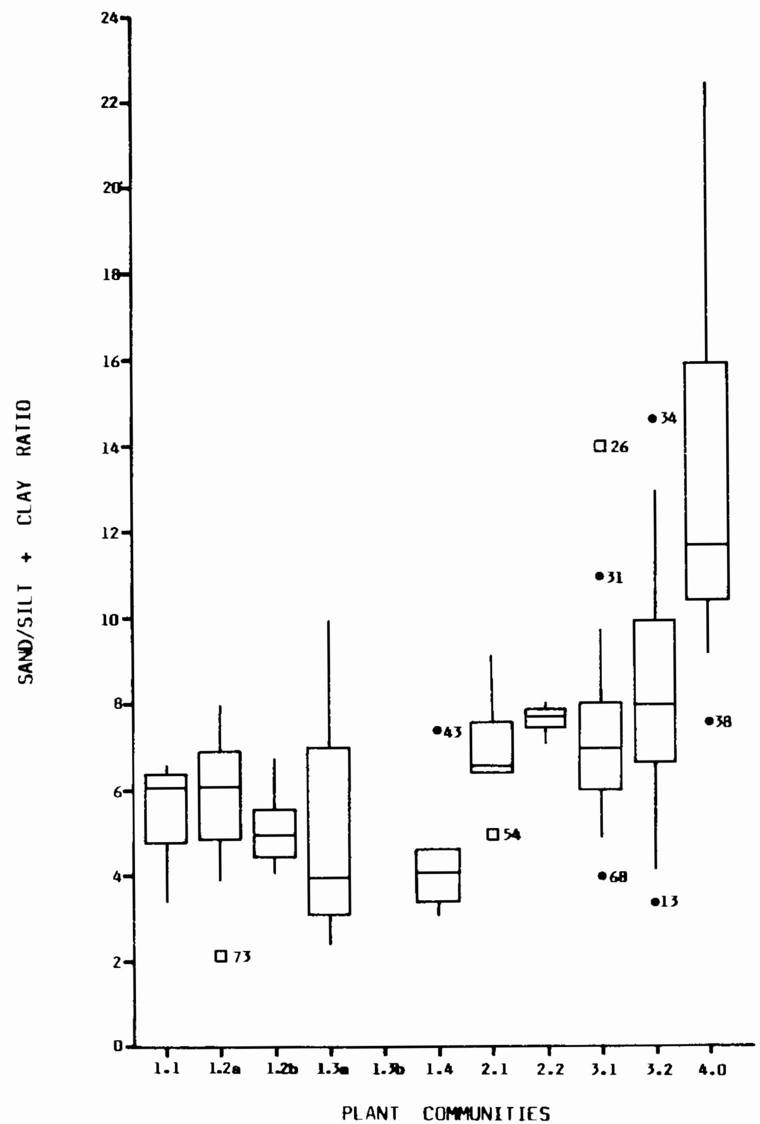


FIGURE 7.30 The location and spread of sand/silt & clay ratio data from each of the plant communities on Vaalputs.

CHAPTER 8 DISCUSSION AND CONCLUSIONS

8.1 CORRELATION OF THE VEGETATION WITH HABITAT CHARACTERISTICS

8.1.a) THE ORDINATIONS

Table 8.1 represents the results of a sample ordination. Samples are listed on the left hand side, and the values in each row are the co-ordinates of each sample on the axes. The axes would be analagous to the principal components in PCA, and the coordinates analagous to the component scores of stands. As indicated by Gittins (1969), although such tables can provide insight into species behaviour and vegetation structure, "interpretation is often aided by plotting the positions of species or stands in relation to pairs of components". Ordination of stands for the Vaalputs data have been plotted and are only shown with reference to the first two axes (Fig. 8.1).

Similarly, Table 8.2 represents the results of a species ordination. The coordinates of the most important differential species in each community described in chapter 7 have been plotted for the first two axes (Fig. 8.2).

The greatest number of succulent species are present from 0 sd to 2.5 sd along axis 1 (Fig. 8.3). This may perhaps be explained in terms of limited soil moisture availability over shallower, more compacted soils (Fig. 8.4), and in terms of "physiological drought" caused, perhaps, by the greater concentration of exchangeable cations (and resulting high pH) in the soil.

Geophytes are most prominent at the opposite end of axis 1 at 4-5 sd. This may possibly be explained in terms of soil moisture conditions which are more favourable in this relatively deep, well-aerated, aeolian sand.

As can be seen in Table 8.1, sample scores are zeroed so that the lowest sample score on each axis is 0, e.g. samples 56, 93 and 61 on

TABLE 8.1 Results of a sample ordination using detrended correspondence analysis, giving the co-ordinates of each sample on the first four axes

Sample Number	Axis 1	Axis 2	Axis 3	Axis 4	Sample Number	Axis 1	Axis 2	Axis 3	Axis 4	Sample Number	Axis 1	Axis 2	Axis 3	Axis 4	Sample Number	Axis 1	Axis 2	Axis 3	Axis 4
1	3.04	2.05	1.91	1.42	45	1.56	0.66	2.21	2.07	89	1.91	3.01	2.86	1.24	133	1.28	2.85	2.44	2.04
2	1.85	0.89	2.76	0.95	46	1.89	0.97	2.77	1.03	90	1.01	3.16	2.36	2.19	134	1.03	2.68	2.41	2.27
3	1.11	1.08	2.40	1.10	47	0.30	2.40	1.78	1.91	91	1.64	0.58	2.77	2.18	135	1.25	2.83	2.43	2.29
4	0.91	1.24	2.61	0.77	48	2.00	1.06	2.20	1.86	92	1.46	0.61	2.90	2.24	136	1.05	2.82	2.48	2.34
5	1.39	0.57	2.53	1.71	49	2.45	1.37	2.92	2.00	93	0.64	0.00	3.13	3.12	137	1.17	1.17	3.11	1.37
6	1.38	0.66	2.49	1.98	50	2.34	1.39	2.44	1.92	94	0.92	0.36	3.15	2.80	138	0.93	0.86	3.22	1.13
7	3.00	1.67	3.09	1.90	51	1.60	0.79	2.24	1.77	95	2.03	0.98	3.06	2.42	139	1.48	1.49	3.27	1.31
8	3.00	1.82	2.44	1.73	52	0.48	1.07	2.80	0.42	96	2.20	1.08	3.20	2.50	140	1.50	1.51	3.33	1.43
9	2.84	1.86	2.40	1.69	53	0.17	1.54	2.28	0.70	97	1.78	1.09	2.91	2.48	141	0.80	0.99	3.09	1.40
10	3.63	1.29	1.13	1.83	54	1.26	0.19	2.22	1.96	98	1.86	1.01	3.02	2.63	142	0.69	0.71	3.02	1.00
11	3.17	2.13	2.86	1.89	55	2.69	1.69	2.02	1.79	99	0.78	0.11	3.03	2.84	143	1.71	0.93	3.03	2.73
12	2.70	1.98	1.62	1.36	56	0.00	1.11	2.59	1.87	100	1.24	0.57	2.91	2.74	144	1.70	0.96	3.33	3.04
13	2.43	1.46	1.84	1.63	57	2.68	1.54	2.40	1.71	101	1.70	0.56	2.85	2.42	145	2.17	1.44	2.66	1.99
14	2.23	1.24	2.07	1.10	58	0.68	2.34	1.84	1.70	102	1.29	0.47	2.75	2.84	146	1.72	1.06	3.20	2.24
15	1.29	0.94	3.01	1.10	59	0.57	1.28	2.38	1.21	103	1.26	0.65	2.75	2.91	147	1.59	0.64	2.61	2.51
16	0.76	1.09	2.44	1.12	60	1.90	1.28	2.99	2.19	104	0.84	0.12	2.90	2.52	148	1.76	0.95	3.07	3.01
17	1.64	1.11	2.96	1.49	61	4.57	1.13	0.00	1.88	105	1.07	0.17	3.02	2.65	149	2.02	0.98	3.16	2.47
18	1.33	2.00	1.80	1.71	62	2.89	1.90	1.80	1.54	106	1.05	0.69	3.01	1.91	150	1.70	0.96	3.14	2.66
19	0.51	1.01	2.57	1.00	63	4.39	1.32	1.84	2.00	107	1.01	0.74	3.19	1.90	151	2.44	1.45	3.36	2.42
20	1.55	0.97	2.47	0.71	64	2.45	1.75	1.93	1.52	108	1.42	0.36	2.43	2.47	152	1.60	1.26	2.97	2.38
21	2.88	1.68	2.64	1.45	65	2.82	1.86	1.47	1.32	109	1.47	0.43	2.40	2.19	153	2.68	1.53	3.20	2.26
22	1.65	1.20	2.82	0.74	66	0.45	0.37	3.10	0.00	110	0.89	2.45	2.19	2.25	154	2.10	1.54	2.80	2.02
23	0.46	1.13	2.62	0.91	67	1.44	0.95	2.75	1.15	111	0.99	2.61	2.25	2.20	155	1.42	3.41	2.37	2.00
24	2.66	1.58	2.36	2.05	68	2.50	2.22	1.87	1.52	112	0.71	1.64	2.46	1.96	156	1.05	3.12	2.73	2.69
25	0.22	1.43	2.24	1.50	69	0.81	0.26	2.97	0.66	113	0.64	0.17	2.95	3.13	157	0.88	0.29	3.11	1.66
26	2.80	1.86	1.90	1.83	70	0.62	0.25	3.13	0.30	114	0.70	0.57	2.83	2.71	158	0.87	0.34	3.11	1.71
27	0.99	1.36	2.19	1.30	71	0.88	3.30	1.80	1.96	115	4.19	2.11	3.57	2.24	159	4.16	1.71	3.17	1.79
28	4.26	1.09	0.69	2.00	72	1.01	0.84	2.72	0.50	116	4.24	1.94	3.13	1.90	160	4.57	1.95	3.35	1.78
29	2.63	1.60	1.89	1.64	73	1.68	1.76	2.11	1.50	117	1.55	0.73	2.65	2.68	161	4.42	2.16	3.78	1.59
30	5.15	0.87	0.03	2.30	74	2.59	1.58	1.66	1.30	118	1.39	0.19	2.48	2.70	162	4.60	1.92	3.73	1.68
31	2.86	1.85	2.20	2.09	75	2.87	2.18	1.33	1.26	119	1.33	0.47	2.87	2.57	163	2.87	1.66	2.90	2.01
32	4.51	0.93	0.56	1.99	76	3.08	2.15	1.99	1.55	120	0.44	1.78	2.23	2.56	164	4.30	2.02	3.57	1.77
33	1.66	1.03	2.83	2.30	77	1.07	2.74	1.77	1.85	121	0.49	0.55	2.77	2.95	165	1.61	2.20	2.13	1.61
34	3.01	1.93	1.54	1.50	78	0.46	3.60	1.42	2.27	122	1.53	0.50	2.53	2.77	166	1.78	2.20	2.00	1.52
35	3.08	2.41	1.38	1.27	79	4.35	0.87	0.50	1.98	123	1.92	0.56	2.68	2.65	167	0.65	0.35	3.04	1.55
36	2.94	2.32	1.39	1.28	80	3.13	2.32	1.26	1.34	124	0.93	1.56	2.41	2.44	168	1.56	0.81	2.73	1.70
37	5.13	0.88	0.05	2.29	81	2.75	2.07	1.70	1.22	125	1.22	1.70	2.51	2.24	169	2.85	2.13	1.43	1.18
38	4.03	1.24	0.92	2.01	82	0.42	3.74	1.43	2.35	126	1.79	1.26	2.88	2.60	170	1.97	0.93	2.66	1.90
39	2.81	2.10	2.15	1.41	83	4.58	1.08	0.43	2.06	127	1.88	1.01	3.05	2.81	171	2.36	1.48	2.73	2.09
40	3.24	2.03	2.68	1.66	84	3.00	2.08	1.39	1.34	128	1.82	1.46	2.78	2.69	172	2.77	1.73	2.07	1.73
41	1.14	0.66	2.04	2.59	85	0.55	3.54	2.02	2.15	129	1.61	1.80	2.48	2.70	173	2.38	1.79	2.63	2.12
42	0.63	1.33	2.46	1.06	86	0.61	1.12	2.85	0.47	130	1.76	1.06	3.04	2.48	174	3.54	1.39	1.23	1.76
43	1.23	1.12	2.68	0.74	87	1.84	0.92	2.82	1.14	131	1.55	1.65	2.59	2.72	175	3.49	2.44	2.73	1.84
44	1.16	0.79	2.85	0.90	88	1.02	1.02	2.58	1.03	132	1.46	0.53	2.50	2.59	176	2.86	1.96	1.87	1.29
															177	2.57	1.61	1.99	1.52
															178	4.20	1.84	3.45	1.69

TABLE 8.2 Results of a species ordination using detrended correspondence analysis, giving the co-ordinates for each species on the first four axes

SPECIES NUMBER	AXIS 1	AXIS 2	AXIS 3	AXIS 4	SPECIES NUMBER	AXIS 1	AXIS 2	AXIS 3	AXIS 4	SPECIES NUMBER	AXIS 1	AXIS 2	AXIS 3	AXIS 4
1	5.15	0.87	0.03	2.30	39	4.25	3.09	3.99	3.08	80	4.72	3.13	4.45	1.23
2	5.05	0.70	-0.26	2.04	41	0.00	-0.37	3.59	0.22	81	0.99	4.78	3.08	0.38
3	4.22	2.98	4.21	2.85	42	-0.62	0.33	3.26	4.14	82	0.72	3.58	2.93	2.01
4	2.47	2.47	0.42	0.71	43	1.36	0.38	3.77	3.16	83	0.52	4.53	3.70	4.00
5	3.05	2.01	2.15	2.83	44	1.95	1.06	1.79	1.20	84	0.76	0.81	2.59	3.44
6	3.22	3.13	0.86	0.53	45	2.87	1.06	1.95	1.75	85	1.84	0.63	4.02	3.84
7	3.22	2.30	1.12	1.34	46	1.11	0.28	3.23	0.85	86	1.09	0.20	3.46	3.42
8	2.90	2.59	1.34	1.00	47	1.25	1.08	2.93	3.15	87	1.26	0.47	4.00	4.14
9	3.60	2.38	3.52	1.84	48	2.65	2.27	1.38	1.16	89	1.34	2.12	1.00	2.78
10	2.62	1.38	3.17	2.81	49	1.44	1.70	3.25	3.25	90	-0.01	3.32	1.01	3.35
11	2.03	1.34	3.67	3.02	50	4.13	2.69	4.03	0.51	91	2.22	3.82	3.82	-0.27
12	1.18	-0.16	2.36	3.02	51	4.36	1.52	4.19	2.22	92	0.89	-0.46	1.04	2.93
13	1.12	0.35	2.01	0.71	52	0.94	0.59	3.33	3.32	93	0.89	-0.46	1.04	2.93
14	1.73	0.22	3.29	0.69	53	1.44	1.72	3.85	1.22	94	5.08	2.26	4.91	1.37
15	0.74	0.07	3.55	2.02	54	2.11	3.23	2.49	0.87	95	4.87	1.57	4.10	1.03
16	0.10	4.40	1.47	3.00	55	2.43	1.42	3.94	3.67	96	4.94	2.04	4.59	0.97
17	0.12	3.54	0.91	2.23	56	2.74	1.96	2.25	0.73	97	5.08	2.26	4.91	1.37
18	0.25	4.08	2.01	3.00	57	3.26	3.22	3.65	2.40	98	5.00	2.68	4.75	1.48
19	0.50	4.04	1.97	2.39	58	4.57	2.43	4.23	1.45	99	5.00	2.68	4.75	1.48
20	0.18	3.93	1.92	3.47	59	4.80	2.73	4.18	3.40	100	4.63	2.32	4.34	1.30
21	0.66	2.76	0.67	0.07	60	4.12	1.78	3.89	1.65	101	4.74	3.16	4.50	0.75
22	0.30	4.58	2.72	3.13	61	0.98	2.22	2.80	3.30	102	5.08	2.26	4.91	1.37
23	0.02	3.07	3.08	1.19	62	1.36	0.38	3.18	3.21	103	4.35	3.11	4.18	0.51
24	1.60	1.12	1.97	1.84	64	4.72	2.35	4.30	1.46	104	3.87	4.10	4.14	-1.68
25	0.97	0.29	3.14	0.17	65	4.43	1.67	4.28	2.49	105	4.84	2.03	4.13	1.17
26	-0.24	0.41	3.13	-0.07	66	4.48	1.85	4.18	1.78	106	4.81	1.66	4.14	0.85
27	-0.19	1.71	1.68	2.59	67	4.60	2.12	4.31	1.32	107	3.96	2.92	0.48	1.31
28	0.24	0.06	3.57	-1.05	68	4.46	1.98	4.17	1.73	108	1.72	0.42	3.93	0.79
29	-0.05	-0.18	3.80	0.41	69	4.90	2.31	4.31	2.07	109	1.27	1.89	3.94	-1.01
30	-0.09	-1.11	2.86	4.04	70	4.81	2.31	4.33	1.92	110	1.09	-0.23	3.23	1.64
31	1.41	2.98	2.18	2.21	71	4.71	2.11	4.37	1.60	111	0.43	3.91	2.10	3.09
32	0.51	-0.40	2.93	1.75	72	4.43	1.75	4.30	2.20	112	1.26	-0.20	3.00	1.44
33	0.97	4.55	2.20	0.76	73	3.87	1.33	4.21	3.01	113	1.13	3.27	0.48	0.73
34	2.47	1.96	2.55	1.85	74	4.90	2.41	4.33	1.68	114	2.19	0.12	4.19	3.58
35	3.82	1.03	4.19	0.90	75	4.95	1.82	3.49	2.16	115	0.80	-0.10	4.05	-0.56
36	1.33	4.55	3.10	0.37	76	4.90	2.89	4.58	1.58	116	4.84	1.51	3.83	1.01
37	0.20	3.51	3.52	3.28	78	4.72	3.04	4.23	1.03	117	4.04	2.91	4.46	1.62
38	0.94	2.77	2.51	1.00	79	0.89	-0.29	1.95	0.81	118	3.81	2.61	4.19	1.23

A KEY TO THE SYMBOLS ON THE ORDINATION DIAGRAMS

SYMBOL	PLANT COMMUNITY NAME AND NUMBER	
◆	1.1	The *Aptosimum depressum* - *Salsola tuberculata* dwarf/low open shrubland community
○	1.2(a)	The *A. depressum* - *Ruschia muricata* - *Zygophyllum retrofractum* low semi-open shrubland community
●	1.2(b)	The *A. depressum* - *Ruschia muricata* low semi-open//moderately closed shrubland community
□	1.3(a)	The *A. depressum* - *Psilocaulon ciliatum* dwarf semi-open shrubland community
X	1.3(b)	The *A. depressum* - *P. ciliatum* - *Ruschia* cf. *R. levynsiae* dwarf semi-open shrubland community
◇	1.4	The *A. depressum* - *Psilocaulon planisepalum* - *Salsola zeyheri* low semi-open shrubland community
▲	2.1	The *Eberlanzia armata* low open//semi-open shrubland community
△	2.2	The *E. armata* - *Ruschia robusta* low open//semi-open shrubland community
•	3.1	The *Stipagrostis brevifolia* - *Ruschia robusta* low/short open grassy shrubland community
▽	3.2	The *S. brevifolia* - *Lycium* spp. complex short open grassy shrubland community
■	4.0	The *Stipagrostis ciliata* var. *capensis* - *Asthenatherum glaucum* low open grassland community

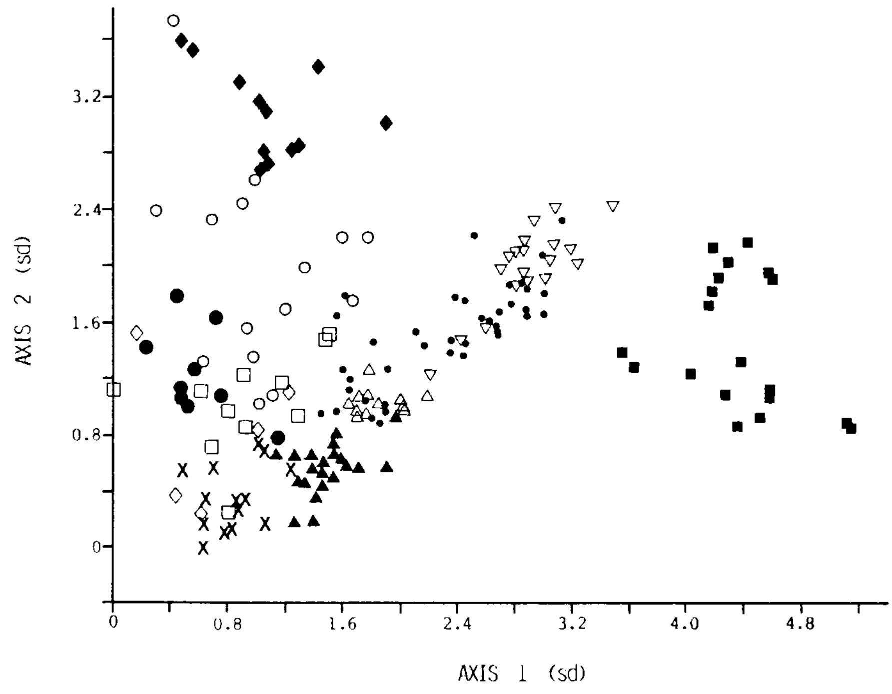


FIGURE 8.1 A detrended correspondence analysis (DCA) ordination of relevés. Scatter diagram with communities indicated along the first and second axes of the ordination.

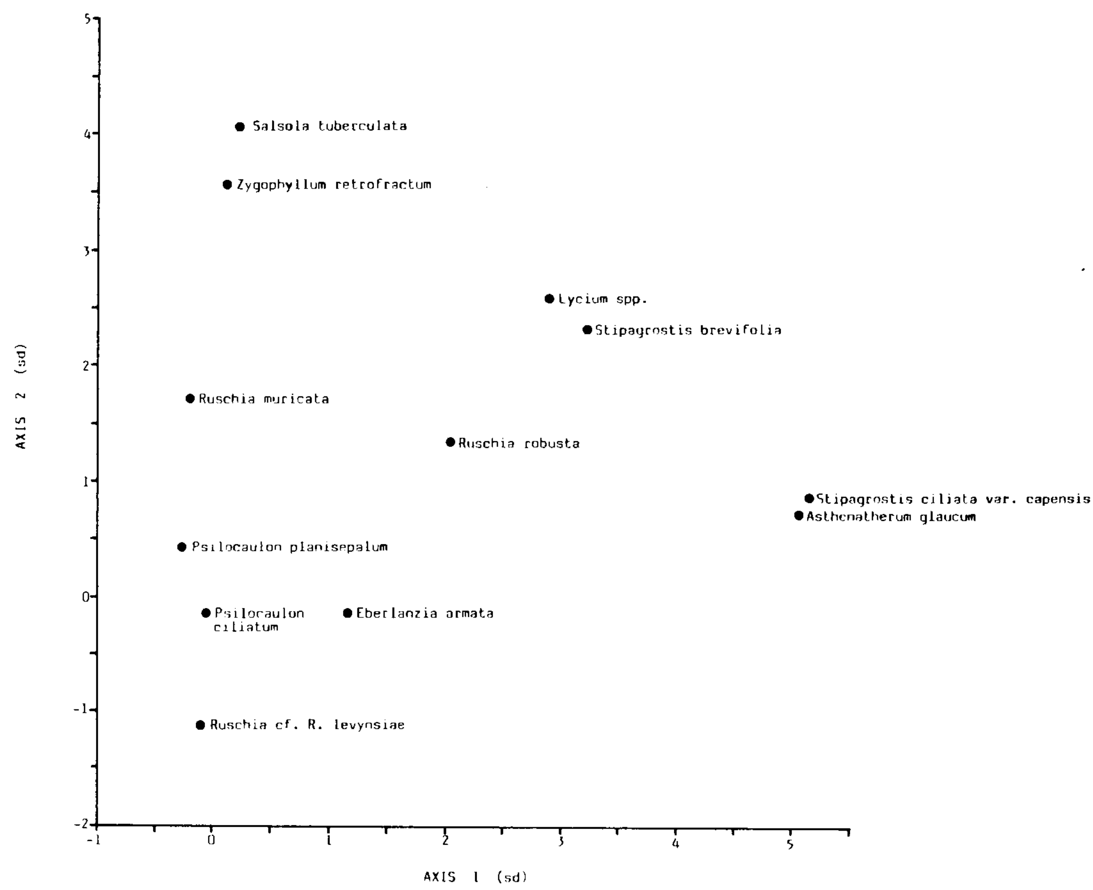


FIGURE 8.2 A detrended correspondence analysis (DCA) ordination of species. Scatter diagram with the most important differential species indicated relative to the first and second axes of the ordination.

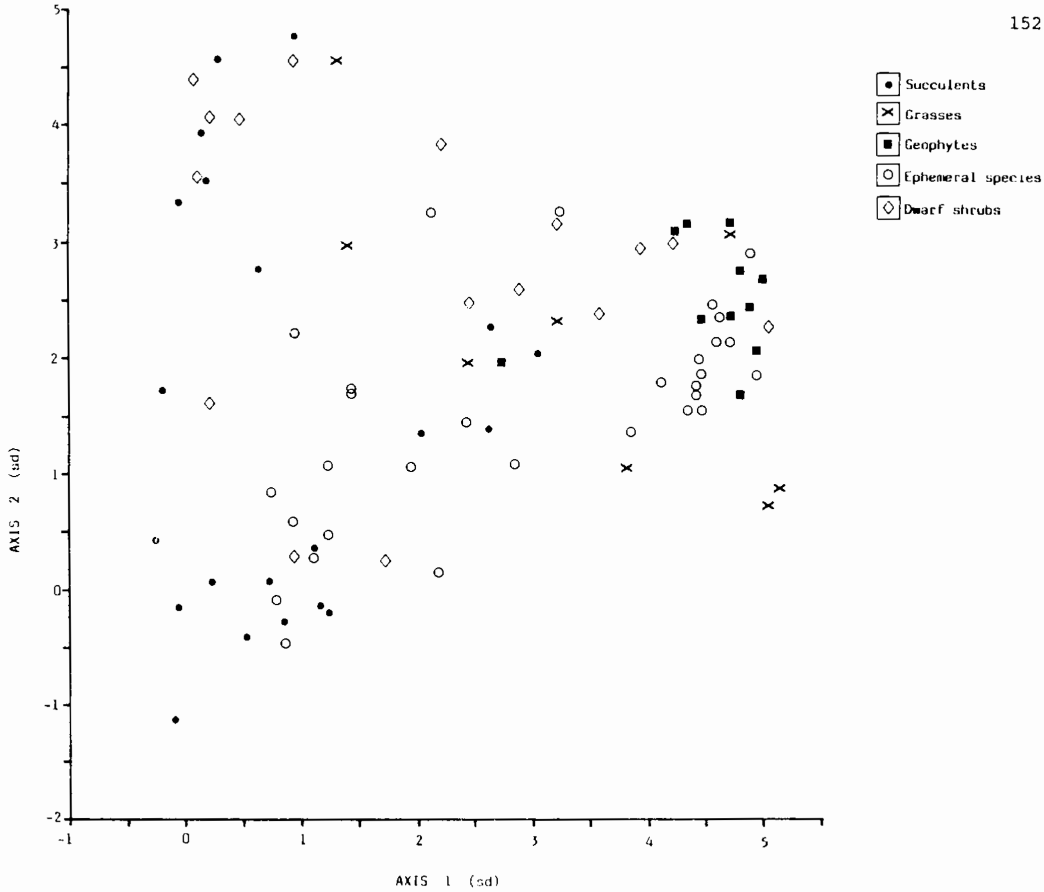


FIGURE 8.3 A detrended correspondence analysis (DCA) ordination or species. Scatter diagram with succulents, grasses, woody dwarf shrubs, annuals and geophytes indicated relative to the first and second axes.

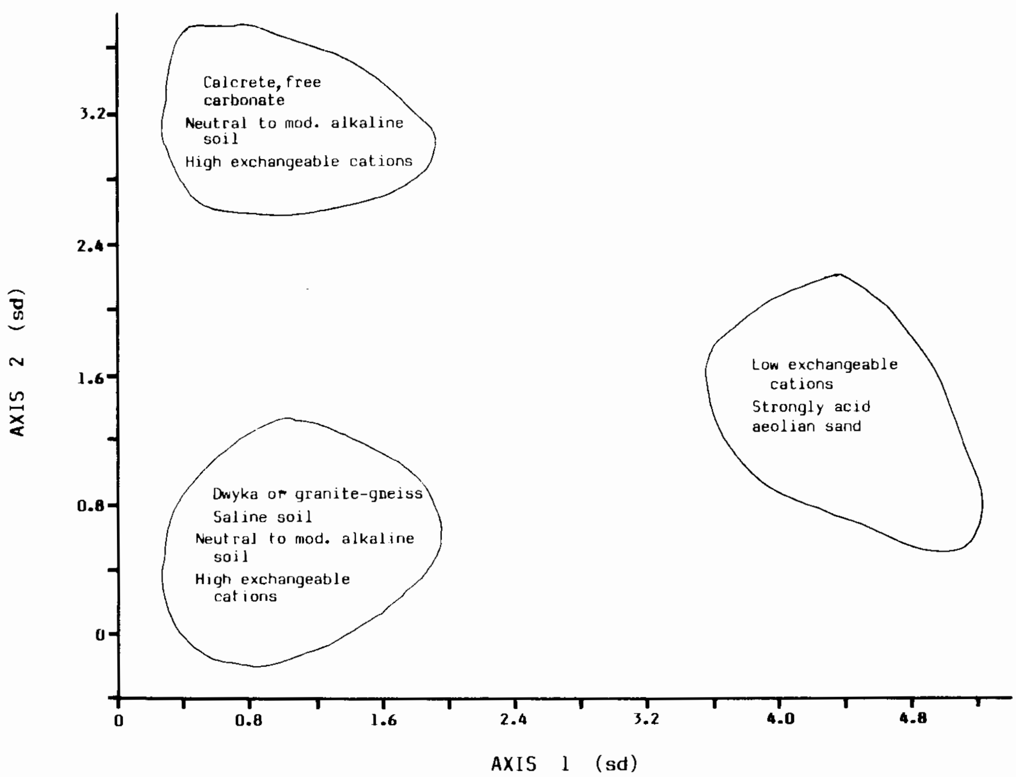


FIGURE 8.4 The three most dissimilar habitats in relation to the first two axes of a detrended correspondence analysis ordination.

axes 1, 2 and 3 respectively. Sample scores are the mean scores of the species that occur in them; hence the species scores have a broader range than the sample scores. In particular, the lowest scoring species will always have a score less than zero (Hill 1979) e.g. Galenia sarcophylla (sp 42) has a score of -0.62 on axis 1, Ruschia cf. R. levynsiae (sp 30) a score of -1.11 on axis 2, and Asthenatherum glaucum (sp 2) a score of -0.26 on axis 3 (Table 8.2).

The eigenvalues for the first four axes are given in Table 8.3.

Table 8.3 The eigenvalues for the first four axes

AXIS	EIGENVALUE
1	0.653
2	0.432
3	0.292
4	0.242

The importance of the scatter diagrams (Figs 8.1-8.3) lies primarily in the distances or spatial relations between the points (samples or species), as well as their position in relation to the origin (Gittins 1969). As Gittins (1969) explains, the closer the points, the greater the ecological similarity of the entities they represent (samples or species), and *vice versa*. He also indicates that points (samples or species) which are diagonally opposite imply a strong negative correlation. These stands or species may be ecologically alike in the sense that they are responding to a common influencing factor e.g. soil moisture content or soil pH, but they differ in reacting to the influencing factor in opposite senses.

The distance of a sample or species from the origin is indicated on the scatter diagrams by the standard deviation of the variable (sd).

Gittins (1969) gives justification for the interpretation that the further a point (sample or species) is from the origin, the more it is related to the components (axes) shown. In this case, the points represented by the Stipagrostis ciliata var. capensis - Asthenatherum glaucum community are furthest from the origin and are, therefore, more related to the ecological controls operating along axis 1 than are the points, representing the Aptosimum depressum - Psilocaulon ciliatum - Ruschia cf. R. levynsiae community, which lie close to the origin.

According to Hill (1979), "for each axis, the length of the gradient is the length of the sample ordination. Even if there is no real variation in the data (zero beta-diversity), the species ordination can be about 3-4 sd in length. On the other hand, a sample ordination of length 4 sd means that species occurring at one end of the gradient are almost completely absent at the other end and vice versa". This can be seen on axis 1 (Fig. 8.2) of the Vaalputs data where the grass species, namely Stipagrostis ciliata var. capensis and Asthenatherum glaucum, which are present on the deeper acid sands at a standard deviation of approximately 5 are absent from the opposite end of the ordination at 0 sd. Similarly species such as Ruschia cf. R. levynsiae, Salsola tuberculata and Ruschia muricata which occur at approximately 0 sd are absent at 5 sd.

Another method which may be used to illustrate the spatial relationships of the samples or species to one another is the construction of three-dimensional models. This has not been done for this investigation, but as Gittins (1969) suggests, it may prove to be a more effective aid to the interpretation of results than the preparation of scatter diagrams.

In an analysis of Vaalputs ordination data, the author judged the edaphic factors to be of major importance and thus initially evaluated and interpreted the ordination results against these data, as illustrated in Figs 8.5-8.13 (for axis 1).

It is possible to analyse and ordinate the various environmental variates jointly with the species data. However, as Gittins (1969) indicates, there is not always agreement in this regard, as it involves inclusion and joint analysis of variates measured on different scales, e.g. species abundance expressed as % cover, soil cations as me/100g dry soil, and soil acidity in pH units. References cited by Gittins (1969) in this respect include: Anderson (1958); Lawley & Maxwell (1963); Seal (1964); Pearce (1965); Williams & Dale (1965); Cattell (1966); Morrison (1967); Ferrari, Pijl & Venekamp (1957); Sokal, Daly & Rohlf (1961) and Rayner (1966).

Species which have a high loading (coordinate value) on one of the axes may provide some indication of the ecological influence or control expressed by that axis (Gittins 1969), e.g. considering the species ordination of Vaalputs data (axis 1 vs axis 2)(Table 8.2 & Fig. 8.2) Stipagrostis ciliata var. capensis and Asthenatherum glaucum are among the species with the highest loadings on the first axis. They both, however, have a high positive loading. There are no species with a high negative loading, although Ruschia cf. R. levynsiae, R. muricata, Psilocaulon ciliatum and P. planisepalum all have a small negative loading. These species differ from the first two by occupying opposite ends on the first axis. From field experience and the Braun-Blanquet table (Table 7.1), it is known that S. ciliata var. capensis and Asthenatherum glaucum are usually associated with relatively deep, strongly acid sands whereas Ruschia muricata, Ruschia cf. R. levynsiae, Psilocaulon ciliatum and P. planisepalum are all associated with shallower, more alkaline (saline or calcareous) soils with higher pH values.

On the basis of this knowledge, axis 1 may, as an initial hypothesis, be regarded as an expression of the possible ecological control exerted by the edaphic factor-complex of soil depth and soil nutrient status, which is operative in distinguishing the main plant communities.

The following edaphic factors have been plotted for each sample position along axis 1:

Soil pH	Fig. 8.5
Soil Depth	Fig. 8.6
Cation exchange capacity (CEC)	Fig. 8.7
S-value (total cations)	Fig. 8.8
Exchangeable Mg	Fig. 8.9
Exchangeable K	Fig. 8.10
Exchangeable Ca	Fig. 8.11
Exchangeable Na	Fig. 8.12
Bray 2 P	Fig. 8.13

Four groups of samples (using communities identified by means of the Braun - Blanquet phytosociological table [Table 7.1]) can be distinguished along the first axis as a result of the important ecological controls operating along this direction.

3.5sd - 5.3sd: community 4.0
2.1sd - 3.5sd: communities 3.2, 3.1 and 2.2
1.2sd - 2.1sd: community 2.1
0.0sd - 1.2sd: communities 1.1, 1.2(a), 1.2(b), 1.3(a), 1.3(b) and 1.4

The first group (Stipagrostis ciliata var. capensis - Asthenatherum glaucum) which is furthest from the origin is very distinct from the other three groups, between which there is a degree of overlap.

Examination of the graphs (Figs 8.5-8.13) of various habitat characteristics (edaphic factors) plotted against the sample positions along axis 1, reveal trends which indicate what the vegetation - habitat relationships may be.

Figure 8.5 illustrates the inverse linear relationship between soil pH (determined in KCl solution) and the samples along the first axis. Samples close to the origin have the highest pH values, and there is a linear decrease in pH with increasing distance of samples from the origin, along axis 1.

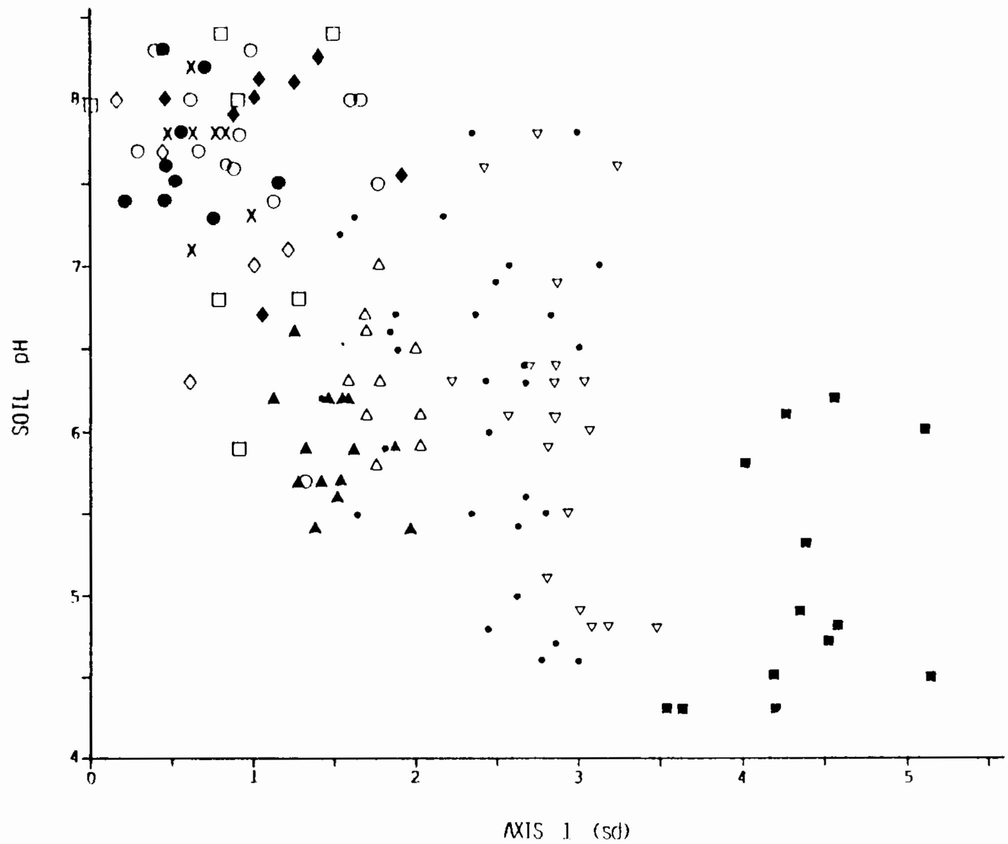


FIGURE 8.5 Soil pH values of samples along the first axis (DCA).

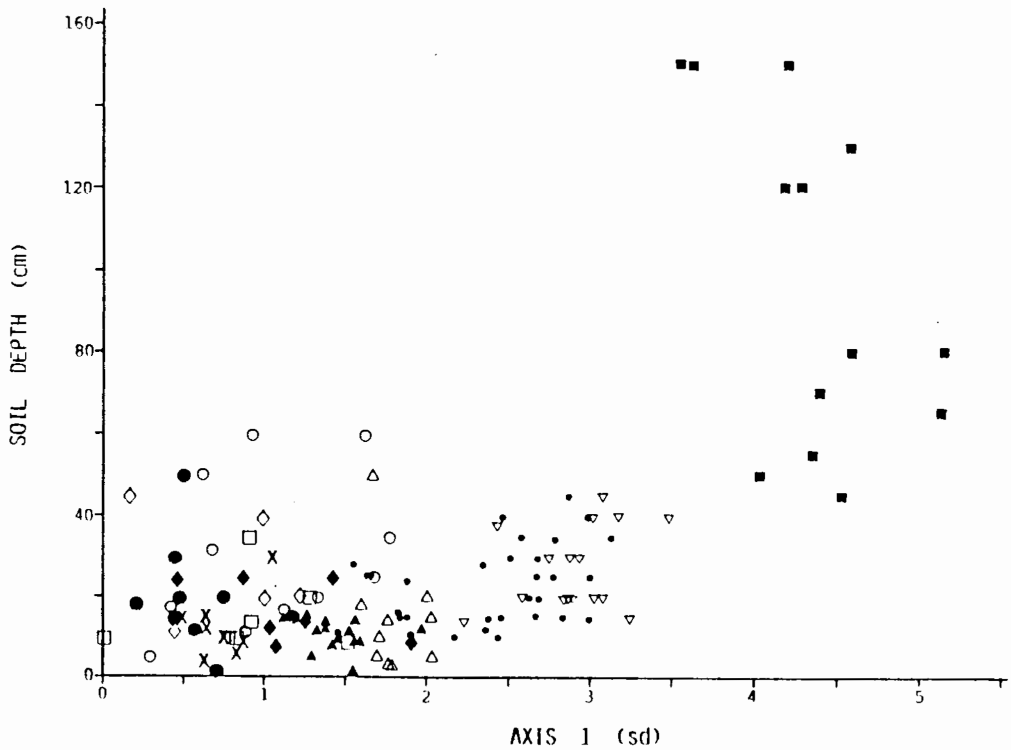


FIGURE 8.6 Soil depth values of samples along the first axis (DCA).

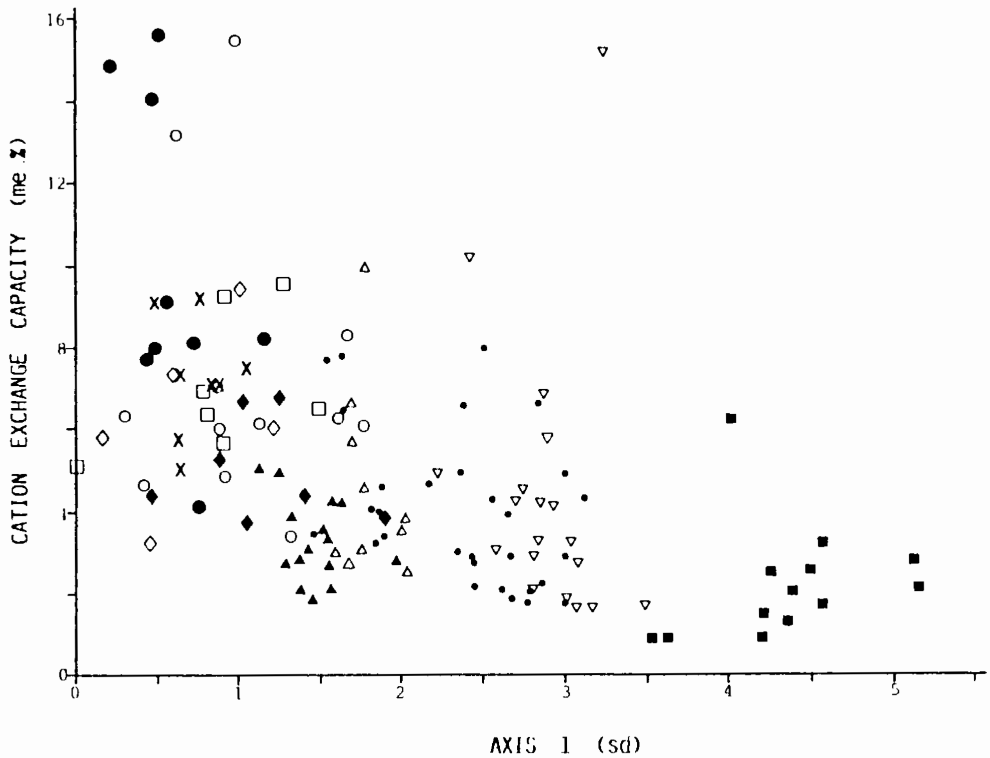


FIGURE 8.7 Cation exchange capacity values of soil samples along the first axis (DCA).

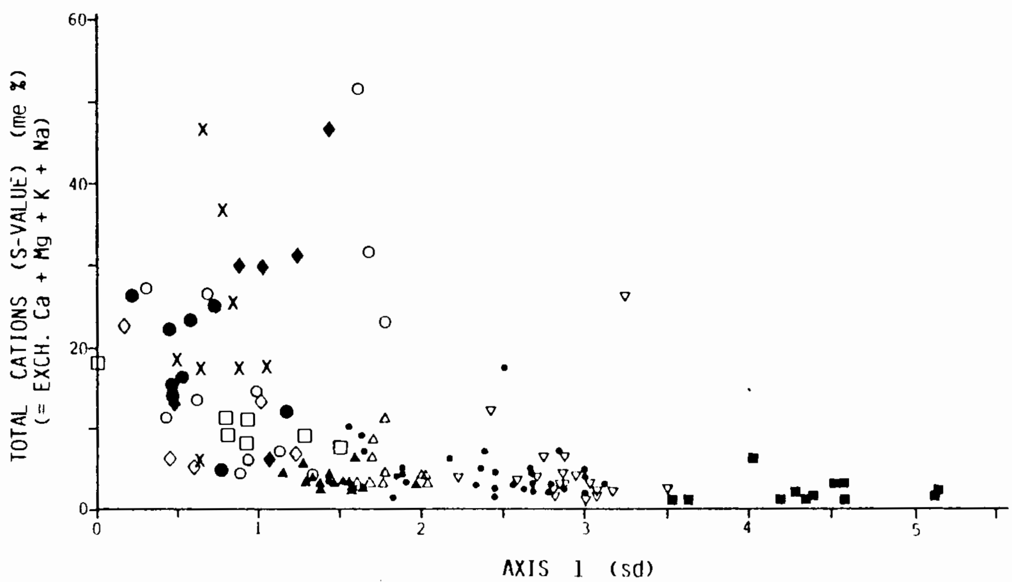


FIGURE 8.8 S-values of soil samples along the first axis (DCA).

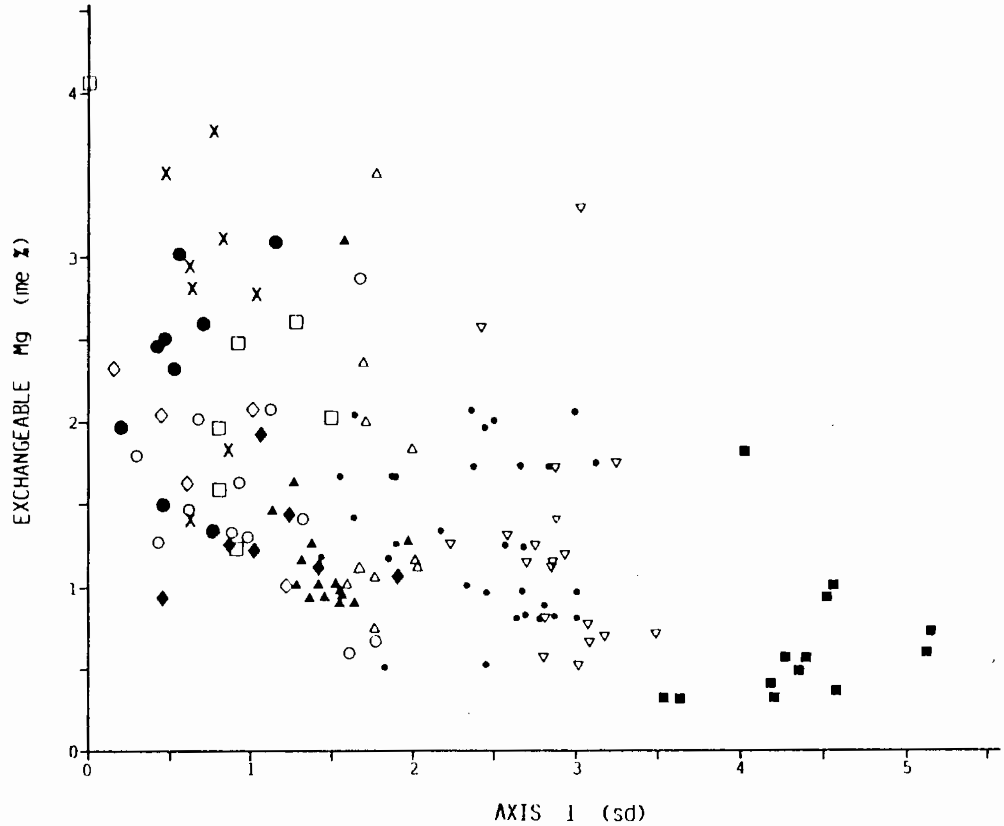


FIGURE 8.9 Exchangeable Mg values of soil samples along the first axis (DCA).

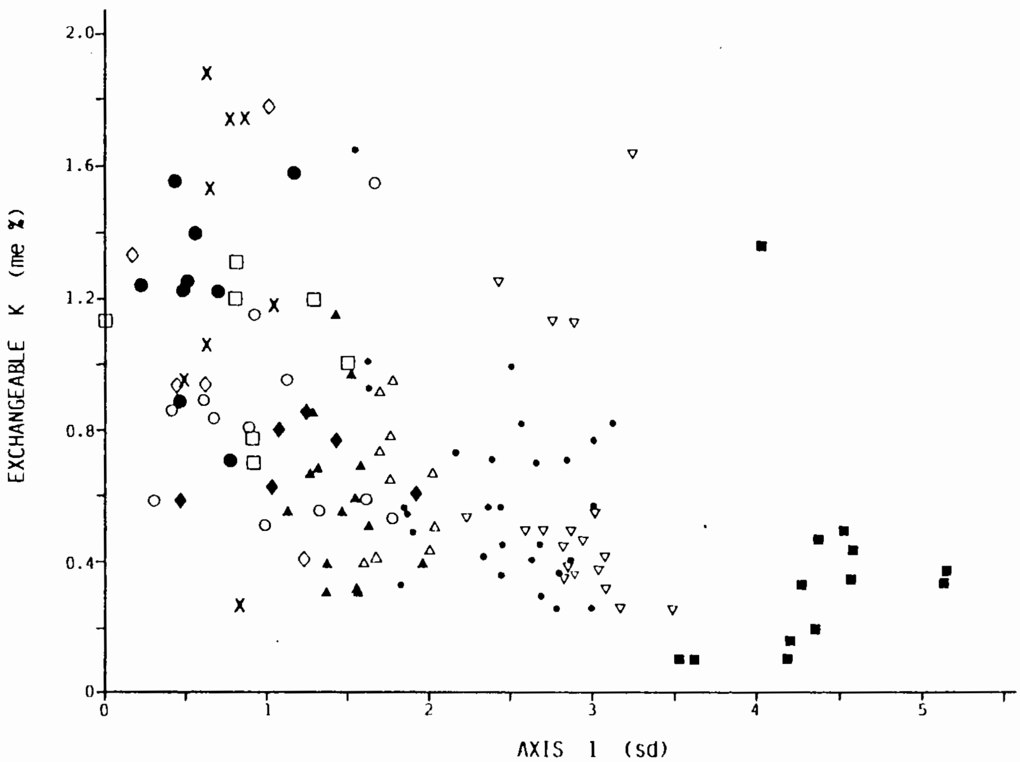


FIGURE 8.10 Exchangeable K values of soil samples along the first axis (DCA).

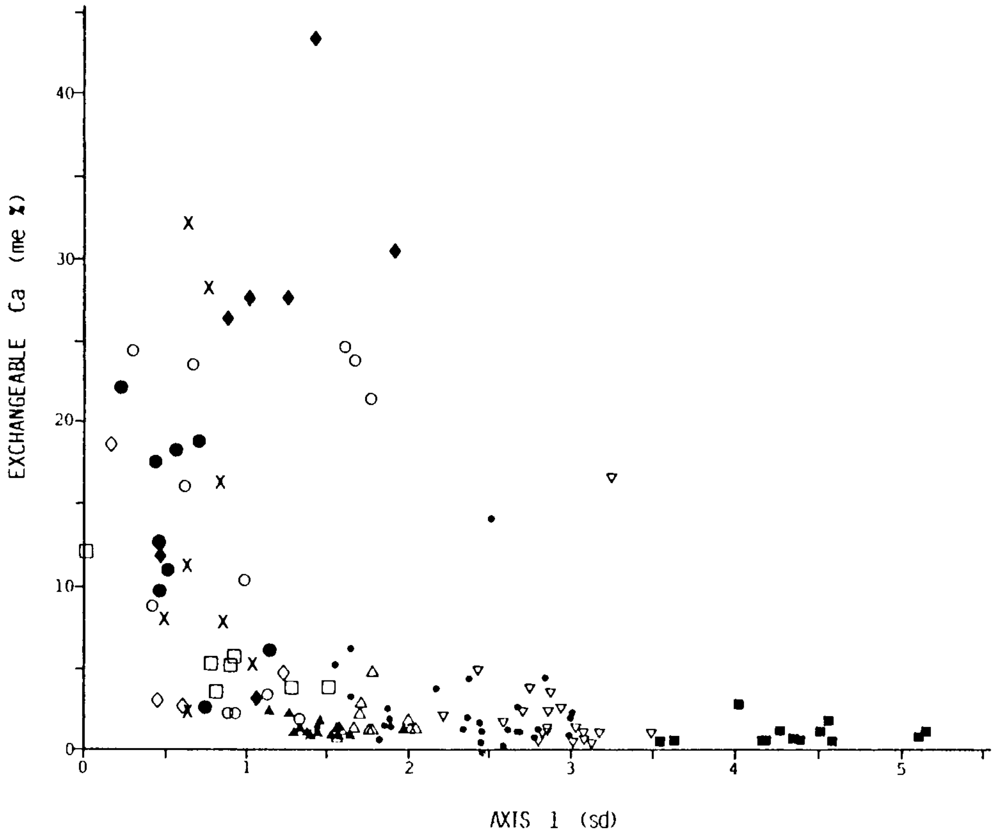


FIGURE 8.11 Exchangeable Ca values of soil samples along the first axis (DCA).

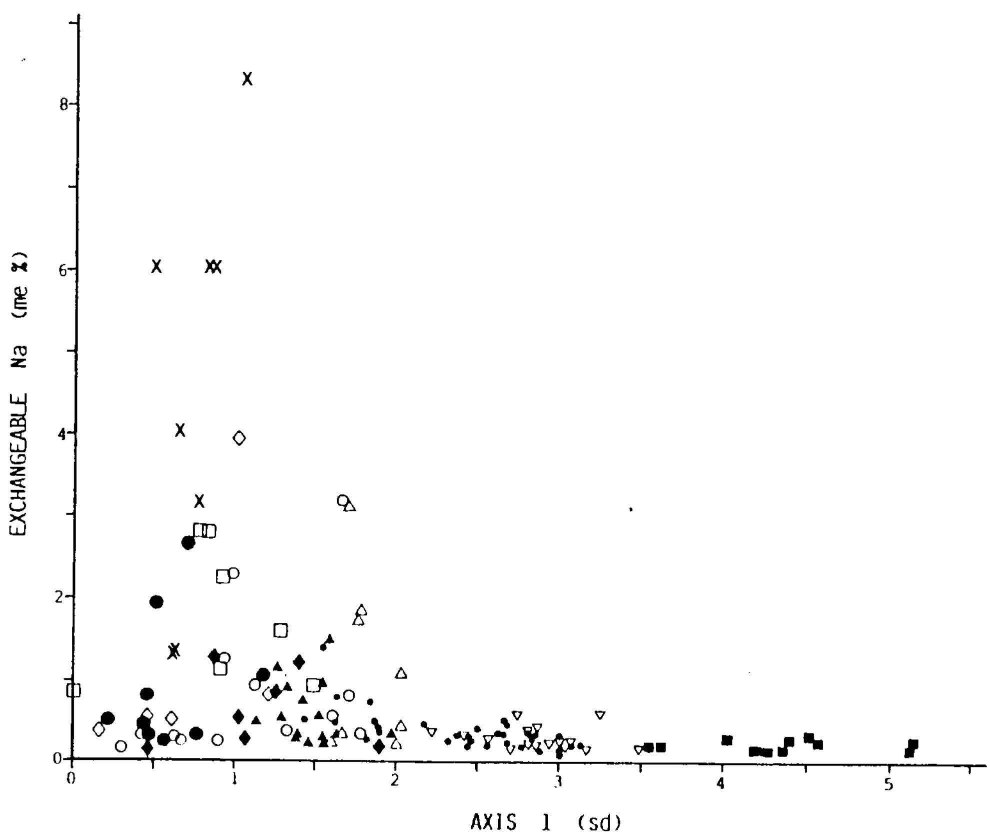


FIGURE 8.12 Exchangeable Na values of soil samples along the first axis (DCA).

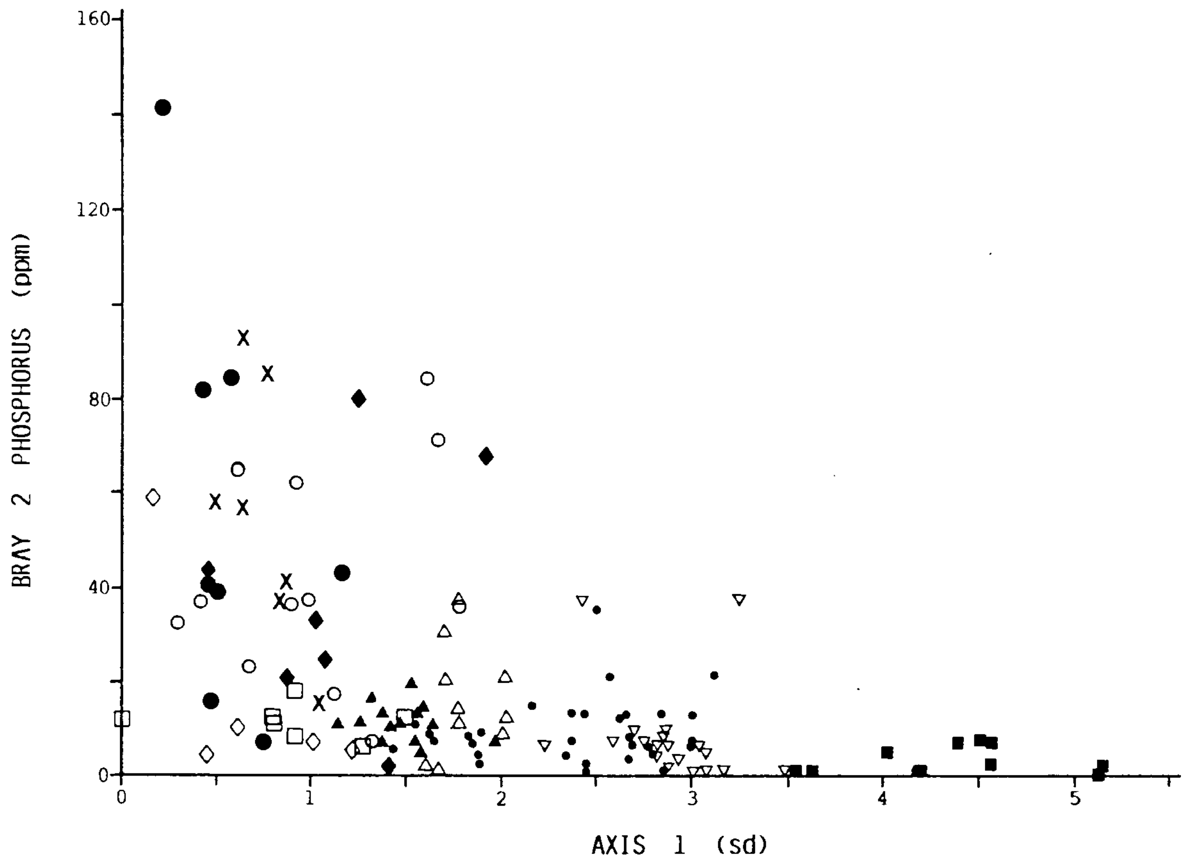


FIGURE 8.13 Bray 2 phosphorus values of soil samples along the first axis (DCA).

Examination of the trends displayed by the other variables along the first axis reveal similar inverse linear relationships between cation exchange capacity (CEC), exchangeable Mg and exchangeable K with increasing distance (sd) of sample points from the origin (Figs 8.7, 8.9 and 8.10).

There is also a decrease in S-value (total cations), exchangeable Ca, exchangeable Na and Bray 2 P ("available" phosphorus) with increasing distance along the axis. In this case the relationship does not appear to be inversely linear. There are consistently higher values for each of these factors for the first group of communities which lie between 0 and 1.2 sd (Figs 8.8, 8.11, 8.12 and 8.13). Also, the *Eberlanzia armata* community (Fig. 8.12) which lies between 1.2 sd and 2.1 sd has higher values for exchangeable Na than do the plant communities lying between 2.1 sd and 5.3 sd.

With the exception of the first group of plant communities (0-1.2 sd) on Fig. 8.6, there is a general increase in soil depth with increasing distance from the origin. The trends displayed by the soil nutrients are opposite to that displayed by soil depth.

8.1.b) INTERPRETATION AND EXPLANATION OF TRENDS ON AXIS 1

Soil pH appears to be the overriding ecological control operating along axis 1. As soil pH values do not mean very much on their own, it is necessary to examine possible causes of the change in pH observed along the gradient, and to relate this to the cation exchange capacity of the soil as well as to the presence of the various exchangeable cations (Na, Mg, Ca and K). In the soil solution, cations as well as anions, are important in plant nutrition as well as limiting the distribution of plants which are perhaps not suitably adapted to withstand the associated ionic conditions.

MacVicar et al (1977) emphasize the importance of soil pH in that "functional groups on surfaces of organic matter, clay and amorphous compounds tend to release protons at specific pH values and this is essentially the mechanism for pH-dependent cation exchange capacity in soils". The higher the pH, the higher the CEC, which is seen to be the case in examination of Figs 8.5 and 8.7.

In dealing firstly with the soils at the extremes of the pH range (Fig. 8.5), the plant communities [1.1, 1.2(a), 1.2(b), 1.3(a), 1.3(b) and 1.4] in the first group (0 - 1.2 sd) are associated with moderately alkaline to neutral soils whereas the Stipagrostis ciliata var. capensis - Asthenatherum glaucum community (3.5 sd - 5.3 sd) is associated with strongly acid soil. The high S-values (total cations) and exchangeable cations (Ca, Mg, K and Na) all contribute to the high pH values measured for the plant communities in the group closest to the origin.

According to Russell (1966), the theoretical maximum pH for soils in which calcium is the dominant exchangeable cation is pH 8.5, but in dry climates where sodium carbonate may be present in the soil, the value may rise higher, to about pH 10. This did not appear to be the case on Vaalputs, where the highest pH values measured were around pH 8.5. One may therefore predict that most of the carbonate present is calcium carbonate ($CaCO_3$) and not sodium carbonate (Na_2CO_3). From the high values of exchangeable Na which are present in some samples, one may expect the sodium (Na) to be present in the form of sodium chloride (NaCl), or possibly as a sulphate. Tests for chlorides (using $AgNO_3$) and sulphates (using HCl + $BaCl_2.2H_2O$) indicate that both of these anions are present, jointly in some samples, and singly in others.

Low pH values, such as those which occur in soils associated with the Stipagrostis ciliata var. capensis - Asthenatherum glaucum community, are usually characteristic of cation - undersaturated soils and nutrient deficiencies, particularly of divalent cations such as Ca and Mg. This is seen to be the case in examination of Table 7.21 and Figs 8.7 and 8.10. At low pH there is normally an increase in solubility of iron (which is evident from the increase in redness in soil colour), manganese and aluminium, which may cause toxicity effects in plants. These elements were, however, not analysed for this investigation. Theoretically, the soluble iron and aluminium produced at low pH may also remove phosphates from solution by precipitation.

The changes in edaphic factors occuring along axis 1 may to a large extent be explained with reference to the composition and weathering of the geological parent material.

There are three main host rocks present on Vaalputs:

(i) Granite - gneiss basement (Fig. 8.14)
(ii) Dwyka tillite and shales
(iii) Calcrete

In addition to this, there are soils produced by in situ weathering of this parent material as well as material which has been transported by wind and deposited on the site.

Different rocks have varying susceptibilities to weathering, for example, granites and gneisses are fairly easily weathered because the conditions (pressures and temperatures) at which their constituent minerals were formed are very different to the pressures and temperatures prevailing at the earth's surface, which is why the minerals are relatively unstable. Conversely, calcretes are more resistant to weathering.

FIGURE 8.14 The granite-gneiss basement on the western edge of the study site.

(i) Granite - gneiss basement

The composition and subsequent weathering of the constituent minerals of the granite - gneiss basement may be largely responsible for the observed soil nutrient status.

The main constituents of the basement granites on Vaalputs are quartz and potassium - and sodium - feldspar. Alkali feldspars are also major constituents of acid and intermediate gneisses. In nature, the common feldspars are silicates of aluminium with

potassium (K) - $KAlSi_3O_8$ (orthoclase and microcline)
sodium (Na) - $NaAlSi_3O_8$ (albite) and
calcium (Ca) - $CaAl_2Si_2O_8$ (anorthite),

although calcium feldspars do not occur to any great extent in the basement rocks on Vaalputs.

Weathering of the micas present in the basement rocks may also contribute to the nutrient status of the soil. The general formula describing the chemical composition of micas is (Deer, Howie and Zussman 1977):

$$X_2Y_{4-6}Z_8O_{20}(OH, F)_4$$

X is mainly K, Na or Ca but also Ba, Rb, Cs etc.
Y is mainly Al, Mg or Fe but also Mn, Cr, Ti, Li, etc.
Z is mainly Si or Al but perhaps also Fe^{+3} and Ti.

Granites and gneisses contain muscovite and biotite as the principal micas (Deer, Howie and Zussman 1977).

Muscovite: $K_2Al_4[Si_6Al_2O_{20}](OH, F)_4$

Biotite : $K_2(Mg,Fe^{+2})_{6-4}(Fe^{+3},Al,Ti)_{0-2}[Si_{6-5}Al_{2-3}O_{20}](OH,F)_4$

The Norabees granite is characterized by having a very low biotite content. It has been described as a fine-to medium-grained quartz-microcline gneissose aplogranite (Andersen _et al_ 1983).

The abundance of microcline ($KAlSi_3O_8$) in this granite may explain the relatively high potassium (K) content of the soils developed over the basement rock, whereas weathering of the micaceous minerals in the granite may contribute to the relatively high magnesium (Mg) content also found in these soils.

The plant communities which are found closely associated with weathered granite - gneiss basement include the Aptosimum depressum - Psilocaulon ciliatum, A. depressum - P. planisepalum - Salsola zeyheri and Eberlanzia armata communities. In all cases the soil is fairly shallow and compacted (Fig. 8.15), but contains relatively high values of exchangeable Mg and K which originate from the feldspars and micas.

According to Russell (1969) the concentration of potassium (K) in the soil solution is usually over ten times lower, and may be nearly a hundred times lower, than the calcium (Ca) concentration, and the level of exchangeable calcium is usually much higher than of exchangeable potassium (K). From Figs 8.10 and 8.11, this is seen to be the case. Because the values of exchangeable K are low relative to exchangeable Ca and Mg, potassium contributes a less significant proportion to the total cations (S-value).

The relatively high cation exchange capacity (CEC) for these same soils may be related to the relatively high clay content compared to soils from the opposite end of the axis (Stipagrostis ciliata var. capensis - Asthenatherum glaucum community). The average sand/silt+clay ratio of the Stipagrostis ciliata var. capensis - Asthenatherum glaucum community (Table 7.22) is 13.257 as opposed to an average sand/silt+clay ratio varying between 4.412 and 6.864 for communities 1.1 to 2.1 (Tables 7.3, 7.5, 7.7, 7.9, 7.11, 7.14 and Fig. 7.30).

Jenny (1983) explains that there may be a charge imbalance (a negative charge) on a clay platelet where, for example, Al^{3+} substitutes for Si^{4+} in the tetrahedral interstices, or where Mg^{2+} substitutes for Al^{3+}, depending on the type of clay present. This negative charge is balanced by extra cations (K^{+}, Na^{+} or Ca^{2+}) which are held by weak electrostatic forces on the oxygen plane so that the system as a whole is electrically neutral. These cations can be exchanged with other cations, e.g. one calcium cation (Ca^{2+}) which is attached to a soil particle may be replaced by two potassium ($2K^{+}$) ions (Jenny 1983). The number of exchangeable cations are a measure of the cation

FIGURE 8.15 Relatively shallow, compacted soil which occurs over the granite-gneiss basement.

FIGURE 8.16 The Aptosimum depressum - Psilocaulon ciliatum community around a basinal area where water and salts collect after rainfall.

exchange capacity which is expressed as milli-equivalents per 100g of material (me%) (MacVicar et al 1977).

The Eberlanzia armata community, and the Aptosimum depressum - Psilocaulon ciliatum community in some places (Fig. 8.16), appear to be associated with slight depressions or basinal areas where there would be an accumulation of salts from run-off. This may partially explain some of the slightly higher exchangeable Na values for this community compared to the Stipagrostis brevifolia (communities 3.1 and 3.2) and S. ciliata var. capensis - Asthenatherum glaucum communities.

(ii) Karoo Sequence - Dwyka Tillite Formation

Andersen et al (1983) have inferred Dwyka suboutcrop from two areas where Dwyka float was noticed on Bokseputs. Dwyka shales have also been intersected in a borehole at a depth of 14m on Bokseputs. This interpretation is consistent with the western limit of the Karoo sequence (Dwyka Formation) as illustrated in SACS (1980) [Fig. 3.5].

According to Du Toit (1939), pans are found to occur on certain geological formations such as the Dwyka, Ecca and Ventersdorp. Van der Merwe (1941) describes the pans on the Dwyka Formation in the Karoo as being very shallow, only slight depressions confined to the surface drainage lines. He suggests that the salts occurring in these depressions are brought in by surface run-off water and by hydrolysis of the mineral constituents of the underlying rock by the accumulating water. This pan formation is a characteristic feature of the Dwyka Formation, and the soils are a geological and not a climatic phenomenon (Van der Merwe 1941). The Dwyka shales were deposited in sea water and would therefore be expected to be fairly saline in arid and semi-arid areas.

From the preceeding paragraph and the fact that Dwyka sub-outcrop was inferred in areas close to where the Aptosimum depressum - Psilocaulon ciliatum - Ruschia cf. R. levynsiae community occurs, it seems reasonable to suggest that the saline soils found in these slight depressions may be due, in part, to run - off as well as to rocks of the underlying Dwyka Formation. This may partially account for the higher sodium (Na), magnesium (Mg) and potassium (K) found in the soils on which Ruschia cf. R. levynsiae grows.

Tests indicate that chlorides and sulphates, together, and in some cases separately, are present in the soils from the A. depressum - P. ciliatum -Ruschia cf. R. levynsiae community as opposed to the predominance of carbonates from the A. depressum - Salsola tuberculata community. The A. depressum - Ruschia muricata and A. depressum - R. muricata - Zygophyllum retrofractum communities may have both or all three of these salts present.

In the A. depressum - Psilocaulon ciliatum - Ruschia cf. R. levynsiae community, the principal source of exchangeable Ca may be the exchangeable Ca present on the clays.

(iii) Calcrete

There are some fairly extensive ridges of calcrete on Vaalputs, as well as small remnant patches which have survived erosion of the calcrete formerly surrounding these patches. Calcrete is produced when superficial deposits are cemented by calcium carbonate ($CaCO_3$) deposited from solutions of calcium bicarbonate [$Ca(HCO_3)_2$]:

Loss of water by evaporation will be one of the causes of deposition of the calcium carbonate, as can be seen from the equilibrium reaction below.

$$Ca(HCO_3)_2 \rightleftharpoons CaCO_3 + H_2O + CO_2$$

The A. depressum - Salsola tuberculata, A. depressum - Ruschia muricata and A. depressum - R. muricata - Zygophyllum retrofractum plant communities which are found on calcrete ridges or on calcareous soils, all have calcium carbonate (CaCO3) as the main source of exchangeable Ca. The high exchangeable Ca values for these soils can be seen on Fig. 8.11 for the plant communities between 0 and 1.3 sd on axis 1.

These plant communities have fairly high exchangeable Na (*Ruschia muricata*), exchangeable K, exchangeable Mg, as well as a relatively high cation exchange capacity and available phosphorus (Bray 2 P), all of which contribute to the high soil pH values recorded within this range of standard deviations.

(iv) *Aeolian sand*

There appears to be a distinction between the plant communities occurring over geological material weathered *in situ* and those plant communities which are found to occur in association with transported (aeolian) weathered material (Figs 8.17 & 8.18).

On Vaalputs one of the indications of aeolian sand is the presence of grasses, namely *Stipagrostis brevifolia* and *S. ciliata* var. *capensis* together with *Asthenatherum glaucum*.

The plant communities characterized by the presence of *S. brevifolia* seem to be related to/associated with aeolian sand possibly mixed to some extent with soil formed *in situ* from the underlying or adjacent granite - gneiss basement material. The presence of transported material will mean that a greater quartz component is added to the soil formed *in situ* (Table 7.22 and Fig. 7.30). The aeolian material is far better sorted, and does not contain as great a concentration of minerals, such as feldspar, which can weather and in that way contribute ultimately to the exchangeable cations in the soil. The greater proportion of quartz and the relatively low proportions of feldspars possibly explains the relatively low nutrient status, in terms of exchangeable cations, of these neutral to strongly acid soils.

The *Stipagrostis ciliata* var. *capensis* - *Asthenatherum glaucum* community on Vaalputs is confined to the areas of relatively deep aeolian (transported) sand which have accumulated on the eastern and southeastern aspects of the approximately parallel ridges. The depressions between the ridges have been interpreted (Levin pers. comm.) from LANDSAT imagery to represent palaeochannels of distributaries of an ancient alluvial fan. The source area of the fan was to the southwest of Vaalputs, and the sand deposits later built up within these depressions.

These aeolian sands are strongly acid, reddish brown in colour and have very low values of exchangeable cations, i.e. are nutrient poor. Their nutrient status may primarily be a function of their source - material which has been sorted during transportation and consists mainly of quartz grains with very few weatherable feldspars and micas. The relatively coarse-grained nature of the sand, its loose compaction and very good drainage, as well as its position in the landscape, all contribute to its susceptibility to leaching of nutrients which may have been available.

The CEC of sandy soils is associated mainly with their organic content, whereas with finer textured soils it is a function of the clay content. Seeing as the organic content of the Bushmanland (Vaalputs) soil is negligible, one would expect the sandy soils to have a low CEC, which is seen to be the case.

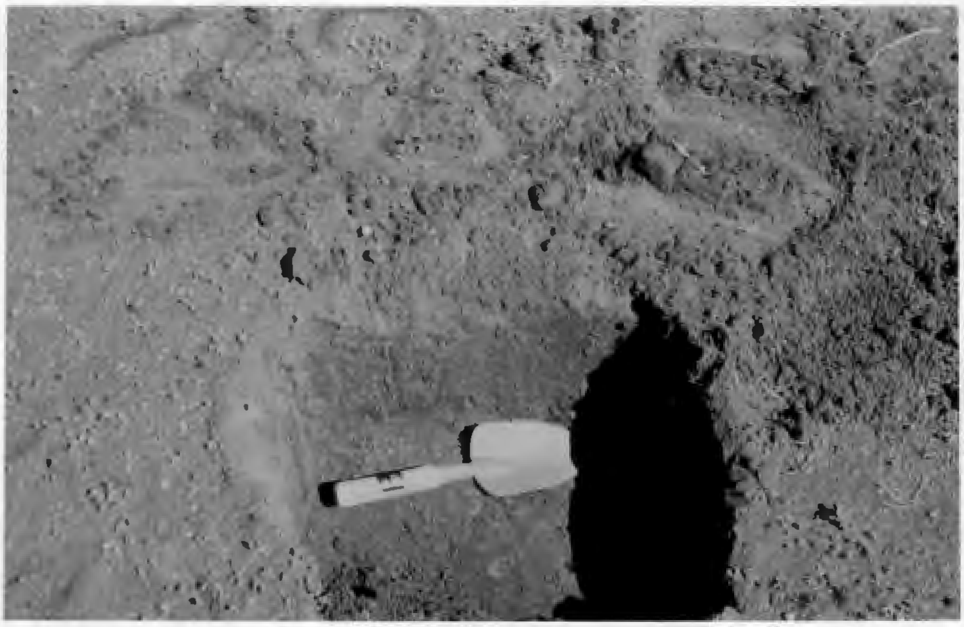


FIGURE 8.17 Aeolian sand mixed with soil formed in situ in the Stipagrostis brevifolia communities.

FIGURE 8.18 Loosely-compacted, well-aerated, aeolian sand in the Stipagrostis ciliata var. capensis community.

8.2 CONCLUSIONS

The ordination confirms the main plant communities described in the vegetation classification using the Braun-Blanquet method.

Eleven plant communities are recognized, varying physiognomically from dwarf/low semi-open shrublands, with a high degree of succulence and spinescence on saline and calcareous soils, to low open grasslands on deeper, strongly acid aeolian sands. Three of the communities are associated with calcrete and calcareous soils; three communities with saline soils; two communities on shallow soils overlying basement or dorbank; two communities on soil mixed with aeolian sand; and one community is associated with deeper, strongly acid aeolian sand.

Four of the eleven plant communities (1.2a, 1.3a, 1.4 and 3.1) appear to be transitional. This may be as a result of disturbance, possibly by overgrazing. Community 3.1, the Stipagrostis brevifolia - Ruschia robusta low/short open grassy shrubland community, may be indicative of an invasion of the grassland by shrubs, possibly as a result of disturbance by overgrazing in this area.

The environmental gradients are complex, with more than one factor apparently influencing the vegetation trends.

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APPENDIX I A VEGETATION MAP OF THE VAALPUTS STUDY AREA

(loose in back pocket)

APPENDIX II A KEY TO THE SYMBOLS ON THE ORDINATION DIAGRAMS

(loose in back pocket)

APPENDIX III CHECKLIST OF PLANT SPECIES

The families and genera of the Angiospermae in the plant checklist are arranged according to Dyer (1975, 1976). There are some departures from Dyer (1975, 1976), as proposed by Bond & Goldblatt (1984), which include the merging of what was formerly recognized as Selaginaceae with Scrophulariaceae following Hilliard & Burtt (1977), and the subdivision of Liliaceae (which is strictly a Northern Hemisphere family) into a number of families. These families include Asparagaceae, Hyacinthaceae, Asphodelaceae and Colchicaceae. In Asparagaceae, Asparagus has been replaced with two genera, Protasparagus and Myrsiphyllum (Obermeyer 1983). The species are arranged alphabetically within each genus.

The numbers listed after each species represent the collecting numbers of Lloyd, whereas the numbers preceded by an asterisk (*: are the collecting numbers of Lloyd & Simpson. Where no herbarium specimen exists, the species name is followed by a blank (no collecting number).

	COLLECTING NUMBER

LICHENES

ROCK LICHENS	
(Lichen)	451
(Lichen)	320
XANTHORIACEAE	
Xanthoria Zahlbr.	
X. marlothii Zahlbr.	218

	COLLECTING NUMBER

ANGIOSPERMAE

MONOCOTYLEDONAE

POACEAE

Ehrharta Thunb.	
E. calycina J.E. Sm.	296
E. pusilla Nees ex Trin.	243
Asthenatherum Nevski	
A. glaucum (Nees) Nevski	424
Karroochloa Conert & Türpe	
K. schismoides (Stapf ex Conert) Conert & Türpe	385
Dregeochloa Conert	
D. pumila (Nees) Conert	369
Pentaschistis Stapf	
P. patula (Nees) Stapf	401
Stipagrostis Nees	
S. brevifolia (Nees) De Winter	336;426
S. ciliata (Desf.) De Winter var. capensis (Trin. & Rupr.) De Winter	425
S. namaquensis (Nees) De Winter	
S. obtusa (Del.) Nees	333;358;428
Schismus Beauv.	
S. barbatus (L.) Thell.	130

ASPARAGACEAE

Protasparagus Oberm.	
P. capensis (L.) Oberm.	463
P. exuvialis (Burch.) Oberm.	365;459

AMARYLLIDACEAE

Gethyllis L.	
G. sp.	258;319

TECOPHILAEACEAE

Cyanella L.	
C. orchidiformis Jacq.	
(= C. pentheri Zahlbr.)	

IRIDACEAE

Moraea Miller	
M. serpentina Bak.	140
Ferraria Burm. ex Mill.	
F. divaricata Swartz	162
Homeria Vent.	
H. schlechteri L. Bol.	161
Gladiolus L.	
G. orchidiflorus Andr.	263

DICOTYLEDONAE

MORACEAE	
Ficus L.	
F. cordata Thunb.	
SANTALACEAE	
Thesium L.	
T. lineatum L.f.	294
POLYGONACEAE	
Rumex L.	
R. lativalvis Meisn.	79;177
CHENOPODIACEAE	
Chenopodium L.	
C. murale L.	396;398
Blackiella Aell.	
B. inflata (F. Muell.) Aell.	107
Salsola L.	
S. aphylla L.f.	173
S. tuberculata Fenzl.	339;384
S. zeyheri (Moq.) Schinz	340
AIZOACEAE	
Pharnaceum L.	
P. sp.	191;252;360
P. sp.	450

Hypertelis E. Mey. ex Fenzl	
H. salsoloides (Burch.) Adamson	284
Galenia L.	
G. fruticosa (L.f.) Sond.	186;341
G. papulosa (Eckl. & Zeyh.) Sond.	341
G. sarcophylla Fenzl	342
G. secunda (L.f.) Sond.	387
Aizoon	
A.sp.	163
Tetragonia L.	
T. fruticosa L.	270
MESEMBRYANTHEMACEAE	
Aridaria N.E. Br.	
A. noctiflora (L.) Schwant.	146;165;219;372
Cheiridopsis N.E. Br.	
C. candidissima (Haw.) N.E. Br.	405;*40
C. meyeri var. minor L. Bol.	304
Dorotheanthus Schwant.	
D. flos - solis (Bgr.) L. Bol.	89;169;350
Drosanthemum Schwant.	
D. giffenii L. Bol.	187
D. schoenlandianum (Schlt.) L. Bol.	152;202;208
Eberlanzia Schwant.	
E. armata (L. Bol.) L. Bol.	65;216;*37
E. cf. ferox (L. Bol.) L. Bol.	*3

ROSACEAE

Grielum L.	
G. humifusum Thunb.	92;237

FABACEAE

Lotononis (DC.) Eckl. & Zeyh.	
L. brachyloba Benth.	354
Lebeckia Thunb.	
L. sericea Thunb.	283;431
Melolobium Eckl. & Zeyh.	
M. candicans (E. Mey.) Eckl. & Zeyh.	351
Crotalaria L.	
C. humilis Eckl. & Zeyh.	404
Sutherlandia R. Br. ex Ait.f.	
S. frutescens R. Br.	347

GERANIACEAE

Sarcocaulon Sweet	
S. crassicaule Rehm	316
S. salmoniflorum Moffett	379
Pelargonium L'Hérit.	
P. carnosum (L.) L'Herit	449;481
P. dasyphyllum E. Mey. ex Knuth	323
P. triste (L.) L'Herit	
P. sp.	356
P. sp.	414

OXALIDACEAE

Oxalis L.	
O. sp.	458

ZYGOPHYLLACEAE

Zygophyllum L.	
Z. gilfillani N.E. Br.	123;421
Z. retrofractum Thunb.	122;364;432
Z. simplex L.	127;457
Augea Thunb.	
A. capensis Thunb.	377

EUPHORBIACEAE

Euphorbia L.	
E. cf. decussata E. Mey. ex Boiss.	371;*44
E. cf. juttae Dinter	436;437;*33
E. mauritanica L.	
E. cf. rudis N.E. Br.	376;*35

ANACARDIACEAE

Rhus L.	
R. undulata Jacq.	*23

MALVACEAE

Radyera Bullock	
R. urens (L.f.) Bullock	352

STERCULIACEAE

Hermannia L.	
H. amoena	284
H. cuneifolia Jacq. var. cuneifolia	149;274;402
H. sp.	*13
H. sp.	*27

PLUMBAGINACEAE

Dyerophytum Kuntze	
D. africanum (Lam.) Kuntze	*22

HYDROPHYLLACEAE

Codon L.	
C. royeni L.	

LAMIACEAE

Salvia L.	
S. disermas L.	264

SOLANACEAE

Lycium L.	
L. cinereum Thunb.	334
L. horridum Thunb.	119;148

SCROPHULARIACEAE

Aptosimum Burch.	
A. indivisum Burch.	151;262
A. procumbens (Lehm.) Stend. var. procumbens	
(= A. depressum Burch. & Lindl.)	291
A. spinescens (Thunb.) Weber	147

Nemesia Vent	
N. azurea Diels	168;242
N. versicolor E. Mey. ex Benth.	167;241
Manulea L.	
M. benthamiana Hiern	78;189;245
Sutera Roth	
S. tristis (L.f.) Hiern	366
S. sp.	230;368
Polycarena Benth.	
P. sp.	190;234;423;446
Zaluzianskya F.W. Schmidt	
Z. bolusii Hiern	193;439
Z. villosa F.W. Schmidt	232;345;363
Hebenstreitia L.	
H. parviflora E. Mey.	155;188;445
H. integrifolia L.	429
Selago L.	
S. minutissima Choisy	275;403
Hyobanche L.	
H. sanguinea L.	
CAMPANULACEAE	
Wahlenbergia Schrad. ex Roth	
W. prostrata A. DC.	184
W. arenaria	394
Lightfootia L'Hérit	
L. sp.	67;156

ASTERACEAE

Pteronia L.	
P. glomerata L.f.	68;120;221
P. scariosa L.f.	60;117;386
P. villosa L.f.	346
Felicia Cass.	
F. australis (Alston) Phill.	110;215
F. brevifolia (DC.) Grau	293
Chrysocoma L.	
C. tenuifolia Berg.	116;314
Helichrysum Mill.	
H. dunense Hilliard	158;417
H. herniarioides DC.	135;203
H. obtusum (S. Moore) Moeser	317
Relhania L'Hérit	
R. sp.	335
Leysera L.	
L. tenella DC.	159;349;442
Eriocephalus	
E. ericoides (L.f.) Druce	64;138;180
E. spinescens	
Cotula L.	
C. barbata D.C.	353
C. sp.	233
Pentzia Thunb.	
P. pilulifera (L.f.) Fourc.	111;214

APPENDIX IV COORDINATES OF PLOTS

The coordinates are given on a grid system north-south and east-west of trigonometric beacon number 56. The coordinate W 61.0/N 19.0 would be a point 6.1 km west and 1.9 km north of the beacon.

PLOT NO.	COORDINATE	PLOT NO.	COORDINATE	PLOT NO.	COORDINATE
1	W 61.0/N 19.0	51	W 67.0/S 5.0	119	W 98.0/S 22.0
2	W 70.0/N 9.0	52	W 71.0/S 5.0	120	W 98.0/S 22.5
3	W 82.0/N 0.0	53	W 75.2/S 5.0	121	W 98.0/S 21.0
4	W 69.0/N 0.0	54	W 76.0/S 5.0	122	W 95.0/S 19.0
5	W 67.0/N 0.0	55	W 60.0/S 10.0	124	W100.0/S 12.0
6	W 63.0/N 0.0	56	W 77.5/S 5.0	126	W 98.0/S 13.0
7	W 53.0/N 0.0	57	W 55.0/S 10.0	128	W 90.0/S 17.0
8	W 49.0/N 0.0	58	W 58.0/S 10.0	130	W 82.0/S 12.0
9	W 44.0/N 0.0	59	W 52.5/S 10.0	132	W 82.0/S 13.0
10	W 38.0/N 0.0	60	W 52.0/S 10.0	134	W 85.0/N 30.0
11	W 23.0/N 0.0	61	W 50.0/S 10.0	135	W 79.0/N 25.0
12	W 11.0/N 0.0	62	W 48.0/S 10.0	138	W 84.0/N 20.0
13	W 63.0/N 17.0	63	W 43.5/S 10.0	140	W 84.0/N 22.0
14	W 65.0/N 16.0	64	W 40.0/S 10.0	141	W 90.0/N 27.0
15	W 70.0/N 8.0	65	W 51.0/N 10.0	143	W 90.0/S 12.0
16	W 72.0/N 0.0	66	W 56.0/N 10.0	145	W 90.0/S 15.0
17	W 76.0/N 0.0	67	W 59.0/N 10.0	147	W 99.0/S 28.0
18	W 78.0/N 0.0	68	W 72.0/N 20.0	149	W 95.0/S 28.0
19	W 74.0/N 0.0	69	W 75.0/N 7.5	151	W 86.0/S 30.0
20	W 66.0/N 0.0	70	W 80.0/N 10.0	153	W 58.0/S 33.0
21	W 65.5/N 0.0	71	W 79.0/N 10.0	155	W102.0/S 2.0
22	W 65.0/N 0.0	72	W 60.0/N 15.0	158	W 80.0/N 2.0
23	W 64.5/N 0.0	73	W 72.0/N 10.0	165	W100.0/N 10.0
24	W 61.5/N 0.0	74	W 38.0/N 24.0	166	W 97.0/N 12.0
25	W 60.5/N 0.0	75	W 48.0/N 27.0	167	W 98.0/N 15.0
26	W 58.0/N 0.0	76	W 40.0/S 20.0	168	W 67.0/N 0.0
27	W 54.5/N 0.0	77	W 30.0/S 23.0	169	W 61.0/N 19.0
28	W 51.5/N 0.0	78	W 25.0/S 24.0	170	W 63.0/N 0.0
29	W 48.0/N 0.0	79	W 23.0/S 23.0	171	W 53.0/N 0.0
30	W 42.5/N 0.0	80	W 18.0/S 25.0	172	W 49.0/N 0.0
31	W 40.5/N 0.0	81	W 14.0/S 26.0	173	W 44.0/N 0.0
32	W 35.5/N 0.0	82	W 18.0/S 17.5	174	W 38.0/N 0.0
33	W 29.0/N 0.0	83	W 20.0/S 14.0	175	W 23.0/N 0.0
34	W 26.0/N 0.0	84	W 24.0/S 10.0	176	W 11.0/N 0.0
35	W 18.0/N 0.0	89	W102.0/S 5.0	177	W 18.0/S 25.0
36	W 15.5/N 0.0	91	W 81.0/S 1.0	178	W 38.0/N 0.0
37	W 14.0/N 0.0	93	W 73.0/S 12.0		
38	W 9.0/N 0.0	95	W 49.0/S 8.0		
39	W 4.0/N 0.0	97	W 56.0/S 5.0		
40	W 1.5/N 0.0	99	W 78.0/S 12.0		
41	W 57.5/N 0.0	101	W 80.0/S 12.0		
42	W 70.0/S 0.6	102	W 62.0/S 2.0		
43	W 70.0/S 1.5	104	W 71.0/S 12.0		
44	W 70.0/S 2.5	106	W 72.0/S 14.0		
45	W 70.0/S 6.0	108	W 64.0/S 15.0		
46	W 70.0/S 7.5	110	W 45.0/S 34.0		
47	W 64.0/S 10.0	112	W 55.0/S 15.0		
48	W 65.0/S 10.0	113	W 12.0/S 29.0		
49	W 67.0/S 10.0	115	W 20.0/S 30.0		
50	W 70.0/S 10.0	117	W 38.0/S 35.0		

APPENDIX V A SUMMARY OF THE STATISTICS OF THE SOIL ANALYSES

COMMUNITY NUMBER	1.1	1.2a	1.2b	1.3a	1.3b	1.4	2.1	2.2	3.1	3.2	4.0
SOIL DEPTH											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	7	5	1	9	4	12	1	3	10	14	45
X(l)	10.5	17.5	15	10	7.5	13	8.5	5	15	20	65
X(m)	14	22.5	18	10	11	20	11	10	22	20	80
X(u)	24	45	20	17	15.5	28	13	18	30	36.5	130
X(n)	24	60	50	35	30	45	15	50	45	45	150
q	13.5	27.5	5	7	8	15	4.5	13	15	16.5	65
r	17	55	49	26	26	33	14	47	35	31	105
x	16.29	31.08	20.11	15.43	12.75	23.00	9.93	13.9	22.93	27.21	97.31
s	7.54	18.45	13.60	9.45	8.08	12.23	4.15	14.08	9.79	9.85	40.40
outliers >	74	157.5	30	52	38	68	23	58	70	119	380
<	-7	-7.5	0	10	-10	-22	-4	-20	-20	20	-10
strays >	44	90	24	31	24.5	44	17	34	46	69.5	230
<	3.5	7.5	9	10	0.5	-1	3.5	-5	1	20	35
SOIL pH											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	6.7	5.7	7.3	5.9	7.1	6.3	5.4	5	4.6	4.8	4.3
X(l)	7.75	7.65	7.4	6.8	7.55	7.0	5.5	6.1	5.5	5.3	4.5
X(m)	8	7.9	7.5	7.9	7.8	7.15	5.7	6.4	6.25	6.1	4.8
X(u)	8.05	8.0	7.8	8.2	8.0	7.7	6.2	6.7	6.7	6.4	5.8
X(n)	8.3	8.3	8.3	8.4	8.3	8.0	6.6	7.3	7.8	7.8	6.2
q	0.3	0.35	0.4	1.4	0.45	0.7	0.7	0.6	1.2	1.1	1.3
r	1.6	2.6	1.0	2.5	1.2	1.7	1.2	2.3	3.2	3.0	1.9
x	7.8	7.7	7.67	7.46	7.76	7.22	5.83	6.37	6.11	6.08	5.05
s	0.53	0.68	0.36	0.96	0.40	0.59	0.38	0.63	0.88	0.95	0.73
outliers >	8.3	8.5	9.3	9.7	9.0	10.45	8.7	8.2	8.95	7.9	10.8
<	6.5	6.4	6.9	1.3	6.3	6.25	4.5	4.6	1.75	1.3	3.0
strays >	8.15	8.2	8.4	8.8	8.4	8.8	7.2	7.3	7.6	7.0	7.8
<	7.25	7.15	7.2	4.6	7.05	6.7	5.1	5.5	4.0	3.7	3.9
BRAY 2 PHOSPHORUS											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	10
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	0.71	7.85	7.14	6.43	14.28	4.28	5.0	1.43	0.71	0.71	0
X(l)	22.50	28.18	39.27	10.00	26.42	5.71	8.21	7.85	5.0	2.86	1.43
X(m)	32.84	36.77	43.55	12.14	49.27	9.28	11.42	14.64	7.85	6.43	2.14
X(u)	55.69	64.26	85.00	12.50	72.12	11.42	13.57	20.71	12.14	7.50	2.86
X(n)	79.97	84.25	371.28	18.56	92.82	59.26	19.28	37.13	35.70	37.84	7.85
q	33.20	36.08	45.73	2.5	45.70	5.71	5.36	12.86	7.14	4.64	1.43
r	79.26	76.4	364.14	12.13	78.54	54.98	14.28	35.7	34.99	37.13	7.85
x	38.56	42.84	91.95	11.73	50.34	16.54	11.28	16.21	9.47	8.61	2.75
s	27.64	23.19	112.60	3.80	29.08	21.11	3.76	11.53	7.11	10.57	2.42
outliers >	169.94	201.71	292.25	14.27	186.37	22.12	24.32	51.09	33.59	12.82	6.46
<	-29.23	-14.77	17.87	-0.73	-87.81	-12.14	-7.84	-26.08	-9.25	-15.02	-2.12
strays >	101.39	119.24	167.90	13.21	117.82	15.70	17.87	32.86	20.72	9.63	4.30
<	1.81	11.00	30.71	5.71	-19.27	-1.43	1.79	-5.72	-0.70	-4.30	0.01
BASE SATURATION											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	66.74	80.63	106.34	97.29	124.36	78.10	65.16	101.33	72.92	53.89	66.09
X(l)	158.46	112.74	123.15	121.43	218.04	119.46	101.26	112.88	100.00	91.85	90.95
X(m)	306.29	186.95	176.18	150.44	274.44	155.13	114.92	114.39	114.44	101.87	103.83
X(u)	449.49	404.79	256.77	153.60	379.93	201.20	123.04	133.07	128.50	128.08	116.48
X(n)	565.72	811.44	311.00	351.55	553.68	386.99	180.65	137.71	219.38	151.74	119.39
q	291.04	292.05	133.62	32.17	161.90	81.74	21.78	20.19	28.50	36.23	25.53
r	498.98	730.81	204.66	254.26	429.32	308.89	115.49	36.38	146.46	97.85	53.30
x	307.81	284.33	187.90	164.19	302.86	182.67	116.77	118.81	118.88	106.46	102.48
s	186.89	224.93	77.89	85.40	133.89	109.28	27.18	12.19	30.00	24.73	16.68
outliers >	1165.49	1493.99	659.72	169.40	907.38	431.55	163.64	226.47	198.80	259.10	179.73
<	-580.72	-258.31	-142.00	-23.62	-63.99	-58.89	32.96	105.33	27.80	41.75	26.55
strays >	735.89	840.47	417.95	159.92	590.91	293.34	139.28	170.43	156.62	180.49	141.78
<	-137.22	-35.68	17.09	63.41	105.23	48.12	73.94	109.86	71.12	71.81	65.19

RESISTANCE											
n	7	12	8	7	8	5	15	10	30	19	13
m	4	6.5	4.5	4	4.5	3	8	5.5	15.5	10	7
l	2.5	3.5	2.5	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	6.5	5.5	6.5	4	11.5	8	23	14.5	10
X(1)	330	800	66	140	35	510	530	245	1000	600	995
X(l)	530	1420	1570	325	55.5	2600	1610	600	2600	2200	5250
X(m)	1100	1820	2100	1120	282.5	2600	4000	2860	3775	3500	6800
X(u)	2950	2500	2790	1600	1050	3300	5350	4100	5800	5000	8100
X(n)	3600	3700	3500	2100	2000	4100	7200	7700	8500	9200	10180
q	2420	1080	1220	1275	994.5	700	3740	3500	3200	2800	2850
r	3270	2900	3434	1960	1965	1890	6670	7455	7500	8600	9185
x	1712.9	1973.3	2060.8	1030.0	601.4	2582.0	3602.0	2851.5	4325.0	4075.8	6271.2
s	1405.0	859.1	1060.5	797.6	719.0	1336.7	2378.7	2424.2	2179.5	2217.6	2473.8
outliers >	12200	5900	6240	4000	4887.5	6800	12100	10300	15925	12500	14600
<	-2320	-580	-1080	-3650	-1079.5	2600	-10340	-10700	-3275	-4300	-2500
strays >	6650	3860	4170	2560	2585	4700	8050	6580	9850	8000	10700
<	-610	620	510	-1265	-398.5	2600	-3170	-3920	250	-400	2150
CATION EXCHANGE CAPACITY											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	3.77	3.45	4.19	5.16	5.05	3.32	1.86	2.57	1.84	1.72	0.98
X(l)	4.2	5.02	8.06	6.04	6.43	5.84	2.75	3.00	2.17	2.48	1.38
X(m)	4.45	6.08	8.30	6.52	7.22	6.69	3.11	4.08	3.20	3.34	2.10
X(u)	6.02	7.39	14.08	8.10	8.33	7.47	4.04	5.67	4.63	4.79	2.69
X(n)	6.82	15.52	15.61	9.57	9.20	7.74	5.05	9.94	8.00	15.20	6.27
q	1.82	2.38	6.02	2.06	1.90	1.63	1.30	2.67	2.46	2.31	1.31
r	3.05	12.09	11.42	4.41	4.15	4.42	3.19	7.37	6.16	13.48	5.29
x	5.07	7.19	10.03	7.07	7.28	6.29	3.31	4.73	3.75	4.49	2.28
s	1.27	3.59	3.91	1.70	1.44	1.66	1.00	2.24	1.81	3.33	1.42
outliers >	13.84	13.94	42.98	15.97	13.88	11.40	8.69	13.62	11.81	12.01	5.64
<	2.95	-0.31	6.86	3.61	2.48	1.62	-2.47	-2.4	-2.96	-1.82	-2.22
strays >	9.15	10.01	25.64	11.26	10.55	9.04	5.9	8.85	7.5	7.68	3.87
<	3.7	2.89	7.58	5.07	4.85	4.15	0.32	0.84	0.12	0.76	-0.06
S-VALUE											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	6.25	4.29	5.16	7.94	6.28	5.74	2.50	3.04	1.85	1.83	1.17
X(l)	21.75	6.94	14.20	8.93	17.49	6.68	3.00	3.42	2.90	2.26	1.40
X(m)	29.97	14.19	16.60	9.36	18.05	8.66	3.36	4.62	3.73	3.31	1.91
X(u)	31.69	26.86	23.52	11.34	31.19	13.40	4.14	6.50	5.02	4.41	2.57
X(n)	46.67	51.77	26.49	18.14	40.64	22.60	6.72	11.22	17.55	20.64	6.51
q	9.94	19.92	9.32	2.41	13.70	6.72	1.15	3.08	2.12	2.15	1.17
r	40.42	47.48	21.33	10.20	34.36	16.86	4.22	8.18	15.70	18.71	5.34
x	27.11	18.59	17.90	10.85	22.54	10.96	3.76	5.62	4.54	4.91	2.29
s	13.28	14.09	7.06	3.46	11.33	6.36	1.21	2.68	3.05	4.54	1.49
outliers >	40.29	90.21	58.12	21.21	96.92	37.10	8.04	15.90	11.50	9.91	5.87
<	-19.35	-29.32	2.2	6.78	14.72	-3.22	1.17	-2.58	-1.23	-2.99	-1.15
strays >	35.13	52.20	37.36	15.29	57.48	22.88	5.70	10.26	7.61	6.61	3.89
<	5.31	-7.57	9.4	8.07	16.38	2.72	2.27	1.02	1.25	0.16	0.38
EXCHANGEABLE Na											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	0.16	0.17	0.24	0.87	1.32	0.37	0.21	0.23	0.16	0.14	0.13
X(l)	0.23	0.29	0.34	1.08	2.25	0.52	0.31	0.35	0.27	0.20	0.18
X(m)	0.59	0.39	0.52	1.61	5.03	0.70	0.50	0.65	0.34	0.24	0.20
X(u)	1.07	1.10	1.10	2.52	6.05	1.40	0.85	1.73	0.44	0.37	0.28
X(n)	1.27	3.21	2.68	2.81	9.32	3.98	1.49	3.16	0.80	3.24	0.34
q	0.84	0.81	0.76	1.44	3.81	0.88	0.55	1.38	0.17	0.17	0.10
r	1.11	3.04	2.44	1.94	7.00	3.61	1.28	2.93	0.64	3.10	0.21
x	0.66	0.87	0.93	1.78	4.54	1.28	0.60	1.04	0.37	0.44	0.23
s	0.49	0.96	0.84	0.84	2.51	1.37	0.39	0.95	0.15	0.69	0.06
outliers >	3.47	4.65	4.00	7.07	11.18	4.90	2.60	7.16	0.97	1.02	0.68
<	-1.57	-0.19	-0.56	-1.57	-11.66	-0.38	-0.67	-1.13	-0.06	0.00	0.08
strays >	2.03	2.52	2.26	4.34	8.1	2.80	1.55	3.9	0.65	0.63	0.44
<	-0.49	0.1	-0.02	0.02	-3.32	0.16	-0.09	-0.24	0.14	0.12	0.14

EXCHANGEABLE K											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	0.58	0.52	0.70	0.71	0.27	0.41	0.31	0.40	0.26	0.26	0.11
X(l)	0.62	0.58	1.24	0.90	1.02	0.73	0.39	0.43	0.41	0.37	0.17
X(m)	0.77	0.83	1.26	1.13	1.36	1.14	0.56	0.70	0.57	0.47	0.34
X(u)	0.82	0.93	1.56	1.21	1.75	1.65	0.69	0.78	0.71	0.54	0.43
X(n)	0.86	1.56	3.89	1.32	1.88	1.78	1.15	0.95	1.01	1.64	1.37
q	0.20	0.35	0.32	0.31	0.73	0.92	0.30	0.35	0.3	0.17	0.26
r	0.28	1.04	3.19	0.61	1.61	1.37	0.84	0.55	0.75	1.38	1.26
x	0.73	0.82	1.57	1.05	1.30	1.14	0.60	0.65	0.57	0.60	0.37
s	0.12	0.31	0.91	0.23	0.54	0.54	0.25	0.21	0.21	0.39	0.33
outliers >	1.07	1.40	3.06	1.58	3.70	4.20	1.31	1.18	1.41	0.89	0.88
<	-0.13	0.70	1.12	-0.28	-0.69	-1.32	-0.46	-0.92	-0.39	-0.13	-0.68
strays >	0.92	1.12	2.16	1.36	2.53	2.67	0.94	0.94	0.99	0.68	0.61
<	0.32	0.07	1.18	0.43	0.34	-0.09	0.05	-0.11	0.09	0.17	-1.19

EXCHANGEABLE Ca											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	3.22	1.90	2.78	3.63	2.47	2.85	0.88	1.25	0.35	0.5	0.53
X(l)	19.23	2.94	9.65	3.92	6.58	3.15	0.99	1.33	1.15	1.09	0.58
X(m)	27.52	13.28	12.73	4.48	12.03	5.15	1.27	1.51	1.48	1.20	0.73
X(u)	29.17	23.75	18.85	5.55	19.77	5.55	1.37	2.94	2.38	2.52	1.13
X(n)	43.50	24.70	22.25	12.08	32.28	18.55	2.40	4.90	14.13	16.63	3.00
q	9.95	20.81	9.20	1.63	13.19	2.70	0.38	1.61	1.23	1.43	0.55
r	40.28	22.80	19.47	8.45	29.81	15.70	1.52	3.65	13.78	16.13	2.47
x	24.43	13.66	13.35	5.59	13.94	6.73	1.27	2.26	2.29	2.70	1.04
s	13.11	9.71	6.53	2.97	10.90	5.90	0.53	1.28	2.60	3.59	0.72
outliers >	37.42	76.10	49.45	10.87	58.47	7.55	1.84	10.09	6.91	9.12	3.13
<	-22.25	-48.79	-5.75	1.09	-20.68	-6.85	-0.44	0.43	-2.10	0.54	-0.17
strays >	32.47	44.69	31.09	7.68	35.25	6.35	1.56	5.80	4.19	5.16	1.93
<	2.64	-17.76	3.49	2.79	-4.33	-0.85	0.42	0.97	0.50	0.87	0.28

EXCHANGEABLE Mg											
n	7	12	9	7	8	6	15	10	30	19	13
m	4	6.5	5	4	4.5	3.5	8	5.5	15.5	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	11.5	8	23	14.5	10
X(1)	0.94	0.61	1.34	1.24	1.42	1.02	0.90	1.02	0.53	0.53	0.33
X(l)	1.11	1.29	1.97	1.79	2.31	1.64	0.94	1.11	0.84	0.75	0.37
X(m)	1.23	1.46	2.47	2.03	2.88	1.87	1.02	1.25	1.22	1.24	0.57
X(u)	1.36	1.91	2.60	2.56	3.32	2.09	1.28	2.01	1.74	1.37	0.74
X(n)	1.93	2.87	3.11	4.06	3.77	2.34	3.11	3.51	2.08	2.58	1.84
q	0.26	0.62	0.63	0.77	1.01	0.45	0.35	0.91	0.90	0.62	0.37
r	0.99	2.26	1.77	2.82	2.35	1.32	2.21	2.49	1.55	2.05	1.51
x	1.29	1.55	2.32	2.29	2.77	1.80	7.91	1.65	1.31	1.22	1.80
s	0.33	0.61	0.61	0.92	0.79	0.47	25.76	0.81	0.50	0.51	0.47
outliers >	2.01	4.16	3.25	5.18	5.49	3.22	2.58	5.81	4.34	2.02	1.59
<	0.48	0.47	-0.53	0.56	-0.57	0.52	0.51	0.41	-1.06	-1.70	-0.63
strays >	1.62	2.81	2.86	3.61	4.19	2.54	1.80	3.53	2.78	1.63	1.08
<	0.86	0.96	0.97	1.30	1.16	1.19	0.77	0.83	0.08	-0.23	-0.03

ORGANIC CONTENT											
n	7	10	9	7	8	6	14	10	28	19	13
m	4	5.5	5	4	4.5	3.5	7.5	5.5	14.5	10	7
l	2.5	2.5	3	2.5	2.5	2	4.5	3	7.5	5.5	4
u	5.5	8.5	7	5.5	6.5	5	10.5	8	21.5	14.5	10
X(1)	1.10	0.70	0.50	0.80	0.65	0.80	0.40	0.20	0.10	0.20	0.20
X(l)	1.33	1.14	1.10	1.16	1.28	1.25	0.63	0.50	0.43	0.40	0.40
X(m)	1.60	1.36	1.45	1.20	1.72	1.40	0.68	0.73	0.65	0.45	0.40
X(u)	1.75	1.52	1.55	1.68	1.95	1.65	0.83	1.00	1.01	0.70	0.55
X(n)	3.16	1.85	2.15	1.70	2.20	2.50	1.01	2.35	2.75	2.15	1.30
q	0.43	0.38	0.45	0.53	0.68	0.40	0.20	0.50	0.58	0.30	0.15
r	2.06	1.15	1.65	0.90	1.55	1.70	0.61	2.15	2.65	1.95	1.10
x	1.72	1.33	1.32	1.34	1.59	1.50	0.71	0.85	0.97	0.67	0.53
s	0.68	0.31	0.50	0.35	0.51	0.57	0.18	0.61	0.98	0.54	0.28
outliers >	2.50	2.29	2.05	4.08	3.13	2.90	1.58	2.35	2.78	1.95	1.30
<	-0.05	0.01	-0.65	0.93	-0.93	0.50	0.38	-0.65	-0.70	0.15	0.40
strays >	2.05	1.83	1.75	2.64	2.42	2.15	1.13	1.54	1.72	1.20	0.85
<	0.78	0.69	0.40	1.07	0.40	0.95	0.53	0.04	-0.03	0.30	0.40

FIELD CAPACITY											
n	6	12	9	7	8	6	14	10	29	19	13
m	3.5	6.5	5	4	4.5	3.5	7.5	5.5	15	10	7
l	2	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5	9.5	7	5.5	6.5	5	10.5	8	22	14.5	10
X(1)	116.09	115.41	116.44	114.96	118.54	117.69	114.26	114.62	114.78	115.53	117.25
X(l)	123.55	122.37	119.33	117.73	120.41	118.36	115.90	116.66	116.59	117.33	118.07
X(m)	129.43	123.53	120.31	119.48	122.28	120.95	117.06	118.33	118.28	120.00	119.59
X(u)	129.66	124.51	122.46	122.12	124.16	123.62	117.64	119.24	120.88	121.44	119.76
X(n)	138.98	141.30	125.03	126.47	134.23	126.69	119.56	120.42	124.92	123.99	124.93
q	6.11	2.15	3.13	4.39	3.75	5.26	1.74	2.58	4.29	4.11	1.69
r	22.89	25.89	8.59	11.51	15.69	9.00	5.3	5.8	10.14	8.46	7.68
x	127.86	124.10	120.59	104.66	123.30	121.38	117.01	117.96	118.91	119.80	119.37
s	7.60	6.03	2.64	41.26	4.84	3.58	1.59	1.91	2.69	2.62	2.06
outliers >	130.81	129.41	133.21	135.29	133.53	136.97	120.54	123.79	133.88	128.64	120.61
<	94.15	116.54	114.43	108.98	111.06	105.41	110.10	108.31	108.14	103.98	110.47
strays >	130.12	126.47	126.76	127.39	127.91	128.96	118.80	121.06	196.08	124.32	120.10
<	111.79	120.04	117.37	114.23	116.67	113.18	113.58	113.32	113.21	111.99	115.03
BULK DENSITY											
n	7	12	9	7	8	6	14	10	29	19	13
m	4	6.5	5	4	4.5	3.5	7.5	5.5	15	10	7
l	2.5	3.5	3	2.5	2.5	2	4.5	3	8	5.5	4
u	5.5	9.5	7	5.5	6.5	5	10.5	8	22	14.5	10
X(1)	1.20	1.42	1.33	1.32	1.11	1.35	1.46	1.37	1.50	1.48	1.50
X(l)	1.32	1.48	1.55	1.48	1.35	1.49	1.54	1.43	1.55	1.53	1.56
X(m)	1.38	1.52	1.58	1.54	1.42	1.57	1.56	1.54	1.60	1.59	1.61
X(u)	1.45	1.55	1.60	1.58	1.46	1.63	1.61	1.59	1.63	1.65	1.61
X(n)	1.60	1.67	1.62	1.65	1.51	1.66	1.71	1.69	1.69	1.70	1.67
q	1.34	0.08	0.05	0.10	0.12	0.14	0.07	0.16	0.08	0.12	0.05
r	0.40	0.25	0.29	0.33	0.40	0.31	0.25	0.32	0.19	0.22	0.17
x	1.39	1.52	1.53	1.52	1.38	1.55	1.57	1.52	1.59	1.59	1.59
s	0.14	0.07	0.12	0.12	0.13	0.11	0.07	0.11	0.05	0.07	0.05
outliers >	1.80	1.73	1.70	1.75	1.66	1.93	1.89	1.84	1.78	1.92	1.61
<	0.99	1.28	1.40	1.18	0.97	1.09	1.47	0.88	1.30	1.20	1.31
strays >	1.59	1.62	1.64	1.65	1.54	1.75	1.72	1.69	1.69	1.81	1.61
<	1.19	1.40	1.49	1.36	1.20	1.33	1.51	1.21	1.45	1.40	1.46
SAND/SILT & CLAY RATIO											
n	3	8	7	4		6	5	3	22	16	10
m	2	4.5	4	2.5		3.5	3	2	11.5	8.5	5.5
l	1.5	2.5	2.5	1.5		2	2	1.5	6	4.5	3
u	2.5	6.5	5.5	3.5		5	4	2.5	17	12.5	8
X(1)	3.47	2.17	4.05	2.43		3.13	4.93	7.09	3.92	3.33	7.53
X(l)	4.77	4.81	4.48	3.09		3.34	6.33	7.41	5.90	6.57	10.38
X(m)	6.07	6.04	4.93	3.87		4.06	6.52	7.72	6.85	7.91	11.46
X(u)	6.32	6.90	5.56	6.95		4.60	7.51	7.85	7.98	9.85	15.86
X(n)	6.57	7.90	6.73	9.86		7.29	9.03	7.97	13.92	14.63	22.47
q	1.55	2.09	1.09	3.86		1.26	1.18	0.44	2.08	3.29	5.48
r	3.1	5.73	2.68	7.43		4.16	4.10	0.88	10.00	11.30	14.95
outliers >	7.57	11.17	8.71	22.32		7.33	12.46	8.47	13.66	19.55	37.86
<	-1.73	-1.34	2.20	-0.81		-0.24	5.38	5.83	1.18	-0.16	4.98
strays >	6.82	8.61	6.82	13.10		5.69	9.49	8.10	10.25	13.73	24.66
<	2.17	2.35	3.57	1.53		1.91	5.95	6.78	4.01	3.88	8.22

n = number of samples
X(1) = lower extreme
X(l) = lower quartile   l = ([m]+1)/2
X(m) = median   m = (n+1)/2
X(u) = upper quartile   u = n-l+1
X(n) = upper extreme
q = interquartile range   q = X(u)-X(l)
r = range   r = X(n)-X(1)
x = mean
s = standard deviation
outliers: > X(m)+6[X(u)-X(m)]
< X(m)-6[X(m)-X(l)]
strays: > X(m)+3[X(u)-X(m)]
< X(m)-3[X(m)-X(l)]

APPENDIX VI PLANT NAMES FOR TABLE 8.2

1	Stipagrostis ciliata var. capensis	41	Galenia crystallina	82	JWL 132
2	Asthenatherum glaucum	42	Galenia sarcophylla	83	JWL 320 (rock lichen)
3	Osteospermum armatum	43	Tetragonia fruticosa	84	Dimorphotheca sinuata
4	Pteronia scariosa	44	Galenia papulosa	85	Galenia secunda
5	Ruschia ceresiana	45	Leysera tenella	86	Moraea serpentina
6	Protasparagus capensis	46	Helichrysum herniarioides	87	Hebenstreitia integrifolia
7	Stipagrostis brevifolia	47	Pentzia pilulifera	89	Hypertelis salsoloides
8	Lycium spp.	48	Mesembryanthemum karrooense	90	Euphorbia cf. rudis
9	Sarcocaulon salmoniflorum	49	Heliophila variabilis	91	Blackiella inflata
10	Euphorbia cf. decussata	50	Pelargonium sp.(356)	92	Helichrysum dunense
11	Ruschia robusta	51	Senecio arenarius	93	Hypertelis sp.
12	Eberlanzia armata	52	Gazania lichtensteinii	94	Crotalaria humilis
13	Aridaria noctiflora	53	Felicia brevifolia	95	Lotononis brachyloba
14	Eriocephalus ericoides	54	Felicia australis	96	Grielum humifusum
15	Sphalmanthus quartziticus	55	Cotula sp.(233)	97	Eriocephalus spinescens
16	Hirpicium alienatum	56	Homeria schlechteri	98	Cyanella pentheri
17	Zygophyllum retrofractum	57	Dimorphotheca polyptera	99	Cyanella orchidiformis
18	Salsola tuberculata	58	Heliophila trifurca	100	Polycarena collina
19	Zygophyllum gilfillani	59	Oxalis sp.(458)	101	Hermannia cuneifolia
20	Psilocaulon articulatum	60	Helichrysum obtusum	103	Lachenalia unicolor
21	Ruschia kakamasensis	61	Zaluzianskya villosa	102	JWL 451 (rock lichen)
22	Titanopsis schwantesii	62	Sutera sp.(368)	104	Lessertia sp. (261)
23	Aptosimum depressum	64	Ferraria divaricata	105	Gethyllis sp. (258)
24	Osteospermum sinuatum	65	Wahlenbergia prostrata	106	Lachenalia namaquensis
25	Salsola zeyheri	66	Hebenstreitia parviflora	107	Aptosimum spinescens
26	Psilocaulon planisepalum	67	Silene sp.(448)	108	Pelargonium carnosum
27	Ruschia muricata	68	Sutera tristis	109	Pelargonium triste
28	Sphalmanthus tetragonus	69	Rumex lativalvis	110	JWL 373
29	Psilocaulon ciliatum	70	Dorotheanthus flos-solis	111	JWL 381
30	Ruschia cf. R. levynsiae	71	Nemesia versicolor	112	Crassula muscosa
31	Stipagrostis obtusa	72	Nemesia azurea	113	Pelargonium dasyphyllum
32	Drosanthemum schoenlandianum	73	Wahlenbergia arenaria	114	Zaluzianskya bolusii
33	Chrysocoma tenuifolia	74	Herrea blanda	115	Cotula barbata
34	Schismus barbatus	75	Pharnaceum sp.(360)	116	Lightfootia sp.(156)
35	Pentaschistis cf. patula	76	Arctotis fastuosa	117	Pharnaceum sp.(450)
39	Albuca cooperi	78	Ehrharta pusilla	118	Radyera urens
36	Dregeochloa pumila	79	Aizoon sp. (163)		
37	Euphorbia cf. juttae	80	Lachenalia mutabilis		
38	Xanthoria marlothii	81	Ruschia cf. namaquana		

APPENDIX II A KEY TO THE SYMBOLS ON THE ORDINATION DIAGRAMS

SYMBOL	PLANT COMMUNITY NAME AND NUMBER	
♦	1.1	The *Aptosimum depressum* - *Salsola tuberculata* dwarf/low open shrubland community
○	1.2(a)	The *A. depressum* - *Ruschia muricata* - *Zygophyllum retrofractum* low semi-open shrubland community
◕	1.2(b)	The *A. depressum* - *Ruschia muricata* low semi-open//moderately closed shrubland community
□	1.3(a)	The *A. depressum* - *Psilocaulon ciliatum* dwarf semi-open shrubland community
X	1.3(b)	The *A. depressum* - *P. ciliatum* - *Ruschia* cf. *R. levynsiae* dwarf semi-open shrubland community
◇	1.4	The *A. depressum* - *Psilocaulon planisepalum* - *Salsola zeyheri* low semi-open shrubland community
▲	2.1	The *Eberlanzia armata* low open//semi-open shrubland community
△	2.2	The *E. armata* - *Ruschia robusta* low open//semi-open shrubland community
•	3.1	The *Stipagrostis brevifolia* - *Ruschia robusta* low/short open grassy shrubland community
▽	3.2	The *S. brevifolia* - *Lycium* spp. complex short open grassy shrubland community
■	4.0	The *Stipagrostis ciliata* var. *capensis* - *Asthenatherum glaucum* low open grassland community

TABLE 7.1 A phytosociological table of Vaalputs

	1.1	1.2(a)	1.2(b)	1.3(a)	1.3(b)	1.4	2.1	2.2	3.1	3.2	4.0	SUMMARY TABLE
COMMUNITY NUMBERS	1.1	1.2(a)	1.2(b)	1.3(a)	1.3(b)	1.4	2.1	2.2	3.1	3.2	4.0	
RELEVE NUMBERS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
DATE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
GRID REFERENCE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
LAND FACET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ALTITUDE (m)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ASPECT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
SLOPE (°)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
GEOLOGY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
SUBSTRATE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
SOIL SERIES CODE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
SOIL DEPTH (cm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
SOIL MOISTURE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
SOIL PH (x10)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
SOIL RESISTANCE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ROCK COVER (%)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
VEGETATION COVER (%)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
FREE CARBONATE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
NUMBER OF PERMANENTLY RECOGNIZABLE SPECIES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
TOTAL NO. OF SPECIES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
RELEVE NUMBERS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NUMBER OF RELEVES

COVER ABUNDANCE VALUE

A. PERMANENTLY RECOGNIZABLE PERENNIAL SPECIES

Species	Cover-abundance values (communities 1.1 – 4.0)	Summary table
DIFFERENTIAL SPECIES OF COMMUNITY 1.1		
Salsola tuberculata	[illegible]	[illegible]
Psilocaulon articulatum	[illegible]	[illegible]
Titanopsis schwantesii	[illegible]	[illegible]
Chrysocoma tenuifolia	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITIES 1.2(a) & 1.2(b)		
Ruschia muricata	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITIES 1.1 & 1.2(a)		
Zygophyllum retrofractum	[illegible]	[illegible]
Zygophyllum gilfillani	[illegible]	[illegible]
Hirpicium alienatum	[illegible]	[illegible]
Euphorbia cf. juttae	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITIES 1.3(a) & 1.3(b)		
Psilocaulon ciliatum	[illegible]	[illegible]
Galenia crystallina	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITY 1.3(b)		
Ruschia cf. R. levynsiae	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITIES 1.1, 1.2(a), 1.2(b), 1.3(a), 1.3(b) & 1.4		
Aptosimum depressum	[illegible]	[illegible]
Psilocaulon planisepalum	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITIES 2.1 & 2.2		
Eberlanzia armata	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITIES 2.2 & 3.1		
Ruschia robusta	[illegible]	[illegible]
Euphorbia cf. decussata	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITIES 2.1, 2.2 & 3.1		
Osteospermum sinuatum	[illegible]	[illegible]
Eriocephalus ericoides	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITIES 3.1 & 3.2		
Stipagrostis brevifolia	[illegible]	[illegible]
Lycium spp.	[illegible]	[illegible]
Sarcocaulon salmoniflorum	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITY 4.0		
Stipagrostis ciliata var. capensis	[illegible]	[illegible]
Asthenatherum glaucum	[illegible]	[illegible]
DIFFERENTIAL SPECIES OF COMMUNITIES 1.2(b) & 1.4 AS WELL AS COMPANION AND INFREQUENT SPECIES		
Salsola zeyheri	[illegible]	[illegible]
Sphalmanthus tetragonus	[illegible]	[illegible]
Aridaria noctiflora	[illegible]	[illegible]
Sphalmanthus quartziticus	[illegible]	[illegible]
Drosanthemum schoenlandianum	[illegible]	[illegible]
Xanthoria marlothii	[illegible]	[illegible]
Stipagrostis obtusa	[illegible]	[illegible]
Pteronia scariosa	[illegible]	[illegible]
Protasparagus capensis	[illegible]	[illegible]
Osteospermum armatum	[illegible]	[illegible]
Galenia sarcophylla	[illegible]	[illegible]
Hypertelis salsoloides	[illegible]	[illegible]
Tetragonia fruticosa	[illegible]	[illegible]
Ruschia ceresiana	[illegible]	[illegible]
Ruschia kakamasensis	[illegible]	[illegible]
Aizoon sp. (163)	[illegible]	[illegible]
Blackiella inflata	[illegible]	[illegible]
Aptosimum spinescens	[illegible]	[illegible]
Galenia secunda	[illegible]	[illegible]
Eriocephalus spinescens	[illegible]	[illegible]
Crassula muscosa	[illegible]	[illegible]
Euphorbia cf. rudis	[illegible]	[illegible]
Ruschia cf. namaquana	[illegible]	[illegible]

B. GEOPHYTES AND EPHEMERAL SPECIES RECORDED DURING 1983

Species	Cover-abundance values (communities 1.1 – 4.0)	Summary table
SPECIES ASSOCIATED WITH COMMUNITY 1.1		
Dregeochloa pumila	[illegible]	[illegible]
SPECIES ASSOCIATED WITH COMMUNITIES 1.1, 1.2(a), 1.2(b) & 1.3(a)		
JWL 132	[illegible]	[illegible]
Felicia australis	[illegible]	[illegible]
SPECIES ASSOCIATED WITH COMMUNITIES 2.1, 2.2 & 3.1		
Sutera sp.(308)	[illegible]	[illegible]
Dimorphotheca sinuata	[illegible]	[illegible]
Moraea serpentina	[illegible]	[illegible]
SPECIES ASSOCIATED WITH COMMUNITIES 1.1, 1.2(a), 1.2(b), 1.3(a), 1.3(b), 1.4, 2.1, 2.2, 3.1 & 3.2		
Pentzia pilulifera	[illegible]	[illegible]
Helichrysum herniarioides	[illegible]	[illegible]
Gazania lichtensteinii	[illegible]	[illegible]
Mesembryanthemum karrooense	[illegible]	[illegible]
Felicia brevifolia	[illegible]	[illegible]
Homeria schlechteri	[illegible]	[illegible]
SPECIES ASSOCIATED WITH COMMUNITY 4.0		
Heliophila trifurca	[illegible]	[illegible]
Pharnaceum sp.(360)	[illegible]	[illegible]
Herrea blanda	[illegible]	[illegible]
Ehrharta pusilla	[illegible]	[illegible]
Dorotheanthus flos-solis	[illegible]	[illegible]
Hebenstreitia parviflora	[illegible]	[illegible]
Wahlenbergia prostrata	[illegible]	[illegible]
Pelargonium sp.(356)	[illegible]	[illegible]
Sutera tristis	[illegible]	[illegible]
Nemesia versicolor	[illegible]	[illegible]
Nemesia azurea	[illegible]	[illegible]
Polycarena collina	[illegible]	[illegible]
Lachenalia unicolor	[illegible]	[illegible]
Silene sp.(448)	[illegible]	[illegible]
Rumex lativalvis	[illegible]	[illegible]
Hermannia cuneifolia	[illegible]	[illegible]
Lachenalia mutabilis	[illegible]	[illegible]
Ferraria divaricata	[illegible]	[illegible]
Gethyllis sp. (258)	[illegible]	[illegible]
Wahlenbergia arenaria	[illegible]	[illegible]
Arctotis fastuosa	[illegible]	[illegible]
Lotononis brachyloba	[illegible]	[illegible]
Grielum humifusum	[illegible]	[illegible]
SPECIES ASSOCIATED WITH COMMUNITIES 3.1, 3.2 & 4.0		
Helichrysum obtusum	[illegible]	[illegible]
SPECIES ASSOCIATED WITH COMMUNITY 3.1 AS WELL AS COMPANION AND INFREQUENT SPECIES		
Leysera tenella	[illegible]	[illegible]
Galenia papulosa	[illegible]	[illegible]
Schismus barbatus	[illegible]	[illegible]
Heliophila variabilis	[illegible]	[illegible]
Senecio arenarius	[illegible]	[illegible]
Dimorphotheca polyptera	[illegible]	[illegible]
Cotula sp.(233)	[illegible]	[illegible]
Pentaschistis cf. patula	[illegible]	[illegible]
Albuca cooperi	[illegible]	[illegible]
Pelargonium carnosum	[illegible]	[illegible]
Zaluzianskya bolusii	[illegible]	[illegible]
Pelargonium triste	[illegible]	[illegible]
Zaluzianskya villosa	[illegible]	[illegible]
Oxalis sp.(450)	[illegible]	[illegible]
Crotalaria humilis	[illegible]	[illegible]
Cyanella pentheri	[illegible]	[illegible]
Cyanella orchidiformis	[illegible]	[illegible]
JWL 451 (rock lichen)	[illegible]	[illegible]
Lessertia sp. (261)	[illegible]	[illegible]
Lachenalia namaquensis	[illegible]	[illegible]
Lightfootia sp.(156)	[illegible]	[illegible]
Pharnaceum sp.(450)	[illegible]	[illegible]
Radyera urens	[illegible]	[illegible]
Hebenstreitia integrifolia	[illegible]	[illegible]
JWL 373	[illegible]	[illegible]
Helichrysum dunense	[illegible]	[illegible]
Hypertelis sp.	[illegible]	[illegible]
Cotula barbata	[illegible]	[illegible]
Pelargonium dasyphyllum	[illegible]	[illegible]
JWL 320 (rock lichen)	[illegible]	[illegible]
JWL 381	[illegible]	[illegible]

THE PLANT COMMUNITY NAMES AND NUMBERS

A. THE APTOSIMUM DEPRESSUM COMMUNITIES ON CALCAREOUS AND SALINE SOILS
- 1.1 The Aptosimum depressum - Salsola tuberculata dwarf/low open shrubland community
- 1.2(a) The A. depressum - Ruschia muricata - Zygophyllum retrofractum low semi-open shrubland community
- 1.2(b) The A. depressum - Ruschia muricata low semi-open//moderately closed shrubland community
- 1.3(a) The A. depressum - Psilocaulon ciliatum dwarf semi-open shrubland community
- 1.3(b) The A. depressum - P. ciliatum - Ruschia cf. R. levynsiae dwarf semi-open shrubland community
- 1.4 The A. depressum - Psilocaulon planisepalum - Salsola zeyheri low semi-open shrubland community

B. THE EBERLANZIA ARMATA COMMUNITIES ON SHALLOW SOILS
- 2.1 The Eberlanzia armata low open//semi-open shrubland community
- 2.2 The E. armata - Ruschia robusta low open//semi-open shrubland community

C. THE STIPAGROSTIS BREVIFOLIA COMMUNITIES ON SOILS MIXED WITH AEOLIAN SAND
- 3.1 The Stipagrostis brevifolia - Ruschia robusta low/short open grassy shrubland community
- 3.2 The S. brevifolia - Lycium spp. complex short open grassy shrubland community

D. THE STIPAGROSTIS CILIATA VAR. CAPENSIS COMMUNITY ON DEEPER, STRONGLY ACID AEOLIAN SAND
- 4.0 The Stipagrostis ciliata var. capensis - Asthenatherum glaucum low open grassland community

ERRATUM

In the summary table, community 1.4 has inadvertantly been placed in the fourth column, whereas it should be positioned in the sixth column.

LEGEND

PLANT COMMUNITIES

- The Aptosimum depressum - Salsola Tuberculata dwarf/ low open shrubland
- The Aptosimum depressum - Ruschia muricata low semi-open/moderately closed shrubland
- The Aptosimum depressum - Psilocaulon ciliatum dwarf semi-open shrubland
- The Aptosimum depressum - Psilocaulon ciliatum - Ruschia cf. Ruschia levynsiae dwarf semi-open shrubland
- The Aptosimum depressum - Psilocaulon planisepalum - Salsola zeyheri low semi-open shrubland
- The Eberlanzia armata low open / semi-open shrubland
- The Eberlanzia armata - Ruschia robusta low open/ semi-open shrubland
- The Stipagrostis brevifolia - Ruschia robusta low / short open grassy shrubland
- The Stipagrostis brevifolia - Lycium spp. complex short open grassy shrubland
- The Stipagrostis ciliata var. capensis - Asthenatherum glaucum low open grassland

MOSAICS

Eberlanzia armata, Stipagrostis brevifolia - Ruschia robusta, Aptosimum depressum - Ruschia muricata

- Stipagrostis brevifolia - Ruschia robusta predominant
- Aptosimum depressum - Ruschia muricata predominant

ROCK OUTCROP

- Granite gneiss (unmapped)

- Roads
- Fences
- Radioactive Waste Disposal Site

NUCLEAR DEVELOPMENT CORPORATION
OF SOUTH AFRICA (PTY) LTD.
GEOLOGY DEPARTMENT

VEGETATION MAP OF THE PLATEAU PORTION OF VAALPUTS

COMPILED BY W LLOYD	DRAWN BY AJH VAN WYK	DATE 85 /09/ 16
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