THE EVALUATION OF THE STATE OF GRASS SPECIES COMPOSITION IN SOME DEGRADED TRIBAL AREAS IN THE ZEERUST DISTRICT (NORTH WEST PROVINCE)

By:

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Supervisor: Dr. P. W. Malan

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IF JEHOVAH DOES NOT BUILD A HOUSE, IT IS IN VAIN THE LABOURER LABOURS THERE.

(PSALM 127:1)



I dedicate this research to my dear parents, Robert and Irene, and to my precious daughter, Gugulethu.



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ABSTRACT

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The evaluation of the state of grass species composition was conducted as an attempt to confirm the survey conducted by the United Nations Convention to Combat Desertification (UNCCD), where the Zeerust District was identified as an area with serious degradation problems. Quantitative data was obtained through botanical surveys (April 2001-February 2002) and verified by household surveys (March 2001-April 2002). Study sites included Braklaagte, Dinokana, Doornlaagte, Serake and Supingstad, with benchmark sites in Madikwe Game Reserve. Between 6-12 survey points per site were selected after consultation with local Agricultural Extension Officers and communities. Survey points included the range of veld condition between bush encroached and severely denuded and eroded areas. The results indicate 12.3 % to 45.1 % loss of vegetal cover. Resistance above 2 000 ohms, base saturation exceeding 100 % and pH values below 5.5 are evidence of soil degradation.

The general profile of the farming household is that of an aging adult community, with however, a relatively good knowledge of farming practices. 52 % of the respondents depend on the government pension fund as a source of income. 60 % of the respondents use crop farming products strictly for household purposes. Poor economic return from farming activities has resulted in overutilization of the herbaceous layer with consequent changes of grass species composition towards retrogression and the establishment of woody species. This environmental degradation is a serious risk to long-term sustainable development. It is therefore, recommended that environmental education programmes and ecological restoration projects be started in degraded areas. The government should set up and enforce land-use policies. Community participation should be encouraged in all land care activities. Land degradation is a real social problem that must be tackled before many people's aspirations of a better life are met.

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CHAPTER 1: INTRODUCTORY BACKGROUND

1. INTRODUCTION

1.1. THE IMPORTANCE OF GRASSES IN SOUTHERN AFRICA

The grass family, Poaceae, is undoubtedly the most successful family of plants on earth (Van Oudtshoorn, 1999). Far too many people think grass is only grass and has no economic value. Grass is the cheapest and most easily exploited source of fodder for ruminant livestock (Tivy, 1982). Almost all farm animals, many antelope species, birds, rodents and insects are dependent on grass as a source of food (Gibbs Russell *et al.*, 1990). The grasses which livestock prefer are termed indicator species. Species such as *Brachiaria nigropedata, Digitaria eriantha, Eragrostis superba, Panicum coloratum, Setaria sphacelata, Sporobolus fimbriatus* etc., are associated with veld in 'good' condition (Van Oudtshoorn, 1999). This does not necessarily imply that if a veld consists of these species is a 'good veld'. Factors such as botanical composition, carrying capacity and annual grass production should be determined before concluding whether a veld is in 'good' condition. Grass species can be identified by odor, growth habits (leaves, stems and roots) and inflorescence. The benefits of knowing grass species for farmers include the following:

- It facilitates management. If the farmer knows which grasses are palatable and how they are utilized, then the decision of shifting animals from one camp to the other becomes easy.
- It simplifies the classification of camps into 'good'-, 'medium'- or 'poor' veld.
- The incidence of over-utilization, under-utilization and trampling is reduced.
- It facilitates the assessment of the grazing and carrying capacity of the veld.

The form and composition of the grass fruit or grain has made grass an important source for the survival and economic prosperity of the human race. The seed and fruit morphology of grasses indicates that the seed, with only a thin, protective outer coating, comprises the bulk of the fruit. Cereal grains contain, in varying proportions, the main food elements necessary for human

nutrition (Tivy, 1982). The grass family, therefore, provides the most highly concentrated forms of food. Cereals and grains have low water-content, which makes their storage and transport to be economic and efficient. Products such as butter, wool, leather etc., are all derived directly or indirectly from grasses (Crowder & Chedda, 1982). Grasses are important for soil stabilization and protection against soil erosion (Bothma, 1989). For example, *Aristida* species which by means of its C_4 photosynthetic pathway is very successful for exploiting semi-arid habitats (Chapman, 1996). This may lie in the unique development morphology and their breeding system plasticity. Grasses are also associated with a dizzying array of fungal symbionts in leaves. Collectively, these features are important to the ecological success of the Poaceae. It also helps to shape the dynamics of a grass population and entire grassland community. Whatever defines their success, grasses play an important role in the earth's bio-geochemistry and help to shape the biological diversity and functioning of communities and landscapes (Williams, 1999).

The grass family owes its ecological success and ecological significance to certain distinctive morphological and physical characteristics. It is distinguished by a homogenous growth form, more marked than in any other family of flowering plants of comparable size. Characteristic of all grasses is an under ground root system which is large and extensive in proportion to the size and volume of the shoot. Lacking taproots, grasses have, however, the ability to produce rapidly a large volume of adventitious roots from the base of the stem in annuals, or from the nodes of rhizomes and stolons in perennials (Tivy, 1982). The roots are covered throughout their length by absorbent root hairs. They form a dense ramifying network which tends to concentrate on the surface layer of the soil. The efficiency with which this root system can take up soil-water and nutrients from a large volume of the soil gives the grass species a competitive advantage over plants of similar rooting depth.

The density and rapidity of growth of their roots and underground stems make the grasses the most effective colonizers and stabilizers of unconsolidated, mobile sediments. Annual weedy species such as crabgrass are the first to colonize the abandoned ploughed ground (Odum, 1989). They are followed in a few years by perennial forbs and grasses (asters, golden rod and broomsedge grass), then woody species. The volume and aggressiveness of root systems of

grasses, combined with their natural adaptation to grazing and burning pressures have given them a competitive advantage over the majority of forbs.

The decline of grasses is a matter of grave concern for the Zeerust District. The grassland ecosystem in this study area is characterized by endemic grasses, and the trees and shrubs are widely scattered. These grasslands have for decades been subjected to a large scale of retrogression due to the influence of man through inappropriate grazing practices. Veld retrogression occurs also through variation of environmental conditions. Without accurate rangeland condition and grazing capacity assessment, it is to be expected that the cover and grass species composition will deteriorate further. This will result in further adverse effects such as soil erosion, ineffective rainfall utilization, decreased production potential and eventually a decline in animal performance as it has been the case in rangelands in other parts of South Africa as discussed below.

Production studies in the Potchefstroom vicinity have shown that veld condition dramatically influence grazing capacity and therefore the economy of a livestock unit (Jordaan, 2001 b). During the 1999/2000 season it was found that 'good' veld produced approximately 112 % more fodder than 'poor' veld. The palatability of the 'poor' and 'good' veld was analysed and approximately 72.4 % of the 'good' veld composition consisted of palatable species, whereas the figure for the poor veld was only 13.7 % (Jordaan, 2001 b). This lead to a grazing capacity figure of approximately 4.8 ha/LSU for 'good' veld during the season, whilst it was 29.4 ha/LSU for the 'poor' veld. The grazing capacity of the 'good' veld was therefore, six times higher than that of 'poor' veld.

In the Molopo District in the North West Province, two rangeland conditions that were identified were composition and cover, namely 'good' and 'poor'cover (Jordaan *et al.*, 2001). The total production was determined with the aid of the dry-weight rank method. from these results it was evident that production of rangelands in 'good' condition was higher than that of rangeland in 'poor' condition. Approximately 84 % of the 'good' rangelands composition was regarded as palatable, and the figure for the 'poor' rangeland was 41 % (Jordaan *et al.*, 2001).

In South Africa, it is now recognised that problems common to the sustainable use of rangelands must be addressed. These factors include rainfall variability, soil fragility or erodibility, human and animal pressure and land use patterns (Anonymous, 2001 a). Rangelands are not in equilibrium and they shift readily between different states in response to grazing pressure, soil degradation and drought. A study in the Stutterheim and Cathcart districts in the Eastern Cape, South Africa showed that more than half the grazing areas were in 'poor' condition, and they were stocked at 155 % more than their current assessed carrying capacity (Bembridge, 1986). Grazing management was 'poor'. Farms in general still had an inadequate number of camps and less than half the camps did not have permanent watering points. This lack of basic development makes it difficult to apply recommended grazing management systems and principles.

A fence-line study was conducted to compare erosion levels, herbage production and grass species composition in Umfolozi Game Reserve (UGR) and the adjacent Kwazulu-Natal (KZN) (Venter *et al.,* 1988). The adjacent KZN area had a long history of abusive grazing practices by domestic livestock, particularly cattle and overstocking had been identified as a problem in this and other areas falling within the Umfolozi Catchment (Anonymous, 1985). In contrast, the stocking rate of large herbivores in the adjacent portion of UGR were reduced to 60 % of the recommended agricultural carrying capacity (Venter *et al.*, 1988). In addition, these large herbivores population have been subjected to natural predation from large terrestrial predators. The assumption was that if there was a long-term higher soil loss rate in adjacent KZN, then a fence line contrast study should show differences in species diversity. Similarly, assuming higher soil losses lead to decreased primary production, then a fence line contrast study should show whether there were any differences in the production potential of the remaining soils. The initial results did not show any significant differences between the two sites, probably because the enclosure plot had just been erected and insufficient time had passed to allow for differences between plots to manifest themselves. However, the total yield was always higher in the UGR exclosure plots than in the exclosure plots in KZN (Venter *et al.*, 1988). Also the total grass species richness was higher in the control plots in UGR than in KZN.

The influence of bush density on the grass component of the herbaceous layer was investigated for three savanna veld types (Molopo Thornveld, Mixed Vaalbos Thornveld and Eastern Grass and Bushveld) in Northern Cape and North Wets Province, South Africa (Richter *et al.*, 2001). In this study the relationship between the bush density, species composition and phytomass production were determined over a four-year period. Bush encroachment had an adverse influence on the density and production of the grass component. Bush Encroachment of 2 500 TE/ha decreased the potential grazing capacity by as much as 33%, 149 % and 58 % in Molopo Thornveld, Mixed Vaalbos Thornveld and Eastern Grass and Bushveld respectively (Richter *et al.*, 2001).

A distinctive feature of the grassland community is the high proportion of the total biomass that is contained in the soil (Tivy, 1982). Grasses are short-lived compared to trees, resulting in much organic matter added to the soil. Consequently grassland soils may contain more humus than forest soils. The dark grassland soils are among those best suited for growing principal food plants such as corn and wheat (Odum, 1989). The extent to which a grassland community modifies its physical habitat is dependent on the specific composition, height and density of vegetal cover. The grassland exerts a much greater effect on the soil than on the atmosphere on the particular site it occupies. The herbaceous layer affects the physical and chemical conditions of the soil. Grasslands, for example, extract many bases from the soil, especially calcium, but return it later to the soil.

During winters, decay is minimal in the grasslands and though there is leaching with the frost-melt in spring, the summer rainstorms only occasionally interrupt the upward movement of soil moisture. With evaporation caused by high temperatures and drying winds, the sub-soil remains dry. Heavy storms leach out some of the sodium and potassium salts, but subsequent upward movements cause calcium carbonate to accumulate. The soil, therefore, becomes basic (Money, 1965). The presence of the herbaceous layer protects the surface from direct insulation to which bare ground would otherwise be subjected, as well as impeding heat loss by outgoing radiation (Tivy, 1982). Much of the grassland is highly vulnerable to soil degradation and erosion (Binns, 1995; Dugain & Fauck, 1969).

Land degradation is proceeding rapidly in many parts of Africa and as it occurs the link between access to agricultural land and livelihood is being severed. In 1956 it was estimated that almost 13 million hectares of veld in South Africa had been badly affected by bush encroachment, and by 1983 it was estimated that 33 % of South Africa savanna vegetation had been dominated by woody species (Department of Environmental Affairs and Tourism, 1999). Land degradation is becoming a major mechanism through which people are being pushed off the land (International Institute for Labour Studies, 2001). People who live in areas where yields have fallen find it difficult to find land in other areas under indigenous tenure systems if restrictions on access to land for outsiders are tightened.

1. 2. RESTORATION OF GRASSLANDS

Restoration has as its eventual objective, the return of vegetation to its original state and function (Tainton, 1981), that is, a veld is restored to a productive and stable condition (Trollope *et al.*, 1990). It is convenient to recognize two facets of the restorative process, namely reclamation and re-vegetation. These two functions are not always separable in practice or in objective, because they are both restorative in purpose. Reclamation is the winning back of the land from a waste or denuded condition to a vegetal condition, irrespective of the nature of that vegetation. Revegetation, on the other hand, implies the re-establishment of vegetation of good structure and vigor as near as possible to the original condition. For example, the effect of past grazing intensity on the vigour of *Themeda triandra* was conducted in Highland sourveld in the Kokstad Research Station in South Africa (Acocks, 1988). Vigour was indexed by measuring the regrowth during a full season's rest of tufts which had not been grazed, which had been leniently or severely grazed during the previous two grazing seasons. A sequential harvesting technique was applied and regrowth was expressed in terms of the above ground herbage mass accumulation. The results show that two seasons of severe grazing had a detrimental effect on the tuft vigour relative to the tufts which had not been leniently grazed. Furthermore it was found that a single rest season appears to be sufficient to restore the vigour of severely grazed *Themeda triandra* tufts (Peddie *et al.*, 1995). While the application of good grazing management

may also be a means of improving vegetation and bringing it back to its original condition, the technique of restoration usually includes soil disturbance, seeding and fertilization.

Some degraded areas are in such poor condition that good management alone will not be able to restore vegetation. Consequently more constructive mechanical and biological restoration methods are needed. Careful assessment of each site is needed before reclamation commences, because the method employed will be determined by the extent and causes of denudation, the urgency of reclamation and financial implications (Van Oudtshoorn, 1999). When the natural plant cover has been damaged either by drought, overgrazing or incorrect burning practices, soils become denuded. Rain can cause an increase in the volume and rate of soil erosion. Steps should be taken to slow down and to spread water as evenly as possible in an attempt to increase infiltration. Various implements such as the ripper, chisel plough, tiller and dyker plough can be used where the terrain allows it. The dyker plough leads to the formation of small puddles on the surface a few centimeters apart. This bring about a macro-climate where water can be collected for seeds to grow. Although mechanical methods seem to be effective, there are some limitations such as inaccessibility of the area, availability of implements and high costs. It is important, therefore to look for alternative methods which will be more feasible and less expensive, but still effective.

Scratch ploughing suffices under conditions of more favorable rainfall where furrows serve as coarse seedbeds. The shallow furrows made along the contours catch many of the seeds which are washed away along the surface and provide protective sites for germination and seedling growth (Pratt, 1963; Scheddler, 1969). On the dry alluvial soils of the Rift Valley in Kenya, cultivating with rigid tines attached to a tractor tool bar, spaced 30-60 cm and set to penetrate the soil to a depth of 15 cm, gave an increase in the number of plants sown species. Placement of cut branches on the soil surface also favored seedling development. By the end of the third season, fair amounts of *Cenchrus ciliaris* and *Eragrostis superba* remained (Pratt, 1964; Bogdaan & Pratt, 1967). Drilling grass seeds into closely grazed or cut swards may improve establishment (Owen & Brzostowski, 1967), but the more intensive mechanical operations are indicated for less

favorable sites (Pratt & Knight, 1964; Van Rensburg, 1965). More dense stands occur when seedlings are made after tillage, with care taken not to cover seeds too deeply.

Grasses have been used widely for oversowing native grasslands and re-seeding denuded areas caused by overgrazing, wind and water erosion. Successful establishment of grasses sown into natural grazing lands lies in the appropriate choice of species, application of suitable techniques of land treatment, use of fertilizers (especially phosphates) and appropriate methods of sowing (Bogdaan & Pratt, 1967; Bogdaan, 1977; Kornelius *et al.,* 1978; Jones, 1979; Cook, 1980). It is generally preferable to use indigenous perennial species. The use of awned seeds also has an advantage when bare areas have to be re-seeded. Awns are bristle-like appendages on the lemma of a spikelet of a grassed (Van Oudtshoorn, 1999). This appendage has sharp-pointed ends which facilitate penetration of seeds into the soil. Rhizomatous and stoloniferous grasses are recommended for disturbed soils, steep slopes and areas where water run-off velocities are high.

Introduced species often displace native species and reduce diversity. *Eragrostis lehmanniana* from South Africa was purposefully introduced to the desert grassland of North America in 1932 in attempt to reseed degraded rangelands and road cuts (Rapport, 1999). This experiment was overly successful because by 1940, *Eragrostis lehmanniana* began to appear in unplanted regions of Arizona and New Mexico (Cox *et al.*, 1984). By 1986, this species was dominant on approximately 146,000 hectares of grassland and former grasslands in south eastern Arizona (Anable *et al.*, 1992). Although this grass has served admirably to prevent further erosion, thus fulfilling the initial purpose for which it was introduced, in many regions it has displaced the native *Bouteloua eriopoda*, lowering the overall range quality (Whitford, 1995). Less obvious effects of introduced species include the alteration of ecosystem functions including the size of nutrients and energy pool. Introduced nitrogen-fixers, for example, can significantly increase soil nitrogen. A competent pasture specialist should be consulted before initiating a re-vegetation program. The easiest approach is direct over-seeding into natural grasslands in strategic places. Strategic places include bedside rocks, cattle posts and dead tussocks. All these provide a better micro-climate for germination of seeds there should be more moisture and shade available. Care

should be taken that the soil in these places is slightly loose and not completely crusted because root penetration will be impossible.

Species which have shown potential for improving of grazing lands include *Cenchrus ciliaris* (which grows on all soil types, with preference for sandy, limy and stony soils), *Chloris gayana* (which grows in well-drained sites and prefers moist soils), *Cynodon dactylon* (which prefers sandy, fertile, damp and disturbed soils) and *Eragrostis superba* (which grows well in sandy, stony soils in disturbed localities) (Pratt, 1964). Grass seed is expensive and scarce and should be harvested locally. This can be done mechanically with the aid of a combination of a harvester, an ordinary vacuum cleaner, picking up by hand, or cutting and bundling sheaves for harvesting at a later stage (Bothma, 1989). For veld reclamation purposes, seeds can be harvested indiscriminately. The seeds of most indigenous grass species have a delayed ripening period and will not germinate before the following growing season. Pioneer grasses such as *Aristida congesta* and *Chloris virgata* can be sown together with species such as *Anthephora pubescens, Cenchrus ciliaris, Digitaria eriantha, Eragrostis curvula, Panicum maximum, Sorghum almum,* and *Themeda triandra* (Bothma, 1989). *Themeda triandra* is the most common grass species in South Africa and is found in all grassveld types, but is more common in undisturbed climax veld (Gibbs Russell *et al.*, 1990).

In the more arid regions, *Eragrostis lehmanniana, Schmidtia kalahariensis, S. pappophoroides* and *Stipagrostis* species can be used for veld reclamation purposes. When seeds are sown in by hand after burning and grazing, cattle can be used to trample in the seeds. There may be a certain amount of germination of annuals which provide a temporary cover to the soil. Therefore, every effort should be made to restore a perennial grass cover as soon as possible (Tainton, 1981). Another oversowing method is by burning the veld and allowing regrowth. This veld must be grazed severely. Seeds can then be sown in, and manure collected in bags can be distributed over the seeds. A large quantity of manure can be obtained by allowing cattle to graze in a certain camp for a short period. A sowing rod can be used for planting. A sowing rod is a hollow pipe shaped like a walking stick round at one end to form a handle pointed at the other end. The point is spring controlled and has a small hole in it so that some seeds fall out each time the point is

pushed into the ground. The branches from indigenous woody species can be used to cover seeded areas. The branches protect the plants from grazing and browsing livestock, and also from severe rain and windstorms. In time, the brush decomposes and the area can be lightly grazed once again. Resting of such areas during the growing season is highly desirable (Van Oudtshoorn, 1999). Periodic rests from grazing during critical growth periods permit the accumulation of plant nutrient reserves and aid seed formation. A system of deferred grazing or seasonal grazing will allow time for seed development and facilitate natural re-seeding. Seedlings and plants do not tolerate heavy shade (Anderson, 1967; Crowder & Chedda, 1982). Improved distribution of animals by fencing and placement of water points are also important (Lange, 1969).

The Department of Water Affairs and Forestry (DWAF) has initiated a Working for Water Programme in 1995 in order to address the problem of woody alien invasions (Barac *et al.*, 2001). The study area is in the vicinity of Elandsfontein near Westonaria. After clearing *Acacia mearnsii* both chemically and mechanically, several restoration technologies were applied to reduce erosion rate. The techniques comprised of a combination of oversowing with a grass seed mixture, lime organic material (cattle dung) application and, loosening of soil surface and brush packing. Monitoring results shown that the most effective technology was the combination of oversowing with grass seed, application of lime and organic material covered with brush. Seed germination tests in the laboratory showed that highest percentage of germination was for *Eragrostis lehmanniana* and *E. curvula*. These results were similar to the high frequency of these two species in the rehabilitation sites under natural conditions (Barac *et al.*, 2001).

Another study was conducted in the Nama karoo by Van der Berg and Kellner (2001). Degradation in this area was characterised by large bare and denuded areas, and it seemed that these areas would not recover by natural successional processes. Some sort of active intervention was therefore, inevitably necessary. A degraded site on the south east of Tafelberg on the farm Thomasplaas in the Middelburg district was identified. Different treatments included ripping, brush packing, oversowing and addition of organic matter. The results indicated that of the sown grass species, *Digitaria eriantha* and *Chloris gayana* established the best, and the karoo shrubs that

were sown in did not establish at all after the first season. It is clear, therefore, that by loosening the soil, oversowing with correct and adapted seed types as well as protection of the seed by brush packing a drastical improvement in the condition of the fields can be obtained. This treatment can thus be recommended to restore bare and degraded patches in arid and semi-arid areas with similar conditions (Van de Berg & Kellner, 2001).

Destruction of trees provides higher initial stands of grasses and more dense population than sowing into regularly grazed rangeland. The suppressive effect of woody plants on grass production and, therefore grazing capacity, is often considered the major reason why clearing of woody plants is viewed as a management option. Bush encroachment results in serious veld degradation that causes a further reduction in production potential, thereby making veld increasingly more drought sensitive (Richter & Meyer, 2001). In situations where high tree densities are encountered and increased grass production is desired, the first operation that may be required will either be total clearing or thinning of trees to some predetermined density. Both selective tree thinning and total clearing by means of mechanical and chemical control methods will result in immediate changes in competition between grass and bush components. This usually has an immense effect on the production and species composition of the grass layer. A dense sward of grass or other adapted plants is the best means of reclaiming gullies protecting conservation works. Much success with gully reclamation can be ascribed to the established of the common reed (*Phragmites australis*), on moist sediments.

A classical ecological theory predicts that degraded vegetation will follow a progressive succession back to the original vegetation (or its projection in time) once the disturbance has ceased (Skarpe, 1991). This is under the assumption that the system still is limited by the factor causing the disturbance, e.g. grazing. If other constraints have become more important e.g. shortage of soil moisture, nutrients or soil itself after erosion, there is no reason to expect a rapid return towards the original condition. If soil erosion has not been too severe, efforts to speed up and /or direct the succession may in such situations help to obtain vegetation that is useful for the local people (Backeus, 1992). In such restoration work, it is essential to find out what is the desired and feasible end result. In many cases, grazing land is given the highest priority. In areas

where grazing is likely to cause renewed degradation, collecting of fodder for stall feeding of livestock may be an alternative provided quantity and quality of fodder production is high enough to justify the high labour input of collecting it (Skarpe, 1991).

1. 3. GRASSLAND BIODIVERSITY

According to Skarpe (1991) and Learch and Mearns (1991), ecologists usually define biodiversity in one of three ways:

- Genetic diversity: or a wide variety of biological information stored within the genes
- Species diversity: many different species of organisms in the world, from *Escherichia coli* to elephants.
- Ecosystem/land diversity: range of habitats or vegetation types that cover the globe. This third definition holds for the discussion below:

According to White *et al.* (2000), grasslands encompass not only non-woody areas, but also savannas, woodland, steppe, shrublands and forest lands. Extensive areas of grasslands and grass-woody association that provide grazing lands occur in all continents and on many larger islands.

Natural grasslands occur extensively around the globe in areas where there is typically a fairly long, dry season. Grasslands are constituted by dense grass cover. The woody growth is absent or confined to isolated clumps or to water courses. Seasonal drought is undoubtedly important in determining grassland distribution, but fire and grazing animals, in removing biomass, often play an overriding role (Peet *et al.*, 1999). Savannas have conspicuous grass cover and woody growth of varying density (Crowder & Chedda, 1982). A mixed savanna comprises a woody-plant grass vegetation complex in which the density of trees, bushes and shrubs is highly variable and the grass cover is well-developed.

The steppe is an open, almost tree-less grassland. Warm steppe refers to vegetation cover of low-growing trees or shrubs with widely spaced annual or perennial grasses, as well as trees grass-herb sub-desert formations (Crowder & Chedda, 1982). The extinction of plant and animal species in grasslands due to land degradation will potentially affect the development of new drugs (Vivian, 1994). It will reduce ecosystem adaptability and lead to the loss of genetic resources.

1. 4. GRASSLAND POPULATION DYNAMICS

One of the most fundamental characteristics of vegetation is its susceptibility to change (Bothma, 1989). Any environmental change must inevitably result in the corresponding minor or major changes in the associated plant community. Factors such as climatic variability, veld burning, temperature changes, invasion of woody species etc. influence vegetation dynamics. Such factors can be intrinsic or extrinsic. Extrinsic factors are independent of plants themselves, and include climate, soil, landforms or (in) direct activities of man such as burning etc. Intrinsically, plants, by their very presence, modify the physical conditions of the sites on which they grow (Bothma, 1989).

From a moment that a particular site is first colonized by plants, the resultant modification of the habitat initiates changes which tend to bring about the replacement of one collection of plants by another. These colonizers are called pioneer species. The addition of soil organic matter permits the growth of other plants which are more demanding of water, nutrients and anchorage. These plants are taller and more aggressive than the preceding species. These are intermediate species or subclimax species. Not only do these plants have better and more stable productive capacity, but offer a better quality grazing as well (Bothma, 1989). The shelter and protection provided by one group of plants allows shade tolerant seedlings, incapable of germinating in exposed soils to establish. These are called climax species, for example, *Digitaria eriantha, Panicum maximum, Setaria nigrirostris* etc. These climax species are in equilibrium with the environment and has a better and more stable production capacity than any of the preceding stages.

The climax population depends on local soil and climatic conditions, and will differ on hills, plains and vleis
(Tivy, 1982).

Fire is one of the most important factors affecting savanna and grassland dynamics, and can be readily manipulated by man (Anonymous, 2001 b). Fire helps to reduce plant biomass and litter, therefore altering energy, nutrient and water fluxes in the soil and atmosphere. The quality of the soil is slightly altered by fires, but not to an extent which harms the soil (Anonymous, 2001 b). Looking at the general effects of fire, the general trend is an increase in the amount of nutrient abundance. Fire can be used to reduce hazardous fuels, prepare sites for seeding, rejuvenate forage for wildlife and domestic livestock, maintain fire-dependent species, control insects and diseases and maintain habitat for endangered species (Anonymous, 1994). The effects of burning on soil productivity depend on the fuel and weather conditions under which burning takes place. Soil moisture, fuel quantities, moisture content, air temperature, humidity and wind are all factors considered in burning prescriptions to reduce fire intensity and the consumption of organic material (Anonymous, 1994). Productivity may be increased after site preparation if desired species can be quickly re-established and occupy the disturbed site to the exclusion of undesired plants.

Grasses are adapted to fires in several ways particularly based on their morphology (Mielke, 1989). They have deep roots and their meristematic tissue which forms the leaves is on or below the ground surface. The highest temperatures during a veld fire are well above the ground surface. The seeds and buds are able to escape fire damage and are able to regenerate quickly. Some other adaptive features of grasses include weediness, that is, the ability to produce abundant seeds (Clapman, 1983; Mielke, 1989). This is the case with perennial grasses which produce seeds one or two years after germination. Many grasses have long spirally twisted bristles called awns attached to their seeds (Van Oudtshoorn, 1999). These awns are sensitive to moisture and they twist and untwist with the changing humidity. By twisting, they drive their seeds until its sharp point enters a crack in the soil where it is protected from fire (Clapman, 1983). Burned veld is more nutritious in spring than unburned veld, largely because the new

season's growth is not contaminated by low quality residual material from previous seasons. The new growth is reported to have a higher nitrogen and mineral content than unburned grass. Burning is also done to destroy parasites, particularly ticks, and to control the encroachment of undesirable plants in the veld. Veld retrogresses if it remains unutilised for any length of time. The required frequency of burning is associated with the rate at which top growth accumulates (Hubbard *et al.*, 2000; Meyer, 1998).

Seedbank evaluation is important in understanding plant community development and successional patterns which can be used in identifying factors regulating population dynamics (Van Rensburg *et al.*, 2001). Seedbank composition along a degradation gradient was evaluated on an Arcadia soil type at Soetdoring Nature Reserve, north west Bloemfontein (Van Rensburg *et al.*, 2001). The treatments included bare soil, veld in 'good', 'moderate' and 'poor' condition which represents a degradation gradient. Seed germination trails were conducted to determine germinability and botanical composition of the seedbank. Four grass species were identified in the seedbank namely, *Aristida congesta, Chloris virgata, Themeda triandra* and *Tragus racemosus*. *A. congesta* occurred in all treatments except veld in 'good' condition and was the only species that germinated on bare soil. *Tragus racemosus* occurred in both the 'poor' and 'moderate' veld, while *Chloris virgata* occurred only in 'moderate' veld. *Themeda triandra* occurred in both 'moderate' and 'good' veld condition, but was the only species in the 'good' veld (Van Rensburg *et al.*, 2001).

Long-term vegetation changes of the grass and woody species composition were studied based on the vegetation surveys at the Towoomba Agricultural Development Centre in the Limpopo Province on a site that has been protected from fire and grazing since 1935 (Jordaan *et al.*, 2002). Between 1941 and 1973, vegetation amps of grasses indicated that climax grassveld areas that were initially characterised by *Themeda-Cymbopogon-Heteropogon* veld were replaced by post-climax grassveld *Enneapogon-Cenchrus ciliaris* veld. The site was severely underutilised whidh led to the degeneration of the grass component. The absence of fire was considered the main reason why bush encroachment occurred in the protected site (Jordaan *et al.*, 2002).

Buckland *et al.*, (2001) has documented the considerable expansion of population of the grass *Brachypodium pinnatum* at the Northern limit of its distribution in Great Britain in a limestone grassland. This was three years after the termination of experimental manipulation of climate changes when plant traits effective for establishment coincide with the removal of current barriers to dispersal. Earlier studies in the journal have documented how the grazing of free ranging cattle impact on the grass invasion of heathlands that has resulted from increase of anthropogenic perturbation of the nitrogen cycle (Lee, 1998). In South Africa, for example, in an experiment conducted by Kraaij and Ward (2001) in Kimberely, the results show significant interactions between rain, nitrogen and grazing in their effects on tree recruitment. According to this research, grass defoliation frees resources and creates space for use by tree seedlings. Conversely, nitrogen enrichment improves the competitive ability of fast growing grasses relatively more than that of the leguminous tree component, thereby suppressing tree recruitment (Kraaij & Ward, 2001).

A well-developed grassland community contains species with different temperature adaptation. One group grows during the cool part of the season (spring and autumn) and another during the hot part (summer). The grassland as a whole compensates for temperature, thus, extending the period of primary productivity. Many species have narrow ranges of tolerance and are accordingly, sensitive to changes (Odum, 1989). Such species can be useful ecological indicators of changes in environmental conditions. Range managers find that the relative abundance of plants that are sensitive to grazing will indicate the approach of overgrazing before it become apparent in the grassland as a whole. Indicator species often prove useful in the evaluation of different successional stages (Odum, 1989; Van Oudtshoorn, 1999; Danckwerts, 2001).

1.5. HUMAN MODIFICATION OF GRASSLAND BIODIVERSITY

1.5.1. AGRICULTURAL PRACTICES THAT MODIFY GRASSLAND BIODIVERSITY

1.5.1.1. LIGHT GRAZING

Light grazing involves the insufficient utilization of the grass sward due to under-stocking or short time spent by grazing animals in one camp (Savoury & Butterfield, 1999; Tainton, 1999). This is called lenient defoliation and leads to the formation of moribund of grasses causing grasses to shade themselves (Anonymous, 2002 a). Walker *et al.* (1981) and Ruess (1987) reported that light grazing may stimulate grass growth and leads to biomass increase. This increase is probably due to the induction of tiller formation of perennial grasses (Tainton, 1999).

1.5.1.2. OVERGRAZING

Overgrazing of rangelands implies excessive use of forage by herbivores with the result that biotic and abiotic components of the ecosystem are so changed that the system cannot recover within ecological time (Conner, 2002). Heavy grazing or too fast rotational grazing causes a decline in grass production in the long run. This occurs because the amount of photosynthetic area is reduced before it may grow to any extent (Anonymous, 2002 a). Heavy grazing pressure may reduce the competitiveness of the grasses (Anonymous, 2002 b).

After grazing, grasses go through three phases of growth. The first phase occurs after plants have been severely grazed. Fewer leaves are left to intercept sunlight and the plant requires more energy for growth than they are able to produce through photosynthesis. To compensate, energy is mobilized from the roots. The roots become smaller and weaker as energy is used to grow new leaves. When growth reaches a quarter to a third of the plant's mature size, enough energy is captured through photosynthesis to support growth and begin replenishing the roots. This is the second phase and is the period of most rapid growth. During this phase, leaves contain sufficient

protein and energy to meet the nutritional needs of most livestock, that is, high quality but low quantity. As plants continue to grow, leaves become more and more shaded. Lower leaves die and decompose. Leaves use more energy for respiration than they can produce through photosynthesis. This is the third phase during which the plant material is stemmy and fibrous. Nutrient content, palatability and digestibility of leaves in this phase is poor- that is, a phase of low quality but high quantity (Pratt, 1993).

According to the principle of controlled grazing, grazing and resting periods should be adjusted to keep plants in the second phase, that is, in the period of most rapid growth. Livestock should, therefore, not be allowed to graze plants so that they enter phase one, because regrowth is slower and will reduce total productivity. Plants should also not be allowed to enter phase three because shading and senescence begin to detract from efficiency of photosynthesis. The harvest of energy from pastures will be maximized by keeping the plants in phase two (Pratt, 1993).

Recovery of the biotic component to a predisturbance condition is common. By contrast, when the abiotic component, especially soil, is subjected to accelerated erosion, fertility loss and structural alteration, such changes are usually irreversible in ecological time. Recovery, 'if ever', can occur only in historical (centuries or millenia) or even geological time (Biot, 1993; Milton *et al.*, 1994).

The mechanism for replacement of relatively palatable perennial species by less palatable annual species was described by Dyksterhuis (1949) as an interaction between grazing and competition. According to this mechanism, competition is reduced in preferentially grazed species and these are subsequently out-competed by less-grazed species. When competition takes place between seedlings, quickly established ephemerals may out-compete slow-germinating perennials (Westoby, 1980). Stochastic variations in rainfall, fires etc., make the process highly dynamic (Walker, 1987). The succession may lead to an almost complete species turnover and to vegetation types dominated by unpalatable poisonous dicotyledonous species, dwarf shrubs or annuals (Acocks, 1975; Werger, 1977; Skarpe, 1986).

In the driest savannas continuous livestock grazing disfavours perennials (Westoby, 1980) and prevents perennial grazing from storing nutrients in their roots (Anonymous, 2002 a). Annual grasses are often palatable, but disappear quickly when rains cease. The grazing-induced vegetation types frequently indicate drier conditions than those recorded by meteorologists (Werger, 1977; Skarpe, 1986). This suggest a decrease in plant available soil moisture caused by reduced infiltration rate, water holding capacity and increased evaporation as a result of trampling and reduced vegetal cover (Skarpe, 1991). Tainton (1999) recommends that veld should be given a rest during flowering in some years to permit the plants to seed.

Many plants and soil organisms lack adaptation to cope with livestock grazing. Severe grazing, that is, inappropriate grazing seasons or excessive stocking rates removes vegetation, reduces litter and destroys biological crusts that protects the soil from wind and water erosion. The composition of the vegetation and the physical properties of the soil may be modified. If the impacts are severe enough, critical thresholds of ecosystem function may be crossed, altering water availability, energy and nutrient supplies and causing ecosystem degradation (Pyke, 2001).

Long-term overgrazing may induce a shift in species composition that in turn affects primary and secondary production (Holechek *et al.*, 1989). Heavy grazing favours the establishment of unpalatable species, thus lowering secondary production (Wilson & MacLeod, 1991). Human modification of grassland diversity also occurs through manipulation of wild animals. In savanna or woodland areas with relatively high rainfall (> 500 mm per annum), game species often initiate the development and maintenance of open grasslands. These changes are often initiated by elephants that may ring-bark or uproot trees. The increase grass production in these cleared areas attracts more grazers. If the grass is not utilized by a sufficient number of animals, dead plant material accumulates, causing moribund conditions (Pyke, 2001).

1.5.1.3. CULTIVATION PRACTICES

Historically, agriculture has been a major ecosystem modifier if the natural environment. Arable agriculture is a process of using the soil and altering its vegetation cover either directly or

indirectly (Crowder & Chedda, 1982). Agricultural activities such as over-cropping, improper ploughing methods, use of heavy agricultural machinery and application of fertilizers had the greatest impact on soil degradation with consequent modifications of plant diversity of the study area.

Rainfed arable land is subjected to a range of degradation hazards such as water, wind, sand blasting of crops and emerging seedlings, plant nutrient depletion and sealing of the soil surface (Anonymous, 2001 c). In arable agricultural areas wind and rain carry away about 25 billion tons of topsoil yearly, worldwide (Anonymous, 2001 b). At such a rate it is estimated that all topsoil will be lost by the middle of this century. Soil erosion causes loss of productivity. It is compensated for by fertilization, pest control and fossil fuel energy. The degradation of cropping land from inappropriate resource utilization is generally expressed in terms of lost production rather than direct observation in the field. Over-cultivation gradually leads to desertification (Anonymous, 2001 b). Under normal soil conditions, an equilibrium between the soil organic matter accumulation and its decomposition exists (Yayock *et al.*, 1988). Cultivation disrupts this natural equilibrium in two ways:

- Relatively little organic matter is usually returned to the soil through unused crop residues and;

- Decline processes are accelerated by such farming operations as over-cultivation which lead to the better aeration as well as enhanced micro-biological activity, surface erosion and leaching.

The greater loss in organic matter normally occurs immediately after the fallow is opened up and farming is started (Webster & Wilson, 1980).

Use of heavy machinery alters the soil structure and, therefore, the growth of plant species. The normal action of the plough is to leave behind a loose surface layer and a dense subsoil where the soil aggregates have been pressed together by the sole of the plough (Goudie, 1990). The

compacting action can be especially injurious when the depth of plough is both constant and long-term, and when heavy machinery is used on wet soil. Soil compaction increases the resistance of soil penetration by roots and emerging seedlings, and limits oxygen and carbon dioxide exchange between the root zone and the atmosphere. Compaction also reduces the rate of water infiltration into the soil which may change the soil moisture status and accelerates surface run-off. Vehicle movements often lead to development of gullies (Yayock *et al.*, 1988). The local residents indicated that gullies in the croplands were caused by tractors (Chapter 5).

Chemical fertilizers and other substances such as sewage sludge are added to the soil to improve crop quality and soil production (Briggs & Courtney, 1985). Intensive applications aimed at maximizing crop yield are not always beneficial and can give rise to many undesirable side effects, in most cases in reduced crop yield. Constituents and impurities in natural fertilizers such as phosphates and heavy metals can accumulate in the soil and affect plant growth. Cadmium, for example, can accumulate in the soil wherein inorganic phosphate or sludge are applied. In the long-term, the accumulation of these elements can lead to lower soil fertility and excessive concentration of unwanted substances in the crops cultivated.

Many of the weeds and pests that attack agricultural crops do so from the base within semi-natural vegetation scattered throughout the landscape. The application of pesticides can add almost similar effects to land as fertilizers (Briggs & Courtney, 1985). The application of fertilizers as fouler sprays may cause leaf scorch, with consequent reduction in the photosynthetic activity and transpiration rate of the plant. The use of herbicides may cause damage to the roots of cereal crops and thereby increase susceptibility of crops to disease. Similarly, root damage may inhibit water and nutrient uptake and reduce yields.

Farmers are profit motivated and are inclined to the over-exploitation of agricultural resources. These strong profit motives, unrealistic land prices, and uneconomic farm sizes have led to the application of many non-adapted farming practices with serious land degradation. These practices endanger the genetic and ecological diversity of plant and animal communities. Wide variations in genetic traits increase the likelihood that at least some individuals of a given species

will survive the environmental change (Cutter *et al.*, 1985). People in the study area depend on their crops and a substantial loss of any of these crops in a given year would almost certainly lead to widespread famine. Rainfed agriculture is practiced in the Zeerust District. It is a major cropping system that provides considerable amounts of crops such as legumes and cereals. Rainfed agricultural lands have been under population pressure and struggle to produce more in order to satisfy the growing population demands.

Man has become a controlling factor in the balance of nature to the extent that he is capable of developing grazing lands in almost any place where grass will grow. By mismanagement, man is responsible for the retrogression of established grasslands, which subsequently leads to the changes in biodiversity such as decline in grass species composition and invasion of woody and weedy species (Crowder & Chedda, 1982).

Species diversity and the abundance of certain species are also indicators of biodiversity in a particular ecosystem. Species extinction is a serious threat to biodiversity. The death of an individual is a natural process. By contrast, the death of an entire species is an irreversible process in which both the basic form and the reproductive potential are lost. The contribution of the species to the total vitality of the planet is also lost. Species extinction can be natural, but humans can accelerate the process (Geach, 2002).

Grasslands have been modified by man through agricultural practices such as clearing of forests, shifting agriculture, continued arable cropping, grazing of domestic livestock, influence on the population of wild game and interference with their habitat and use of fire. These are secondary determinants of grasslands, but even the primary determinants such as climate and soil, have been modified by man either directly or indirectly (Teague & Smit, 1992). Similarly the pressure to increase animal production has led to many semi-natural grasslands being intensified by re-seeding, herbicides and fertilizer application (Watkinson & Ormerod, 2001).

The effect of grazing is especially important in an environment with variable rainfall (Anonymous, 2002 a). Accelerated soil loss may lead to a long-term reduction in species

diversity (Venter *et al.*, 1989). If the long-term soil loss rates exceed those of soil genesis, the productivity of the system will ultimately decline. Grassland biodiversity depends upon the level of grazing, that is, light grazing or overgrazing.

1. 5. 1. 4. SUBSISTENCE FARMING IN THE ZEERUST DISTRICT

Despite the poor nutrient status of the soils (Chapter 4) and periodic droughts, the majority of inhabitants in the Zeerust District still depend on subsistence farming for survival (Chapter 5). Agricultural activities have always played an important role in the life and well-being of this community. Traditionally, crop production and livestock rearing have been an important aspect of the everyday life of the majority of people. Many customs and traditions relate to and emanate from the agricultural activities (Cowley, 1985). Agricultural production, both crop- and livestock husbandry are greatly dependent on the capacity of rangelands to sustain biodiversity. It is the poor and politically marginalised who are at the mercy of changing climatic and environmental conditions.

Many low-income and landless people earn a great proportion of their income from the sale of livestock production. Even non-owners benefit by looking after cattle of livestock owners. Livestock production provides rural people with one of the few market-based opportunities for income and employment to those with limited land or capital.

1.5.2. NON-AGRICULTURAL PRACTICES THAT MODIFY GRASSLAND BIODIVERSITY

1.5.2.1. COLLECTION OF FUELWOOD

Collection of fuelwood from natural woodlands caused serious destruction of vegetation. According to Gupta (1988), collection of fuelwood occurs as a response to energy needs of the people. Fuelwood is primarily used for cooking, heating, lighting and beer brewing. To cover these needs, most households resort to free gathered biomass fuels, and if wood is difficult to

collect, dried dung of domestic animals is used. This robs the grasses of the organic matter in animal droppings (Gupta, 1988) and therefore causes modifications in biodiversity.

1. 5. 2. 2. CONSTRUCTION

With rapid population expansion in the Zeerust District there has been an increased need for a place to live, work and recreation. This means there is an increased demand for resources such as soil and sand for bricks, poles for fencing and roofing, all obtained at the expense of plant species in the grazing lands (Sombroed & Sene, 2000). Soil mining activities remove the vegetal cover of grasses, causing a decline in grass species composition. The topsoil is removed and the land becomes scarified. The loss of soil is accompanied by loss of nutrients, resulting in the formation of acidic soils.

1. 6. CAPACITY OF GRASSLANDS TO SUPPORT BIODIVERSITY

Biodiversity is considered a globally important resource since it forms the basis of human needs such as food, fibre and medicines. The 6 billion people living on the planet today, with the majority concentrated in developing countries and among the poorest nations, are totally dependent on the services provided by the environment (Geach, 2002). Biodiversity is at the root of our ability to adapt to an increasingly uncertain future (Geach, 2002). The decline of grasses reduces the capacity of grasslands to support biodiversity. The need for improved rangelands to sustain the growing demand for meat production in the country should never be underestimated.

Grasslands are managed for forage production. A high degree of biodiversity is a desirable conservation goal and the effects of grazing on the ecosystem are of wide concern. As grazing pressure increases and competitive relationships within the sward are modified, the structure and botanical composition of the sward are also modified (Perevolotsky, 1998). Crawley (1983) argued that the primary way in which herbivores affect plant species diversity is not by grazing plants to extinction (although this can happen), but rather by selective feeding which modifies

competition among plant species. Some species can survive because competition from aggressive species that have been grazed, is reduced. A decline in rangeland condition implies that palatable perennial species are being replaced by annual and weaker perennial species which are unacceptable for livestock grazing (Jordaan, 1998). In such grasslands, fewer animals can be kept and the condition of livestock is usually poorer with a subsequent fall in the value of the land (Jordaan, 2001 a).

Often, biodiversity increases with increasing production (Grime, 1973). Milchunas *et al.*, (1988) suggested that in semi-arid grasslands, diversity tends to decline with grazing intensity, while in subhumid grasslands diversity tends to increase. Several other studies (Macnaughton, 1977; Mazumder *et al.*, 1988; Mazumder, 1994 a, b; Leibold, 1996), have also suggested interactions (such as trampling) between grazers and resources as strong determinants of plant community responses. Some studies, however, seem to suggest resource and productivity as the sole determinant of species diversity (Rosenweg & Abramsky, 1993; Tillmann, 1993; Abrams, 1995). It is also possible that if grazers reduce plant density, a reduction in plant species richness could also be due to estimates based on fewer individuals (Proulx, 1998). In low-nutrient ecosystems, an increasing grazing pressure is consistently associated with a decline in species richness, probably due to a limited capacity for regrowth of edible species after grazing.

Southern Africa's real wealth lies in biological diversity and the central government needs to pay attention to this issue so that our genetic heritage can be conserved. Declining soil productivity, increasing poverty and disasters such as droughts, floods and famine are the challenges that have to be met. These environmental challenges are not mutually exclusive, but are inextricably linked to the social, economic and cultural context. Short-sighted economic self-interests are increasingly hampering global efforts to find solutions to these environmental issues, poverty and inequality as well (Geach, 2002).

Globally, important resources such as biodiversity and 'environmental space' (i.e. the capacity of ecosystems to provide environmental services such as clean air and water) are increasingly being privatized (Geach, 2002). They are becoming commodities to be traded and the responsibility of

environmental governance is being passed from communities and governments to individuals and corporations. The local impact of land degradation and loss of species are likely to be severe. South Africa has ratified both the Convention to Combat Desertification, but action on the ground level has been slow (Geach, 2002).

From a conservation perspective, grasslands are important in terms of biodiversity, whether this be plant diversity or large grazing animals of African savannas (Caro, 1999). The influence of man on the development and maintenance of grasslands has been more widespread and significant than all other biotic influence (Crowder & Chedda, 1982). Man has wrought such modifications of grasslands and other vegetation communities that they bear little or no resemblances to what they might have developed had man not interfered (Moore, 1964).

1. 7. OBJECTIVES OF THE STUDY

The objectives of this study are to:

- conduct a survey of grass species composition in the Zeerust District and relate the distribution of grasses to veld retrogression.

- analyse soil samples for nutrient status and use this data to confirm soil degradation.

- verify the botanical surveys by studying attitudes, perceptions and indigenous knowledge of local communities with regard to veld retrogression, land-use and land degradation.

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CHAPTER 2: THE STUDY AREA

2. 1. INTRODUCTION

This research is conducted in the Zeerust District (former Lehurutshe District), North West Province (Figure 2. 1). The selection of this area follows from a survey conducted between May 1997 and March 1998 in 35 agricultural regions in the country (Hoffman *et al.*, 1998). The survey was conducted for the United Nations Convention to Combat Desertification (UNCCD) as a first step to address the problem of land degradation in South Africa. The information was gathered during a series of participatory workshops in which a structural data sheet was used to assess the extent of soil and vegetation degradation in each magisterial district. In terms of this analysis, the North West Province has been rated the fourth degraded province in South Africa.

As part of the review of land degradation, information about soil and land degradation in the North West Province was gathered at four workshops held during May 1997. Based on the inputs of the agricultural extension officers and nature conservationist, three consensus maps were produced. According to these maps, the magisterial districts around Mafikeng have been identified in Hoffman's National Audit as a hotspot with the highest status of land degradation. This includes the magisterial districts of Molopo, Mankwe-Madikwe and Zeerust (Figure 2. 1). Loss of plant cover and changes in species composition are a serious problem in the Zeerust District.

Zeerust is located at 25^0 E, 25^0 S. This is 90 kilometers north-east of Mafikeng. A number of study sites have been selected, and include Dinokana, Braklaagte, Supingstad, Serake and Doornlaagte (Figure 2. 2). The benchmark site is Madikwe Game Reserve (Figure 2. 2). A benchmark is a veld with the best possible botanical composition and cover (Tainton, 1981). The basis of veld condition assessment is to compare a site with a veld which is in excellent condition in terms of defined management objectives in the same ecological zone. Madikwe Game Reserve was selected due to practicable management systems in this site. The identification of Madikwe Game Reserve as a benchmark has been subjective. It was selected based on the

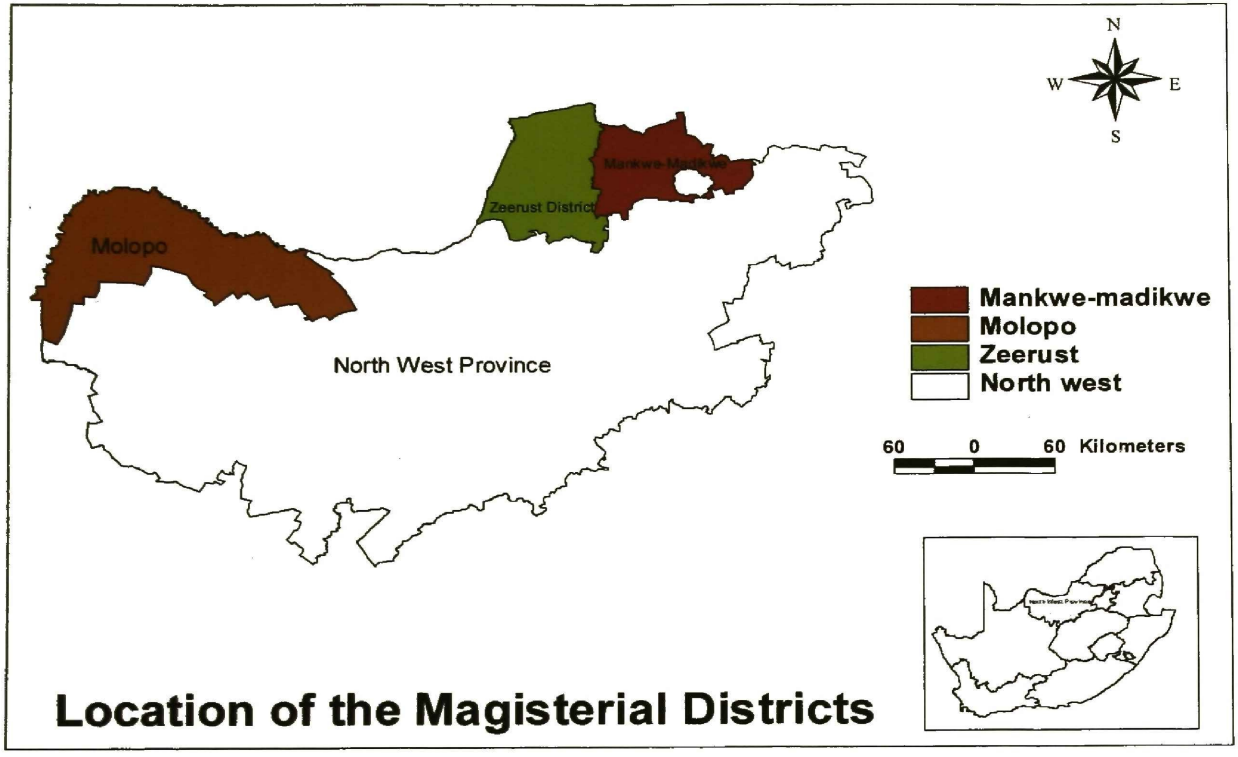


Figure 2.1: Location of the Magisterial Districts (Department of Geography, NWU)

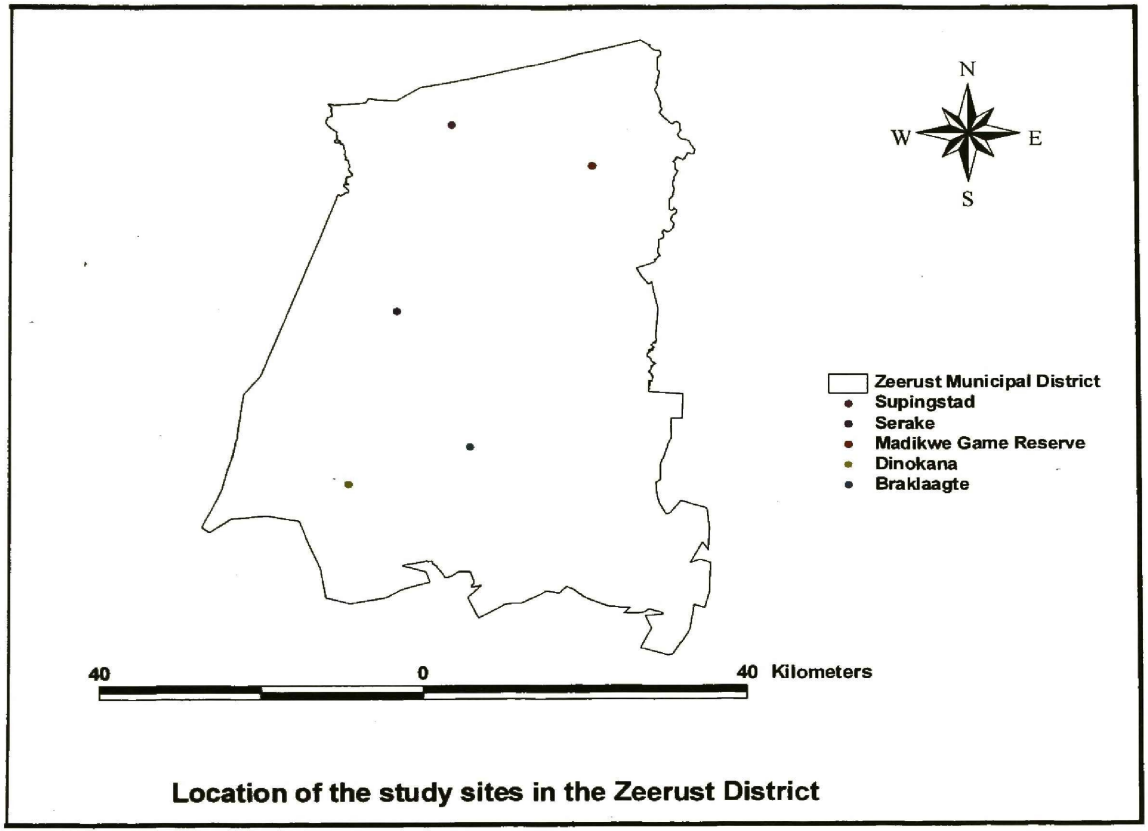


Figure 2.2: Location of study site(Department of Geography, NWU)

productive capacity and its ability to support long-term animal production while conserving the water and soil resources. Madikwe Game Reserve however, has been affected by seasonal rainfall changes and land-use practices (Chapter 3). It is therefore, not surprising that there has been retrogression in this site as well.

2. 2. GENERAL DESCRIPTION OF THE STUDY AREA

2. 2. 1. VEGETATION

According to Figure 2. 3 the study area includes the following vegetation types:

CLAY THORN BUSHVELD (VEGETATION TYPE 14)

Clay thorn bushveld is also called turf thornveld (Low & Rebelo, 1996). This vegetation type occurs on black and red turf clay soils (Low & Rebelo, 1996). Turf clay soil occurs in Serake (Chapter 4). Overgrazing and deterioration of the grass sward cause a serious increase in cover of the woody species (Low & Rebelo, 1996). Woody species such as *Acacia erubescens, A. karroo, A. mellifera, A. nilotica, A. tortilis, Dichrostachys cinerea, Grewia flava* and *Maytenus heterophylla* form impenetrable thickets.

MIXED BUSHVELD (VEGETATION TYPE 18)

The mixed bushveld represents a great variety of plant communities, with many transitions and variations (Low & Rebelo, 1996). The vegetation ranges from 'good veld' of *Digitaria eriantha, Panicum coloratum* and *Panicum maximum* which are good for grazing, to a less useful veld where *Eragrostis lehmanniana, E. rigidior, Enneapogon cenchroides* and *Tragus berteronianus* dominate. Woody species which are most important in mixed bushveld include *Acacia erubescens, A. mellifera, A. tortilis, Combretum* species, *Dombeya rotundifolia* and *Terminalia sericea.* The mixed bushveld is good for large livestock, goats and wild animals, and is also good for cultivated pastures. Mixed bushveld occurr particularly in Supingstad (Chapter 3).

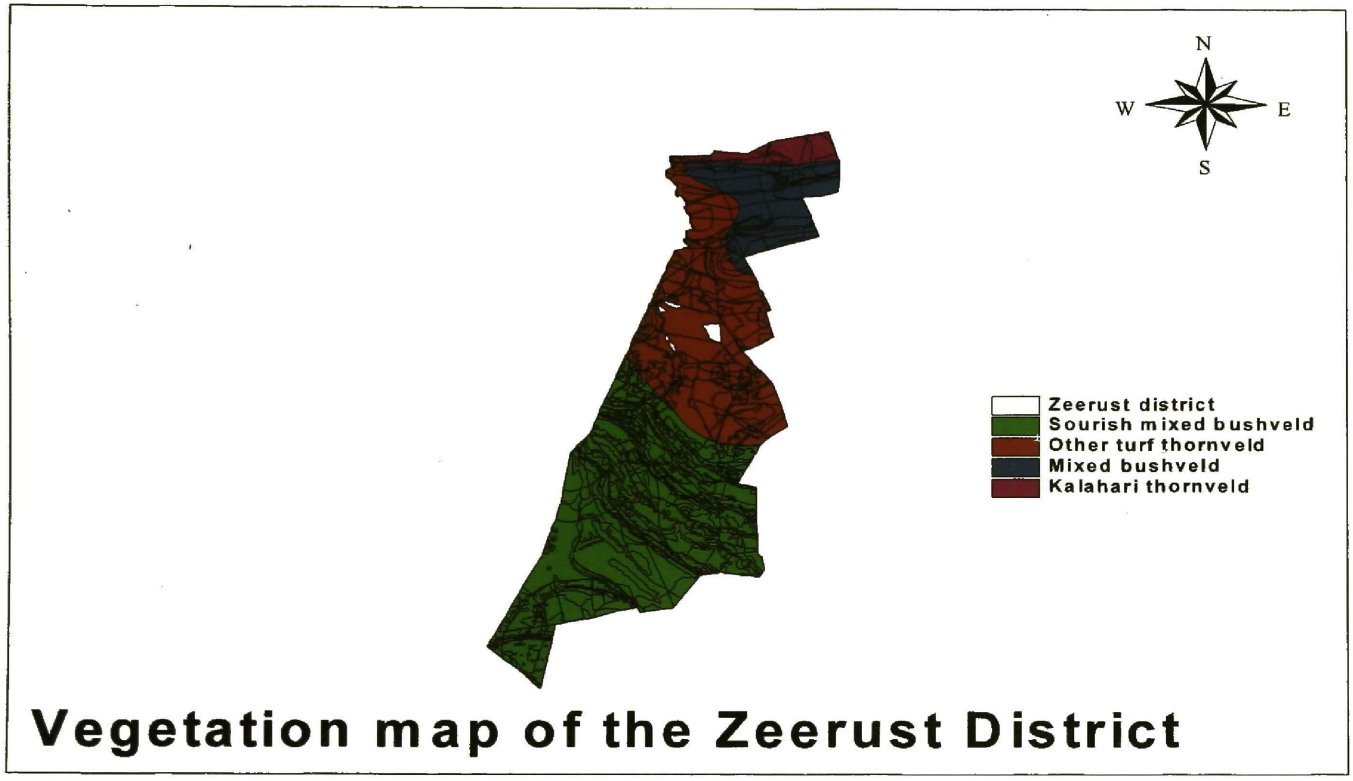


Figure 2.3 : Vegetation map of the Zeerust District (Department of Geography,NWU)

The sourish mixed bushveld is characterized by dense cover of grasses and is capable of withstanding moderate levels of overgrazing. Reduced production does occur in sourish-mixed bushveld. Retrogression under both selective and excessive grazing is associated with both a drop in cover and changes in species composition to a more pioneer dominated and less palatable veld type. The sourish mixed bushveld is an open savanna type associated with trees such as *Acacia caffra, A. karroo, A. nilotica, A. tortilis, Grewia* and *Rhus* species. The grassveld is largely dominated by grasses such as *Aristida diffusa, Bothriochloa insculpta, Chloris virgata, Digitaria eriantha, Eragrostis curvula, E. rigidior, E. superba, Panicum coloratum, P. maximum, Tragus berteronianus* and *Urochloa mozambiscensis.*

KALAHARI PLAINS THORN BUSHVELD (VEGETATION TYPE 30)

Kalahari Thornveld occurs on soils that are sandy to loamy in texture (Low & Rebelo, 1996). The grass cover depends on the amount of rainfall during the growing season. Grazing by livestock influences the structure of this vegetation type. The grasses include *Aristida congesta, Bothriochloa insculpta, Eragrostis lehmanniana, E. rigidior, Panicum maximum* and *Urochloa mozambiscensis.* According to Tainton (1981), the carrying capacity of Kalahari Thornveld is 10-35 ha/au/annum (hectares per animal unit per annum). This veld type is good for livestock and game farming (Low & Rebelo, 1996).

Acacia tortilis is the most dominant encroaching species. The dominance of this tree indicates overgrazing and excessive veld trampling (Van Oudtshoorn, 1999). *Acacia tortilis* is commonly found growing in association with other *Acacia* species such as *A. caffra, A. erioloba, A. erubescens, A. karroo, A. mellifera* and *A. nilotica.* The other woody species include *Boscia albitrunca, Boscia foetida, Celtis africana, Dichrostachys cinerea, Euclea crispa, Grewia flava, Maytenus heterophylla,* and *Ziziphus mucronata.*

2. 2. 2. CLIMATE

Climate is a major determinant of the geographical distribution of species and vegetation types (Tainton, 1981). The climate of a locality implies the average weather conditions observed over the past 30 years or so. Weather conditions refer to atmospheric elements observed over a short period of time. Within any area of general climatic uniformity, the local conditions of rainfall, temperature, light, humidity and wind play an important role in the production and survival of plants. Climate directly affects vegetation and, thus, the vulnerability or resilience of land to further degradation.

TEMPERATURE

Temperature is one of the key factors regulating growth, primarily through the direct influence on the rate of metabolic processes. Temperature influences physical processes such as transpiration (Tainton, 1981). The increase in the rate of evapotranspiration due to an increased pressure gradient between the leaf and atmosphere gives rise to a depletion of the soil water content. Temperature determines the duration of the growing season (Jordaan & Du Plessis, 1998). The average minimum and maximum temperatures in the Zeerust District are given in Figure 2. 4.

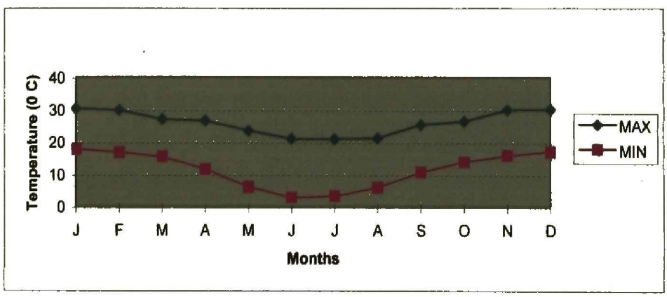


Figure 2. 4: Average minimum and maximum temperature (^{0}C) of Mafikeng-Zeerust (1989-1999) (University of North-West, Department of Geography).

According to Figure 2.4, temperatures in the Zeerust District are higher in Summer (November to January) and lowest during the winter months especially in June and July. The average minimum temperatures ranges from 10.5 ^{0}C to 17.6 ^{0}C during summer and 5.8 ^{0}C to 15.3 ^{0}C in Winter. Soil temperatures affects the rate of mineralisation of soil organic matter (Yayock *et al.*, 1988), the rate of evaporation from the soil and more directly the physiology of plants. The physiology of dry matter accumulation is restricted at high soil temperatures. Temperature significantly affects soil formation due to its influence on the rate of chemical reaction. As long as the moisture status is adequate, the rate of soil formation increases with temperature (Whiteman, 1980).

RAINFALL

In the Zeerust District, rain falls mostly during summer months, and during winter months there is little or no rainfall (Figure 2. 5). In the Zeerust District, much of the rain falls in heavy downpours during the mid-summer period that is November to February (Figure 2. 5). As a result, run-off is high and moisture penetration into the soil is correspondingly low. Excess water will affect leaching through and out of the soil profile (Whiteman, 1980). On open soil surfaces or where the vegetative cover is poor (e.g. Dinokana and Braklaagte) the impact of these heavy downpours played a role in the initial stages of soil erosion (Section 3.3, Chapter 3). In these sites, topsoil has been removed and this resulted in the formation of gullies (Section 3.3, Chapter 3). Added to this are the high evaporation and transpiration losses associated with temperature at this time, so that extreme moisture deficiency retards growth. The long-term average rainfall in the Zeerust District is 0.2 mm to 31.6 mm during winter, and 11.2 mm to 124.7 mm during summer months (Figure 2.5).

Rainfall in the Zeerust District is unpredictable and unreliable, often fluctuating around the mean of 600 mm annually (Cowley, 1985; Environmental Potential Atlas for North West Province, 2000). The Zeerust District is in the North West Province where the mean annual precipitation is between 480-560 mm. A rainfall that fluctuates between 250-750 mm, is typical for a grassland or savanna vegetation (Crowder & Chedda, 1982). A karoo is characterised by rainfall below

250 mm. Most of the grasses that can persist in this environment escape dry periods in the form of seeds.

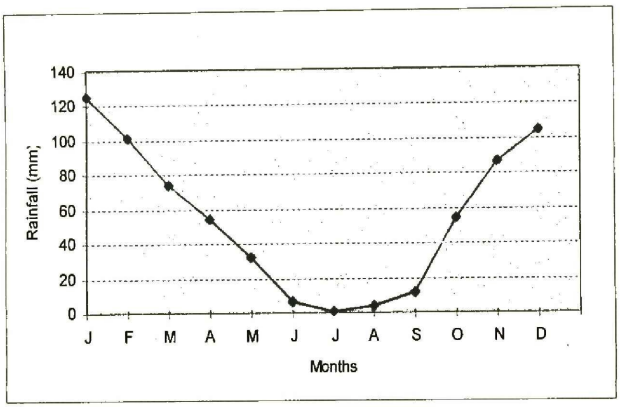


Figure 2. 5: Long-term average rainfall (mm) in Mafikeng/Zeerust (1989-1998) (Department of Geography, UNW).

Frequently the beginning of the rainy season and the onset of the dry season are changeable. It therefore, becomes difficult to predict accurately or to anticipate rainfall patterns from year to year (Tainton, 1981). The growing season of most grasses usually extends from September to April (Van Oudtshoorn, 1999). Rainfall has very significant effects. Moisture is required in the soil for many important chemical and biological processes.

2. 2. 3. SOILS AND GEOLOGY

Soil is a natural resource formed from a complex of interactions between climate, topography, parent material, time and organisms (Van der Merwe, 1973). The living plant is the most directly active soil-forming agent. Types of vegetation cover are related to soil development (Van der Merwe, 1973). The principle of classification of soils embody the characteristics of the soil, the process and regime under which they evolved and the factors which influenced their

development (Crowder & Chedda, 1982). Soil types in the study area are indicated in Figure 2. 6.

Soils in the Zeerust District are red-yellow-grey latosols (Cowley, 1985; Environmental Potential Atlas for North West Province, 2000). A most striking characteristic of these soils is the red colour due to a high degree of oxidation of iron compounds into ferric oxides. In addition, silicates are frequently split into their component parts and the silica is leached, leaving an excess of free aluminium and ferric oxide in the soil (Crowder & Chedda, 1982). This further intensifies the red colour. The latosols include ferrallitic soils and ferralites comprising most of the yellowish, reddish brown and red soils formed in well-drained sites. The soils contain little primary minerals other than those resistant to weathering such as quartz. Bases and other soluble materials have been washed out. Reserves of nutrient cations are less and total available phosphates usually low (Crowder & Chedda, 1982).

Red and yellow latosols are characterized by having a high clay fraction consisting of kaolinites with about 10-15 % of ferric oxide and small to moderate amounts of free aluminium oxide (Crowder & Chedda, 1982). According to Bothma (1989), red soil usually indicates good drainage. They vary in texture from sand to clay and the soil organic matter tends to increase with increasing clay content and rainfall. Those soils of intermediate texture often contain horizons of clay accumulation not far below the surface. The latosols are often deep or very deep soils. The deeper the soil, the higher the yield of plant material per unit area. These soils tend to have relatively low available water holding capacity. This can be a significant disadvantage on the sandier types. Latosols are generally characterized by good physical properties, but poor to very poor nutrient status. In the southern parts of the Zeerust District where latosols occur in rockier land, the soils have a lower crop production potential (Cowley, 1985). Due to high clay content in Latosols (Low & Rebelo, 1996) and the dry climate the red soils are unsuitable for cultivation, but have high grazing potential.

The major prevalent soil series includes quartzite, igneous, shale, granite, slate, Sheppardvale and Hornfels (Low & Rebelo, 1996). These rock types give rise to lowlands or valleys. Quartzite is

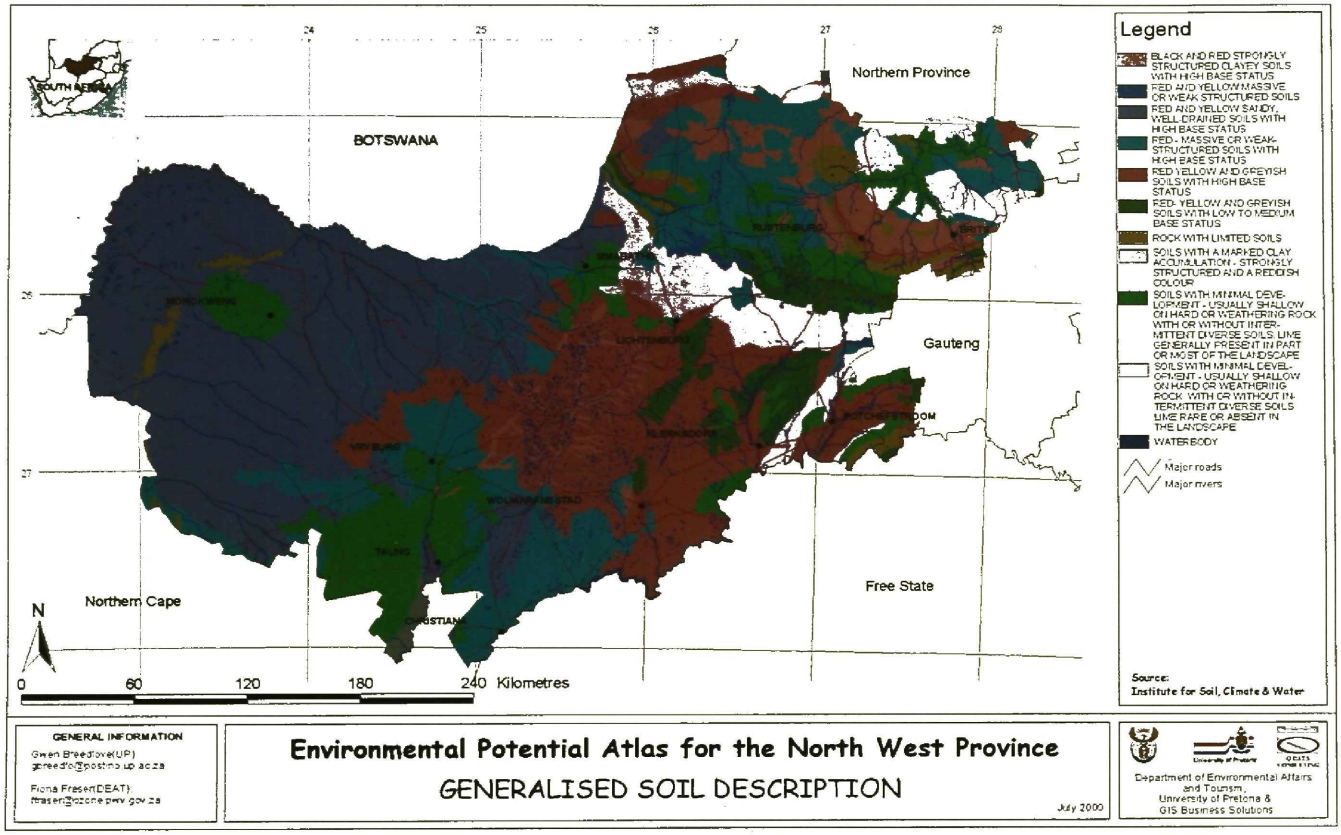


Figure 2.6: Soils of the North West Province

a metamorphic rock consisting chiefly of quartz grains (Cornelius & Hurlburt, 1976). Quartzite rocks possess a high resistance to physical and chemical weathering, therefore weathers slowly. Accordingly it forms hills and ridges. Weathering of this rock type usually gives rise to deep, sandy red soils with dominant medium sand. These soils are valuable for crop production but their fertility status is inherently low. Trace elements and phosphorus are common. Shale is a fine-grained classic sedimentary rock consisting of tightly packed sediments. It consists mainly of clay minerals. Shale and Slate are closely related rocks which are fairly soft and undergo rapid mechanical weathering before sedimentation to form sedimentary rocks. The rocks give rise to soil with clay content and dominant fine sand.

LAND TYPES

According to the Land Type Survey Staff (1984), a land type is defined as an area that can be shown on 1: 250 000 scale and that displays a marked degree of uniformity with respect terrain forms, soil pattern and climate. These are the features with which one land type differs from another.

The Zeeust District also consists of a variety of land types. In Doornlaagte, the soil has a characteristic black colour which has a clayey texture (see Chapter 4, section 4.3), indicating Ea land type. This site was previously used for farming, indicating the good fertility status, which has presently declined due to degradation. Such soils are according to Potgieter *et al.,* (1995) difficult to manage.

In some study sites in Serake, the soils are red-yellow in colour indicating Ah land types. These soils have a good drainage as compared to the soils in Ea land types where soils have a poor drainage system and also very poorly aerated (Soil Classification Working Group, 1977). However, the Ea land type soils have a high base status because the nutrient bases easily cling to the colloidal particles of the clay molecule. In Doornlaagte, for example, the soils have high concentration of nutrient cations than in Serake. Other land types include Fa, Bc, Ab, Ac, Ah, Ba, Bb, Bc, Ea, Fa, Fb etc. Fa land types usually accommodate pedologically young landscapes

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that are not predominantly rock or not predominantly alluvial or Aeolian and in which the dominant soil forming processes have been weathering, the formation of rothic topsoil horizon and clay illuviation. Bc land types are eutrophic, with red soils widespread.

These land types have characteristic red-yellow apedal soil. This soil is subject to wind erosion. This soil is suitable for cultivation of crops such as maize and groundnuts under special cultivation practices. This soil is ideal for crop production provided soil depth and clay percentage are not limitations.

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CHAPTER 3: GRASSLAND RETROGRESSION

3. 1. INTRODUCTION

Vegetation is dynamic in character and, whenever environmental conditions change, vegetation will change as well. Whenever change leads to veld improvement, it is called progressive succession (Bothma, 1989). Change in grass species composition leading to veld degradation is called retrogression. Retrogression of the grass component inevitably reduces the capacity of the grassland to support livestock.

When a grassland becomes retrogressed, certain species characterize different successional stages and they can be used as indicators of veld condition. Veld condition in this context is described as the capacity of the veld to produce livestock products over an extended period of time without the degradation of the vegetation and soil (Danckwerts, 2001). Knowledge of indicator species is, therefore, of utmost importance as it helps an ecologist to detect changes and manipulate them in the right direction. The increaser and decreaser species are good indicators of veld conditions. The decreaser species are plants that occur naturally in the veld which is excellently managed and decreases in importance (as measured by frequency or ground cover) when the veld is subjected to unsustainable land-use such as overgrazing (Bothma, 1989; Danckwerts, 2001). They are generally the most palatable plants such as *Themeda triandra, Panicum maximum, P. coloratum, Cenchrus ciliaris* (Danckwerts, 2001). They may also include species that are negatively affected by animals in other ways such as trampling (Bothma, 1989). Increasers are plant species that occur naturally in the veld and increase when the veld is either overgrazed or undergrazed (Bothma, 1989). They may be less palatable species, or may increase simply because there is less competition from decreasers for water and nutrients. Grasses such as *Eragrostis lehmanniana* and certain *Aristida* species are good indicators of a veld which has been disturbed (Van Oudtshoorn, 1999). If management measures are not taken timeously, then in no time, the grassland will be unsuitable for livestock grazing.

Grassland retrogression in tribal areas becomes worse, especially during prolonged droughts when there is little vegetation. Grazing animals break up the soil, making it more susceptible to

erosion. Soil erosion affects all soil types in South Africa. On average, soil loss in South Africa is 2.5 tonnes per hectare per year with a maximum of 60 tonnes per hectare per year (Barnard & Newby, 1999). This is more than eight times the rate of soil formation and is clearly unsustainable. Changes in grass species composition towards a thornveld savanna is accompanied by the increase of woody species, a phenomenon known as bush encroachment (Tainton, 1981; Moleele, 2001). The common woody encroachers are *Acacia* species - *A. caffra, A. erubescens, A. karroo, A. mellifera, A. tortilis* and *Dichrostachys cinerea* (Bothma, 1989). In certain areas such as in the Northern Cape, the encroachment of *Acacia mellifera* has caused a 50 % decrease in the grass cover (Bothma, 1989). While grasses cannot survive in dense woody communities because they are denied water, trees can survive in a dense grassland community. The fuel loads in areas where the grass layer has retrogressed also mean that a fire cannot be used to help control bush encroachment (Tainton, 1999).

Overgrazing causes the transformation of a grass-dominated vegetation into a woody-species dominated vegetation, a condition locally termed bush encroachment (Moleele, 2001). In this way, the vegetation consists of an upper story of trees and shrubs and a lower story of herbs, usually grasses, between which there is a competitive imbalance (Tainton, 1981; Brown, 1999; Hubbard *et al.*, 2000; Archer & Stokes, 2000). In the natural system, grass is a superior competitor for moisture because it is able to extract water from the upper layers of the soil before it reaches the deeper roots of the trees (Bothma, 1989). In an encroaching condition, overgrazing reduces the content of soil moisture and inhibits grass growth (Barnard & Newby, 1999). This reduced competition favours the encroaching species that are able to extract water from great depths (Bothma, 1989; Moleele, 2001). The development of a dense over-story of woody species reduces the diversity of the under-story of grass species because the over-story reduces light intensity reaching the under-story. This situation is worsened by absence of browsers in the study area. Retrogression of tall and mid-grasses occurs as grazing pressure increases until a threshold is reached (Anonymous, 2002 c). After a certain amount of grazing pressure and herbaceous retrogression, shrubs become the dominant vegetation.

Examples of modifications in grass species composition that were caused by grazing were observed in the increase in *Aristida junciformis,* and *Sporobolus pyramidalis* in Natal, and *Bothriochloa insculpta* and *Aristida congesta* in the arid areas of the country (Bothma, 1989). In the study area *Sporobolus pyramidalis* is rare, while grasses such as *Aristida congesta, A. junciformis, Bothriochloa insculpta, Eragrostis lehmanniana, Chloris virgata* and *Tragus berteronianus* are common indicators of retrogression. Livestock production, which is often the dominant component of total secondary production can serve as an indicator of major changes and can be estimated directly from actual livestock production. It can be established also from trends in the number of livestock that are maintained on the rangelands over extended periods of time.

The first phase of a grassland which is in the process of retrogression is called primary degradation. This phase is characterized by a rapid degradation of the original plant community. Degradation involves the reduction in productive capacity which occurs when the density of the valuable, productive and soil protecting species decline. Such species include *Themeda triandra, Fingerhuthia africana, Panicum* and *Pennisetum* species. These valuable species are then replaced by less palatable grazing tolerant pioneer species. This process is much slower than the elimination of original species. During this phase, the ground cover is poor so that active soil erosion takes place. This phase is called the primary depopulation phase and is followed by re-colonization. Grasses such as *Eragrostis lehmanniana* and *Aristida* species become important as colonizers of gaps which develop in the sward. These species have high rates of reproduction and therefore colonize degraded areas rapidly (Tainton, 1999).

Continuing poor management leads to desertification of grasslands. Desertification is not the spreading of the existing deserts, but the slow process of soil degradation and consequent lowering of soil production potential (Hoffman *et al.,* 1999). Various degradation processes are occurring in the climatic climax grasslands of southern Africa. Bosch (1988) describes the initial

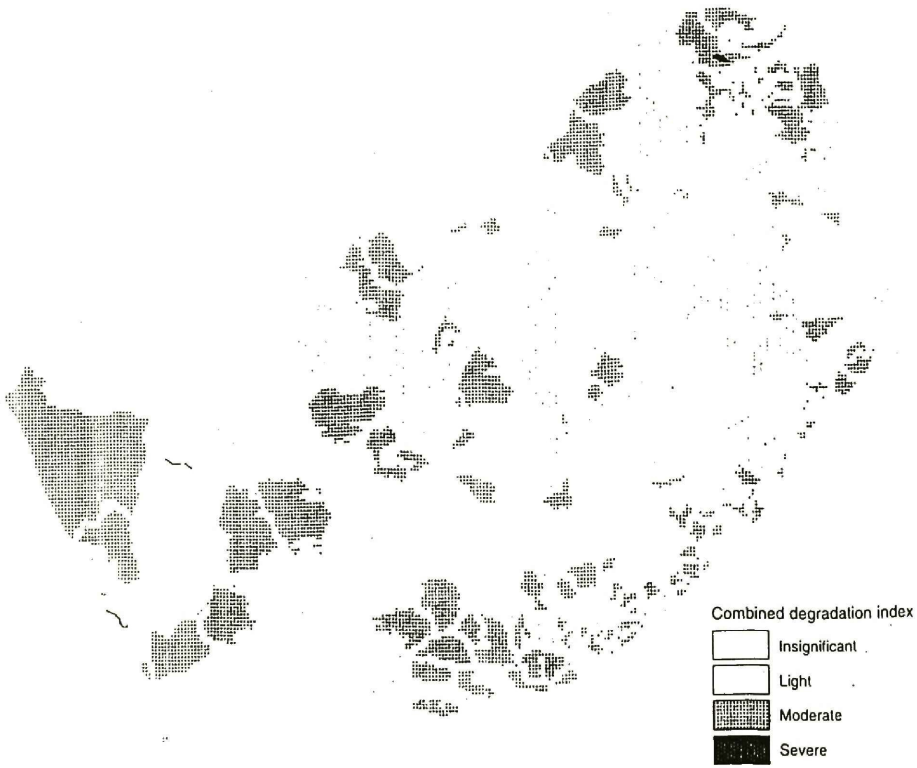


Figure 31: A combined (combination of soil and veld degradation) index of land degradation in each of the 367 magisterial districts of South Africa (Hoffman & Ashwell, 2001).

Figure 3. 1 is a combined degradation index (CDI) of the magisterial districts of South Africa (Hoffmann & Ashwell, 2001). The CDI is the combination of the soil degradation index (SDI) and veld degradation index (VDI) and it measures the severity and rate of soil and vegetation degradation in the provinces. According to this figure, North West is rated a severely degraded province. For the North West province, the VDI is 122 and the SDI is 149 and the CDI is 270 (Hoffmann & Ashwell, 2001). It was from these findings that the loss of plant cover and changes in grass species composition were identified as serious problems in the Zeerust District (Hoffmann & Ashwell, 2001). This survey on the evaluation of the state of grass species composition in the Zeerust District is an attempt to confirm Hoffmann's findings about land degradation in the Zeerust District.

3. 2. MATERIALS AND METHODS

MATERIALS

1. Wheel-point apparatus
2. Measuring tapes
3. Topographic maps of the selected sites
4. Data recording sheets
5. Vegetation markers
6. Global Positioning Systems (GPS)

METHODS

THE WHEEL-POINT METHOD OF SURVEY AND MEASUREMENT OF SEMI-OPEN GRASSLANDS AND KARROO VEGETATION IN SOUTH AFRICA (TIDMARSH & HAVENGA, 1955).

The wheel-point method was designed for the determination of grazing values and measurement of the vegetal changes of pastoral changes (Tidmarsh & Havenga, 1955). This method is used for surveys in vegetation types variously known in South Africa as mixed Karoo, false Karoo or

broken veld. Such veld types are composed of large numbers of tussock grasses, long growing creeping grasses and a large number of small desert herbs as well as annual grasses. The wheel-point method of survey has been adapted to some of the requirements of agronomy in which field there appears to be considerable scope for its use.

Some workers have reported that in Australian grasslands, 300-500 sample points per unit area (field or paddock) are sufficient for a reasonably accurate determination of the composition of pasture (Tidmarsh & Havenga, 1955). Botanical composition expressed in percentage cover is one of the best means of studying ecological changes and trends in development of a pasture. The wheel-point method is simple and requires minimal trained personnel.

PROCEDURE

The selected sites were located using topographic maps and a GPS apparatus. A 50 m X 50 m area was measured with a tape and clearly demarcated with markers. One of the spoked wheels of the wheel-point apparatus is marked off in order to locate equidistant sampling points on vegetation. The rest of the wheel is used to carry free points, and each revolution of the wheel would then furnish a point. All strikes (including strikes on bare patches) and species were recorded until the counter in the apparatus indicated that the number of samples were completed. The data obtained was used to calculate average basal cover, species frequency and percentage bare ground for each site. Soil samples were taken from study sites (Chapter 4, section 4. 2) for analysis of soil nutrient status.

3. 3. RESULTS AND DISCUSSION

Based on the species frequency data obtained from the analysis, an index of similarity (Si) was used to compare the similarity in species composition between Madikwe Game Reserve and each of the study sites (Table 3. 1). The higher the value of Si, the greater the similarity between the two samples (Venter *et al.*, 1989).

The formula for the similarity index is:

$$Si = \frac{2C}{A + B}$$

where A = number of species in sample A (Madikwe Game Reserve)

B = number of species in sample B (Braklaagte, Dinokana, Doornlaagte, Serake or Supingstad).

C = number of species common to both samples.

TABLE 3. 1: Comparison of species composition between Madikwe Game Reserve and study sites using the similarity index (Si)

Sites	A	B	C	Similarity index (Si)
Braklaagte	24	16	12	0.67
Dinokana	24	13	12	0.61
Doornlaaagte	24	18	16	0.8
Serake	24	21	15	0.67
Supingstad	24	20	13	0.59

N.B.: A = 24 for all sites because it is the number of grass species in the study sites of the Madikwe Game Reserve.

However, the similarity in species composition does not necessarily mean that the 'condition' of the veld in the survey sites is the same. Hence a benchmark site, Madikwe Game Reserve, is used to correlate the condition of the sites. This is done by comparing the percentage frequency of the grass species and indicators such as bare ground at each site with the results in benchmark sites.

MADIKWE GAME RESERVE

TABLE 3. 2: LOCATION OF BENCHMARK SITES:

A total of six sample sites were monitored.

SITE NO.	LOCATION
1	24° 48' 23.7" S, 26° 17' 19.8" E
2	24° 50' 16.0" S, 26° 16' 16.7" E
3	24° 49' 30.4" S, 26° 16' 41.8" E
4	24° 48' 24.0" S, 26° 17' 20.0" E
5	24° 50' 17.5" S, 26° 16' 07.0" E
6	24° 50' 35.5" S, 26° 16' 42.0" E

DESCRIPTION OF GRASSLANDS IN MADIKWE GAME RESERVE

The local grassland is composed mostly of perennial grasses (Figure 3. 2). Perennial grasses are plants in which the vegetative structures (also called perennating organs) (rhizomes, stolons etc.) live year after year (Raven *et al.*, 1971). These grasses thus, do not complete their life cycle within one year as is the case with annual species. Perennial grasses produce flowers and seeds, and then die. Their underground parts, however, live through the winter or dry season and send up new shoots the following year (Sullivan, 1986; Roberts, 1981). These grasses fill up these special storage organs (rhizomes, stolons etc.) with food such as starch during summer. Each spring, a terminal bud uses some food to send up new flowers and leaves.

Food stored in the lateral buds causes the rhizome to branch, and in this way the plant is propagated from one year to another. The success of perennial grasses is also determined by the position of the dormant perennating bud relative to the ground level (Loveless, 1983). These buds lie beneath the soil where they are protected from extremes of atmospheric temperature and to the full force of drying winds. The most important perennial grasses growing locally include *Bothriochloa insculpta* (21 %), *B. radicans* (11.8 %), *Digitaria eriantha* (43.6 %), *Eragrostis*

rigidior (13.9 %) and *Heterepogon contortus* (19.8 %) (Figure 3. 2). The total percentage frequency by perennial grasses growing locally is 91.7 %.

Botanical composition, expressed in frequency, is the best means of studying ecological changes in the development of a pasture (Tidmarsh & Havenga, 1955). Frequency is the probability of finding a species in the sample area or quadrat. It indicates the number of plants to the nearest point of the Wheelpoint apparatus. The rooted cover at ground level is least subject to drastic variations according to season, or to the incidence of grazing or other agents of defoliation.

Changes in the values of the basal cover have more ecological significance than changes in the canopy. In general, perennial grasses produce more foliage than annual grasses (Jordaan, 1994). According to Heady (1975), perennial grasses maintain cover all year round. Perennial grasses have extensive root systems, and therefore protect the soil from erosion more effectively than annual species (Muir, 1998). *Eragrostis rigidior,* common locally with a frequency of 13.9 % (Figure 3. 2) is good for soil stabilization, but this is only possible if this grass is not overgrazed (Van Oudtshoorn, 1999). The dominance of perennial grasses locally indicates that the veld has a good resistance against soil erosion. *Bothriochloa insculpta* which is common locally with a frequency of 21 % (Figure 3. 2) is good for protecting and stabilizing erodible soil (Van Oudtshoorn, 1999).

Annual grasses are short-lived because they complete their life-cycles within a year (Roberts, 1981). Unlike perennial grasses, the emphasis falls on vigorous seed production rather than production of foliage (Jordaan, 1998). In annual grasses, the bud for starting the next season's growth is inside the seed in the form of the shoot meristem of the embryo plant (Loveless, 1983). These grasses survive the adverse season in the highly resistant form of dormant seeds. Little energy is made available by these grasses for leaf production with a consequently low leaf mass yield (Jordaan, 1994) and also a low grazing value. *Melinis repens* (3.4 %), for example, is relatively palatable but has low leaf production (Van Oudtshoorn, 1999).

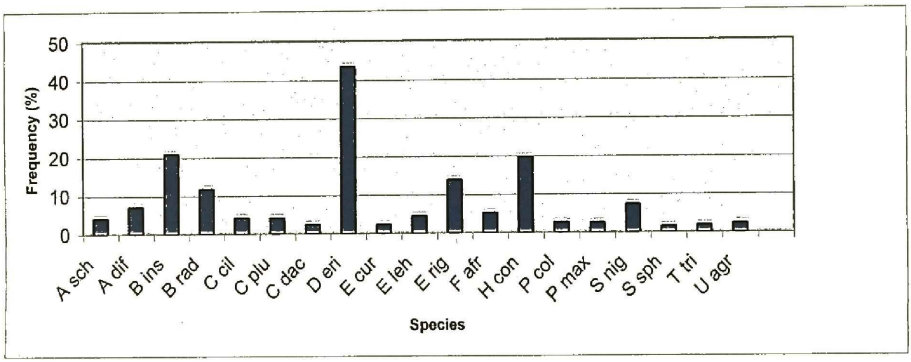


Figure 3. 2: Frequency of perennial grasses* in Madikwe Game Reserve.

Figure 3. 3 indicates that annual grasses form 7.6 % of the frequency in Madikwe Game Reserv

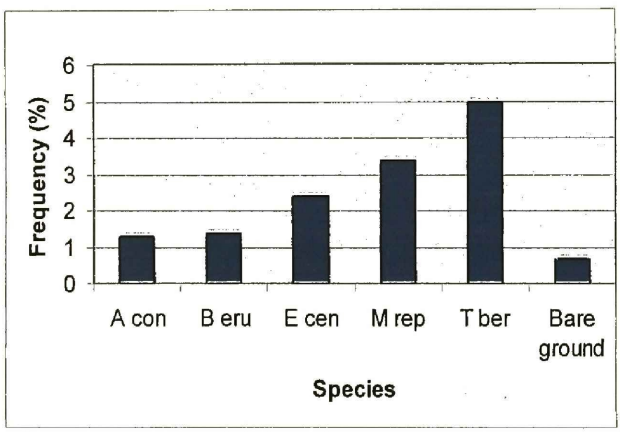


Figure 3. 3: Frequency of annual grasses* in Madikwe Game Reserve.

*Full species names can be found in Appendix B.

Due to their rapid growth, annual grasses can spring up in the bare patches during limited period when water is available. These seeds can survive in the soil during long periods of drought which sometimes extend over many years. Then, when sufficient water is available, they can germinate rapidly (Raven *et al.*, 1971). They too, are good for soil stabilization. *Enneapogon cenchroides* (2.4 %) is a useful grass which quickly colonizes and protects the disturbed veld (Van Oudtshoorn, 1999).

Veld in 'good condition' refers to the capacity of a grazing land to support grazing animals without the deterioration of vegetation. The local grassland is in poor condition in terms of production of forage because most prominent grasses are less palatable or unpalatable. Palatability in this context refers to the total acceptability of the grass plant for grazing and is influenced by factors such as nutritional value, fibre content, unpalatable chemical substances and percentage moisture (Jordaan, 1998). Palatable species occur naturally in the veld that is well managed and decrease in importance when the veld in question is subjected to unsustainable land-use such as overgrazing (Bothma, 1989; Danckwerts, 2001). *Digitaria eriantha* is prominent at a frequency of 43.5 % (Figure 3. 2). This grass can endure heavy grazing. *Digitaria eriantha* is regarded as the best natural and cultivated pasture. Its dominance in the veld is an indication of a veld in 'good condition' (Van Oudtshoorn, 1999). Although the implication for the high frequency *Digitaria eriantha* may mean that this grassland has a good capacity for providing livestock grazing, the other palatable grasses such as *Panicum maximum* (2.7 %) and *P. coloratum* (2.8 %) are not abundant, which means continuous veld management practices are still essential to improve veld condition.

Digitaria eriantha is mostly abundant in sites located in site 1 (24^0 48' 23.7" S, 26^0 17' 19.8" E), site 3 (24^0 49' 30.4" S, 26^0 16' 41.8" E); and site 4 (24^0 48' 24.0" S, 26^0 17' 20.0" E). *Digitaria eriantha* is often sown into the veld where veld condition is poor. *Digitaria eriantha* is preferred by impala (Van Oudtshoorn, 1999). Other palatable grasses growing locally include *Panicum coloratum* (2.8 %), *P. maximum* (2.7 %), *Setaria nigrirostris* (7.5 %), *S. sphacelata* (1.7 %), *Themeda triandra* (2 %) and *Melinis repens* (3.4 %) and occur at low frequencies (Figure 3. 2 and Figure 3. 3). *Panicum maximum* delivers a high leaf production and has a good seed

production. This grass is therefore a popular cultivated pasture and is especially used to make hay (Van Oudtshoorn, 1999). *Themeda triandra* is palatable and it increases when veld is burned regularly and if overgrazing is absent. *Setaria nigrirostris* has a reasonably good leaf production, well-utilized, but less acceptable for grazing when mature (Van Oudtshoorn, 1999). *Cenchrus ciliaris* is a good grazing grass with a high leaf production and palatability (Van Oudtshoorn, 1999). It is a most popularly cultivated pasture in more arid areas. *Setaria sphacelata* is a good pasture grass with a high palatability and leaf production (Van Oudtshoorn, 1999). This grass is not drought resistant and is unable to withstand continuous grazing.

Palatable grasses lose their vigour as a result of repeated removal of leaves (the plant's energy factory) and the constant drain on its nutrient reserves (Hurt, 2000). When the plant is unable to replenish these reserves by producing new leaves during rest periods to carry out photosynthesis, it will eventually die. The place initially occupied by palatable grasses will be taken by other grasses which are either better adapted to heavy grazing or which are relatively less palatable. As the desirable plants become weaker and die off, the number of roots present in the upper layer of the soil decreases, and this reduces the competitive ability of grasses (Hurt, 2000). Bare areas between grasses also become larger as the grasses become fewer or die. This causes a decline in the effective use of rainfall in the area. These conditions are ideal for woody plants to establish.

Heteropogon contortus which is common with a frequency of 19.8 % (Figure 3. 2) is only palatable early in summer, after which it becomes hard and less acceptable for grazing (Van Oudtshoorn, 1999). *Heteropogon contortus* grows in open grasslands in well-drained soils. Less palatable grasses increase simply because there is less competition from the palatable species for water and nutrients (Danckwerts, 2001). Unpalatable grasses locally include *Aristida congesta* (1.3 %), *A. diffusa* (7.2 %)and *Bothriochloa insculpta* (Figure 3. 2 and Figure 3. 3). *Cymbopogon plurinodis* (4.2 %) has essential oils which give it a bitter taste, and is therefore not a good grazing grass (Van Oudtshoorn, 1999). *Bothriochloa radicans* is aromatic, hard and fibrous (Van Oudtshoorn, 1999) and is therefore, unpalatable.

Environmental conditions do play a role in changes in grass species composition. Many grasses are adapted to a wide range of temperatures, but grow more luxuriantly within the optimal range. *Panicum maximum* thrives well in the hot lowland, but when grown at higher altitudes, herbage yields are reduced (Crowder & Chedda, 1982). Frost-free conditions favour the establishment of *Bothriochloa insculpta, Heteropogon contortus, Panicum maximum* and *Themeda triandra* (Tainton, 1981). *Panicum coloratum* and *Setaria* species are relatively frost tolerant.

In the Zeerust District, summer days are warm with cooler nights. Winter days are cool with cold and sometimes frosty early mornings (Cowley, 1985). The rhizomatous and stoloniferous perennial *Cynodon dactylon* (2.5 %) which occurs at a low frequency in the benchmark sites (Figure 3. 2), grows well in warm temperatures. This grass shows little cool season growth and is damaged by frost (Whiteman, 1980). Frost usually occurs when the temperature falls below freezing point (Jordaan & Du Plessis, 1998).

Theoretically, provided that environmental conditions do not change drastically, a community of palatable species will be relatively stable, capable of reproducing and maintaining a constant composition, structure and biomass (Tivy, 1982). As indicated by the low frequencies of the palatable grasses, it is clear that the state of equilibrium of the veld has been disturbed. Alterations in the climate or soil make-up or land-use have initiated a process of retrogressive change in species composition. If this occurs at flowering and seeding time, these species produce fewer seeds, and therefore decrease recruitment of new individuals into the population (Bothma, 1989). This indicates a loss of veld palatability in the local grassveld, and is a sign of veld retrogression. As duration of grazing increases, these species are trampled, consumed and they decline.

The soil condition also had an effect in veld retrogression in the benchmark sites. The base saturation exceeds 100 % (Figure 4. 6, Chapter 4). Although a high base saturation contributes to veld palatability, a high base saturation of over 100 % causes the formation of brack in the soil, and can be detrimental to plant growth (Jordaan, 1994). There is excess accumulation of calcium and a deficiency of phosphorus (Figure 4. 1, Chapter 4), both of which indicate chemical

degradation of the soil. Limited veld palatability explains why palatable grasses such as *Cenchrus ciliaris, Panicum coloratum, P. maximum, Setaria sphacelata* and *Themeda triandra* occur in low frequencies (Figure 3. 2).

The rich herbaceous layer of perennial grasses in Madikwe Game Reserve can be explained in terms of good pasture management systems. Fire application is one of the practicable management strategies used. The objectives of veld burning include removal of unpalatable growth left over from previous seasons, which would not be acceptable to grazing animals. If this grass is not removed, it tends to smother the plant so that it becomes moribund (Tainton, 1981). Burning effects growth stimulation during seasons when there is little young forage available on the veld and thus provides green feed for game when it does not occur naturally.

Bush encroachment in Madikwe Game Reserve is being kept under check by management practices such as the introduction of browsers. Large browsers such as elephants and giraffes (Figure 3. 4) keep trees from encroaching by pushing them over and browse their crowns.



Figure 3. 4: The use of browsers in Madikwe Game Reserve reduces bush thickening and improves the growth of grasses.

Smaller animals like antelope browse lower growing shrubs and young trees and keep them at a height at which they are likely to be killed by fire (Hoffman & Ashwell, 2001).

BRAKLAAGTE

TABLE 3. 3: LOCATION OF SURVEY POINTS:

A total of 12 sample sites were monitored.

SITE NO.	LOCATION
1	25° 21' 16.5" S, 26° 06' 00.5" E
2	25° 21' 22.2" S, 26° 06' 00.9" E
3	25° 21' 35.0" S, 26° 06' 21.0" E
4	25° 21' 23.16" S, 26° 06' 11.2"E
5	25° 21' 24.1" S, 26° 07' 5.00" E
6	25° 20' 02.6" S, 26° 04' 10.5" E
7	25° 22' 17.2" S, 26° 07' 09.5" E
8	25° 23' 24.2" S, 26° 06' 10.9" E
9	25° 21' 42.0" S, 26° 06' 33.5" E
10	25° 21' 45.5" S, 26° 06' 20.1"E
11	25° 18' 42.1" S, 26° 07' 45.0" E
12	25° 20' 12.7" S, 26° 04' 40.5" E

DESCRIPTION OF GRASSLANDS IN BRAKLAAGTE

The local grassland is in the initial stage of veld retrogression which is usually characterized by poor soil cover and the decline of soil-protecting perennial grasses (Tainton, 1981). Perennial grasses form 49 % of the sward (Figure 3. 5) and annual grasses constitute 18 % of the sward (Figure 3. 6).

Prominent grasses growing locally include *Aristida congesta* (10.2 %) (Figure 3. 6), *Bothriochloa insculpta* (17.4 %) and *Urochloa mozambiscensis* (13 %) (Figure 3. 5). The occurrence of *Aristida congesta* indicates poor veld management, but is excellent for covering bare patches (Van Oudtshoorn, 1999).

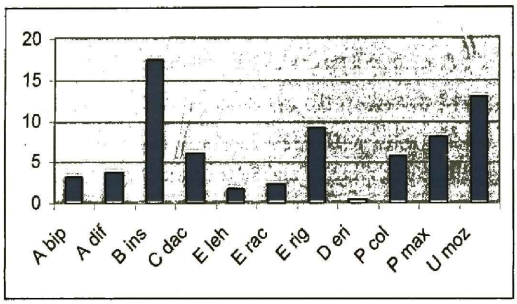


Figure 3. 5: Frequency (%) of perennial grasses in Braklaagte.

In some of the local sites, annual grasses dominate. These sites occur at 25^0 21' 16.5" S, 26^0 06' 00.5" E; 25^0 21' 23.16" S, 26^0 06'; 11.2" E; 25^0 20' 02.6" S, 26^0 04' 10.5" E; 25^0 22' 17.2" S, 26^0 07' 09.5" E; 25^0 21' 45.5.16" S, 26^0 06' 20.1" E and 25^0 20' 12.7" S, 26^0 04' 40.5" E. The dominance of annual grasses in grasslands indicates veld retrogression.

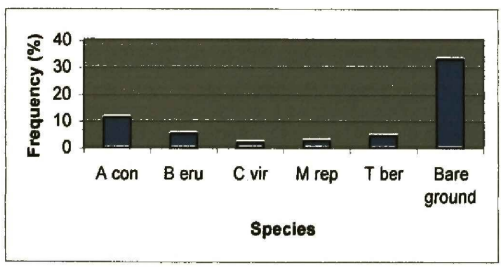


Figure 3. 6.: The occurrence of annual grasses in Braklaagte.

Annual grasses compared to perennial grasses are not efficient for building maximum resistance against soil erosion because they are short-lived, and as they die, a large portion of the ground surface becomes bare. Compared to Madikwe Game Reserve, the grassland in Braklaagte has less resistance against soil erosion. Annual grasses in the local grassland include *Aristida congesta* (10.2 %), *Brachiaria eruciformis* (5.4 %), *Chloris virgata* (2 %), *Melinis repens* (2.6 %) and *Tragus berteronianus* (4.6 %) (Figure 3. 6). According to Table 3. 1, the similarity index (Si) for Madikwe Game Reserve-Braklaagte is 0.67. Seven (7) of the eleven (11) perennial grasses that occur in Braklaagte also occur in Madikwe, and four (4) of the five (5) annual grasses also co-occur, meaning that the species composition is almost the same in these two sites.

In order to ensure maximum protection of the soil, a well developed root system is essential. Perennial plants have extensive root systems that are good for soil-binding (Muir, 1998). The most important factor leading to the death of the plant that is being grazed, resulting in veld retrogression and subsequent soil erosion is the repeated and severe defoliation under continuous high grazing pressure without sufficient rest periods. Translocation of mineral nutrients from the shoot to the roots in perennial grasses takes place after the flowering cycle has been completed. This usually occurs in late summer or autumn. These stored nutrients are utilized again when growth resumes in spring. A large number of roots of perennial grasses die off and are replaced by new roots by utilization of the stored mineral nutrients. Repeated severe defoliation has a negative influence on root growth as well as the size of the root system. The resistance of the plant to grazing and drought is thus, reduced (Bothma, 1989).

Overgrazing is not the only factor that causes veld retrogression. The combined influence of soil form, soil depth, moisture regime, altitude, aspect and topography determines changes in grass species composition. For example, Malan (1998), found that in the southern Free State, soil moisture, habitat disturbance, soil type and altitude determine the distribution of grassland communities. In the Karoo, however, it seems that activities of man play a more important role in the determination of vegetation changes (Roux & Opperman, 1982).

Retrogression in local grasslands has been influenced by chemical degradation of the soil. Soils in Braklaagte are characterized by low base saturation and high acid saturation (Figure 4. 13, Chapter 4). Nutrients such as phosphorus, calcium and nitrogen have leached into the soil profile, making the soil to be acidic. These nutrients (Figure 4. 11) are therefore, not readily available for plant growth. Both low base saturation and excessive acidity reduces veld palatability (Jordaan, 1994).

Although the local soil has a clayey texture, it has a poor water-holding capacity as indicated by high resistance (Figure 4. 9, Chapter 4). This indicates that there is less water available for the plant due to less usage of rainfall. Water use efficiency expressed in kilogram phyto-mass for each millimetre of evaporation is a convenient and suitable tool to evaluate the productivity of a grassland ecosystem (Snyman, 1999).

Snyman (2000) conducted a survey to investigate the ability of a veld to efficiently utilize soil-water in the semi-arid Central Grasslands of the Free State, and to determine the influence of veld retrogression on water-use efficiency and productivity. This study identified the seasonal soil-water withdrawal pattern under different compositional states, as well as the extent of water loss from bare soil. The results from Snyman's (2000) study have shown that grassland in 'good' condition was dominated by *Themeda triandra* (56 %). In the grassland that was in 'moderate' condition, *Eragrostis chloromelas* (38 %) was dominant. *Tragus koelerioides* (40 %) dominated in the grassland that was in 'poor' condition. Grassland in 'good' condition consisted of 66 % decreaser species. The grassland in 'moderate' condition consisted of 61 % increaser II (a) species, while there were 63 % increaser II (c) species in a grassland in 'poor' condition (Snyman, 2000). Grasslands in 'good' condition evapotranspirated on average more water than grassland with a 'poor' vegetation composition over the four growing seasons. In this research also, where decreaser species dominate in the veld, then such a veld may be regarded to be in 'good' condition.

Drought is one of the factors that accelerate veld retrogression. According to Cowley (1985), the Zeerust District was hit by a drought around the early 1980's. According to the residents in

Braklaagte, the drought was prolonged and the dry spell lasted long enough to cause damage. Although Madikwe Game Reserve might have been hit by the same drought, veld management practices in this site counteracted the effects of drought. Drought is a period during which the soil-water content remains below a certain user-defined value. Shortage of rainfall has led to lack of water in the soil, dams and reservoirs. Animals congregated around the drinking points, causing rapid degradation. As shown by their stock records, many farmers in Braklaagte had allowed their cattle to build up during years of normal rainfall, too many to be supported during years of drought. Naturally, when the inevitable drought arrives, farmers are reluctant to cut back their herds. When it became evident that the drought will be prolonged, many grazing areas, including this site, were already overgrazed. Drought is the most important factor limiting livestock production. According to subsistence farmers, there was a great loss of animals during this period (Chapter 5). Drought intensifies and worsens soil erosion and land degradation (Binns, 1995).

Resumption of plant growth after a drought depends on the developmental stage of vegetation as well as on the severity of the drought. The rate of regrowth of plant organs after a stress period depends on the amount of stored plant reserves which are translocated to the organs. Perennial grasses and shrubs exhibit contrasting regrowth responses. Shrubs are adapted for survival and good rains often lead to rapid regrowth in shrubs after long summer drought. Grasses are less resistant to drought. Good spring and summer rains, on the other hand, are used less efficiently by shrubs, giving the grasses a competitive advantage. From this it follows that the timing of a drought can have a significant impact on the dynamics of grazing land composition.

Drought avoidance involves a wide range of mechanisms designed to reduce water deficit during drought periods or avoid drought periods altogether. A good example of the latter is provided by annual grasses which grow and set seed over the wet season, and then pass through the dry season as seed (Whiteman, 1980). Other mechanisms include leaf shedding and restriction of transpiration and deep rooting.

The cyclic nature of the annual precipitation and the unreliable distribution of the seasonal rainfall of South Africa result in long extensive drought and shorter seasonal drought. In South Africa, grasslands and forestry together utilize approximately 62 % of the rainfall (Bennie *et al.*, 1997). As rainfall is the limiting environmental factor that determines grassland production in semi-arid areas (Snyman, 1998), sustainable utilization of the grassland ecosystem must emphasize the capturing and efficient use of water. Although the farmers cannot control rainfall, they can directly or indirectly influence its effectiveness through sound pasture management practices (Snyman, 1999).

A sufficient understory of grasses is lacking in the grazing lands in Braklaagte. Lack of sufficient fuel provided by grasses reduces the use of fire as a management tool (Bothma, 1989). The grasslands in Braklaagte are characterised by large bare grounds of more than 30 % (Figure 3. 6) compared to a bare ground of 0.7 % in Madikwe Game Reserve. This means that the soil surface is exposed to negative environmental condition such as extreme hot conditions and soil erosion due to less vegetation. Burning in the grasslands in Braklaagte will therefore not be feasible as a management option. Instead, a restoration programme such as re-seeding should be started in the denuded sites. The establishment of a perennial community is essential for preventing the establishment of exotic annual weedy species. It is critical that seeding be completed within the window of opportunity, because the annuals will continue to dominate the site causing further retrogression. It is imperative that desirable species be established so that weeds such as cheat grass do not invade and cause further site degradation. When restoring retrogressed areas such as these, non-intrusive, non-native plant species are appropriate for use when native plant species are either not available or cannot compete with already established non-native species. While native species are preferred and should be used where feasible, the major concern must be the ecological functioning of the perennial plant community.

One of the factors that contributed to retrogression of the grassland in Braklaagte is overgrazing. The presence of *Aristida bipartita* (3. 2 %) (Figure 3. 5) indicates heavy overgrazing (Van Oudtshoorn, 1999). Also, where *Aristida congesta* (Figure 3. 6) occur in natural veld, it is usually a sign of overgrazing (Van Oudtshoorn, 1999). Despite the denuded condition of the

grassland, cattle were still allowed to graze there during the survey. Through the phase of retrogression, called primary depopulation, species such as *Aristida congesta* invades the area. Grasses such as *Eragrostis rigidior* (9. 2 %) and *E. lehmanniana* (1.8 %)(Figure 3. 5) also become important as colonizers of gaps which develop in the sward.

Legislature played an important role in the decline of grass species in Braklaagte. In the decades after the election of the apartheid government in 1948, the massive population removals of Africans from 'White' to 'Black' rural areas that were already overcrowded and under stress led to the new and increasingly unpopular conservation measures. This was under the influence of the Land Acts that were passed by the government which include the 1913, 1936 and 1945 Land Acts (Letsoalo, 2001; Binns, 1995; Oosthuizen, 2001). The history of Braklaagte, as revealed from the household surveys, indicates that people were forcefully pushed into agriculturally marginal areas. This resulted in land-use which was frequently inappropriate. Overstocking, for example, became a common necessity in response to meeting the food demands of the growing population.

In Braklaagte, the farmers allow their livestock to rise in several ways. Herd sizes are allowed to grow during wet years to be sustained by the limited pasture growth in dry years. Large stock numbers are kept as insurance against years of drought and famine. This is based on the assumption that the more cattle a man has, the more they are likely to survive a bad year (Webster & Wilson, 1980). There is no absolute security against complete disaster, but relative security lies in the maintenance of large numbers so that even after a heavy loss, enough might remain for subsistence and the re-building of the herds. The Department of Agriculture, Conservation and Environment through extension officers has for many years recommended appropriate stocking rates for sustainable livestock production (Hoffman & Ashwell, 2000). Little or no attempt is made to reduce their livestock to numbers which might reasonably be expected to survive on the available fodder and water resources.

To keep fewer cattle would mean less income and decreased economic stability. The farmers keep cattle for a wide variety of purposes such as for meat, milk, draught power for ploughing,

ritual slaughter, bridal and education payments and investments in cash sales. In Braklaagte, this is clearly indicated by their slogan 'cattle is an African Bank'. Webster and Wilson (1980) refers to cattle as a 'bank account on the hoof'.

Land degradation in Braklaagte is characterized by increased rates of run-off and inefficiency of use of rainfall. The rate of water run-off is due to a low vegetal cover. Some of the trees have their roots exposed due to the action of water (Figure 3. 7).



Figure 3. 7: Roots of trees in one of the survey points in Braklaagte are exposed due to soil erosion.

The most important single factor affecting water run-off is the amount and type of vegetative cover (El-Hinnawi & Hashmi, 1982). While land remains under the undisturbed conditions of the grass cover, its surface is protected from the impact of rainfall (Webster & Wilson, 1980). The structure of the topsoil combined with the presence of leaf-litter allows a high proportion of rainfall to infiltrate so that there is little run-off (Goudie, 1990; Webster & Wilson, 1980). Intense soil erosion has taken place in the grazing lands in Braklaagte, resulting in the formation

of gullies, whilst compared to Madikwe Game Reserve, there is no gully erosion in the benchmark sites.

The protection which grass plants affords the soil is normally much greater than that given by most non-grass plants (Tainton, 1999). The density of grassland is dependent primarily on the efficiency of perennial plants to continue producing new tillers to replace those which die naturally after flowering or prematurely for any reason (Tainton, 1981). For a given crown cover, grasses have a much greater basal cover and they provide a complex network of roots immediately below the ground surface. Stands of perennials are much more effective than stands of annual grasses because they provide a much more stable cover (Tainton, 1999).

Poor management of pastures in Braklaagte also includes the elimination of fire in the tribal grazing areas. Elimination of fires leads to the declining of the herbaceous layer (Henrichs, 2001; Mielke, 1989; Krebs, 1978; Hubbard *et al.,* 2000). According to Henrichs (2001), grazing reduces perennial species regardless of fire frequency. The cover of perennial grasses increases and that of annual grasses decreases with the burned/ungrazed treatment. Fire increases matrix species while grazing decreases matrix grasses and increases cover of ruderal forbs and woody species. The matrix species are also indicators of veld which is in good condition. If these species occur in lower frequency in the study sites, this would mean the veld is not at its maximum capacity to support livestock. The use of fire in Madikwe Game Reserve as a management tool has contributed to the rich herbaceous layer of grasses.

The grasslands in Braklaagte are not in 'good' condition in terms of supporting livestock feeding. Prominent grasses such as *Bothriochloa insculpta* and *Aristida congesta* are not palatable. *Urochloa mozambiscensis* is a palatable pasture grass of medium leaf production and is well grazed by livestock. Continuous selective grazing of this highly palatable grass can cause a serious decline in veld condition.

DINOKANA

TABLE 3. 4: LOCATION OF SURVEY POINTS:

A total of eight sample sites were monitored.

SITE NO.	LOCATION
1	25° 25' 32.25" S, 25° 50' 44.7"E
2	25° 27' 50.0"S, 25° 53' 22.0"E
3	25° 27' 50.0"S, 25° 54' 02.8"E
4	25° 29' 37.0"S, 25° 55' 55.0"E
5	25° 25' 45.2"S, 25° 50' 54'6"E
6	25° 27' 59.9"S, 25° 53' 42.5"E
7	25° 27' 42.8"S, 25° 54' 22.8"E
8	25° 29' 57.0"S, 25° 55' 35.0"E

DESCRIPTION OF GRASSLANDS IN DINOKANA

The index of similarity is 0.61 (Table 3.1), indicating that Madikwe Game Reserve and Dinokana have few common species. The most important grasses growing in Dinokana are *Aristida congesta* (8 %)(Figure 3. 9), *Cynodon dactylon* (16.3 %), *Eragrostis lehmanniana* (9.4 %) and *E. rigidior* (9.9 %) (Figure 3. 8). *Cynodon dactylon* is the most prominent with a frequency of 16.3 % (Figure 3. 8). *Digitaria eriantha* occurs at a frequency of 4 % in Dinokana, whilst its frequency is 42 % in Madikwe Game Reserve (Figure 3. 2). From this it can be seen that Madikwe Game Reserve would have 'better' veld condition than the rangelands in Dinokana.

Cynodon dactylon is a relatively palatable pasture grass which can withstand intensive grazing (Van Oudtshoorn, 1999). This grass plays an important role in natural soil erosion control because of its lawn-like habit. The total frequency is 54.9 %, and the perennial grasses are prominent forming 40.6 % of the cover. Annual grasses constitute 14.3 % of the cover (Figure 3.

9) compared to 7.6 % in Madikwe Game Reserve (Figure 3. 3). The perennial grasses form 91.7 % in Madikwe Game Reserve (Figure 3. 2). This indicates that in terms of resistance against soil erosion, the grasslands in Dinokana are in a 'poor' veld condition compared to the grasslands in Madikwe Game Reserve.

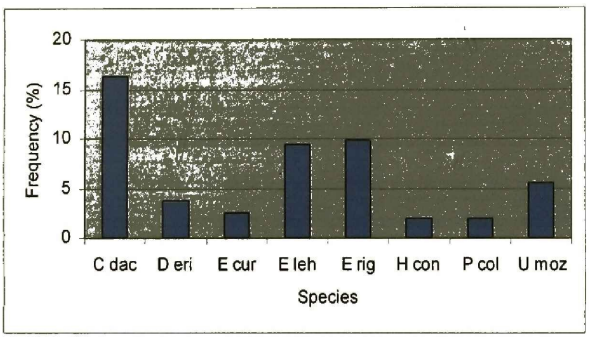


Figure 3. 8: Frequency (%) of perennial grasses in Dinokana.

The bare ground in Dinokana is 45.1 % (Figure 3. 9) in comparison to the 0.7 % in the benchmark site in Madikwe Game Reserve (Figure 3. 3). This large bare ground indicates that grasslands in Dinokana are susceptible to soil erosion. According to Anonymous (2002 a), a reduction in vegetation extent and vigour provide important indicators of a more general process of soil quality decline. According to Cuff (1984), bare ground influences the risk of erosion when it exceeds 20 %.

Due to the influence of this large exposed surface area of the soil, rill and gully erosion had already occurred in Dinokana during the survey. Areas at most risk of vegetation depletion include areas of high altitude and/or land with very low soil fertility Anonymous (2002 a). Altitude and soil fertility have also contributed to the large bare patches in Dinokana. The sites at 25^0 25' 32. 25" S; 25^0 50' 44.7" E and 25^0 25' 45.2" S, 25^0 50' 54'. 6" E are located on a slope. According to Ludick (1998), the slope of a landscape influences the development of the

herbaceous layer, the grazing capacity and erosion vulnerability. The organic matter becomes depleted through run-off and the soil becomes less fertile.

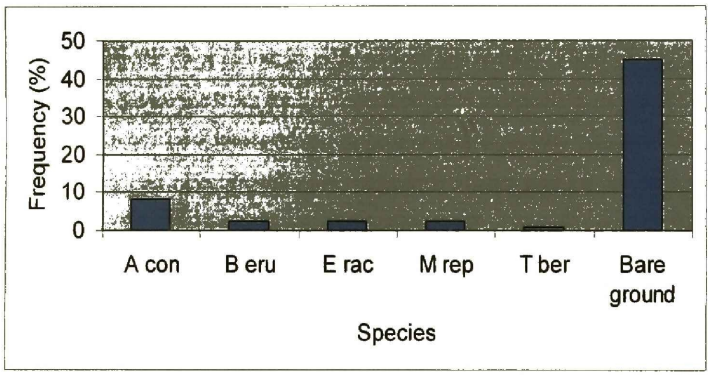


Figure 3. 9: Frequency (%) of annual grasses in Dinokana.

Water carries away soil if it is not absorbed by soil and/or vegetation (Beinart, 1984). Soil washing is potentially dangerous because it removes the valuable topsoil, essential to the growth of vegetation more gradually. The production capacity of a field could drop significantly in this way over a short period of time. If the vegetation cannot establish roots easily, less water will be absorbed. This initiates a cycle of decline which would soon produce gullies (Beinart, 1984).

Nutrients are easily leached from the soil during heavy rains. During the survey, the local soils had a reduced nutrient status. According to Figure 4. 15 (Chapter 4), there has been leaching of basic cations which include calcium, potassium, phosphorus and nitrogen. The high resistance (Figure 4. 9, Chapter 4) indicates that the soil has a poor water-holding capacity (Anonymous, 1997) even though it is a loam soil. In this way there is less water available for grasses growing in these sites. Shortage of water influences veld retrogression. The soil also is strongly acidic. According to Bickelhaupt (1993) and Brady & Weil (1996), lower pH values are detrimental to the activity of beneficial micro-organisms. In such areas, plant growth rates are very slow and reduce the ability of grasses to recover from overgrazing (Brady & Weil, 1996). Owing to the

reduced vegetal cover, this site has a limited resistance against soil erosion as compared to benchmark sites. In fact, during the survey, both rill and gully erosion were evident in the local sites.

When the vegetal cover is lost in areas of low soil fertility (Figure 4. 15, Chapter 4) and low rainfall, it may take centuries for the vegetal cover to re-establish even with the total removal of grazing animals. Low levels of soil organic matter especially coupled with dry environment, result in restricted plant growth rates, reduced resilience and greater susceptibility to erosion. Restoration of soils depleted in organic matter is a slow process and may take decades or even centuries to achieve to achieve. The local soil has a lower soil organic matter content (Figure 4. 16, Chapter 4) as compared to that of soils in Madikwe Game Reserve (Figure 4. 4, Chapter 4). Soil organic matter is the most influential of all the soil quality factors on plant growth. Susceptibility to erosion, soil fertility, soil structure, soil water-holding capacity and biological activity are all influenced by soil organic matter (Anonymous, 2002 c).

The settlements in Dinokana have also influenced veld retrogression. Heavily denuded sites are located within the local village, and the frequent movement of local inhabitants up and down slope in search of slate causes deep furrows. Slate is used for decorating the houses. Madikwe Game Reserve is no longer used as a settlement area, and this also explains why the rate of degradation is minimal there.

Digitaria eriantha (3.6 %) and *Panicum coloratum* (2 %) are most important grasses that add to veld palatability in the local grassveld. *Digitaria eriantha* occurs locally with a frequency of 3.6 % (Figure 3. 8), while it occurs at 43.5 % in Madikwe (Figure 3. 2). According to Van Oudtshoorn (1999), *Digitaria eriantha* grows well in a variety of habitats. It grows especially well in moist soils. According to Van Oudtshoorn (1999), *Heteropogon contortus* (1.8 %) is a good grazing grass, but the nutritional value declines rapidly with time, making it undesirable for livestock grazing. This indicates that the local grassland has a limited capacity to sustain livestock grazing. For this to be achieved, enough camp resting should be provided to allow full recovery of these palatable grasses. Livestock which include donkeys, cattle, sheep and goats,

were observed here during the survey. Overgrazing by such animals causes reduction of the vegetal cover (refer to section 3. 4. 1. 2) causing high run-off and donga erosion.

Denudation of bare patches can be stopped through restoration measures. One method of reclaiming this veld requires the manipulation of animal numbers, veld division into camps and veld resting (Tainton, 1981). Multi-camp systems, aimed at reducing selection by employing short, intense bouts of grazing coupled with long rests between grazing were long proposed in the late 1960's (Acocks, 1966; Roberts, 1970). Such non-selective or short-duration grazing systems were and remain contentious (O'Reagain & Turner, 1992) because they advocated much higher stocking density rates than those generally recommended (Savoury, 1987; Tainton, 1985). The advantage of non-selective grazing system contented that the periods of rest afforded each camp long time to counter any negative effects of intense defoliation. The period of occupation is short enough to avoid grazing of regrowth (Acocks 1966; Howell, 1977). A limited degree of camping may facilitate management of temporal and spatial variations in vegetation composition and productivity (Morris & Tainton, 1996).

Time is also a critical factor from the animal's standpoint. Cattle graze selectively, grazing the palatable plant material first, avoiding coarser, less palatable feed. Grazers graze most on the first days of grazing on a new pasture. As the days pass, stock spoil more and more grass through trampling, dung and urine contamination. Forage also gets older and less digestible, and the animals start to graze less. On heavily stocked continuously grazed pastures, regrowth will be grazed as soon as it is available. The grass which is in the first phase of regrowth is highly nutritious, but there is generally not enough of it to support high levels of animal production. If animals are forced to graze material which pass through their gut slowly, their daily intake will drop because they cannot fit any more feed in their rumen. The result is poor animal performance (Pratt, 1993).

When grass production declines, woody species increase and lead to the ultimate loss of grazing lands. The local vegetation in Dinokana is sparse with a limited number of woody species (The method used was the Technique for describing woody vegetation composition and structure in

inventory type classification, ordination and animal habitat surveys) (Coetzee & Gertenbach, 1977). Woody species observed in Dinokana during the survey include *Acacia karroo, A. tortilis, Dichrostachys cinerea, Euclea crispa* and *Ziziphus mucronata. Acacia* species are most important in the initial stages of the bush thickening process, and broad-leaved plants predominate later in the successional sequence (Hurt, 2000). Once the latter phase has been reached, grass production is drastically reduced. This means that local sites could be in the initial stage of bush encroachment.

The sites located at 25^0 29' 37. 0" S, 25^0 55' 55. 0" E and 25^0 29' 57.0" S, 25^0 55' 35.0" E were once used as croplands. Secondary succession took place in the past in these sites. Like any other previously vegetated area, the sites undergone seral stages until species such as *Digitaria eriantha* became established (Figure 3. 8). This grass occurs at a low frequency (Figure 3. 8), and this indicates change is towards veld retrogression. Grasses such as *Cynodon dactylon, Eragrostis rigidior, Aristida congesta* and *Brachiaria eruciformis* (Figure 3. 8 and Figure 3. 9) become colonizers of bare patches.

DOORNLAAGTE

TABLE 3. 5: LOCATION OF SURVEY POINTS:

A total of 12 sample sites were monitored.

SITE NO.	LOCATION
1	25^0 14.40' 40.15"S, 26^0 19' 18.7"E
2	25^0 14.40' 40.15"S, 26^0 19' 41.4"E
3	25^0 14' 15.7"S, 26^0 19' 36.8"E
4	25^0 14' 47.2"S, 26^0 19' 30.4"E
5	25^0 19' 10"S, 26^0 16' 07.7"E
6	25^0 14' 44.0"S, 26^0 19' 22.7"E
7	$25^0$14'15. 0" S, 26^0 19' 18.7"E
8	25^0 14.4' 08.5" S, 26^0 19' 41.4" E
9	25^0 14' 15.7" S, 26^0 19' 36.8" E
10	25^0 14' 47.2" S, 26^0 19' 30.4" E
11	25^0 19' 10" S, 26^0 16' 07.7"E
12	25^0 14' 43.0" S, 26^0 19' 21.8" E

DESCRIPTION OF GRASSLANDS IN DOORNLAAGTE

Doornlaagte was occupied by the local inhabitants in 1996. Like in the benchmark sites, the grassveld is not over-utilized as indicated by a thick, herbaceous layer of grasses The similarity index for Madikwe Game Reserve-Doornlaagte is 0.8 (Table 3. 1), indicating that these two sites have a homogenous herbaceous layer. The rich herbaceous layer of grasses (Figure 3. 10) indicates that the soil is stabilized and protected from soil erosion.

Grasses such as *Digitaria eriantha* (3.1 %), *Panicum coloratum* (5.2 %), *P. maximum* (7.1 %) (Figure 3. 11) and *Themeda triandra* (7.5 %) are associated with a 'good' veld condition (Van Oudtshoorn, 1999).



Figure 3. 10: Rich herbaceous layer of grasses in the grazing lands in Doornlaagte.

Like in Madikwe Game Reserve, perennial grasses dominate. Perennial grasses form 93.9 % (Figure 3. 11), while annual grasses form 10 % (Figure 3. 12) of the basal cover. The most important perennials growing locally include *Bothriochloa insculpta* (18.7 %), *B. radicans* (20 %), *Cymbopogon plurinodis* (29.4 %), *Setaria nigrirostris* (40.43 %) and *Urochloa mozambiscensis* (14.7 %).

Setaria nigrirostris occurs with a frequency of 40.43 % (Figure 3. 11) in the local grassveld. *Setaria nigrirostris* is locally prominent particularly at sites located at 25^0 14' 44. 0" S, 26^0 19' 22. 7" E and 25^0 14' 43. 0" S, 26^0 19' 21. 8" E. *Setaria nigrirostris* is a palatable grass with a reasonably good leaf production. It is well utilized, but becomes less acceptable for grazing when mature (Van Oudtshoorn, 1999). *Urochloa mozambiscensis* is a palatable grass with

medium leaf production and is well-grazed by livestock (Van Oudtshoorn, 1999). Continuous selective grazing of this highly palatable grass can cause serious decline in veld condition. *Bothriochloa insculpta* is unpalatable because of its aromatic taste, and it becomes hard and fibrous later in the season (Van Oudtshoorn, 1999). When this grass colonizes disturbed sites, it is difficult to replace it with better grazing by using normal grazing practices. *Bothriochloa insculpta* is effective in protecting and stabilizing soils.

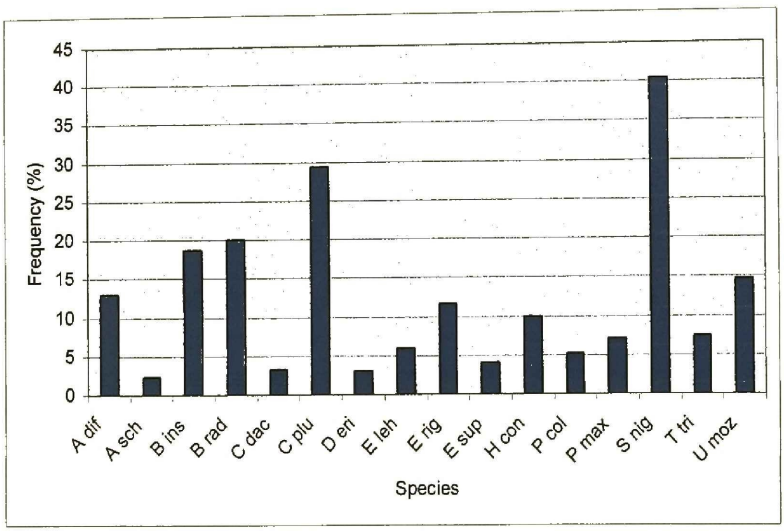


Figure 3. 11: Frequency (%) of perennial grasses in Doornlaagte.

Grasses form a thick moribund in grazing lands in Doornlaagte. The thick moribund of grasses is as a result of the elimination of fires as an effective pasture management tool. Unlike in Madikwe Game Reserve, the grazing areas in Doornlaagte have not been burnt. The general fear among the residents is that due to unreliability of the rains, the area might remain bare for a long time. This point is argued from the fact that upon burning, the nutrient capital in an area is reduced (Rickfels, 1990; Web Development Team, 1995). The elements in ash are water-soluble and as a result are lost through leaching and erosion. Although this justifies the fear of local

inhabitants, fire acts as a decomposer to burn the accumulated litter. These materials become easily available for recycling (Krebs, 1978; Rickfels, 1990).

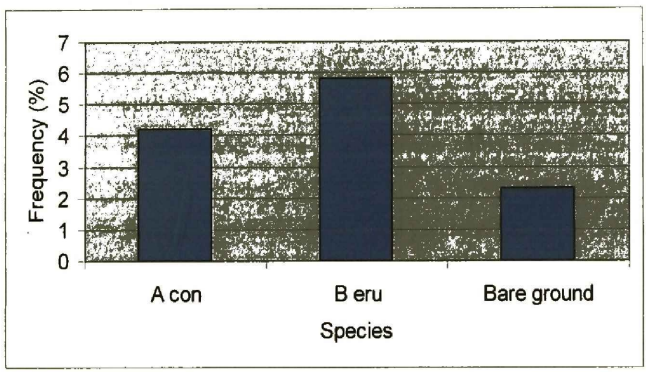


Figure 3. 12: Frequency (%) of annual grasses in Doornlaagte.

Grass litter accumulation has been cited as an important factor contributing to reduced yield when fires are suppressed (Foster, 1998). The rich ashy residue is an excellent bed for many herbaceous species whose productivity is reduced without application of fire (Mielke, 1989; Foster, 1998; Krebs, 1978). One of these species is *Themeda triandra*, which occurs at a frequency of 7.5 % (Figure 3. 11). This grass is desirable, yet its frequency is low indicating a decline in veld palatability. This results in inadequate nutrition, and is generally blamed for the low production of livestock. Grunow (1973) proposed three general methods for increasing the production of natural veld as a resource of livestock feed. These are by veld fertilization, reinforcement with legumes and more productive grasses and by veld replacement with better grass and legumes.

Burning results in increased frequency of species such as *Themeda triandra* (Bothma, 1989). The mineral enriched soil obtained from burning, promotes rapid growth when moisture conditions are normal. The recommended time of burning is just after the spring rains when the ground is still wet and will not stay bare as long as in winter (Bezuidenhout & Kuun, 1975).

Many of the world's grasslands owe their existence to man-made or natural fires. If the local community completely eliminate fire as a pasture management tool, they should embark on alternative methods of effective veld management. Factors such as grazing intensity, the number of rest camps and frequency of rest periods will require continual adjustments.

A heap of dumped waste materials in one of the sites is a sign of unsustainable land-use practice which leads to veld retrogression. Soils become contaminated by the dumping of hazardous waste materials (El-Hinnawi & Hashmi, 1982). Soil degradation from pollution occurs when air emissions are deposited on land. It also occurs as larger amounts of hazardous materials as well as conventional wastes are disposed both on and within the soil. However, the actual extent of pollution in this site was not measured due to unavailability of equipment. The existence of this dumping site is an indication of poor land-use. Compared to Madikwe Game Reserve there is no dumping of waste in the grazing areas.

Lack of pasture management in Doornlaagte is evident because of broken fences. Lack of fences discourages rotational grazing which results in excessive defoliation of grasses. There were signs of excessive trampling on the ground in one of the survey sites. The grasses were flattened against the ground surface, substantial quantities of dung and urine deposits indicated that animals spend nights in the veld. Some of the woody species growing locally include *Acacia karroo, A. erioloba, A. mellifera, A. tortilis, Ehretia rigida, Grewia flava, Tarchonanthus camphoratus* and *Ziziphus mucronata.* The existence of these woody species should not be ignored because if veld management is not practiced, then the area will be dominated by bushes, making it unsuitable to support livestock.

SERAKE

TABLE 3. 6: LOCATION OF SURVEY POINTS:

A total of 12 sample sites were monitored.

SITE NO.	LOCATION
1	25^0 02' 28.3" S, 25^0 55' 45.4" E
2	25^0 09 30.2" S, 25^0 53' 43.3" E
3	25^0 09' 29.3" S, 25^0 53' 44.3" E
4	25^0 09' 28.0" S, 25^0 53' 42.2" E
5	25^0 09' 04.2" S, 25^0 58' 28.0" E
6	25^0 08' 42.4" S, 25^0 58' 47.8" E
7	25^0 03' 08.3" S, 25^0 55' 59.8" E
8	25^0 09 58.7" S, 25^0 53' 59.6" E
9	25^0 09' 59.3" S, 25^0 53' 55.3" E
10	25^0 09' 46.0" S, 25^0 53' 58.8" E
11	25^0 09' 54.2" S, 25^0 58' 49.0" E
12	25^0 08' 54.9" S, 25^0 58' 57.6" E

DESCRIPTION OF GRASSLANDS IN SERAKE

The herbaceous layers of Madikwe Game Reserve and Serake are not homogenous because the two sites have few common species. As a result, the similarity index is low (0.67, Table 3.1). *Cymbopogon plurinodis* is most prominent with a frequency of 34.5 % (Figure 3. 13). The thick stands of *Cymbopogon plurinodis* indicate that selective grazing is occurring in the local grassveld. *Cymbopogon plurinodis* is particularly abundant at sites located at 25^0 02' 28.3" S, 25^0 55' 45.4" E, 25^0 03' 08.3" S, 25^0 55' 59.8" E and 25^0 09 58.7" S, 25^0 53' 59.6" E. *Panicum coloratum* (16.1 %) and *Eragrostis rigidior* (17.3 %) are the most important grasses growing

locally (Figure 3. 13). *Cymbopogon plurinodis* and *Eragrostis rigidior* have low palatability and indicate that vegetation is overgrazed.

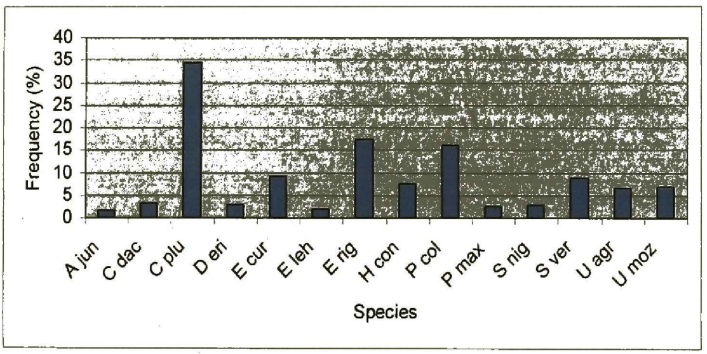


Figure 3. 13: Frequency (%) of perennial grasses in Serake.

The local soil is chemically degraded, and this influences veld retrogression. There is an accumulation of nutrients such as magnesium, potassium and calcium (Figure 4. 23, Chapter 4). There is invasion of woody species, and increased bush densities lead to the decline of local grasses (Anonymous, 2001 a). Overgrazing leads to the decline of perennial grasses (Skarpe, 1991). This grazing effect is evident in the grassland occurring at 25^0 09' 28" S, 25^0 53' 42.2" E because the frequency of perennial grasses is lower than that of annual grasses. Plants react to herbivory by changes in quantity and chemical composition of biomass produced and in morphology, thus, promoting or deterring further herbivory. Vegetation reacts on direct or indirect effects by changes in species composition and physiognomy, to the advantage or disadvantage of different herbivores. In South America, most Savanna grasslands do not tolerate intensive grazing, but endure, or require almost annual burning (Skarpe, 1991).

Ecosystem balance has been disturbed through inappropriate land-use which has triggered competition between grasses and woody species in the grazing lands in Serake. This competition, most probably triggered by overgrazing (cattle were grazing here during the survey), is in favour of woody species due to their better competitive capabilities of extracting water.

Skarpe (1990) indicated that in heavily grazed areas, the trees whose abundance increased were the shallow-rooted *Acacia mellifera* and *Grewia flava*. Trees are able to make more effective use of deep water than grasses can (Walker & Noy-Meir, 1979; Stuart-Hill, 1985). Any management activity which increases water penetration to a greater depth in the soil profile should stimulate growth in already established trees (Anonymous, 2001 a). *Acacia mellifera, A. nilotica, A. tortilis* and *Dichrostachys cinerea* are encroaching woody species growing locally. The grasses are declining locally as indicated by a bare ground of 12.3 % (Figure 3. 14).

The state of grass species composition towards retrogression in Serake can be attributed to the grazing systems.

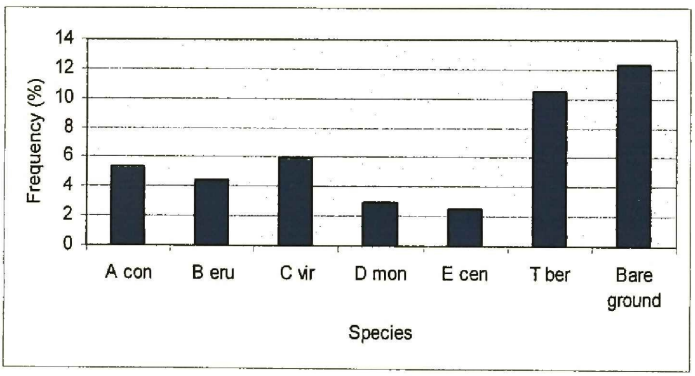


Figure 3. 14: Frequency (%) of annual grasses in Serake.

The tribal grazing area in Serake is located within reach of the village. As a result, the grazing land has been used intensively and suffered considerable degradation. If poor pasture management such as overstocking and overgrazing continues, this grassland will eventually be susceptible to desertification (Figure 3. 15). Desertification results in the reduced productivity of desirable plants, undesirable alteration in biomass and the diversity of the micro- and macro-fauna and flora and includes hazards of human occupancy. To halt desertification, soil conditions must be made favourable for plant growth. Desertification in Madikwe Game

Reserve is limited as shown by the rich herbaceous layer. Reduction in plant cover accelerates soil erosion by wind and water. As vegetation cover and soil are reduced, raindrop impact and water run-off increases. Water is lost from the land instead of soaking into the soil to provide moisture for plants (Anonymous, 2002 b). According to Van Oudtshoorn (1999), the occurrence of *Tragus berteronianus* (10.5 %) (Figure 3. 14) in natural veld indicates retrogression. *Chloris virgata* (5.9 %) is one of the first grasses to colonize bare patches. This grass is inclined to increase during high rainfall seasons (Van Oudtshoorn, 1999). A perceived problem is that soil loss may lead to a long-term reduction in species diversity (Venter *et al.*, 1989).

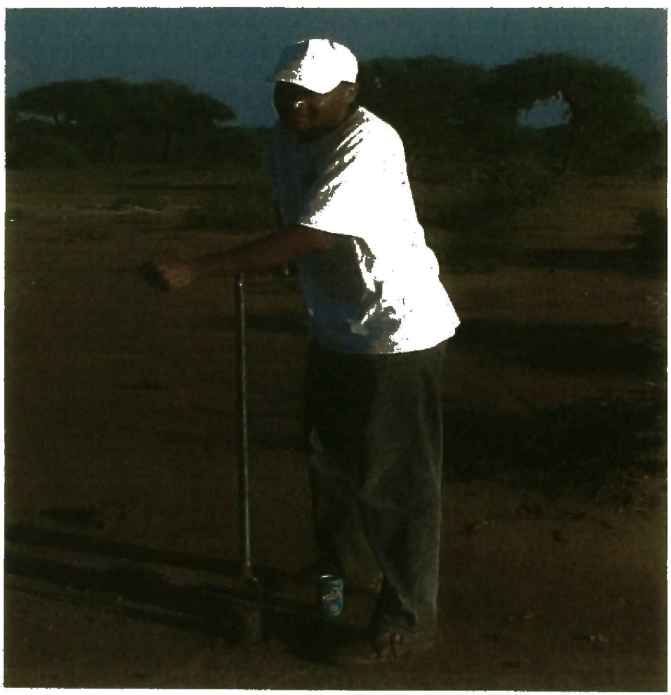


Figure 3. 15: Large, bare, compacted ground surfaces make the rangelands susceptible to desertification.

Restorative measures are necessary in local grasslands. Re-seeding may also be necessary in this site as a restorative measure. According to Howell (1977), community participation is important in restoration of degraded areas. Participation does not only mean getting local people to accept planning decisions. It becomes effective if people recognise why the plan is necessary. It also becomes beneficial if people are given an opportunity to participate in planning and implementation.

SUPINGSTAD

TABLE 3. 7: LOCATION OF SURVEY POINTS:

A total of 10 sample sites were monitored.

SITE NO.	LOCATION
1	24^0 46' 32.0" S, 26^0 06' 38.1" E
2	24^0 47' 00.8" S, 26^0 05' 23.5" E
3	24^0 48' 01.8" S, 26^0 02' 29.9" E
4	24^0 46' 32.0" S, 26^0 00' 16.6" E
5	24^0 45' 54.6" S, 26^0 58' 59.5" E
6	24^0 46' 43.4" S, 26^0 06' 58.1" E
7	24^0 47' 10.8" S, 26^0 05' 36.5" E
8	24^0 48' 11.8" S, 26^0 02' 49.9" E
9	24^0 46' 45.9" S, 26^0 00' 34.6" E
10	24^0 46' 54.6" S, 26^0 59' 34.5" E

DESCRIPTION OF GRASSLANDS IN SUPINGSTAD

Panicum maximum is prominent with a frequency of 27 % (Figure 3. 16). *Panicum maximum* is highly palatable and regarded as a good grazing grass. It grows well especially in the shade of

large trees (Van Oudtshoorn, 1999). Although this grass also occurs in Madikwe Game Reserve, it is not prominent there (Figure 3. 2). *Bothriochloa radicans* (14.9 %), *Eragrostis lehmanniana* (19.8 %), *E. rigidior* (14.9 %) and *Setaria nigrirostris* (9.7 %) are important perennials growing locally (Figure 3. 16).

Palatable grasses are particularly found in sites located at 24^0 46' 32.0" S, 26^0 06' 38.1" E, 24^0 48' 01.8" S, 26^0 02' 29.9" E and 24^0 46' 32.0" S, 26^0 00' 16.6" E. Palatable grasses include *Cynodon dactylon* (4.7 %), *Eragrostis lehmanniana* (19.8 %), *Panicum coloratum* (8.3 %), *P. maximum* (27 %), *Setaria nigrirostris* (9.7 %), *S. verticillata* (7 %) and *Urochloa mozambiscensis* (9.5 %) (Figure 3. 16). If proper management practices such as camp resting are not implemented, these palatable grasses may be completely grazed off and the area becomes occupied by unpalatable grasses.

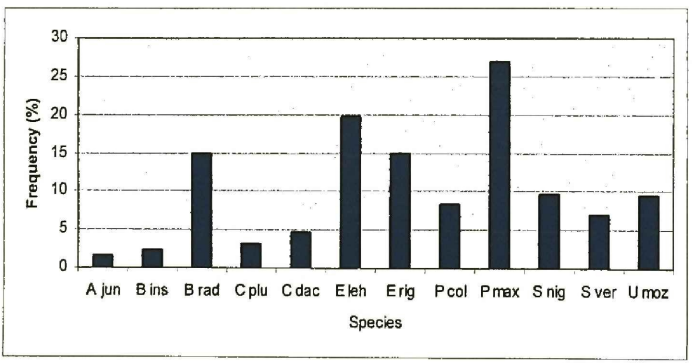


Figure 3. 16: Frequency (%) of perennial grasses in Supingstad.

Perennial grasses form 70.1 % (Figure 3. 16), while annual grasses form 21.9 % (Figure 3. 17) of the frequency. The frequency of perennial grasses growing locally is lower than that of benchmark site (97.7 %, Figure 3. 2), indicating that local grassland has a limited resistance against soil erosion. 8.1 % of the ground surface is not covered by vegetation (Figure 3. 17),

compared to the 0.7 % in Madikwe Game Reserve (Figure 3. 3). This makes the soil susceptible to erosion.

The bare areas indicate that grasses are being grazed off and this influences veld retrogression. Grasses are lost through trampling and grazing by livestock. The presence of *Urochloa mozambiscensis,* which is common in this grassland, indicates overgrazing of the natural veld. The change in species composition in the grassveld located at 24^0 47' 10.8" S, 26^0 05' 36.5" E is influenced by topography and settlements (Figure 3. 18). The area is rocky and grasses growing in this survey point are short.

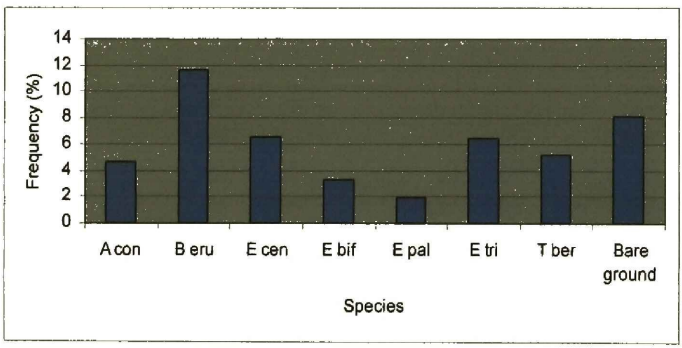


Figure 3. 17: Frequency (%) of annual grasses in Supingstad.

The similarity index for Madikwe-Supingstad is 0.59 (Table 3.1), indicating that few species are common between the two sites, and the herbaceous layer is therefore not homogenous. Invasive woody species locally include *Acacia tortilis, A. mellifera* and *Dichrostachys cinerea,* forming dense thickets (Figure 3. 19). Trampling is more concentrated in the gaps between thickets. Bad veld management through replacement of multi-species animal groups (browsers, grazers and mixed feeders) with grazers (cattle and sheep) led to this condition. The defoliation by grazing livestock causes the depletion of the vegetal cover and the increase in bush encroachment (Meyer, 1998; Hoffman & Ashwell, 2001, Archer *et al.*, 2000).



Figure 3.18: A survey point in Supingstad where settlement influence veld retrogression.



Figure 3. 19: A survey point where veld retrogression is accompanied by woody species thickening. Dominant species include *Acacia tortilis, A. mellifera* and *Dichrostachys cinerea.*

Boer goats are appropriate browsers to be employed in bush encroachment control (Meyer, 1998). Even then, the effective control can be obtained by means of a grazing system where a high frequency as well as intensity of grazing can be ensured. It is important to keep a possible overlap in diet between grazers and browsers in mind, since Boer goats will be forced to consume more grass when browsing material becomes limited (Meyer, 1998).

Like in other publicly owned lands where there are no governmental regulations, the grazing lands in Supingstad are mismanaged through overstocking. Each livestock owner is trying to maximize his use of the land. Forage not used by one individual's herd will likely be used by another farmer's herd. In such instances, the owner is willing to sacrifice production per animal and sometimes total herd production of meat or milk because to him animal numbers are more important than quality (Conner, 2002).

According to the residents of Supingstad, the grazing land is too small for farming purposes. Various reasons for this include bush encroachment and retrogression of the herbaceous layer. According to Conner (2002), unregulated use results in degradation. The remedy for this problem is either privatization of the land, or governmental regulation which restricts the number and/or time period that the livestock can graze on a given area. One way of regulating grazing is by issuing grazing permits. The grazing management generally consists of striving to balance the desire for maximizing annual profit per unit area with the necessity of leaving some reserve forage for emergency use and allowing for improvement in the production of the rangeland. Publicly owned grazing land is characterized by its intended role in meeting non-market goals of conservation, preservation and equity of opportunity to enjoy unique recreational and anaesthetic experiences. The role of grazing management is expanded to include facilitating many simultaneous but different land-uses and land-users. It amounts to keeping livestock from damaging the resources and improving veld condition (Conner, 2002).

It should be noted that although it is evident that land-use plays a role in land degradation, environmental factors should not be ruled out (Crowder & Chedda, 1982). Grass adaptation and productivity are largely determined by the amount and distribution of rainfall (Crowder &

Chedda, 1982; Tainton, 1981). Herbage yields of grasses are seasonal and closely follow cyclic patterns of rainfall (Crowder & Chedda, 1982). In South Africa, annual precipitation over the country as a whole is relatively low and evaporative losses are high (Crowder & Chedda, 1982). Moisture stress is therefore, a factor which exerts a major effect on plant survival. Rainfall is the greatest single limiting factor for plant production in South Africa, particularly in the semi-arid and arid parts of the country. All plants need water for processes such as germination, growth and reproduction (Jordaan & Du Plessis, 1998). Although only approximately 1 % of the absorbed water is constructively used, large amounts are needed for a variety of plant functions.

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CHAPTER 4: SOIL DEGRADATION

4. 1. INTRODUCTION

All terrestrial life depends on the fragile crust of soil that coats the continents. Soil is the rocks that have been disintegrated. It is a necessary medium for plants, a home for certain insects and animals as well as a medium from which we get minerals. It is important, therefore, to treat soil as a 'living' entity, and to learn to respect it. The soil covering the surface of the earth has taken millions of years to form. Soil is formed at a rate of only 1 cm every 100-400 years and it takes 3 000-12 000 years to build enough soil to form productive land. This precious covering is extremely slow to form (El-Hinnawi & Hashmi, 1982; Jordaan, 1998).

Although it takes a long time for soil to be formed, it can be destroyed in a moment. When soils become so degraded that no food or animals can survive on it, the lives of people are affected. This means that soil is a non-renewable resource and once destroyed, it is gone forever. If we disregard this, a time will come when there would not be enough soil left to sustain life on earth.

The capability of the soil to serve as a habitat for the plant and to produce plant materials for harvest constitutes fertility, or alternatively, yielding capacity or productivity (Schroeder, 1984). A distinction can be made, particularly by husbandry and plant nutrient, between soil fertility, directly attributable to the soil as such, and site fertility, which includes the contributions of climate, situation and husbandry. The final expression of fertility is yield, measured on a natural soil by annual production of dry matter per unit area, amplified by description of the diversity of vegetation and seasonal variation in productivity; high total yield, great botanical diversity and low year to year variation indicating high fertility. Fertile soils give consistently good yields without the addition of fertilizers and responds well in increased crop to the application of manures and fertilizers and to irrigation if these are needed. Soils may have high inherent fertility and yet yield poorly because other factors limit growth so there is a distinction between: Potential soil fertility: that is, maximum attainable with optimisation of all factors, and actual soil fertility: that is fertility status under ruling unimproved conditions (Schroeder, 1984). According

to Van der Watt and Van Rooyen (1995) soil fertility describes the condition of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants, when other growth factors, such as light, water, temperature and physical condition of soil, are favourable.

Soil degradation is a serious problem in South Africa (Hoffman & Ashwell, 2001). Approximately 5 % of the soils are affected by erosion, and the average soil loss is 2.5 tonnes per hectare per year with a maximum of 60 tonnes per hectare per year (Barnard & Newby, 1999). This is more than eight times the rate of soil formation and is clearly unsustainable. The highest levels of soil degradation in South Africa occur in cropland, grazing land and settlements (Hoffman & Ashwell, 2000).

Chemical deterioration may consist in loss of nutrients, acidification, salinization, pollution and toxicity. Loss of nutrients, mainly sodium, phosphorus and potassium, occurs where agriculture is practiced on poor soils. Soil salinization is the concentration of salts in the topsoil and occurs due to poor management of irrigation schemes (Sombroed & Sene, 2000). Soil acidification is caused by some application of mineral fertilizers (Barnard & Newby, 1999). Pollution of various types and origin can strongly reduce the agricultural capacity of soils.

Physical degradation is encompassed in soil compaction and crusting, water logging, soil erosion and eventually desertification (Barnard & Newby, 1999). Soil compaction usually results from the use of heavy machinery on unstable soils or from cattle trampling, sealing and crusting usually due to the impact of raindrops. Waterlogging occurs mostly in inappropriately irrigated areas.

Soil degradation has an appalling impact on rural communities. Soils become degraded because people in the affected areas are driven by poverty to get as much out of the land as possible in the short time (Ponniah, 1998). The rapid population growth has resulted in the available per capita of land dropping from 0.86 hectares in 1970 to 0.5 hectares in 1980, and it is estimated that this will drop to a further 0.2 hectares per capita by 2020 (Barnard & Newby, 1999). Thus, there has

been an increased need for a place to live, work, recreation etc. This means there has been an increased demand for resources such as building materials e.g. poles for fencing and roofing, obtained at the expense of trees, soils for making bricks leaving the land scarred, collection of firewood as a response to energy needs, construction of roads and bridges which cuts across the existing rangelands. Rapid population growth has led to the intensification of arable agricultural production and overstocking in pastoral lands as response to meet the demand for food.

Soil degradation in settlement areas is most severe in North West Province (Hoffman & Ashwell, 2001). Reasons for increased rates of soil degradation in the North West Province are:

1. absence or poor management of soil conservation work;
2. poor cultivation practices or veld management;
3. legacy of betterment planning;
4. lack of soil conservation regulation or law enforcement;
5. overstocking above recommended carrying capacity;
6. poor planning of settlements;
7. deforestation; and
8. removal of sand and topsoil for building.

The study conducted for the United Nations Convention to Combat Desertification in South Africa, rated the North West Province as one of the provinces where land degradation is a problem. In their study, Hoffmann *et al.* (1999) identified the Zeerust District as one of the areas with serious soil degradation (Figure 3. 1).

A decline in grass species frequency is a good indication of soil degradation. The first phase is characterized by a decline of the productive capacity of the soil which occurs when the density of the valuable, productive and soil protecting grass species decline (Tainton, 1999). Such species include *Themeda triandra, Fingerhuthia africana, Panicum* species, *Cenchrus ciliaris* and *Digitaria eriantha.* These valuable species are replaced by less palatable grazing tolerant species such as *Aristida* species, *Eragrostis lehmanniana* and *Urochloa mozambiscensis* (Chapter 3).

Usually during this stage, the grass cover is poor resulting in active soil erosion. Continuing poor management leads to desertification, primarily caused by overgrazing where livestock strips the land of its vegetation and expose it to erosion.

Desertification is worsened by inequitable land ownership. It should be no surprise that the former homeland areas are amongst the most severely degraded areas in the country. As a result of the unjust distribution of land, agricultural land in the former homelands has been overgrazed and over-cropped for decades, and in cases now, degraded beyond repair. In addition, land tenure laws and practices in the homelands and townships did not encourage people to conserve land they did not own. Desertification occurs all over the world, affecting 900 million people in 99 countries by destroying the soil's capacity to support livestock or crops. 24 Million tonnes of topsoil are lost due to desertification around the world every year (Hoffman & Ashwell, 1997 a, b). The displacement of topsoil by wind action is more widespread in arid and semi-arid climates than under more humid conditions, where wind action may create deflation hollow dunes. The loss of topsoil reduces fertility because as the soil becomes denser and thinner, it is less penetrable by the roots of plants.

4. 2. MATERIALS AND METHODS

MATERIALS

1. Soil auger
2. Brown paper bags for soil collection

METHODS

A soil auger was used for soil sampling in each study site. In each case, the topsoil harvests from the A-horizon was discarded because naturally, these consists of organic matter from leaf litter. The soil from the B-horizon was collected, and labelled according to the study site. Soil samples were taken in areas with homogenous vegetation. Due to the slight inaccuracy of the GPS

apparatus, the grid references of some soil samples are slightly off-course from the original site (location) grid readings.

The sampled soils were sent to the Agricultural Research Council* – Institute for Soil, Climate and Water for analysis. The soil factors that were analysed include soil macronutrients, resistance, electrical conductivity, soil organic matter, carbon, pH and texture. These soil factors are good indicators through which chemical degradation can be established in an area (Berger & Iams, 1996).

4. 3. RESULTS AND DISCUSSION

MADIKWE GAME RESERVE

TABLE 4. 1: LOCATION OF SURVEY POINTS:

Six sample sites were monitored.

SITE NO.	SOIL SAMPLE NO.	LOCATION
1	20	24^0 48' 23. 7" S, 26^0 17'19. 8"E
2	16	24^0 50' 16. 0" S, 26^0 16' 06.7"E
3	17	24^0 49' 30. 7" S, 26^0 16' 41.8"E
4	40	24^0 48' 24.0" S, 26^0 17' 20. 0"E
5	36	24^0 50' 17. 5" S, 26^0 16' 07"E
6	37	24^{0}50' 35. 5" S, 26^0 16'42. 1 "E

*Agricultural Research Council – Institute for Soil, Climate and Water. Private Bag x 79. Pretoria, 0001. Tel. (012) 310 2500.

NUTRIENT COMPOSITION OF THE SOIL

Madikwe Game Reserve is one of the major tourist attraction sites in the North West Province with its different intra-regional and domestic categories.

It depends on the continued availability of a number of generally renewable resources such as fauna, flora and the soil. The distinctive wildlife scenery and game hunting is a feature which gives it a special characteristic to tourism. Increased visiting has resulted in the pressure of use of the natural resources. For example, there has been a greater need to build tourist facilities such as accommodation facilities, camp sites, picnic grounds and roads for effective game drives. The effect has been the degradation of soils and vegetation, a process that robs the area of its natural beauty.

Figure 4. 1 indicates fertility of soils in Madikwe Game Reserve. Cutter *et al.* (1985), defines soil fertility as the ability of the soil to supply essential nutrients to plants. Nutrients such as nitrogen, sulphur, phosphorus, magnesium, potassium and calcium are needed in larger quantities, and are termed macronutrients (Bornman *et al.* 1989; Evans, 1999; Smith, 1999). Phosphorus and nitrogen are the main limiting nutrients (Yayock *et al.*, 1988).

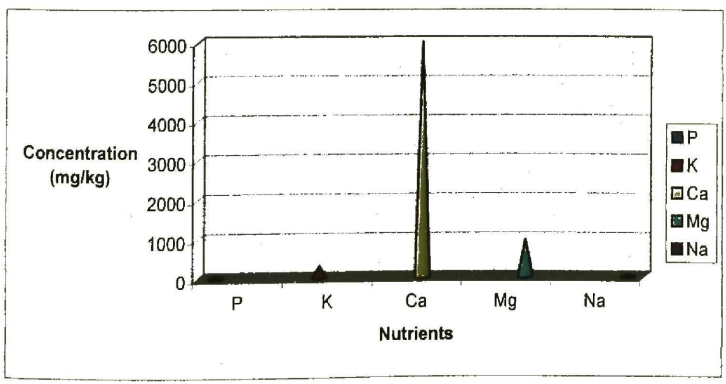


Figure 4. 1: Nutrient composition of soils in Madikwe Game Reserve.

Table 4. 2: Acceptable limit of soil indicators (Adapted from Bornman *et al.*, 1989)

Soil indicator	Acceptable range
SOM (%)	1.5-2.0
C: N	10: 1 - 14: 1
EPP (cmol(+)/kg)	(3-7)
SAR	1
Base saturation (%)	50-95
Acid saturation (%)	5-15

The site located 24^0 48' 24.7"S, 26^0 17' 20.0"E has a slightly higher phosphorus content than other local sites. The local terrain unit of this site can be classified as scarp, according to Ludick (1998). A scarp consists of exposed rocks and normally accommodates little vegetation. Soil levels of phosphorus are usually related to the soil parent material. The parent rocks in this site are igneous and are characterized by high phosphorus content (Whiteman, 1980). Nett loss of phosphorus in the soil occurs as a result of removal of plant or animal materials particularly through grazing (Whiteman, 1980). As a limiting factor in plant growth, phosphorus is probably second in importance to nitrogen. Unlike nitrogen, phosphorus, however, is not readily replaced by natural inputs. It is unlikely, therefore, that efforts to remedy phosphorus loss through soil fertilization in these grazing lands would be practical. Supplementary wildlife diet with phosphorus-rich food is a possible solution (Smith, 2002). Phosphorus is important in the germination of seeds and the growth of roots (Smith, 1999). Deficiency symptoms include chlorosis, death of older leaves and purple coloration due to anthocyanin production. Potassium content in local soils is 172.50 mg/kg (Figure 4. 1). Potassium promotes general vigour, disease resistance and sturdy growth (Smith, 1999; Courtney & Trudgill, 1984; Simpson, 1983).

The exchangeable potassium percentage (EPP) of the soils in Madikwe Game Reserve (Figure 4. 2) is lower than the acceptable limit (Compare Table 4. 2). This means that there are antagonistic ions which compete with potassium for uptake. According to Figure 4. 1, these are magnesium and calcium ions.

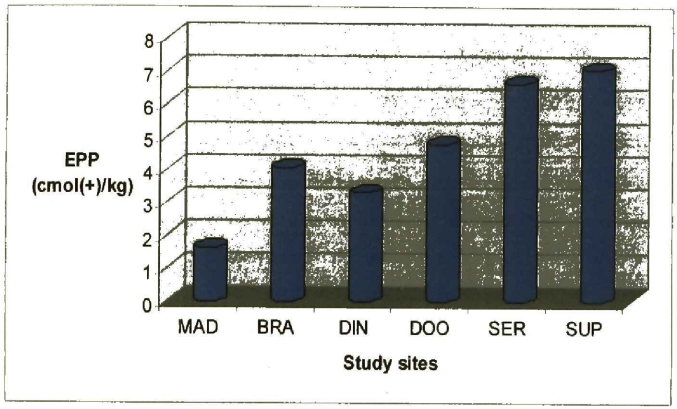


Figure 4. 2: Exchangeable Potassium Percentage of soils in the Zeerust District.

KEY:

MAD = Madikwe Game Reserve

BRA = Braklaagte

DIN = Dinokana

DOO = Doornlaagte

SER = Serake

SUP = Supingstad

Magnesium and calcium drives off potassium ions from the ion exchange complex and makes them liable to leaching. This lowers the EPP of the soil. Magnesium content is 941.33 mg/kg in local soils (Figure 4. 1). Magnesium is vital to chlorophyll production, and is also important in most enzymatic reactions (Courtney & Trudgill, 1984; Smith, 1999; Simpson, 1983). Excess magnesium causes calcium deficiency (Smith, 1999). Calcium content is 5985.00 mg/kg (Figure 4. 1). Calcium is a major ingredient in cell walls and is important for root development (Smit, 1999; Simpson, 1983). The sodium content is 17.67 mg/kg in local soils (Figure 4. 1). The sodium adsorption ratio (SAR) of the soils falls below 1 (Figure 4. 3), meaning that these soils,

therefore, do not have a sodium hazard. The SAR of a soil gives information on the comparative concentration of sodium, calcium and magnesium (Macvicar *et al.*; 1977, Bornman *et al.*, 1989). The SAR of the soil takes into account that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions. Alkali soils are associated with SAR greater than 4, which indicates a sodium hazard. Saline soils have a high soluble salt content of which sodium forms a high proportion. If this soil leaches with a low content of salt, a sodic soil would be formed (Macvicar *et al.*, 1977).

Nitrogen content is 0.13 % in Madikwe Game Reserve soils (Figure 4. 4). Nitrogen stimulates leaf and stem growth (Smith, 1999). Nitrogen has thus, the most pronounced effect on plant growth and development (Yayock *et al.*, 1988).

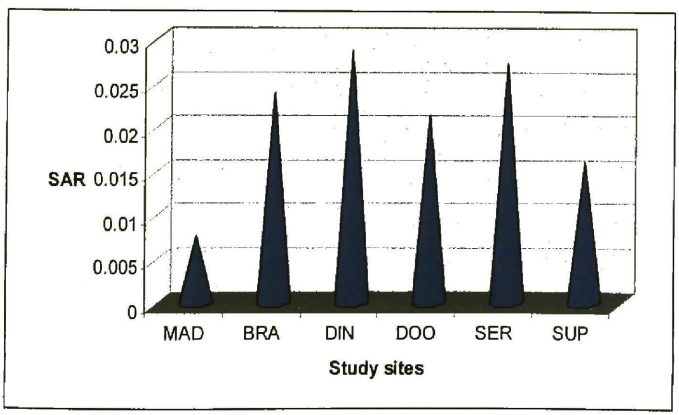


Figure 4. 3: Sodium Adsorption Ratio (SAR) of soils in the Zeerust District.

A decline in such an essential nutrient is likely to cause a decline in both plant and livestock productivity. The carbon content of Madikwe Game Reserve soils is 1.95 % (Figure 4. 4). Carbon dynamics of rangelands are affected by grazing, fire and their interactions (Archer & Boutton, 2000). These burning effects are manifested primarily via their effects on plant species composition. Local soils have wide C: N ratios (Figure 4. 4).

The soil organic matter content is 2.44 % (Figure 4. 4), which is higher than the amount usually occurring in South African soils (Table 4. 2, adapted from Bornman *et al.* 1989). The residues which form organic matter come mainly from a rich herbaceous layer of grasses, herbs, shrubs and trees (Anonymous, 2001 c). When present in sufficient amounts, soil organic matter improves the soil water holding capacity, increase cation exchange capacity and improves soil structure (Ahn, 1970; Buckman & Brady, 1969; Nye & Greenland, 1960; Jordaan, 1998). According to Smit (1999), soil under tree canopies has higher concentrations of nitrogen, soil organic matter, phosphate and exchangeable cations like potassium, magnesium and calcium compared to soil from open areas. This was not the case in the study sites with high bush densities (TE/ha). In some of these sites, wind and water erosion was evident and this has led to the eroding of the top soil, with consequent lower nutrient status.

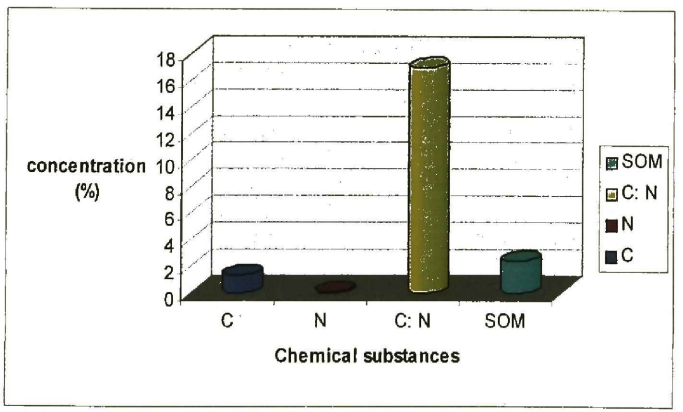


Figure 4. 4: Chemical composition of soils in Madikwe Game Reserve

The use of fire as a pasture management practice in Madikwe had an influence on soil fertility. According to Anonymous (2000), looking at the effect of fire on soil nutrient abundance, the general trend is an increase in nutrient availability. Mineral salts such as Ca, P, K and Mg often increase after a fire (Anonymous, 2001 b; Anonymous, 2000). Fire makes water-soluble cations immediately available for uptake by plants (Raison, 1979; Wright & Bailey, 1982). According to

Anonymous (2000) the only nutrients that show a decline at all after a fire are nitrogen and sulphur due to the volatilization of these nutrients at high temperatures. Anonymous (2001 b) reports an increase in total nitrogen after a fire. Nitrate levels also rise after a fire (Kramer, 1973; Christensen, 1976; Worcester, 1979). Burning increases total carbon and total nitrogen in the soil (Potter *et al.*, 2001; Li, 1998).

SOIL pH

The pH of soils in Madikwe Game Reserve is 8.08 (Figure 4. 5). Using the pH scale (Table 4. 3), it follows that soils in Madikwe Game Reserve are slightly alkaline.

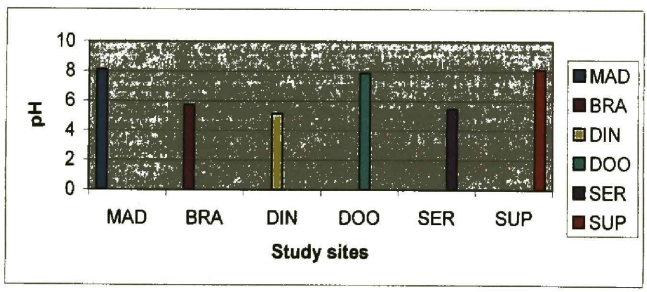


Figure 4. 5: pH of soils in the Zeerust District.

This alkalinity is as a result of excessive accumulation of basic cations - potassium, magnesium and calcium. The effect is base saturation which exceed the acceptable range for grasses (Table 4. 2). The base saturation of Madikwe Game Reserve soils is as high as 105.25 % (Figure 4. 6).

Base saturated soils influence veld palatability (Jordaan, 1998). The higher the base saturation, the more palatable is the veld. However, high base saturation of over 100 % is undesirable for plant growth. It indicates that there are free salts in the soil (Hattingh, 1998). Sites with high base saturation are located 24^0-50'16''S, 26^0 16' 41''E; 24^0 49' 30. 7" S, 26^0 16' 41.0'' E; 24^0 50' 17. 5'' S, 26^0 16' 07' E and $24^0$50' 35.5'' S, 26^0 16' 42.1" E (Table 4. 1). Due to high base

saturation, the acid saturation is low. According to Smit (1999), soils under tree canopies often exhibit higher pH values. A higher pH under canopies of savanna trees will enhance the availability of exchangeable cations.

Table 4. 3: The pH scale (Adapted from Anonymous, 1997)

pH	Inference
> 4.5	Extremely acidic
4.5-5.0	Very strongly acidic
5.1-5.5	Strongly acidic
5.6-6.0	Moderately acidic
6.1-6.5	Slightly acidic
6.6-7.3	Neutral
7.4-7.8	Slightly alkaline
7.9-8.4	Moderately alkaline
8.5-9	Strongly alkaline
> 9	Very strongly alkaline

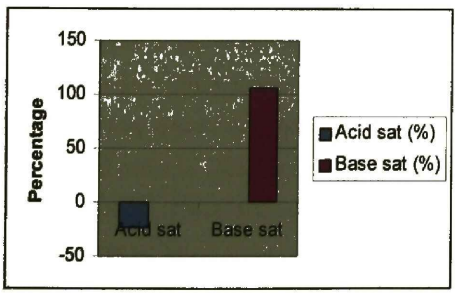


Figure 4. 6: Acid and base saturation of soils in Madikwe Game Reserve.

SOIL TEXTURE

The proportion of sand, clay and silt are indicated in Figure 4. 7. Local soils have a sandy-clay texture.

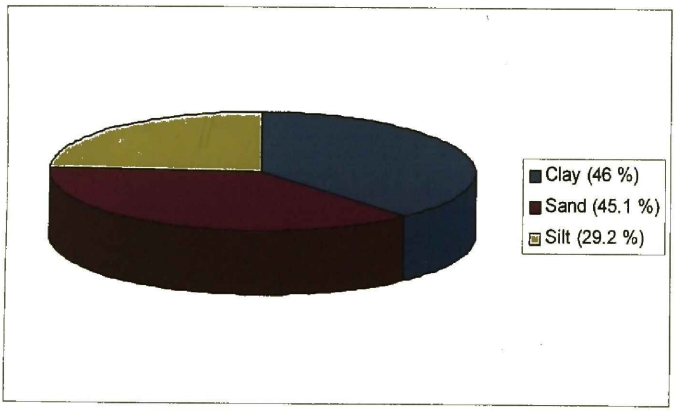


Figure 4. 7: Textural classes of Madikwe Game Reserve soils.

The clay content of the local soil is 46 % (Figure 4. 7). The cation exchange capacity (CEC) (Figure 4. 8) indicates that the principal clay present is montmorillonite (Bornman *et al.*, 1989). The CEC is 36.57 cmol(+)/kg (Figure 4. 8) in these soils. The CEC of a soil refers to the amount of negative charge on the colloids (clay and humus) in a specific soil (Bornman *et al.*, 1989). Apart from higher CEC's, montmorillonite clay has high cohesiveness. Cohesiveness is indicated by the high base saturation in these soils (Figure 4. 6), which occurs when basic cations cling to the colloidal particles. Montmorillonite clay has low stability and high shrinking and swelling capacity (Wrigley, 1981). Soils with a high clay proportion have a higher water holding capacity (Simpson, 1983). Much of the clay fraction has colloidal properties. Clay has negative electrical charges on its surface, which causes it to attract positively charged ions. The cationic plant nutrients are held by clay sufficiently strongly from being easily leached (Simpson, 1983; Anonymous, 2001 d).

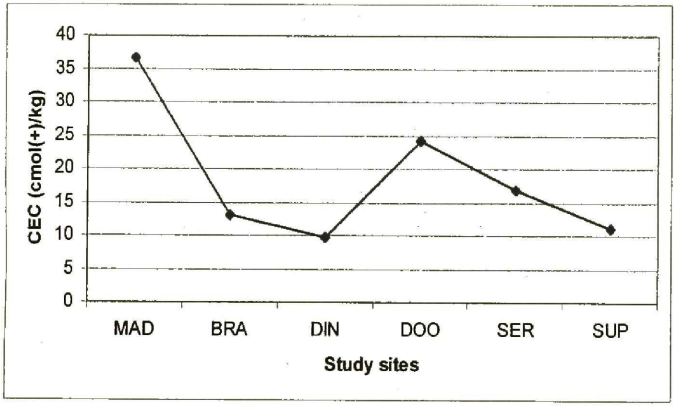


Figure 4. 8: Cation Exchange Capacity (CEC) of soils in the Zeerust District.

Plant roots can remove or absorb them so that they are available to the plant. The colloidal properties make clayey soils to retain water (Simpson, 1983). Soils in the Madikwe Game Reserve are characterized by high resistance (Figure 4. 9). A high resistance indicates that the soil has poor water-holding properties (Anonymous, 1997). The high resistance is due to the sandier texture of the soil. The sand content is 45.1 % (Figure 4. 7). As clay becomes wet, it becomes plastic, capable of moulding. It also becomes cohesive and leads to cultivation problems (Simpson, 1983).

According to Hartsock *et al.* (2002), there is a close correlation between soil texture and electrical conductance (EC). Clays greatly impact EC because of the exchange cations and water films associated with them. EC is the ability of materials to transmit or conduct an electric current (Doerge *et al.*, 2002). The conduction of electricity in the soil takes place through the moisture-filled pores between soil particles. The EC of the soil is, therefore, influenced by interaction among pore continuity, water content, salinity level, CEC, depth and temperature. EC also correlates to the CEC: the higher the EC, the higher the CEC (Anonymous, 2001 a; Moore & Wolcott, 2001). The electrical conductance (EC) of the local soils is 29.4 mS/m (Figure 4. 10).

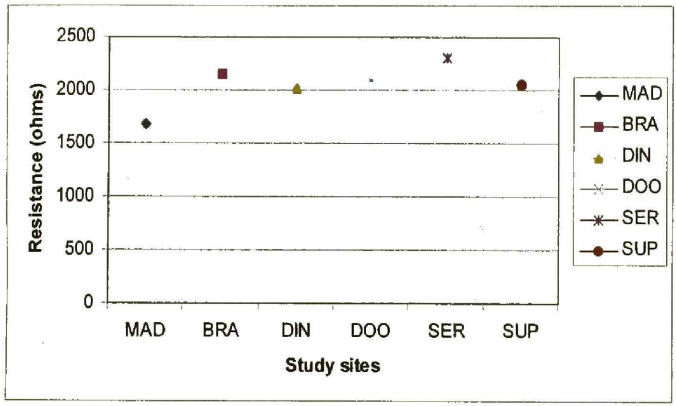


Figure 4. 9: Resistance of soils in the Zeerust District.

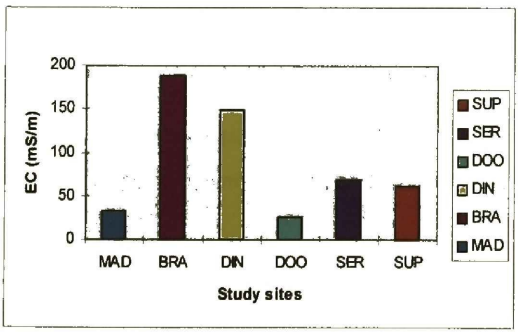


Figure 4. 10: The electrical conductance (EC) of soils in the Zeerust District.

BRAKLAAGTE

TABLE 4. 4: LOCATION OF SURVEY POINTS:

A total of 8 sample sites were monitored.

SITE NO.	SOIL SAMPLE NO.	LOCATION
1	19	25^0 21' 23. 6"S, 26^0 06' 11. 2"E
2	4	25^0 18' 24. 1"S, 26^0 07' 05. 0"E
3	5	25^0 20' 02. 6"S, 26^0 04' 10. 5"E
4	6	25^0 21'16. 5" S, 26^0 06' 00. 5"E
5	39	25^0 21'19. 18"S, 26^0 06 09. 2"E
6	24	25^0 18' 22. 0"S, 26^0 09' 06. 0"E
7	25	25^0 18' 04. 2"S, 26^0 05' 09. 5"E
8	26	25^0 21' 17. 6" S, 26^0 06' 02. 8"E

N.B: Soil samples were taken in areas with homogenous vegetation. Due to the inaccuracy of the GPS apparatus, some of the grid references are slightly off course from the original grid readings.

NUTRIENT COMPOSITION OF BRAKLAAGTE SOILS

The phosphorus content of the local soil is 3.40 mg/kg (Figure 4. 11). Because it is low, it cannot be seen well in Figure 4. 11. It is lower than that of Madikwe Game Reserve soils (3.72 mg/kg, Figure 4. 1).

Recent work in extensive savanna rangelands of Southern and Western Africa has shown that phosphorus is depleted in grazing lands. Phosphorus is deposited around water points where there is no vegetation (Smith, 2002). Phosphorus is one of the elements required in greater amounts for life on earth.

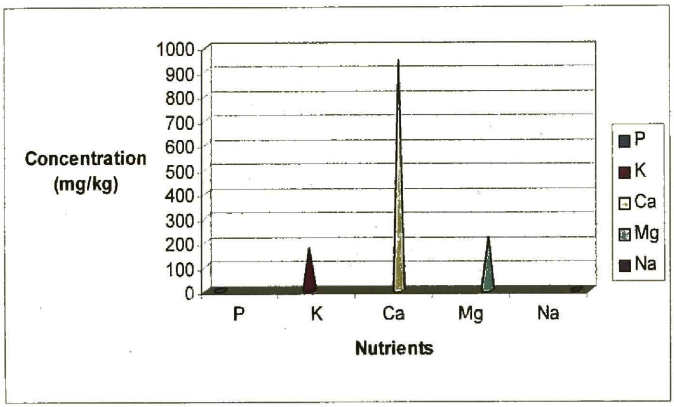


Figure 4. 11: Nutrient composition of Braklaagte soils

In the Kalahari Savanna of Botswana, phosphorus loss has been extensively found in areas subjected to 40 years of livestock use. As normal contents of phosphorus are very low in the Kalahari, any further loss may be enough to cause malnutrition in livestock. The increase in pH from liming acid soils increases phosphorus availability in phosphorus deficient soils (Whiteman, 1980).

Magnesium, calcium, potassium, sodium content (Figure 4. 11) and soil organic matter (Figure 4. 12) of the local soils are lower than in soils of the benchmark site (Figure 4. 1). Soil samples in Braklaagte were harvested in bare areas where trees have been uprooted by soil erosion. According to Smit (1999), soils in such open areas have lower content of these nutrients as compared to soil under tree canopies. This means the soils in Braklaagte are more chemically degraded than soils in Madikwe Game Reserve. Like in Madikwe Game Reserve, the local soil is not sodic because the SAR (Figure 4. 3) is below 1.

A portion of nutrients in the local soils has been lost through run-off and erosion. When this occurs, the remaining portion becomes concentrated into fertile islands (Schlesinger *et al.*, 1990;

Whitford, 1995). This pattern of distribution of resources results in reduced nutrient concentration, limited micro-organism abundance and activity for the whole area. Grazing animals have stripped the land of vegetation and exposed the soil to water erosion. More than 30 % of the ground surface is not covered by vegetation (Figure 3. 6). Topsoil has been lost and some of the trees were uprooted and the roots exposed. This is called sheet erosion (Goudie, 1990; Webster & Wilson, 1980). During this survey, the process of erosion had extended to gully erosion. The water deepened the gully. The increasing water velocity further increased erosion by means of which the gully deepened its way up the slope to the top of the watershed. The deepening of the bed led to under-cutting and caving-in of the banks. As the material was rapidly washed away, vertical banks were left to be under-cut by the next floods.

Degradation of the soil is more serious in the sense that it will be expensive to restore these sites. The soil regeneration processes are predominantly slow and often irreversible (El-Hinnawi & Hashmi, 1982; Sombroed & Sene, 2000). The most important single factor affecting run-off erosion is the nature and amount of vegetation cover of the land (El-hinnawi & Hashmi, 1982). While land remains under undisturbed or grass, its surface is protected from the impact of rainfall (Webster & Wilson, 1980). The good structure of the topsoil is combined with presence of leaf litter and allows a high proportion of rainfall to infiltrate so that there is little run-off (Goudie, 1990; Webster & Wilson, 1980).

Due to degraded soil structure, the local grassveld has a limited capacity to produce enough fodder for livestock grazing. 15 grass species occur in the grasslands in Braklaagte (Chapter 3, Figure 3. 5 and Figure 3. 6), with a frequency of 67 %. None of the perennial grasses exceed a frequency of 20 % (Figure 3. 5), which indicates 'poor' veld condition. The phase of veld retrogression evident in Braklaagte is called the primary depopulation phase, which is characterized by poor soil cover so that active soil erosion take place (Tainton, 1999). Heavy overgrazing caused nutrient stress on domestic livestock. This is especially the case in areas where there is non-subsistence economy (Seligman & Perevolotsky, 1994; Seligman, 1996). Maintenance of economic viability of animal production under heavy grazing usually requires appropriate supplement and breeding schemes (Landau *et al.*, 1995). Clearing woody species,

dominated by *Acacia tortilis,* resulted in an improvement in the grazing capacity from 9. 1 ha/animal unit to 7. 3 ha/animal unit in a mixed savanna (Smit, 1999). In the Kalahari Thornveld a reduction in tree density improved grazing capacity from 45. 8 ha /animal unit (230 kg grass dry matter per hectare) to 8.7 ha/animal unit (1 200 kg grass dry matter per ha) (Smit, 1999). This difference may be ascribed to soil type and soil fertility, which are considered important determinants of the magnitude of increased grass production after tree thinning. In years of higher rainfall, higher grass yields are attained in thornveld on relatively fertile soils than in sandveld on nutrient poor soils.

The carbon and nitrogen content in local soils (Figure 4. 12) are lower than that of benchmark site (Figure 4. 4). The biological potential of the site may be diminished (Verstraete, 1986) or destroyed altogether by significant nett loss of C and N resources. Disturbance generally produces an initial decrease in total C and basal respiration. The most evident disturbance is overgrazing as indicated by bare patches. The ratio and metabolic quotient tend to increase immediately following disturbance and then to decrease gradually during recovery.

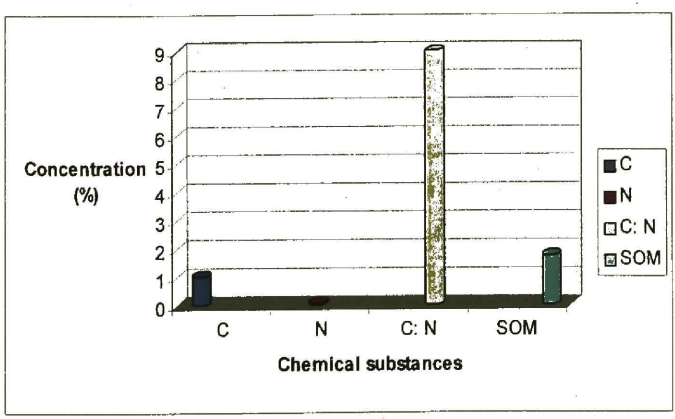


Figure 4. 12: Chemical composition of Braklaagte soils.

Sites located at 25^0 20' 02.2''S, 26^0 04' 10.5''E were invaded by woody species during the survey. There was an increased carbon content and nitrogen content compared to other local sites. Prominent woody species observed include *Acacia tortilis, A. karroo, A. nilotica, Ziziphus mucronata* and *Maytenus polyacantha.* When herbaceous vegetation is replaced by woody vegetation, there is carbon and nitrogen accumulation in the local soil (Archer *et al.*, 2000 a; Johnson *et al.*, 2001). Woody species have transformed the grassland into savanna, and this process leads to the transformation of savannas into dense shrublands. At this rate, the potential to alter land surface-atmosphere interactions and carbon and nitrogen sequestration and cycling at regional and global scales may be significant (Archer *et al.*, 2000 a). Burning increases total carbon and total nitrogen in the soil (Potter *et al.*, 2001). Veld burning is one of the practicable management strategies applied in Madikwe Game Reserve. This explains why soils in Madikwe Game Reserve have a carbon and nitrogen content that are higher than in the soils in Braklaagte.

During the last century, the plant communities of large proportions of southwest United States have changed from grassland to shrubland (Buffington & Herbel, 1965; Grover & Musick, 1990; Schlesinger *et al.*, 1990; Virginia *et al.*, 1992). This transformation in the landscape has been variously attributed to drought, overgrazing, fire suppression, increasing density of rodents or the interaction of these factors (Grover & Musick, 1990; Schlesinger *et al.*, 1990). Regardless of the cause, Schlesinger *et al.*, (1990) have hypothesized that the transition from grassland to shrubland resulted in a redistribution of soil resources such that they became concentrated in patches favoring establishment of woody species. In grasslands and shrublands, resources are concentrated in patches associated with vegetation that is surrounded by resource-depleted bare ground (Hook *et al.*, 1991). Vegetation is more distributed spatially within grasslands, and the relative difference between resource concentration under plants versus bare ground is less in grasslands than in shrublands (Schlesinger *et al.*, 1996).

The C: N ratio (Figure 4.12) of the local soils is narrower than in Madikwe Game Reserve soils (Figure 4. 4). This indicates that the soil has been greatly disturbed (Bornman *et al.*, 1989). Plant materials are composed mainly of carbon, proteins and fats with smaller amounts of lignin, waxes and resins. The carbohydrates are composed of sugars, starch, hemicellulose and

cellulose. These are decomposed by the soil fauna to provide their energy. Proteins are decomposed to amino acids mainly to provide body tissue of the organisms and also for the various nitrogen transformations that take place. These processes cause a gradual narrowing of C: N ratio (Fitzpatrick, 1986).

The soil condition in Braklaagte, therefore, is 'bad' in terms of sustaining livestock production and resistance against soil erosion. This decline in soil fertility and retrogression of the herbaceous layer accelerate desertification. According to the United Nations Environmental Programme (UNEP) World Atlas, overgrazing is the most common cause of desertification worldwide (Smith, 2002). A common misconception about desertification is that it spreads from a desert core like a ripple in a water pond. The absence or presence of a nearby desert has no direct relation to desertification (Smith, 2002).

Desertification begins as a spot on the landscape (which can be around water points or in a cultivated field) where irrational land-use has become excessive (Dregne, 1986). In Braklaagte, land degradation is likely to cause desertification if the irrational use of rangelands continues. Although the residents in Braklaagte stated that degradation has been caused by droughts that hit the area around the 1980 's, according to Dregne (1986), this is a misconception. Droughts do increase the likelihood that the rate of degradation will increase on non-irrigated land if the carrying capacity is exceeded. Well-managed land will recover from drought when the rains return. The detrimental combination is irrational land-use during good periods and its continuation during the periods of deficient rainfall (Dregne, 1986).

Land degradation is by no means a new problem despite the attention focused on it in recent years. Desertification in Africa and elsewhere began long before the 1969-1973 drought struck the Sahel. These droughts were so severe that the world's attention became focused on the human aspects of land degradation and led to the convening of the 1977 United Nations Convention to Combat Desertification. Drought only placed additional stress on the biological resources (Dregne, 1986). Due to the increasing sedentary pastoralists, pressures on cultivated land led to a shortening of fallow period in the shifting cultivation cycle, and cultivation was

extended to more precarious drier regions. Crop harvests became less reliable and more variable. Concurrently pastoralists were deprived of some of their best grazing lands as the cultivators moved in (Delwaulle, 1977). This led to increase in population and livestock. The provision of improved veterinary services and the lack of a viable market system helped assure that animal numbers grow rapidly (Widstrand, 1975). The result was inevitable: overgrazing and accelerated desertification.

SOIL pH

Unlike Madikwe Game Reserve which is characterized by alkaline soils (Figure 4. 5), the pH is low, forming moderately acidic soils (Figure 4. 5). Low pH values are undesirable because a number of nutrients may be affected (Fitzpatrick, 1986). The exchange cations including calcium decreases as pH decreases (Whiteman, 1980). The deficiency of calcium causes chlorosis in plants, causing plants to die, and thereby accelerating veld retrogression. The influence of pH on plant growth is indirect and results from the imbalance of nutritional elements (Wrigley, 1981). Unlike in Madikwe Game Reserve where base saturation exceeds 100 % (Figure 4. 6), local soils are characterized by a lower base saturation (Figure 4. 13). The acidic saturation (Figure 4. 13) is higher than soils of the Madikwe Game Reserve (Figure 4. 6).

The acid saturation of 58.3 % is higher than the acceptable limit (Table 4. 2) and has a negative effect on plant growth. Soil of the site located at 25^0 20' 02.2"S, 26^0 04' 10.5"E has a neutral pH. None of the soil samples sampled in Madikwe Game Reserve has a neutral pH. When the soil reaction (pH) is around the 'neutral' point, all minerals are sufficiently available to satisfy the plant requirements (Tivy, 1982). There is also enough calcium to counteract acidity, maintain the stability of clay-humus complex and promote crumb structure (Tivy, 1982). In this soil however (refer to Figure 4.11), some nutrients such as calcium, potassium and magnesium are present in lower concentration compared to the soil in the benchmark sites.

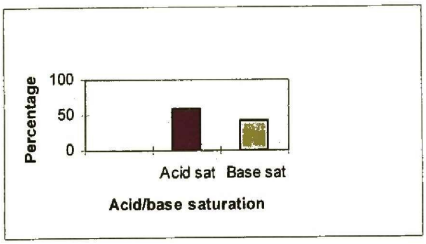


Figure 4. 13: Acid and base saturation of Braklaagte soils.

SOIL TEXTURE

The local soils have up to 39.4 % proportion of silt (Figure 4. 14). According to Simpson, (1983), medium textured soils with high silt content are vulnerable to erosion. This explains why there has been heavy erosion that resulted in the formation of gullies. Silty-clay soils are slightly gritty, moderately smooth, very sticky and plastic. It also forms extremely cohesive balls and long threads which bend into rings easily (Fitzpatrick, 1986). Silty-clays are cold and slow to warm up in spring (Simpson, 1983). The cold-wet conditions, especially at the time of seedling emergence cause slow penetration of the soil by the roots.

This restricts the amount of nitrogen taken up, and could be one of the reasons why there is a nitrogen deficiency in local soil. Textural classes in local soils include clay, silty clay, sandy clay, clay loam, sandy clay loam and loam soils. There are no silty-clay and loam soils in Madikwe Game Reserve (Refer to Figure 4. 7). According to Bahre and Shelton (1993) and Berger and Iams (1996), silt and clay contribute to the EC of a soil. The clay content is 35 % (Figure 4. 14). The soil has EC higher than in Madikwe Game Reserve (Figure 4. 10) due to the high content of silt-clay proportion. The CEC of Braklaagte soil is lower than that of soils in Madikwe Game Reserve (Figure 4. 8). This means Madikwe Game Reserve soils have a greater potential to hold plant nutrients than the soil in Braklaagte. Based on the CEC, it follows that the mineral clay present is kaolinite.

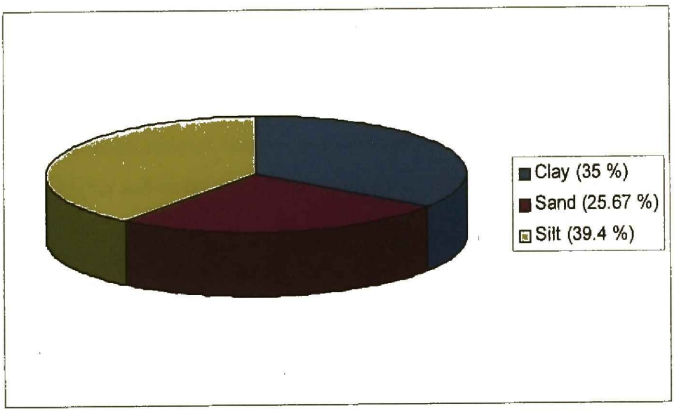


Figure 4. 14: Textural classes of Braklaagte soils

Kaolinite clay has flat crystal flakes roughly hexagonal in shape. These flakes are built up of double layers, one of silica lattice, and the other an aluminium lattice, bonded together by shared oxygen atoms. Each of these double layers is held to the next by hydroxyl ions at smaller and fairly constant distances in a non-expanding lattice. Kaolinite is formed from the weathering of feldspars (Wrigley, 1981). Like in other types of kaolinite clays, local soils have poor water holding capacity as shown by the high resistance. Resistance of these soils is over 2 000 ohms and is higher than that of soils in Madikwe Game Reserve (Figure 4. 9). Nutrient elements cannot be taken up in adequate amounts as a result of leaching. The plants then suffer a reduction in the quality and quantity of vegetal material produced (Macvicar, 1999). There is a lower frequency of grass species in this grassveld compared to benchmark sites (Chapter 3).

High resistance indicates reduced soil moisture content. According to Anonymous (2001 e), there is a reduction in soil moisture availability accompanying woody plant invasion. There is invasion of woody species, which include *Acacia tortilis, A. karroo, A. nilotica, Ziziphus mucronata* and *Maytenus polyacantha.* Aguiar *et al.* (1996) found that an increase in woody plant cover correlated with a decrease in total transpiration. The conclusion suggested that grassland–shrubland transition would result in a decrease in the transpiration rate, and therefore,

in the amount of water absorbed from the soil that is lost to the atmosphere. It was found from these studies that water evaporation decreased as the density of woody plants increased (Aguiar *et al.*, 1996). In another study in Texas rangelands, Carlso *et al.* (1990) found that in plots with just herbaceous material, there was higher soil water content than plots with herbaceous material have a higher soil-water content than plants with a mixed vegetation structure.

DINOKANA

TABLE 4. 5: LOCATION OF SURVEY POINTS:

A total of 5 sample sites were monitored.

SITE NO.	SOIL SAMPLE NO.	LOCATION
1	14	25^0 25' 32.25"S, 25^0 50' 44.7"E
2	15	25^0 27' 50'.0'S, 25^0 54' 02.8"E
3	34	25^0 25' 22.8"S, 25^0 50'42.6"E
4	35	25^0 27' 49.5"S, 25^0 54' 01.6"E
5	41	25^0 29' 37.0"S, 25^0 55' 55.0"E

NUTRIENT COMPOSITION OF THE SOILS IN DINOKANA

According to Figure 4. 15, the local soil has phosphorus, potassium, calcium and magnesium content that are lower than in Madikwe Game Reserve soils (Figure 4. 1). Compared to benchmark sites, local sites have been exposed to erosion. The process of leaching is depleting some of the ions, making them to be available in non-acceptable quantities (Bornman *et al.*, 1989). This deficiency of nutrients indicates a decline in soil fertility and thus, influences veld retrogression. This data correlates with that of vegetation surveys as evidenced by species composition of 13 grasses (Figures 3. 8 and figure 3. 9) forming a frequency of 54.9 % (Section

3. 3, Chapter 3). Soil organic matter content (Figure 4. 16) is lower in local soils compared to that of the soils in Madikwe Game Reserve (Figure 4. 4).

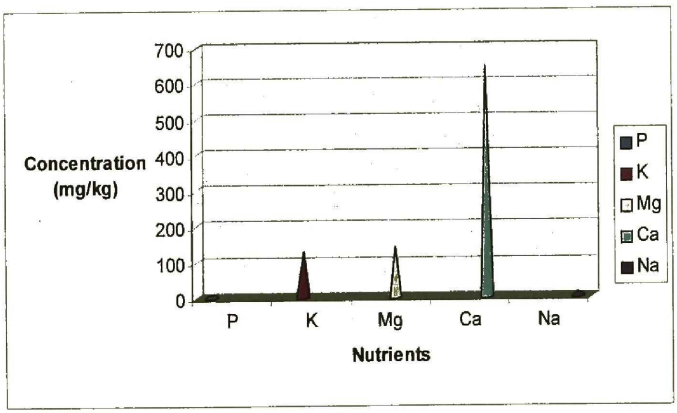


Figure 4. 15: Nutrient composition of Dinokana soils.

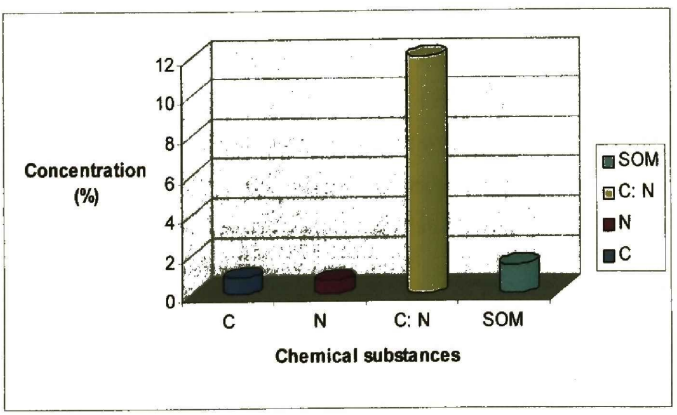


Figure 4. 16: Chemical composition of Dinokana soils.

One of the factors which deplete SOM is severe denudation due to overgrazing. The ground surface is denuded in Dinokana grazing lands, with a bare ground of 45. 1 % (Figure 3. 9, section 3. 3 Chapter 3). The nett result of overgrazing is a decline in the quantity of soil organic matter (Archer *et al.*, 2000 a; Simpson, 1983). The rate of soil organic matter loss is influenced by soil temperature, aeration and availability of water. If organic matter losses from cultivated soils lead to critically low organic matter contents varying between 1-3 %, serious management problems can occur in soils of all texture groups (Simpson 1983).

The carbon: nitrogen ratio (Figure 4. 16) falls below those of soils in Madikwe Game Reserve (Figure 4. 4). This indicates that local soil is virgin soil, not disturbed by cultivation. The local soils have no sodium hazard because the SAR is below 1 (Figure 4. 3).

SOIL pH

Local soils are characterized by pH values (Figure 4. 5) which are lower than in soils of Madikwe Game Reserve (Figure 4. 5). According to Figure 4. 5, the pH is 5.11, indicating that these soils are strongly acidic. This acidity is due to the deficiency of basic cations. Soil acidity does not fall below 6 in Madikwe Game Reserve soils. Such low pH values are detrimental to the activity of beneficial micro-organisms (Bickelhaupt, 1993; Brady & Weil, 1996). The bacteria are hindered from breaking soil organic matter (Yayock *et al.*, 1988; Townsend, 1973; Bornman *et al.*, 1989; Landon, 1991). This results in an accumulation of undecomposed organic matter and the tie-up of nutrients. The soil organic matter also increases acidity of a soil (Fitzpatrick, 1986).

Parent materials that gave rise to the formation of the acidic soils in Dinokana are acidic igneous rocks and sedimentary rocks. The acidic igneous rocks have low calcium, and magnesium content (Ludick, 1998). These nutrients are deficient in local soils (Figure 4. 15). Sedimentary rocks could have high potassium but shortages of phosphorus and trace elements are common. The local soils have a high acid saturation of 61 % (Figure 4. 17). The base saturation is not above 100 % and is lower than that of Madikwe Game Reserve soils (Figure 4. 6). Although acidity is an important factor in the availability of plant nutrients, many chemical compounds

found in strongly acidic solutions of soil cause toxicity (Courtney & Trudgill, 1984). Strongly acidic soils result in the precipitation of phosphorus by colloidal fractions forming insoluble aluminium and ferric compounds that are toxic to plants (Townsend, 1973; Simpson, 1983; Landon, 1991). Strongly acidic soils give rise to calcium and phosphorus deficiency with a resultant unpalatable veld (Jordaan & Thiart, 1998). This is reflected in Figure 4. 15.

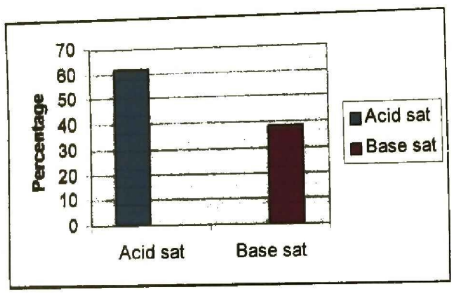


Figure 4. 17: Acid and base saturation of Dinokana soils.

Plants that survive in very strongly acidic soil types have adopted a number of physiological strategies, such as reduced transpiration (Courtney & Trudgill, 1984). This reduces the throughput of water in the plant and therefore reduces uptake of water-soluble elements (Courtney & Trudgill, 1984). In strongly acidic conditions, the vegetation may become yellow and stunted (Jordaan, 1998).

SOIL TEXTURE

Local soils have a silt content of 30.85 % (Figure 4. 18) that is higher than in Madikwe Game Reserve soils (29.2 %, Figure 4. 7). As a result, soils have a higher EC than in the soils of Madikwe Game Reserve (Figure 4. 10). The local soil textures include loam, sandy-clay loam, clay loam and sandy loam. The CEC indicates the presence of kaolinite clay. Kaolinite is characterized by lower water holding capacity and is indicated by high resistance of the local soil (Figure 4. 9). These textural classes are from sedimentary rocks. Sandy red soils occur at 25^0 27'

50"S, 25^0 54' 02.8"E of the site. These soils are derived from these rock formations. The inherent fertility status is low due to low base saturation is low and soil acidity is a problem.

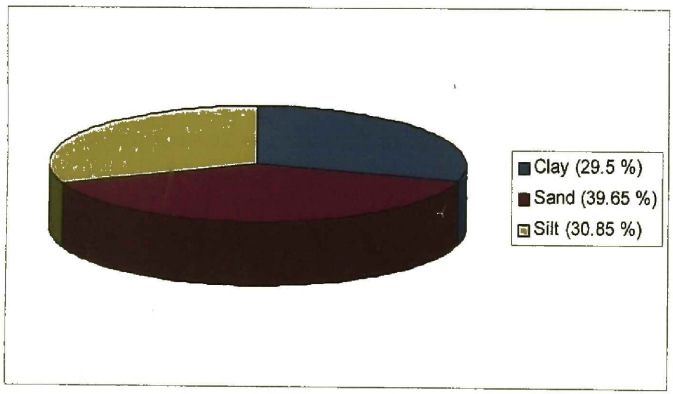


Figure 4. 18: Textural classes of Dinokana soils.

The veld derived from these parent materials is inclined to be unpalatable due to the low base status being moderate to low. Palatable grasses do occur locally (Chapter 3), but have been overutilised as shown by low frequencies. Such overgrazed or abused veld always gives the impression that it is a sourveld and is unpalatable (Ludick, 1998).

Local soils have higher resistance compared to soils in Madikwe Game Reserve (Figure 4. 9). This indicates physical degradation of the soil, and influences veld retrogression. Water is essential for normal plant growth and makes up a large percentage of the weight of the plant (Herrera & White, 1994). As soil moisture is depleted, soil moisture tension increases and it becomes more difficult for the plant to extract nutrients. Soil moisture tension is a measure of the energy or force by which water is held by the soil. Although plants can withdraw moisture up to the permanent wilting point, their growth usually declines because signs of permanent wilting occurs. In order to obtain good results and growth, soil moisture must be made available above the wilting point.

Rainfall is the main source of water in Dinokana. The rainwater is not efficiently absorbed by the soil for use by plants as shown by high resistance. Instead, most of the water is lost as runoff. As a result, rainfall has contributed to the removal of a layer of relatively good pasture and organic matter. Webster and Wilson (1980) refers to this damage as 'sheet' erosion. The term 'splash' erosion is preferred because of the effect of the raindrops in breaking the soil aggregates into smaller, more easily transportable particles. Splash erosion progressed and formed small channels in which run-off water concentrates, giving rise to rill erosion. These channels have widened due to the volume and velocity of water, resulting in the formation of gullies (Webster & Wilson, 1980).

During the survey, the ground surface was hard and compacted. Soil texture is also important in determining the potential for soil compaction. Soil compaction is another form of physical degradation (Sombroed & Sene, 2000). According to Chad (2001), compaction is simply the increase in bulk density. Coarse-textured soil bulk densities are not affected by grazing intensity. Bulk density increases with grazing intensity on fine-textured soils (Chad, 2001). This means there must be a greater awareness for the effects of overgrazing on soils with a high clay fraction. During the survey, cattle, goats, sheep and donkeys were grazing on the site. There is no soil erosion in the sites studied in Madikwe Game Reserve.

DOORNLAAGTE

A total of 8 sample sites were monitored.

TABLE 4. 6: LOCATION OF SURVEY POINTS:

SITE NO.	SOIL SAMPLE NO.	LOCATION
1	10	25^0 14' 40.15"S, 26^0 19' 18.7"E
2	11	25^0 14' 08.5"S, 26^0 19' 30.4" E
3	12	25^0 10' 42.5"S, 26^0 19' 22.7"E
4	13	25^0 20' 02.6"S, 26^0 19' 22.7"E
5	30	25^0 14'39.0.13"S, 26^0 17' 19.4"E
6	31	25^0 14' 09.5"S, 26^0 20' 31.2" E
7	32	25^0 10' 40.5"S, 26^0 18' 21.8"E
8	33	25^0 20' 03.6"S, 26^0 18' 20.6"E

N.B.: Some of the grid references of some soil samples are slightly off course from the original readings due to the inaccuracy of the GPS apparatus.

NUTRIENT COMPOSITION OF DOORNLAAGTE SOIL

Phosphorus and calcium contents of the local soils (Figure 4. 19) are lower than in Madikwe Game Reserve soils (Figure 4. 1), while there is accumulation of magnesium, sodium and potassium (Figure 4. 19). High calcium and magnesium contents result in high CEC's (Bahre & Shelton, 1993; Landon, 1991). The EPP (Figure 4. 2) is within acceptable limits indicating that there is efficient potassium exchange between the soil solution and the plants. The local soil has no sodium hazard because the SAR is below 1 (Figure 4. 3)

The new government handed Doornlaagte to the local inhabitants in 1996. Prior to this relocation, the major land-use pattern was commercial arable farming. Excessive fertilization

with materials rich in calcium and magnesium resulted in the build-up of these nutrients. Calcium build-up can result in the formation of excess calcium carbonate (Brady & Weil, 1996). The high concentration of calcium in the soil horizon is not conducive to optimum root growth for many crops. Where carbonate concentrations are found at or near the soil surface, which is often the case in areas of low rainfall, serious micronutrient deficiencies can result for plants that are not adapted to these conditions (Brady & Weil, 1996). If the local inhabitants wish to reclaim it back for arable farming, additional fertilization for phosphorus build-up will be required. Phosphorus will then, not be limiting for crops such as grains and vegetables (Bornman *et al.*, 1989). These are the most common type of arable agricultural crops in the Zeerust District.

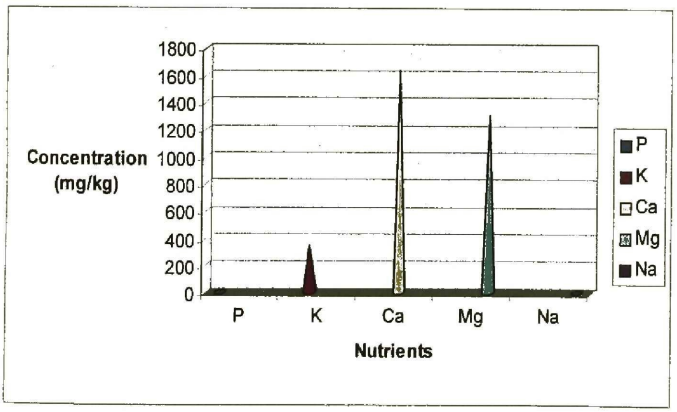


Figure 4. 19: Nutrient composition of Doornlaagte soils.

The soil organic matter (SOM) content of 2.1 % (Figure 4. 20) is lower than that in Madikwe Game Reserve (2.44 %, Figure 4. 4). The soil organic matter has promoted higher plant productivity in local soils. The result has been a thick herbaceous layer of grasses (Figure 3. 10, Chapter 3) which forms a frequency of 100 %, and the site has minimal bare patches (Figure 3. 12). According to Bornman *et al.* (1989), Bloem (1998), Tainton (1999), Ellerbrock *et al.* (2001) and Diels *et al.* (2001), soil organic matter increases the water-holding capacity of the soil. Local soils have wide C: N ratio (22: 1 in Figure 4.20) than soils in Madikwe Game Reserve (Figure 4.

4). According to Russel (1973), the C: N ratio may be as high as 17:1 in wetter or more poorly drained soils and acidic conditions.

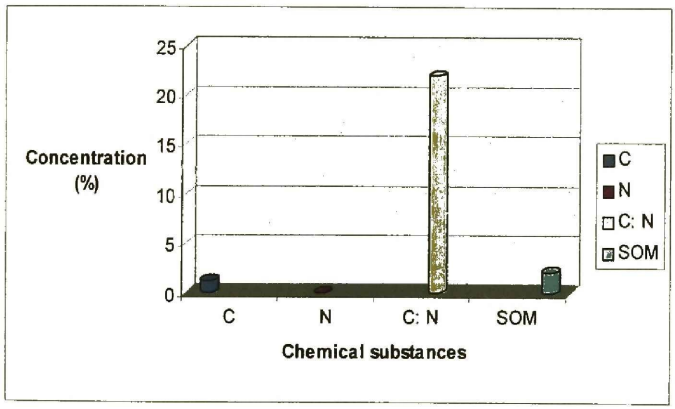


Figure 4. 20: Chemical composition of Doornlaagte soils.

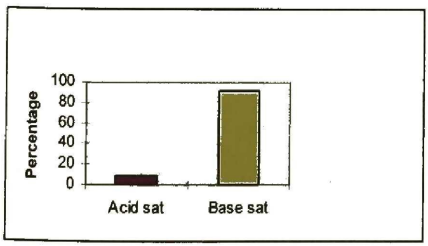


Figure 4. 21: Acid and base saturation of Doornlaagte soils.

SOIL pH

The pH value (7.87 in Figure 4. 5) indicates moderately alkaline soils. Soil alkalinity indicates good nutrient holding capacity. Unlike in Madikwe Game Reserve where soils are characterized by base saturation which exceed 100 % (Figure 4. 6), the base saturation of local soils fall within

acceptable limits (Figure 4. 21). Acid saturation is 8.8 % (Figure 4. 21) and is acceptable for plant growth. Leaching of nutrients has made soils occurring 25^0 14' 40.15"S, 26^0 19' 18.7"E and 25^0 14' 08.5"S, 26^0 19' 30.4" E to be moderately acidic.

SOIL TEXTURE

Soils occurring locally are grey and black in colour. The black colour indicates the presence of clay (Jordaan & Thiart, 1998). The black clay soils usually come from Arcadia, Rensburg, Bonheim, Milkwood and Willowbrook parent materials. The proportion of clay is 45 % in local soils (Figure 4. 22).

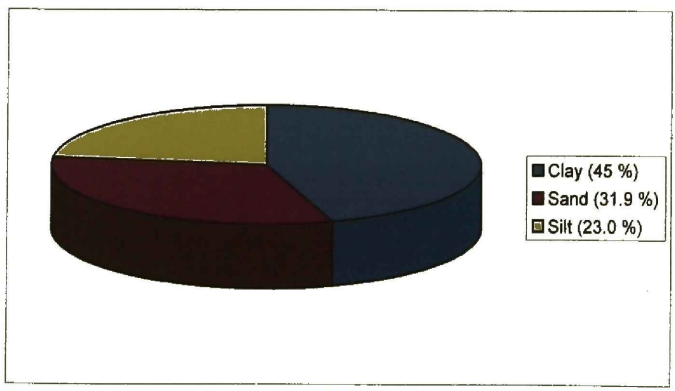


Figure 4. 22: Textural classes of Doornlaagte soils.

The sites where clay soil is most evident are located at 25^0 14' 08.5"S, 26^0 19' 30.4" and 25^0 10' 42.5"S, 26^0 19' 22.7"E. Moving towards 25^0 14' 40.15"S, 26^0 19' 18.7"E, sandy-clay loam and clay loam soils can be found.

According to Jordaan and Thiart (1998), the grey colour of a soil is an indication of excess water during the rainy season. The sand helps the soil to absorb water more rapidly and can make use of high intensity rain showers. In this way, the soil becomes easily oversaturated with water.

The local soils have resistance that are higher than that of soils of Madikwe Game Reserve (Figure 4. 9). This indicates that, unlike Madikwe Game Reserve soils, these soils loose substantial amount of water through leaching. This indicates physical degradation of the soil. During the process of leaching, nutrients sieve through the lower soil profiles and become deficient. This means that nutrients cannot be firmly held to the colloidal particles. The CEC indicates the presence of illite and kaolinite clay. Kaolinite clay in these soils is characterized by low cohesiveness. The higher the EC, the higher the yield (Anonymous, 2001 a; Moore & Wolcott, 2001)

SERAKE

TABLE 4. 7: LOCATION OF SURVEY POINTS:

A total of 9 sample sites were monitored.

SITE NO.	SOIL SAMPLE NO.	LOCATION
1	18	25 ^{0} 09' 29.3"S, 25^0 53' 44.0" E
2	1	25 ^{0} 09' 28.3"S, 25^0 53' 42.2" E
3	2	25 ^{0} 08' 42.4"S, 25^0 58' 47.8"E
4	3	25^0 02' 28.3" S, 25^0 55' 45.4"E
5	38	25^0 09' 18.1"S, 25^0 57' 11.2" E
6	21	25^0 09' 28.0"S, 25^0 53' 42.2" E
7	22	25^0 08' 42.0"S, 25^0 58' 48.0"E
8	23	25^0 03' 08.3" S, 25^0 55' 59.8"E
9	42	25^0 02' 14.3" S, 25^0 05' 40.4"E

NB: The exact locations of these reference points are slightly off course due to the inaccuracy of the GPS apparatus. However, soil samples were taken from soils with homogenous vegetation.

NUTRIENT COMPOSITION OF SOILS

Phosphorus, sodium, potassium, calcium and magnesium contents locally (Figure 4. 23) are lower than in Madikwe Game Reserve soils (Figure 4. 1). According to Simpson (1983) and Landon (1991), phosphorus deficiency is caused by combination of phosphorus with iron and aluminium compounds that are not readily available to plants. Like in Madikwe soils, this soil has no sodium hazard because the SAR is below 1 (Figure 4. 3). EPP falls within the acceptable range (Figure 4. 2). This indicates that potassium dominates other ions during the adsorption and exchange at the clay-humus exchange complex (Simpson, 1983).

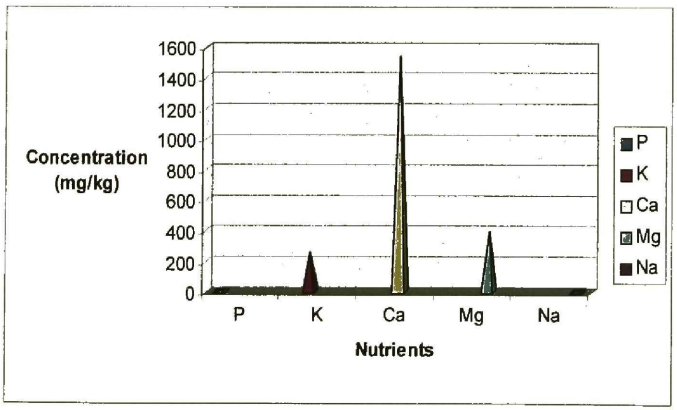


Figure 4. 23: Nutrient composition of Serake soils.

The carbon and nitrogen content in local soils (Figure 4. 24) are lower than in soils of Madikwe Game Reserve (Figure 4. 4). One of the factors contributing to the low C content is the absence of burning (Briggs & Courtney, 1985; Potter *et al.*, 2001). Soils occurring at 25 ^{0} 09' 29. 3" S, 25^{0} 53' 44.0" E have a slight carbon accumulation compared to other local sites. These soils are characterised by wider C: N ratios (Figure 4. 24). The wider ratio indicates a greater accumulation of carbon in relation to nitrogen.

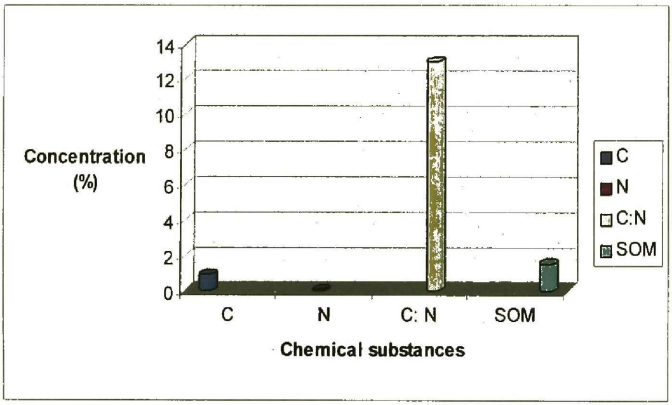


Figure 4. 24: Chemical composition of Serake soils.

There is invasion of woody species in local grassvelds. The encroaching tree species are *Acacia karoo, A. mellifera* and *A. tortilis.* When herbaceous vegetation is replaced by woody vegetation, there is carbon and nitrogen accumulation into the soil (Archer *et al.*, 2000 b). Narrow C: N ratio occurs particularly in soils located at 25^0 09' 28.3"S, 25^0 53' 42.2" E. This indicates that these soils are not disturbed by cultivation, that is, they are virgin soils (Bornman *et al.,* 1989).

The La Copita case study (Archer *et al.*, 2000 b) clearly indicates this bio-geochemical consequence of woody plant expansion. In this study, soil and plant carbon mass have increased 10% and 10-fold, respectively, with succession from pre-settlement savanna grassland to present-day savanna woodland over the past 100 years. Ecosystem carbon storage will continue to increase as present-day woody vegetation communities mature and expand into the remaining herbaceous areas. Increases in ecosystem carbon mass are accompanied by increase in soil nitrogen pools. Increases in carbon and nitrogen pools occur in spite of nitrogen mineralisation, nitrogen oxide fluxes, soil respiration, and non-methane hydrocarbon emissions. Invasion of woody plants on high-clay content soils is very slow (Archer *et al.*, 2000 b). These results are of potential global significance, given that large areas of South Africa have been undergoing similar land-cover changes over the past century (Archer *et al.*, 2000 b). Carbon values of soil organic

matter afford a direct and powerful technique for reconstructing vegetation change in the affected areas (Boutton, 1999). The demonstrated capacity for carbon sequestration in this semi-arid system suggests the need to re-evaluate traditional perspectives on woody plants in rangelands as governments and industries seek ways to mitigate greenhouse emissions (Archer *et al.*, 2000 b)

Soil degradation influences the state of grass species composition in the grasslands in Serake. Results of vegetation surveys indicate a poor soil cover (Figure 3. 15, Chapter 3). A larger portion of the ground surface is not covered by vegetation, and this accelerates soil erosion and is an indication that local grasslands are susceptible to desertification. Reduction in plant cover results in reduction in plant nutrients in the soil and plant productivity eventually drops (Anonymous, 2002). Many factors contribute to the destruction of land by desertification.

Another cause of desertification is deforestation. Trees hold the soil together and help to water the land by channelling rainwater into the soil. When they are chopped down, the soil is eroded by the elements and is unable to hold water. There were chopped down trees and the grasses were heavily grazed in Serake. During the survey, some of the local inhabitants were seen with wheelbarrows and axes, searching for suitable poles to be used as building material. The high extent of denudation is a sign of desertification.

SOIL pH

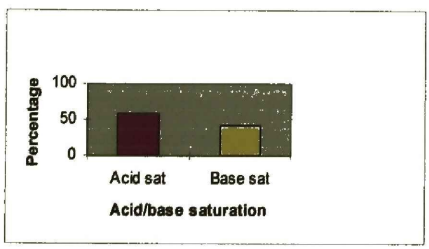


Figure 4. 25: Acid and base saturation of Serake soils

Figure 4. 5 indicates that local soils are moderately acidic with a pH of 5.25 (refer to Table 4. 3). Acidity has a pronounced effect on many micro-organisms affecting aspects of fertility. Liming of acid soils increase soil organic matter decomposition and releases N and possibly sulphur and phosphorus. Plant disease incidences may be affected by soil pH. The broader adaptability of fungi to acid conditions makes fungal disease more prevalent under acid conditions and less so after liming (Whiteman, 1980). The local soils have an acid saturation of 59.2 % (Figure 4. 25) which is higher than that of soils in Madikwe Game Reserve (Figure 4. 6). However, soils occurring at 25^0 09' 18.1"S, 25^0 57' 11.2" E are characterised by high base saturation of over 100 % like in Madikwe Game Reserve (Figure 4. 6). This confirms chemical degradation of the local soil.

SOIL TEXTURE

Based on the proportion of sand, clay and silt (Figure 4. 26), local soils can be classified as sandy-clay-loam soils. However, clay and clay-loam soils also occur. The site located 25^0 02' 28.3" S, 25^0 55' 45.4"E was once used for arable farming. The soil is loam textured in this site. The electrical conductivity of this soil (Figure 4. 10) indicates that this soil is suitable for growing sorghum, and soybeans. In order to grow maize, the electrical conductance would have to be lowered to 50 mS/m (Bornman *et al.*, 1989). Maize is one of the staple food crops in Serake. The EC of local soils (68.5 mS/m) is higher than that of soils in Madikwe Game Reserve (Figure 4. 10).

CEC of local soils are lower than those of soils in Madikwe Game Reserve (Figure 4. 8). Kaolinite is the principal clay present as indicated by the CEC. Soils occurring at 25^0 09' 29.3"S, 25^0 53' 44" E and 25^0 09' 18.1"S, 25^0 57' 11.2" E have turf clay. The high clay proportion of local soils (37 %) (Figure 4. 26) results in high EC's of the soil. The high resistance of up to 2 300 ohms indicates that less water is available for the plants. Insufficient water especially in the topsoil layers causes a decline in grass species composition. The high EC (Figure 4. 10) are also due to compaction of the soil by grazing animals in the local sites. The more compacted the soil, the higher the EC. The ground surface in these sites is hard and compacted.

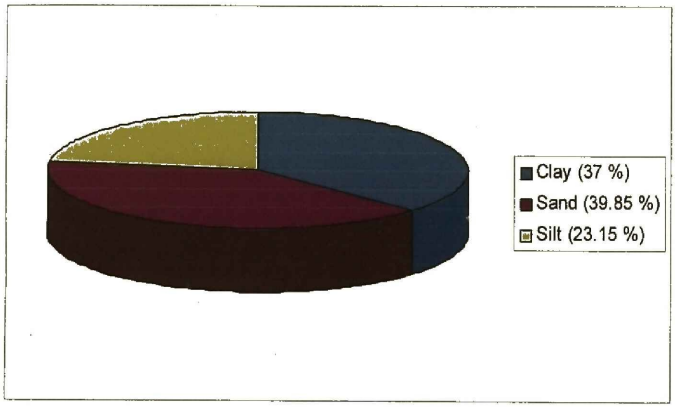


Figure 4. 26: Textural classes of Serake soils.

Pre-existing soil texture and moisture conditions are important variables to consider when investigating the relation between soil compaction and grazing intensity. Wet soils will compact more readily than dry soils, that is, less force is required to compact a wet soil than to compact a dry soil to the same density when dry. Coarse-textured soils bulk densities are not affected by grazing intensity. The bulk density increases with increasing grazing intensity on fine textured soils (Chad, 2001).

SUPINGSTAD

TABLE 4. 8: LOCATION OF SURVEY POINTS:

A total of 10 sample sites were monitored.

SITE NO.	SOIL SAMPLE NO.	LOCATION
1	7	24^0 46' 32.0" S, 26^0 6' 38.1" E
2	8	24^0 48' 00.0" S, 26^0 02' 29.9.1" E
3	9	24^0 45' 54.6.0" S, 26^0 58' 59.5" E
4	27	24^0 45' 30.0" S, 26^0 6' 39.3" E
5	28	24^0 46' 32.0" S, 26^0 06' 26.2" E
6	29	24^0 45' 55.0" S, 26^0 58' 58.5" E

NUTRIENT COMPOSITION OF THE SOIL

The phosphorus content (Figure 4. 27) is higher than soils in Madikwe Game Reserve (Figure 4. 1). Calcium, potassium, sodium and magnesium are lower than that of soils in Madikwe Game Reserve (Figure 4. 1). This indicates chemical degradation of the soil. Like in Madikwe Game Reserve, the EPP is within the acceptable limit (Figure 4. 2) (Compare Table 4. 2). This indicates efficiency of exchange of potassium ions and less competition from antagonistic ions. The SAR (Figure 4. 3) is below 1, thus indicating that the local soil does not have a sodium hazard.

The carbon and nitrogen content of local soils (Figure 4. 28) are lower than in Madikwe Game Reserve soils (Figure 4. 4). Loss of soil organic carbon is caused by soil erosion, leaching and formation of bicarbonates and carbonates (Brady & Weil, 1996). In arable lands, most likely in the long term, soil productivity will decline and the unit of cost crop production will rise (Brady & Weil, 1996). The site located 24^0 46' 32.0" S, 26^0 6' 38.1"E has more woody species and consequently has accumulation of carbon as compared to other sites in Serake.

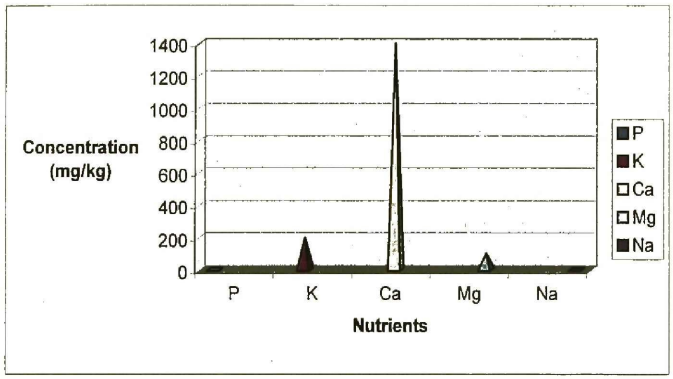


Figure 4. 27: Nutrient composition of Supingstad soils.

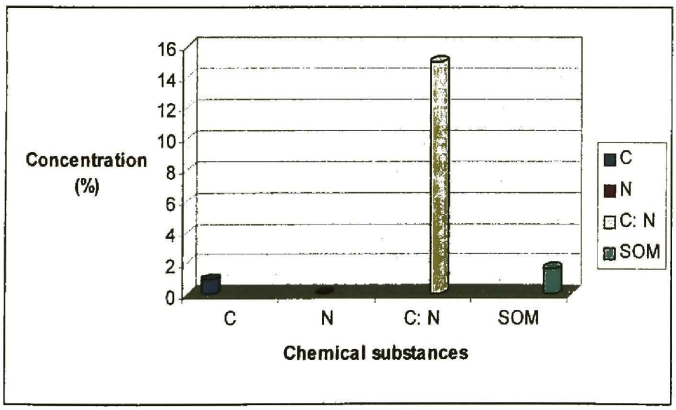


Figure 4. 28: Chemical composition of Supingstad soils.

This is because invasion of woody vegetation increase above and below-ground nett primary production and foster carbon and nitrogen accumulation (Archer *et al.*, 2000 a). The encroaching species include *Acacia karroo, A. mellifera, A. nilotica, A. tortilis* and *Dichrostachys cinerea.* Once established, woody plants alter soils and microclimate in their islands of fertility (Archer *et al.*, 2000 a).

Three mechanisms have been proposed to account for this:

- Woody plants act as nutrient pumps, drawing nutrients from deep soil horizons and laterally from areas beyond the canopy. These nutrients are deposited beneath the canopy via the stem flow, litter fall and canopy leaching.

- Tall aerodynamically rough woody plants trap nutrient–laden atmospheric dust which the rain washes off the leaves and into the sub-canopy soil.

- Woody plants may serve as focal points attracting roosting birds, insects and mammals seeking food, shade or cover. When these animals defecate, the soil may be enriched.

For all these reasons, soil carbon and nitrogen pools should increase subsequent to woody plant colonization in grazed grasslands (Archer *et al.*, 2000 a)

Local soils contain 1.68 % soil organic matter (Figure 4. 28). This indicates that soils in Madikwe Game Reserve are more fertile than Supingstad soils. There is a fundamental proposition that trees, and more specifically leguminous trees like the *Acacia* species are important in establishing areas of enhanced soil fertility (Smit, 1999; Young, 1997). Smit (1999) reported that an *Acacia tortilis* community produced an amount of 2. 32 ton litter per hectare annually. This causes nitrogen enrichment and also an increase in soil carbon content. While the base-richness of the parent material is initially important in determining soil fertility, biological activities are important in the creation and maintenance of localized areas of enhanced soil fertility, often on base-poor substrates.

Trees improve soil fertility by processes which increase additions to the soil, reductions from the soil, and the improvement of physical, chemical and biological conditions (Young, 1997). The most important processes are those by which trees control water run-off and minimize soil erosion, maintain soil organic matter and physical properties, increase nutrient inputs through fixation and uptake from deep soil horizons and promote more closed nutrient cycling.

SOIL pH

The local soils are moderately alkaline (Figure 4. 5). Like in Madikwe Game Reserve, base saturation of above 100 % is evident in Supingstad soils (Figure 4. 29).

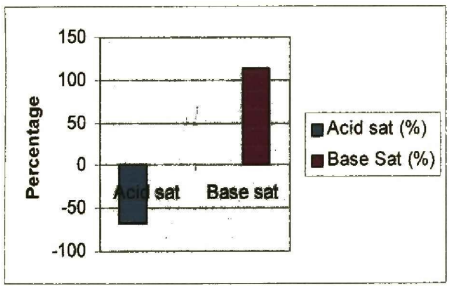


Figure 4. 29: Acid and base saturation of Supingstad soils.

This indicates chemical degradation of the soil. Due to excessive dominance by basic cations, there is a low acid saturation (Figure 4. 29) like in Madikwe Game Reserve soils (Figure 4. 6). This means there are less negatively charged nutrient ions in the soil. This is undesirable because anions are required for neutralization of the CEC.

SOIL TEXTURE

Local soils contain 26.5 % silt and 24.5 % clay (Figure 4. 30). This result in EC's that are higher than that of Madikwe Game Reserve soils (Figure 4. 10). Soil texture varies from clay-loam to sandy-clay-loam. The CEC's indicate the presence of illite and kaolinite clay. The high sand content (49.02 %) (Figure 4. 30) increases drainage of the soil. Local soils have a resistance above 2 000 ohms (Figure 4. 9), indicating poor water-holding capacity. In soils occurring at 24^0 46' 32.0" S, 26^0 6' 38.1" E and 24^0 48' 00.0" S, 26^0 02' 29.9.1" E have resistance lower than in Madikwe Game Reserve indicating that there is more moisture available in the soil (Anonymous, 2001 a).

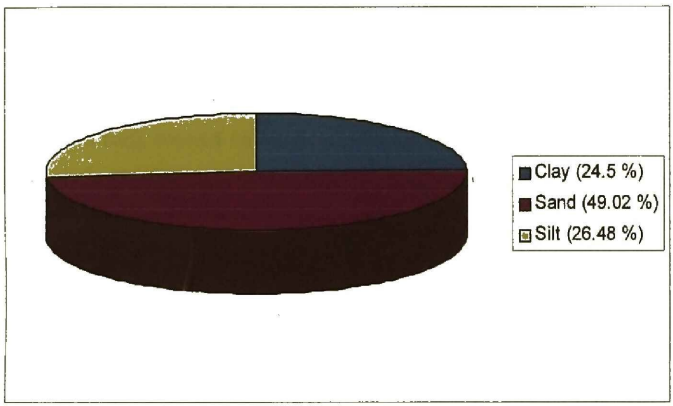


Figure 4. 30: Textural classes of Supingstad soils.

The high EC (Figure 4. 10) is also due to soil compaction, particularly in soils occurring at 24^0 45' 54.6.0" S, 26^0 58' 59.5" E. According to Doerge *et al.* (2002), this correlates with texture. The soil in this site has the highest clay content as compared to all other local sites. Soils with water-filled pore spaces that are connected directly with neighbouring soil pores tend to conduct electricity more readily. Soils with high clay content have numerous, small water-filled pores that are continuous and usually conduct electricity better than sandier soils.

The major land-use pattern that contributes to pasture degradation locally is poor management, particularly overstocking. Farmers want to keep as many cattle as they can. To keep fewer cattle would mean less income and decreased economic stability. Cattle, more than any other form of livestock, are significant to the local Supingstad community. Cattle farming are their way of life and an integral part of their religion and a dominating factor in their social organisation. A great social prestige is attached to the ownership of large herds of cattle (De Wilde, 1967). Livestock are regarded as a wealth and more valued than money or any other possession that a man might have.

The widespread reluctance to market cattle regularly may not so much stem from an emotional attachment to these animals. It is from a concept that cattle are a store of wealth or savings from which withdrawals are made for special ceremonial or social occasions. The cattle can be sold in the drier years to compensate crop failure (De Wilde, 1967). Webster & Wilson (1980) refers to cattle as 'a bank account on the hoof'. Market prices and new commercial forces have linked inappropriately with traditional attitudes to livestock numbers as wealth and drought insurance. This furthers the recent inordinate increase in grazing pressure. Through the work of the agricultural extension officers based in the village, the farmers were introduced to better veterinary care for livestock. This considerably decreased the loss of animals through diseases, resulting in overstocking (Webster & Wilson, 1980). When more and larger herds of cattle compete for the same rangeland, they may exceed the natural productivity of the area. This destroys the vegetal cover and accelerates erosion.

Overgrazing as a result of overstocking also has an impact on the composition of grass species (Bothma, 1989). There has been the transformation of a grass-dominated vegetation into woody species dominated vegetation. In this way, the vegetation consists of an upper story of trees and shrubs and a lower story of herbs, usually grasses between which there is a competitive imbalance (Archer & Stokes, 2000; Brown, 1999; Hubbard *et al.*, 2001; Tainton, 1981). In the natural system, grass is a superior competitor for moisture because it is able to extract water from the upper layers of the soil before it reaches the deeper roots of trees (Bothma, 1989). In an encroaching condition, overgrazing reduces the content of soil moisture and inhibits grass growth (Barnard & Newby, 1999; Bothma, 1989). This reduced competition favours the woody species that are able to extract water from greater depths than grasses (Bothma 1989; Moleele, 2001).

Traditional management practices are predicated on the notion that 'proper grazing' can minimize woody plant invasion problems. The implicit assumption is that adjusting stocking rates to maintain grass composition cover and biomass will minimize tree and shrub encroachment (Brown, 1999). Trees can also be controlled through burning. Depending on the objective of using fire as a management tool, a veld - burning program should adhere to the following activities:

- Burn before plants and litter are too dry to avoid intensive fires.
- Burn with the wind (not against the wind) to speed up the passage of fire. Burning against the wind always burns too deep, is more devastating and heats the ground more (Du Preez & De Leneer, 1992).
- Only burn the area strictly needed.
- Alternate burn and non-burn seasons to let fire susceptible species have a chance to regenerate, and to maintain diversity (Cutter *et al.*, 1985; Du Preez & De Leneer, 1992).

4. 4. EXTENT OF SOIL DEGRADATION IN SOUTH AFRICA

Despite the concerted efforts of many dedicated conservationists, the stewardship over vital resources has not met the challenge (Addler, 1985). Soon after World War I, a Drought Investigation Commission (DIC) was appointed to investigate the claim that the climate of South Africa changed, resulting in a succession of bad droughts with consequent stock losses (Tainton, 1981). The evidence collected, suggested that the efficiency of the rainfall had been much reduced as a result of the denudation of the soil surface (Anonymous, 1923). The Commission, therefore, recommended that every effort be made to reduce soil erosion, to restore the vegetative cover of the veld and to establish methods of veld management and fodder production which would stabilize the veld and soil and would ensure a more reliable supply of livestock feed.

The DIC reported that accelerated erosion and desertification were attributable to man's misuse of the land. Ross (1948) reported that widespread soil degradation and veld denudation were to be observed in all parts of the country. Tidmarsh (1948) also found that in the Karroo and adjacent grassveld areas, considerable deterioration of the veld had taken place over decades. Many eminent international scientists have also alluded to the serious state of veld degradation and erosion in South Africa (Robertson, 1968).

The South African soil mantle is highly diverse, complex and largely susceptible to erosion (Scotney & MacPhee, 1990). About 80 % of the country comprises of slightly weathered and calcareous soils which tend to be shallow and of unfavorable morphological properties, chemical

composition and clay mineralogy. Topsoils of very low organic matter content (< 5 %) characterize almost 60 % of the country. Over 30 % comprise excessively sandy soils (< 10 % clay) which are particularly vulnerable to wind erosion (Van Oudtshoorn, 1999).

In January 1995, South Africa became a signatory of the United Nations Convention to Combat Desertification (UNCCD) and ratification followed soon after in September 1997. In this approach, one workshop was held in each of the 35 agricultural regions. A total of 367 magisterial districts were covered in this survey. Out of these, 262 (71 %) were managed predominantly (50 % of the area) under a commercial land tenure system and 105 (29 %) under a communal land tenure system. Not surprisingly, the communal areas conform closely to the former homeland (Transkei, Bophuthatswana, Venda and Ciskei) and national or self-governing states (e.g. Kwa Zulu-Natal, Kwa-Ndebele, Lebowa, Gazankulu and Qwaqwa) network of apartheid South Africa. They also include former coloured reserves of Namaqualand (e.g. Leliefontein, Concordia, Kommagas, Pella and Steinkopf) (Hoffman *et al.*, 1998). In general, workshop participants felt that soil degradation is highest in the grazing lands, croplands and settlements in each magisterial district. They also found that these values were on average 2-4 times higher in communal areas than in commercial areas. Sheet erosion is the most important form of soil degradation in the grazing lands and settlement in the Zeerust District. Rill, gully and donga erosion is the most important type of soil degradation in Braklaagte (Figure 4.31) and Dinokana.

Accurate estimates of soil erosion in South Africa are not yet available (Van Oudtshoorn, 1999), but according to Addler (1985), sediment losses for large catchments are in the order of 300 million tons per annum, or an average of 3 tons/ha/annum for the country. This estimate is based on the sediments carried by major rivers and does not reflect gross over the landscape. Assuming a sediment delivery ratio of 0.06 for larger catchments, actual soil losses could be as high as 50 tons/ha/annum in some areas.



Figure 4. 31: Donga erosion in Braklaagte.

Braune & Looser (1989) suggest rates of natural erosion in South Africa of between 0.5 and 1.4 cm per 1 000 years. They give the rate of accelerated erosion as 12 cm/ 1 000 years. This implies that current soil losses may be more than 20 times the rate of soil formation.

According to the survey for the UNCCD, the severity of soil degradation in grazing lands was highest in KwaZulu-Natal, Northern Province and Eastern Cape, and lowest in Mpumalanga, Gauteng Province and Western Cape (Hoffman *et al.*, 1999). The reasons cited for the low status are as follows:

- Stock numbers were adjusted to fit the carrying capacity, extension officers have been involved in accurate assessment of individual farms.

- Various state schemes such as grass conversion scheme, stock reduction schemes and drought subsidy scheme have benefitted the veld.

- Higher amount of rainfall over the last 10 years has improved the vegetal cover and reduced run-off and soil erosion.

- Improved veld management programmes including longer resting cycles, rotational grazing systems and increased planted pasture areas has reduced the pressure on the veld.

- Farm sizes have increased which has facilitated lower stocking rates.

The continuing degradation of soil and veld resources in South Africa led the government to declare a National Grazing Strategy in 1985 (Van Oudtshoorn, 1999).

4. 5. SOIL EROSION

Soil erosion is the removal of the top layer of the soil. Soil erosion is a natural process and it becomes a problem when the soil loss leads to a significant reduction in the soil quality resulting in lower productivity. Soil erosion implies movement of sediments over the landscape. Major shifts in soil fertility results from such movements and in severe cases, during floods, large deposits may cause untold damage to downstream properties (Looser, 1985).

Soil erosion represents a loss of capital not generally recognised in the value of farmland. Economics, in ecological terms, is the study of how humans, individually and collectively, use scarce resources to satisfy their needs or goals (Fergusson, 1966; Robbins, 1923; Samuelson, 1964). The primary goal of man is related to economics and management of natural resources. Farming activities in most societies are market-driven, therefore there is a need to maximise profits in one way or another to meet the market forces. Stocking rate is one of the major factors affecting the potential magnitude of profits. In most cases, the results are soil degradation and veld retrogression. At high stocking rates, production costs generally increase. Farmers counterbalance these costs by allowing overutilisation of the veld. In this way the grasslands become overgrazed, large denuded areas becomes visible, the soil is washed away by rainfall and eventually soil fertility declines. This leads to high probability of catastrophic losses of animals.

It is seldom appreciated that the cost of soil degradation will ultimately fall on the shoulders of future generations (Van Oudtshoorn, 1999).

The start of water erosion depends upon the severity of impact of raindrops, the rate of precipitation and the slope of the land (Simpson, 1983). Once the nutrient-rich topsoil is removed (Figure 4. 32), few plants will grow in the soil again. Without the soil and plants, the land becomes desert-like and unable to support life. The erosion of the land has become catastrophic in character, and the 'living' soil is removed too quickly for its usefulness as a growing medium to be exploited for the benefit of man (Townsend, 1973).

The initial form of erosion is known as splash erosion. The two main processes are the detachment of soil materials from the surface by raindrop impact and the transport of sediments by drop splash and/or overland flow. Once the infiltration capacity of the soil is exceeded by the rainfall rate, run-off begins to concentrate in small channels, soil particles are transported and scouring of the soil surface begins. This produces the next type of erosion known as rill erosion.

Splash erosion with a minimum degree of rill erosion is commonly known as sheet erosion. As the process continues, run-off in the rills becomes deeper and wider to form the most spectacular type of erosion known as gully erosion (Webster & Wilson, 1980). Fast flowing water undermines the outside bank of a channel, causing its eventual collapse. This results in the widening of the stream or river. Tunnel erosion occurs in the veld adjacent to gullies. It is characterised by the appearance of vertical or horizontal tunnels which may ultimately collapse.

Soil erosion has been regarded as an important phenomenon in South Africa since the turn of the century and even before (Webster & Wilson, 1980). The study of soil erosion has been approached from a number of perspectives: it is considered a geo-morphological and environmental processes with the ability to create, modify and destroy landforms; as a threat to agricultural production and self-sufficiency; as a factor which increases costs of surface water storage and as inhibitor of socio-economic development. More recently it has occupied a

position of importance as one of the more obvious indicators of land degradation and desertification.

4. 6. CAUSES OF SOIL EROSION

4. 6. 1. OVERGRAZING

Overstocking causes overgrazing, which in turn accelerates soil erosion. The basal and canopy cover of the grassland community play an important role in the dissipation of much of the energy of the falling raindrop - an energy which would otherwise be used to pound and pulverise the soil surface (Tainton, 1981). In this way, the soil's ability to erode is reduced. The basal cover and the canopy of the veld at the time of intense precipitation may exert an important influence on the infiltration of water in the soil by protecting the soil surface from direct raindrop impact. The physical obstruction to water movement across the soil which is provided by the plant base, increases the period during which water may infiltrate into the soil. In so doing, it allows much of the rain to soak into the soil and reduces run-off and erosion. The rate of soil loss increases as the veld condition and vegetation cover decline (National Department of Agriculture, 1999). A decline in vegetal cover result in less litter on the ground which can result in an increased sheet erosion. The plant roots hold the soil in position and prevent it from being washed away.

4. 6. 2. TOPOGRAPHY

Topography is an important factor influencing the rate of soil erosion. The steeper and the longer the slope, the greater the rate of soil erosion. Splash erosion is mainly of concern in slopping terrain as it leads to a nett transport of soil particles down the slope. Heavy splash by raindrops can lead to compaction of the topsoil, decreasing the soil permeability. The top of the slope is usually well-drained as soil moisture moves downhill, leaving air in the pore spaces moist of the time. Over time, the fine clay particles are carried downslope leaving the soil sandy. Plant roots can penetrate easily to deep levels to withdraw enough soil water from there. These soils have lower erosion potential and are normally more stable.

In the midslope soil moisture moving from the crest starts to dam up as a result of the clay-rich soil just downhill. The soils are well-drained with a higher erosion potential. In the footslope, the soil has been waterlogged as a result of the long-term accumulation of clay which does not allow water to infiltrate. Plants that grow in these soils are limited to those that can adapt their root system to grow laterally above the hard clayey layer. These highly, that is, soils with higher resistance drained soils have high erosion potential (National Department of Agriculture, 1999).

4. 6. 3. FUELWOOD COLLECTION

Collection of fuelwood (Figure 5. 3) from natural woodlands has caused serious destruction of vegetation in the Zeerust District. According to Gupta (1988), collection of firewood occurs as a response to energy needs of the people. Fuelwood is primarily used for cooking, heating, lighting and beer brewing. To cover these needs, most households in the Zeerust District resort to free-gathered biomass fuels, and if wood is difficult to procure, dried dung of domestic animals is used. This robs the grasses of the organic matter in animal droppings.

4. 6. 4. SOIL TEXTURE

Soil texture has been referred as one of the most important factors controlling the susceptibility of soil to erosion. Water erosion is not a serious problem in sands, loamy sands and coarse sands because of rapid infiltration rates in these soils. Light soils with high fine sand contents give rise to sheet or rill erosion. The most serious effects are found on medium textured soils and on poorly structured clay soils. Most clay soils have resistance to soil erosion because of their cohesive properties and high soil organic matter. Low organic medium textured soils rich in silt or fine sand are vulnerable because of the ease with which these particles move in the flowing water (Simpson, 1983). Compaction causes the soil to lose its structure and cohesion (ability to stick together), and it erodes easily.

The principal effects of soil erosion are impoverishment of the soil causing greater susceptibility to droughts and making agricultural production more difficult and expensive. Soil degradation

modifies physical and chemical soil characteristics (refer to section 4.3). The persistent and long-term degradation will affect both plant and animal species which can survive in an area and their rate of regrowth. Erosion significantly reduces plant successional recovery through losses in nutrients and soil organic matter (section 4. 3).

4. 7. REFERENCES

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CHAPTER 5: SOCIAL SURVEYS IN THE STUDY AREA

5. 1. INTRODUCTION

The ways in which people understand natural processes and agricultural practices influence the use and status of the land. Hoffman and Ashwell (2001) recognizes two broad knowledge systems namely 'western scientific' and indigenous knowledge systems. Traditional knowledge often takes into account the natural and social contexts when addressing problems. In recent years, western science has begun to recognize the value of traditional philosophies and practices. Until recently, western scientific thoughts dominated agricultural policy and practices and indigenous knowledge systems tend to be marginalized.

Societies everywhere are closely inextricably linked to the natural environment in which they are embedded. Almost everywhere, the environment has been considerably changed by human activities (Vivian, 1994). Environmental degradation, which includes depletion of renewable and non-renewable resources, causes stress upon societies. Environmental decline may induce changes in settlement patterns and, thus, disrupt established social relationships.

Veld retrogression cannot be separated from that of sustainability. This research is a component of a major project which aims at sustainable development of rural communities in the Zeerust District. In the new dispensation, South Africa is embarking on a path of national development, seeking both economic growth, equity and sustainability within its policies and practices. In line with international debate, the Department of Environmental Affairs and Tourism (DEAT) (1996) views sustainable development as:

"development that meets the needs of the present without compromising the ability of future generations to meet their own needs" and "development that delivers basic environmental, social and economic services to all without threatening the viability of the natural, built and social systems upon which these systems depend".

Environmental degradation can therefore be understood within the context of the society that the environment supports (Vivian, 1994).

5. 2. MATERIALS AND METHODS

MATERIALS

Questionnaires (Appendix A)

METHODS

A formal questionnaire was administered to members of the tribal authority and households in the Zeerust District during March 2001–April 2001. The aim of this household survey was to assess the attitudes, perceptions and knowledge of the local inhabitants with regard to changes in grass species composition, land-use, land degradation and restoration principles.

Fifty six subsistence farming households were selected for this study. These farmers share communal grazing areas. The interviews were conducted by an integrated team of research students which included geographers, ecologists, botanists, historians with some assistance from agricultural extension officers in the local areas. In this survey, information on socio-economic characteristics of farmers, cattle production, arable farming as well as access to farming support services and infrastructure were collected. The information obtained was used to make recommendations concerning awareness and educational programmes which will ensure sustainability of the affected communities.

5. 3. RESULTS AND DISCUSSION

The following information on the age structure is important in order to make an assessment of the ability of the adults to contribute to the household income by any means of physical labour. From this survey, 87 % of the respondents interviewed were males, of which 81 % were older

than 50 years of age. The mean age of the male respondents was 65 years. Out of the 13 % of female-headed households, 9 % were widowed, and all of them were older than 50 years. The mean age for females in this survey was 57 years. These figures contrast with the general perception that the majority of rural farmers are women. This difference could be due to the fact that retrenchments and downturn of economy could have caused the influx of older men who are less likely to be employed as migrant workers into the rural areas. The migration of young people to urban areas might also be a factor contributing to the high proportion of elderly people. The general profile of the farming household thus appears to be that of an aging adult community, with however, a relatively good knowledge of farming practices. 52 % of the respondents depend on the government pension fund as a source of income, while 16 % rely on agriculture, 13 % earn their income from casual jobs, 7 % earn a salary and 5 % depend on their children who are employed elsewhere for assistance.

5. 3. 1. LAND-USE PRACTICES IN TARGET AREAS

5. 3. 1. 1. LIVESTOCK FARMING PRACTICES

Livestock production in the grazing areas is characterised by the integration of cattle, sheep, goats, donkeys and some poultry (Figure 5. 1).

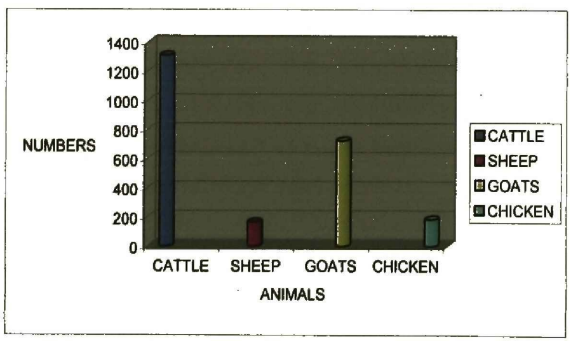


Figure 5. 1: Livestock farming records in the Zeerust District.

The mixture of these grazers and browsers has generally been reported to promote more effective utilization of both the browse and the herbaceous plants (Stuart-Hill, 1985). However, due to inappropriate land-use practices in the Zeerust District, the balance has been disturbed and there has been overutilization of the rangelands resulting in land degradation (section 3.3, Chapter 3).

NB: Establishing the correct figures for livestock was difficult due to the following main factors:

1. Some respondents did not seem to know the exact figures of their livestock by themselves.

2. Livestock numbers change over a short period of time due to theft, slaughtering, selling, loss due to drought and thunderstorms or diseases.

3. The figures that were obtained from the respondents did not correlate with official data from the extension officers records because the records were not yet updated.

Case studies on household histories indicate that livestock rearing has always been an important aspect of the everyday life of people in the Zeerust District. Although livestock provides subsistence benefits to people, they also contribute to land degradation. Farmers in Braklaagte, Serake and Supingstad stated that the grazing camps are too small to accommodate all the cattle. Farmers in Supingstad stated that overstocking is caused by cattle from neighboring fields which 'illegally' graze in their rangelands. The respondents possess few herds of cattle per farmer. When put together in the same rangeland, cattle become too many for the camp to accommodate. This results in overstocking in communal rangelands, another inappropriate land-use practice that leads to degradation of natural vegetation.

The Zeerust District was overstocked by 200 % in 1982 (Cowley, 1985). Extensive grazing has been associated with loss of vegetative land cover, soil compaction and a decline in grass species composition with ultimate threat to desertification. The results from the vegetation surveys also verify these effects of overstocking (Section 3.3, Chapter 3). In Braklaagte for example, the

species composition for perennial grasses is 49 %, whilst that of annual grasses is 18 % (Figure 3. 5 and Figure 3. 6). This means that 33 % (Figure 3.6) of the soil surface is exposed to unfavourable weather conditions such as soil erosion (Figure 3.7, Chapter 3). Overgrazing in Serake has resulted in formation of bare patches (Figure 3. 15) which may initiate the process of desertification.

The impact of livestock on the environment depends on site-specific and management conditions. It is probably true to say that in stable and secure traditional societies, common property resources are managed carefully and are conserved (Warren & Agnew, 1988). When societies are under stress, either from political or economic pressure or from climate, or the management group is removed, then the individual has little choice but to make the best he/she can of what is available.

Farmers in the Zeerust District sell livestock for different purposes and under different conditions (Figure 5. 2). These include buying food, household support,

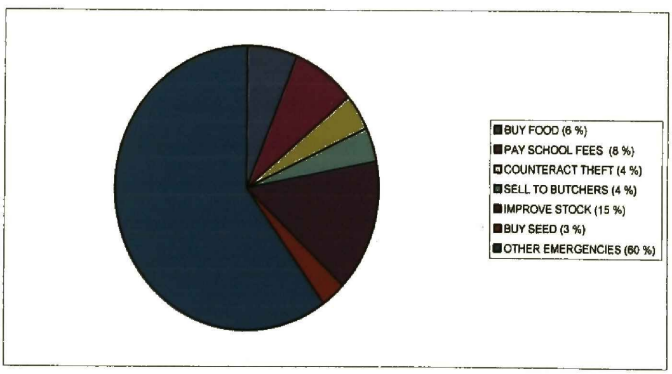


Figure 5. 2: Reasons for selling cattle in the Zeerust District.

education, funerals, weddings, payment of debts, to buy salt for animals, to avoid theft, to renew the herds etc. These responses do not reflect the farmers' willingness to sell or slaughter cattle in order to counteract overstocking. Instead, the respondents want to have more cattle as a security against droughts. These farmers prefer to have cattle rather than money in the bank. They value cattle more than money as reflected in their slogan 'Cattle is an African Bank'. The community would like their children to follow in their footsteps, i.e. to keep cattle. The farmers, however, voices their insecurities about the dedication of their children to this traditional lifestyle of cattle rearing.

68 % of the farmers used the word 'bad' in an assessment of the condition of their rangelands. Invasion of woody species, poor soil quality, decline of palatable grasses, veld denudation, water scarcity, soil erosion, dongas, gullies and absence of camps were given as reasons for 'bad' veld conditions. The results of the vegetation surveys also gives evidence of 'bad' or 'poor' veld conditions. Figure 3.19, for example indicates bush encroachment in the study area, where species such as *Dichrostachys cinerea, Acacia mellifera* and *A. tortilis* are most evident. The survey points that are encroached are characterised by high carbon: nitrogen ratios (Figure 4. 20, Figure 4. 24 and Figure 4. 28).

Poor soil quality is indicated by alkalinic soils with a pH above 8 (Figure 4. 5), especially in Madikwe Game Reserve, Doornlaagte and Supingstad and acidic soils particularly in Dinokana (Figure 4. 5). The high base saturation of over 100 % particularly in Madikwe Game Reserve (Figure 4. 6) and Supingstad (Figure 4. 29) characterises the soils. These high base saturation which results due to excessive accumulation of nutrients have influenced veld palatability in these sites. For example palatable grasses such as *Panicum coloratum, Themeda triandra* and *Urochloa mozambiscensis* occur in lower frequencies of below 10 % in Madikwe Game Reserve (Figure 3. 2) and Supingstad (Figure 3. 16). In other sites also, these grasses occur in lower frequencies such as Braklaagte (Figure 3. 5), Dinokana (Figure 3. 8), Doornlaagte (Figure 3. 11) and Serake (Figure 3. 13). Furthermore, soils are characterised by high resistance of over 2 000 ohms (Figure 4.9). This shows the inability of the soils to hold water for a long time, resulting in leaching of nutrients in some survey points (Figure 4. 12). For example, most nutrients in

Braklaagte (Figure 4. 11) are lower in concentration as compared to survey points in Madikwe Game Reserve (Figure 4. 1) where there is no excessive leaching.

Several cases of lumpy skin diseases have been reported and the cattle are attacked by ticks. If the community is to lead a sustainable life, the prevailing conditions in rangelands raise doubts as to whether livestock farming will be the major land-use type in future. If it does, land degradation is going to accelerate even more.

The invasion of woody species increases biomass and would appear on satellite imagery as an increase in vegetative cover, whereas it is a loss in productivity for people on the ground (Warren & Agnew, 1988). According to the respondents, bush encroachment is brought by various factors including seed dispersal, absence of burning and the fact that there is no more ploughing in the crop fields. None of the respondents, however, associates invasion of woody species with injudicious land-use activities such as overstocking. 58 % of the respondents indicated that bush thickening is the main problem in the grazing areas and bushes should be eradicated in order to improve conditions in the rangelands. According to the respondents several measures to control the invasion of woody species include burning, cutting and use of chemicals. The main draw back in these methods is the resprouting nature of trees and shrubs, especially *Dichrostachys cinerea*. Chemical control has not been equally successful in all rangelands. In Serake, for example, woody plants were chemically controlled in one grazing field and the decrease in density of *Acacia mellifera* resulted in the recovery of grasses. In another area where chemicals were applied, however, grasses have not yet grown. The respondents suspect the soil type as causing delayed recovery of grasses. According to farmers, lack of cooperation amongst themselves is one of the reasons why there is no success in bush clearing. 21 % of the respondents indicated that other measures to improve the conditions in the rangelands includes fencing off of the area for camp rotation, and provision of more land by the government.

71 % of the respondents indicated that the effective way of preventing soil erosion in the rangelands include the use of sandbags, branches and terraces. This very existence of indigenous knowledge on soil conservation does indicate local residents understanding of soil erosion and

conservation. These measures that were regulated by the Reconstruction and Development Programme (RDP) schemes organized by the Department of Agriculture in the past to control erosion by filling dongas with stones, collapsed with the fall of the Bophuthatswana government. During the survey, 21 % of the respondents indicated that they are waiting for the intervention by the government. Preventing soil erosion requires political, economic and technical change. Political and economic change should address the distribution of land and the possibility of incentives to encourage farmers to manage their land sustainably. Aspects of technical change include avoiding overgrazing and making sure there are always plants growing in the soil.

5. 3. 1. 2. CROP FARMING

Crop farming is practiced in Braklaagte, Serake and Supingstad. In Doornlaagte the lack of title deeds is a constraint to crop farming. Crop farming products include maize, sorghum, sunflower, watermelons, beans and sweet reeds. Rain is in a positive and negative way important for the quality of the residents' crops. The quality becomes good when it has rained well, and on the other hand, heavy rainfalls that occurred in the year 2 000 destroyed most of their crops. Most of the harvested products last for the period of one year. 60 % of the respondents use these crop farming products strictly for household purposes, 18 % sell their products and the remaining 24 % use their product both for selling and household purposes. However, most of the respondents are no longer actively involved in crop farming due to physical, financial and environmental challenges. These products are dependent on water, and the farmers usually target the rainy seasons as the time for ploughing. The unreliability of the rain leads to the bad quality of crops.

Lack of fences increase the attack of crops by pests such as rabbits and sometimes cattle. Encroachment of unwanted vegetation and lack of equipments such as tractors, ploughs, fertilizers, seeds and shortage of able-bodied labour made the respondents to consider crop farming as a difficult activity. Also, agricultural extension services have generally been unavailable or their work is not effective enough. In general, there is low agricultural input as a means of adding to household needs due to drought and degradation in crop fields. Under conditions of low agricultural inputs, extensive cultivation of staple grains contributes to land

degradation. This data suggests that promotion of crop farming in the Zeerust District should be taken into consideration.

5. 4. WATER SUPPLY IN THE STUDY AREA

50 % of the respondents rely on the common water supply source of which the service fee has to be paid for. 39 % of the respondents buy water from other residents who have boreholes and only 2 % of the respondents have their own boreholes or running tap water in their houses. Communal grazing systems in the Zeerust District are based around a common central water source such as boreholes, dams and water pans around which livestock graze. Some of these are broken and cannot be repaired because of bad infrastructure. This data indicates that there is a serious water supply problem in the study area.

The most important factor limiting agricultural production is the availability of water. Rainfall is extremely variable in South Africa and it is often stated that the country has a limited agricultural production (Anonymous, 2001).

5. 5. NON-AGRICULTURAL LAND-USE PRACTICES IN TARGET AREAS

5. 5. 1. COLLECTION OF FUELWOOD

In this survey, 90 % of the respondents depend on neighbouring farms and rangelands for the supply of fuelwood (Figure 5. 3). Fuelwood is paid for, the price depending on the mode of transport used - donkey cart, tractor etc. Collection of fuelwood is linked in many ways to rural poverty and government policies such as the 'Betterment' planning (Hoffmann & Ashwell, 2001). Settling of large numbers of people in rural villages without provision of electricity left these people highly dependent on the gathering of fuelwood. Some respondents have access to electricity, but the majority of them use it only for light and ironing. Wood remains the most important fuel for purposes such as cooking, beer brewing and heating (Figure 5. 4).



Figure 5. 3.: Fuelwood collection in the Zeerust District.

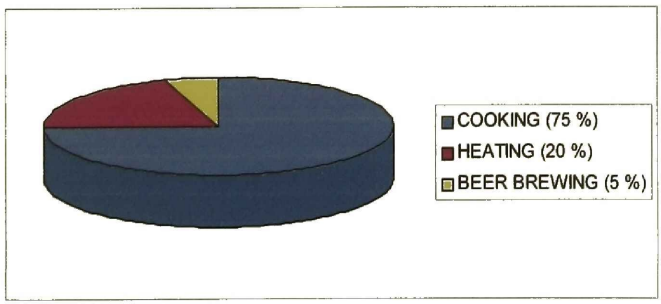


Figure 5. 4: Use of fuelwood in the Zeerust District.

5. 5. 2. CONSTRUCTION

Regardless of how conservatively the resources are used, the fundamental fact is that growing numbers of people unavoidably place increasing demands on the natural and social environment

(Hanson, 1992). Building materials therefore, become an essential need for construction. Population census data for the Zeerust District is given in Figure 5. 5.

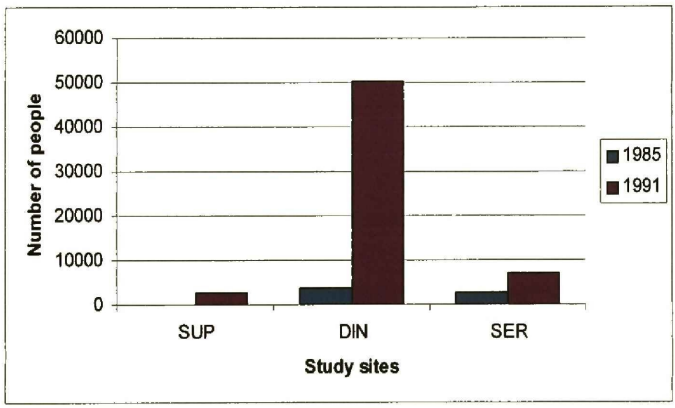


Figure 5. 5: Population census for the Zeerust District 1985/1991 (Statistics South Africa, 1991; Bophuthatswana Government, 1985).

KEY:

SUP = Supingstad

DIN = Dinokana

SER = Serake

Construction, as used in this context, is used for the building of schools, houses and roads that link the village with the town. Some respondents live in mud-houses. Soil mining for building these houses has left the land scarified. In Dinokana, soil mining completely removes vegetation and the top layer of soil. There are 19 grass species in Dinokana (Figure 3. 8 and Figure 3. 9), constituting a frequency of 54. 9 %. The bare ground ground is 45.1 % in this site (Figure 3. 9). According to (El-Hinnawi & Hashmi, 1982) it may take 20-25 years before such sites are again covered by vegetation.

A great percentage of wood for constructing fences around arable fields, livestock enclosures and fences around the homesteads and for roofing has occurred at the expense of the rangelands. This harvesting of poles resulted in the decrease in the density of the surrounding woody communities. Wood for dwelling construction is an infrequent requirement in most households.

5. 6. MIGRATION EXPERIENCES AND INFLUENCE ON RANGELAND DEGRADATION

The information given by respondents show that 85 % of them have been forced to leave a place in relation to political justification, as shown by their frequent reference to farm owners as well as to the government. The farm owners had subjected them to the demands which they could not or did not want to fulfil. For example 43 % of the respondents had to migrate because they were not allowed to keep more than three cattle in the 'White' farmers land and were not allowed to keep chicken. 20 % indicated that they had to leave because older children who were not working were not allowed to stay in the farms any more. 67 % of the respondents were affected by circular migration (Blacks working in urban areas, but leaving their families in rural areas). Circular migration could be explained in terms of the constraints apartheid had placed on migration, or the large existence of large institutions such as gold mine labour systems to sustain it (Oosthuizen, 2001). For most of the respondents, the moving back and forth between the workplace and homes became a way of life. They were accustomed to it that they preferred to keep their families in rural areas even after the abolishment of influx control. The migrant labour so induced left women and children with a particular labour shortage. Once women of economically active age also started moving to urban areas, it was often only children and the elderly who were left to manage the land. In many cases, the result was under-farming, with production below subsistence levels and insufficient to invest in conservation measures (Hoffman & Ashwell, 2001).

There were several conflicts in Braklaagte, centred around the legacy of apartheid. In 1938, a conflict started when the central government attempted to evict the residents and move them to Serake. Serake is another marginalized area that was under the erstwhile Bophuthatswana government. This attempted eviction was in response to the creation of 'Black homelands'.

Homelands were too small to accommodate all the people (Bundy, 1988). In 1942, the government ordered that farmers should mark their cattle with a 'Z' for 'Zeerust', of which the community refused. There was conflict in 1957 when the government started to force the women to have identity documents. These two issues indicated control, domination and segregation by 'White' people. According to the respondents, there was another unsuccessful attempt by the government to forcefully move the residents to Serake in 1957*. When these lands were repossessed from them, residents were forced to turn some of the rangelands into residential lands in order to accommodate all people. This caused numerous environmental problems. The rangelands became overstocked. Presently, there is degradation in the form of soil compaction, erosion dongas, gullies and soil acidity. The demands for water and firewood led to the degradation of resources around the villages. This was also verified by vegetation surveys as indicated in Figure 3. 18 in Supingstad were degradation due to settlements have contributed to a bare ground of 8.1 % (Figure 3. 17). Fencing around the pastures did not remain for long as they were broken down and some were stolen by local inhabitants to be used in their own homes. This eviction from traditional land was done in response to the Native Land Act no. 27 of 1913 (Oosthuizen, 2001; Letsoalo, 2001; Hoffman & Ashwell, 2001).

This act restricted Black ownership of the land to 7% of the area of South Africa and permitted only customary rather than freehold tenure (Hoffman & Ashwell, 2001). The traditional land tenure system ensured that every mature married man had access to land (Oosthuizen, 2001). This included a residential site with garden lot, some arable land and access to communal grazing land. In this way the land belonged to the community and not to individuals.

'Blacks' were turned into migrant labourers in 'White' dominated agriculture, mining and industry (Hoffman & Ashwell, 2001). This undermined the black people's self-sufficiency and the environmental sustainability of their agriculture. Those who had cattle were not allowed to keep more than five cows, the reason being to control overstocking. They were compelled to sell cattle at the prices determined by the 'White' farm owners.

*This information was obtained from the interviews and given by respondents themselves.

Those who sold cattle without the farm owners' knowledge were chased away from the farm. It was only after the fall of the 'Apartheid' government that respondents came to live in their original localities again. Some people in Doornlaagte came from neighbouring farms such as Enselsberg, Richlough, Oliphantsvlei, Koedoespoort, Koppieskraal etc. Most of the people in Serake came from Leeuwfontein, Komane (Rooikopfontein) and Witkleigat. Some respondents in Supingstad originated from Vleisfontein and Nietverdient. Those from Gopane, Botswana and Lekgophung migrated as a result of internal conflicts on chieftainship and employment.

The government's intervention in communal areas to combat land degradation which occurred due to overcrowding were controversial. Land-use policies were designed and imposed on the communal areas. Betterment was a well-researched plan based on the technical principles of the time. The Betterment Scheme was introduced by Proclamation 31 of 1939 (Hoffmann & Ashwell, 2001). It combined practical land reclamation, such as gully rehabilitation, with land use planning. The way in which it was implemented not only failed to ensure sustainable land use but also served to alienate the people from the land where it was implemented, scattered rural settlements were concentrated into villages, areas were prescribed for grazing and cultivation, and livestock culled. In some cases, fields were fenced off into camps to enable rotational grazing, anti-erosion measures were implemented and dipping tanks were built to combat stock disease (Hoffman & Ashwell, 2001).

Migration policies resulted in inequitable distribution of resources and this is to blame for a large proportion of land degradation (Blaikie, 1986; Blaikie & Brookfield, 1986). The need to survive with the desire to profit resulted in poor land-use decisions which resulted in significant soil degradation (Hoffman *et al.,* 1999). For example, overstocking became a common necessity and cultivation of slopes was the only alternative.

Effective actions against environmental degradation require first and foremost empowering and equipping of local communities to take up reins of resource management. The approach should take the willingness of the residents as its point of departure. Farmers in Supingstad for example, have indicated that they need capacity building workshops on land care projects. If sustainable

development is the key goal, then with implementation of skills-upgrading programmes these rural communities will be able to effectively manage their land. They will also have the democratic right to determine what forms of agricultural enterprise to engage in. The role of the state should be to establish a policy framework within which services to farmers and incentives for them and support in their decision making will be ensured. An important factor in this context is the provision of enabling environments with specific regard to the question of how to combine longer-term concerns for environmental rehabilitation and conservation with the pressing short-term needs of household food security. Also important are the technologies and related measures to be promoted that build upon the traditional knowledge such as those that will in the short-term generate tangible benefits for the farmers.

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CHAPTER 6: GENERAL DISCUSSION AND CONCLUDING REMARKS

6. 1. GENERAL DISCUSSION

The Zeerust District is situated in the Savanna Biome (Cowley, 1985). The Savanna Biome is characterised by undisturbed interaction of trees and grasses to create a biome which is neither grassland nor forest. In the Zeerust District, this interaction has been imbalanced in nature, and has resulted in the retrogression of the herbaceous layer (Chapter 3). This confirms Hoffman's National Audit (Hoffmann *et al.*, 1999), that loss of plant cover (Chapter 3) and soil degradation (Chapter 4) are a serious problem in Zeerust District. The transformation from a grass-dominated vegetation into a tree-dominated vegetation is evident in some study sites.

It is evident that land-use did contribute to veld retrogression in Zeerust District. Agriculture has always played an important role in the life of Bahurutshe (Cowley, 1985). Many customs and traditions relate to and emanate from agricultural activities. Due to overstocking, inadequate camp rotation, inadequate water sources and lack of veld burning, there has been veld retrogression in the Zeerust District.

Grasses such as *Aristida* and *Eragrostis* species occur in local grasslands. These grasses indicate a poor veld condition. The dominance of annual grasses in some study sites indicates that grasslands are heading for desertification. Most palatable grasses such as *Digitaria eriantha, Panicum coloratum, P. maximum* and *Setaria nigrirostris* rarely occur, or have lower frequency in most sites (Chapter 3). Unpalatable grasses such as *Aristida congesta, A. diffusa, Bothriochloa insculpta, B. radicans, Eragrostis rigidior* and *Tragus berteronianus* are common and abundant in most sites. This indicates a decline in the capacity of local grasslands to support livestock grazing. The benchmark site is also affected by veld retrogression (Chapter 3).

Loss of grasses has been accompanied by general deterioration of soils. Chemical soil degradation in the Zeerust District is encompassed in loss of basic nutrient cations, resulting in strongly acidic soils, particularly in Braklaagte and Dinokana. Where soils are alkalinic (e.g in

Madikwe, Doornlaagte, some sites in Serake and Supingstad), land-use practices have played a role in soil degradation. Such areas were used for crop farming, and excessive application of fertilizers caused accumulation of basic cations. High base saturation of over 100 % which characterises soils particularly in Madikwe, Doornlaagte and Serake (Chapter 4) have contributed to a decline of veld palatability. Physical degradation of soils is evident, resulting in poor water-holding capacity, crusting and soil erosion (particularly in Dinokana and Braklaagte).

Linked to the causes of land degradation in the Zeerust District, is the issue of legislation. According to Oosthuizen (2001), recent developments regarding land-use in South Africa revolves around two critical types:

- The use of land for residential purposes
- The agricultural use of land

These are 'burning' issues to the majority of residents in the Zeerust District. The redistribution of land in South Africa has become a controversial issue since democracy in 1994. The land reforms do not only involve the provision of land on predominantly 'White' commercial farms for the landless. It also means the opening up of areas such as national parks for members who formerly inhabited these areas (Oosthuizen, 2001). Some of the residents in the Zeerust District were evicted from the area now occupied by Madikwe Game Reserve, the benchmark of this research. The impact of legislature on degradation is a 'burning' issue for all community members who experienced it. The majority of residents have submitted land claims.

Various environmental factors such as light intensity, temperature, evapo-transpiration, rainfall, drought, etc. are also involved in vegetation changes (Hoffman *et al.*, 1990). Various species respond in a markedly different manner under the same set of environmental conditions (O' Connor, 1985). *Cynodon dactylon,* for example, which is the most abundant perennial grass in Dinokana, (Chapter 3) is damaged by frost, while *Panicum coloratum* and *Setaria* species are relatively frost tolerant (Whiteman, 1980). *Urochloa mozambiscensis* has low frost tolerance and cannot withstand waterlogging (Whiteman, 1980). Plant growth increases as light intensity

increases up to the point of light saturaion of leaves in a canopy exposed to full sunlight (Blackman & Templeman, 1938).

It is clear that explanations of causes of degradation are never simple. Not one cause of degradation stands alone. Although veld retrogression is evident in the Zeerust District, it is, therefore, not the consequence of a single factor. It can be speculated to be either natural factors such as climate or drought, or due to land-use activities such as absence of veld burning to control woody vegetation and to revive the herbaceous layer of grasses, overstocking, lack of camp rotation, shortage of water for livestock, over-cropping, excessive application of fertilizers, population pressure, ignorance, greed and inequality (Archer & Stokes, 2000; Brown, 1999; Warren & Agnew, 1988). These factors are diverse and complex, because both natural and anthropogenic factors invariably co-occur. It is therefore, difficult to ascertain which may be the proximate cause of ecosystem change (Moleele, 2001). It is likely that the effect of these factors has been compounded by synergistic effects.

According to Bothma (1989), changes in vegetation in relation to soil depth, suggest that land-use, and not climate, drives the decline of grasses. However, these factors can act together to bring about land degradation. Human-induced changes contribute to the variation in climate, causing drought. Vegetation absorbs solar radiation, and the removal through misuse of land such as through over-cultivation, overgrazing and deforestation leaves the earth surface bare and this increases the tendency of the soil to reflect sunlight (Buys *et al.*, 2001). The air on the soil surface becomes cooler, and with cool on the surface and warm air above, the convective activity in the air is reduced. Cloud formation and precipitation are then suppressed, causing drought. Drought results in the decline of grasses (Buys *et al. et al.*, 2001), and as vegetation dies off and soil is disturbed, the storage of carbon will decrease and emission carbon increases, heating up the atmosphere (Buys *et al.*, 2001). Another interaction of climate and land-use is the burning of fossil fuels which increases the discharge of the greenhouse gases such as carbon dioxide, methane, ozone, fluorocarbons and nitrogen oxides which heats up the atmosphere (Buys *et al.*, 2001). These gases are transparent to visible solar radiation but absorbs or reflects back to the

earth the infra-red solar radiation. This increases temperature in the atmosphere and has an effect on the hydrological processes causing reduction in rainfall (Buys *et al.*, 2001).

6. 2. CONCLUDING REMARKS

Livestock rearing has always been an integral part of residents in the Zeerust District. Livestock is dependent on the production capacity of the rangelands. The conservation of natural agricultural resources such as soils, livestock, vegetation and water is, therefore, vital for their household food security. Natural vegetation remains the most economic source of fodder for livestock in the Zeerust District. Efforts should therefore, be made to keep rangelands in optimum condition for forage production. Protection and conservation of these natural resources can be achieved through sustainable land-use practices. These land-use activities include adjusting livestock according to the carrying capacity of the rangelands, practicing rotational grazing, veld burning and control of woody species.

Soil management programmes which are aimed at promoting dense vegetal cover and in turn improve soil structure should be developed. Soil conservation should be based on covering the soil to protect it from raindrop impact, improving aggregate stability and increase surface roughness to reduce velocity of runoff.

Environmental education with sustainable agricultural as the aim is one of the most important social practices which can contribute to the deceleration of environmental deterioration and the reclamation and ecologically sustainable management of degraded areas. Within this framework it is hoped that residents in the Zeerust District will critically reflect on their perceptions of themselves as being stewards of scarce and non-renewable resources. Land degradation is more than just an environmental problem which jeopardizes biodiversity and threatens sustainability of livestock. It is a real social problem that must be tackled before many people's aspirations of a better life are met.

6. 3. RECOMMENDATIONS

An effective response to land degradation calls for improving the incentives of farmers to care for their land and improving their access to the knowledge and inputs required for proper care. The following policy actions should be considered:

- There should be increased research and technology for land management and improved spread of information through widely linked, user-friendly information systems for farmers and the communities at large.

- In response to the out-cry by farmers who need provision of fertilizers, the government should promote land-improving investments such as building up of soil organic matter through widely used user-friendly systems for farmers.

- The government should encourage long–term improvements by securing property and rights of access to natural resources.

- Unlike the government-imposed Betterment schemes, the government should develop planning systems for sustainable land-use that involve key resource user groups.

- The economic environment for farmers should be improved by developing market infrastructure, correcting distorted price incentives.

- Information has to be collected to start rehabilitation and restoration programmes in degraded areas.

- Community education programmes should be started and community participation be encouraged.

The most important factors to overcome in programmes to combat land degradation are the economic imperatives that drive the people to degrade the land with little or no consideration of the risk of loss of sustainability. Poor people cannot easily postpone immediate consumption for future returns, nor will they ignore the pressing needs even if the use of these resources jeopardizes their long-term viability (Hopper, 1988).

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SUMMARY

The objectives of this research have been achieved. These objectives as set out in Chapter 1 were to:

1. conduct a survey of grass species composition in the Zeerust District and relate the distribution of grasses to veld retrogression.

2. analyse soil samples for nutrient status and use this data to confirm soil degradation.

3. study attitudes, perceptions and indigenous knowledge of local communities with regard to veld retrogression, land-use and land degradation.

In an attempt to address these aims, botanical surveys were conducted. Prior to this research, relatively little was known about the extent and severity of degradation of rangelands in the Zeerust District.

Soils were analysed for nutrient status. The data obtained indicated that local soils are both chemically and physically degraded (Chapter 4). Large surfaces of the ground are not covered by vegetation (Chapter 3). These results confirm Hoffman's (1999) findings that loss of vegetal cover and soil degradation are a serious problem in the study area.

The respondents interviewed, are subsistence farmers, practicing both crop and livestock farming. The results obtained, revealed that these farmers value cattle as a convenient way of saving money until it is exchanged for cash. Due to absence of proper pasture management in the area, the rangelands have been overutilised, resulting in changes in grass species composition towards retrogression. Local inhabitants blame the legacy of apartheid on degradation problems. Their lands were taken and they had to overstock their grazing lands to make a proper living. Invasion of woody species is also a problem in grazing areas. The most important encroachers include *Acacia mellifera, A. nilotica, A. tortilis* and *Dichrostachys cinerea.*

Grassland retrogression has become a serious threat to food security in the study area, and it makes the people and the land vulnerable to drought and poverty. Furthermore, when a retrogressed rangeland cannot be restored, it leads to migration of people. In most households that were interviewed, many able-bodied people have migrated to townships for employment because the income from farming is not sufficient to meet all the household needs. This negatively affects family relationships.

As a management strategy to alleviate poverty and to reduce migrant labour, the government can use this data to draw environmental policies and action plans in affected areas. The majority of residents have submitted land claims. This data will provide recommendations to government departments dealing with issues of land restitution. Most sites are severely degraded and need restoration. Efforts to stop veld retrogression and to maximize utilization should be given top priority. The results of this survey are significant as they would form a basis for the construction of a temporal inventory for the North West Province.

Land degradation will thus, continue until there is balance between the basic needs of communal farmers, their sustainability and their prospects for a better future on their land.

APPENDIX A

QUESTIONNAIRE FOR THE SURVEY

Team:

Community of:

Date:

Length of interview:

Is the MR (husband) alive?

Is the FR (wife) alive?

1.1.1. (MR) How old are you?

1.1. 2. (FR) How old are you?

1.2. How many **own** children do you have that are still alive?

1.3. How many **own** children live with you in this house?

1.4. How old are these children?

1.5. Are there relatives or grandchildren living with you in this house?

1.6. Are there other people living with you in this house?

yes: 1.6.1 Do you receive any support or money from those people?

2.1. (MR) Where were you born?

2.2. (MR) Where was your parents' house then?

2.3. (MR) Where did your parents work then?

2.4. (MR) After your place of birth, what was the next place you moved to?

2.5. (MR) When did you move there?

2.6. (MR) Did you move there with family or alone?

2.7. (MR) Why did you move there?

2.8. (MR) How did the person for whom you worked treated you?

2.9. (MR) Do you want to go back to any of the places you have lived in?

yes: 2.9.1. (MR) To which place would you like to go back to?

no: 2.9.2. (MR) Why do you want to stay here?

3.1. (FR) Where were you born?

3.2. (FR) Where was your parents' house then?

3.3. (FR) Where did your parents work then?

3.4. (FR) After your place of birth, what was the next place you moved to?

3.5. (FR) When did you move there?

3.6. (FR) Did you move there with your family or alone?

3.7. (FR) Why did you move there?

3.8. (FR) How did the person for which you worked treat you?

3.9. (FR) Do you want to go back to any of the place you have lived in?

yes: 3.9.1. (FR) To which place would you like to go back to?

no: 3.9.2. (FR) Why do you want to stay here?

3.10. Where did you get married?

3.11. Where did you live when your children were born?

3.12. When you first came into this settlement, did you have to build a house all by yourself?

yes: 3.12.1. How did you get the money and the materials to build the house?

no: 3.12.2. Did somebody allocate a house to you or did you move into the house of a relative first?

3.13. Were you ever forced by a person such as a farmer or a government official to leave a place?

yes: 3.13.1. Have you, yourself or has any other member of your household ever received money because you had to a place?

yes to 3.13.1: 3.13.2. What did you spend the money for?

4.1. (MR) Do you get a pension from the government?

yes: 4.1.1. (MR) What is the pension used for?

4.1.2. (MR) Who is planning what the pension is used for?

4.2. (MR) Did you ever get a package when you left a job?

yes: 4.2.1. (MR) On what did you spend the money?

4.3. (MR) Is there something else that you do in order to make a living for the family?

4.4. (MR) What decisions do you make in the household?

4.5. (FR) Do you get a pension fund from the government?

yes: 4 .5.1. (FR) What is the pension used for?

4.5.2. (FR) Who is planning what the pension is used for?

4.6. (FR) Did you ever get a package when you left a job?

yes: 4.6.1. (FR) On what did you spend the money?

4.7. (FR) Is there something else that you do in order to make a living for the family?

4. 8. (FR) What decisions do you make in the household?

4.9. (FR) What are the children doing in order to make a living for the family?

4.10. Do you have any support from children that are not living in your household?

4.11. What is the most important source of income for your family?

4.12. What do you think are the things that one needs most to make a living?

4.13.What do you often spend the money for?

4.14. Among these things, what is the most expensive thing that you spend money for?

4.15. How difficult is it for you to buy these products?

4.16. Does somebody in your family collect firewood or do you hire people from the community to firewood?

If they hire: 4.16.1. Do you have to pay it?

4.16.2. How much do you have to pay?

4.17. Does somebody in your family fetch the water you need in your house or do you buy it from somebody?

If they buy: 4.17.1. From whom do you buy it?

4.17.2. In what quantities do you buy?

4.17.3. How often per week or per month do you buy?

4.17.4. How much do you pay?

4.18. Do you have electricity?

yes: 4.18.1. What do you pay for electricity?

4.18.2. What do you use it for?

4.19. Do you own a vegetable garden or a garden plot somewhere?

yes: 4.19.1 What do you grow in there?

4.19.2. What are you doing with those products?

4.20. Are you satisfied with what you are having now?

4.21. Was your life better or worse under the old (Mangope) government?

4.22. Why so?

5.1. Who in your household has arable land?

5.2. Are you member of cooperation?

5.3. Do you have several plots or only one?

5.4. Where is the land situated?

5.5. How large is the plot?

5.6. Describe type and the quality of your products!

5.7. What are you using the products for?

5.8. If you have a normal harvest, for how long do you have food for yourself and for your family?

5.9. Do you have brothers or sisters that own arable land?

yes: 5.9.1. Do they support you occasionally with products from their fields?

5.9.2. Do you support them occasionally with your products?

5.10. Are you satisfied with the soil of your plot?

5.11. What can be done to make crop farming better?

5.12. Who should make plans to do so: **only** the farmers, the farmers **together with** the extension officers, or just the extension officers alone?

5.13. Would you say that it is rather easy or hard to be a crop farmer.

5.14. Why so?

5.15.Would you give up farming for a better job somewhere else?

yes: 5.15.1.What would you like to do?

no:5.15.2.Why do you want to stay a farmer?

5.16. Do you keep animals?

yes: 5.16.1. What animals?

5.16.2. For what purposes do you keep them?

6.1. How much cattle do you have now, i.e. bulls, heifers, calves?

6.2. On which farming area does your cattle graze?

6.3. Do you loan your cattle to somebody to watch it for?

yes: 6.3.1. Why are you doing so?

6.3.2. How did you chose that person?

6.3.3. What was your agreement with that person?

6.4. Do you personally care for your cattle or is it somebody else?

somebody else: 6.4.1. Who is it?

6.4.2. Do you pay that person/ these persons?

6.4.3. What are you doing if you are not watching for your cattle?

6.5. Do people in the community keep cattle to worship ancestors?

yes: 6.5.1. How are they worshipping the ancestors?

6.6. Do you sometimes slaughter your cattle?

yes: 6.6.1. For what purposes are you doing so?

6.7. Do you sometimes sell your cattle?

yes: 6.7.1. For what purposes are you doing so?

6.7.2. Where are you selling your cattle?

6.8. If you say 'Kgomo ke polokelo ya motswana', why is that a good advice?

6.9. If one gets a good job in a town, should he give up cattle farming or keep on with it?

6.10. Do you wish your children to keep cattle or rather to work in the towns?

6.11. Why so?

6.12. Who do you think is a wealthy farmer in your community and why?

6.13. What makes a person respected in your community?

6.14. If as the people say, 'cattle is an African bank', would you describe yourself as a farmer who has enough heads of cattle to cope with a situation when money is needed?

yes: 6.14.1. Would you like to have more cattle?

no: 6.14.2. How many heads of cattle do you think one need?

6.14.3. Should one rather have lots of bulls or lots of heifers?

6.15. Do you keep other animals?

yes: 6.15.1. What kind of animals do you have?

6.15.2. For what purposes do you keep them?

6.16. Are the grazing areas belonging to the communities in good or bad conditions?

6.17. Why so?

6.18. Are there camps on the farming area your cattle graze on?

yes: 6.18.1. Are the fences of the camps in a good or bad conditions?

6.18.2. Do people use those camps?

6.18.3. Why?

no to 6.18: 6.18.4. What can be done when a field is overgrazed?

6.19. Are there thorn bushes on the grazing areas?

yes to 6.19: 6.19.1. What are the reasons that thorn bushes appear on the grazing areas?

yes to 6.19: 6.19.2. What are the farmers doing against thorn bushes?

yes to 6.19: 6.19.3. Do you think that what the farmers are doing against thorn bushes is successful?

6.20. Do you have dongas and gullies around here?

yes to 6.20: 6.20.1. What are the reasons that dongas and gullies appear?

yes to 6.20: 6.20.2. What are farmers doing against dongas?

yes to 6.20: 6.20.3. Do you think that what the farmers are doing against dongas is successful?

6.21. Have you experienced droughts?

yes to 6.21: 6.21.1. When in your life did you experience droughts?

yes to 6.21: 6.21.2. What are reasons for drought?

yes to 6.21: 6.21.3. What are the communities doing against droughts?

yes to 6.21: 6.21.4. Do you think that what communities are doing against droughts is successful?

6.22. Would you say that it is rather easy or rather hard to be a cattle farmer?

6.23. Why so?

6.24. What would you like to improve as for cattle farming?

6.25. Are you satisfied with the work of the extension officers?

6.26. Why so?

6.27. Who do you think should make plans as to how to improve the conditions of the grazing areas: **only** the farmers, the farmers **together with** the extension officers, or **just** the extension officers alone?

APPENDIX B

LIST OF GRASS SPECIES SAMPLED IN THE STUDY AREA

NAME OF SPECIES	ABBREVIATION
Andropogon schirensis	*A. sch*
Aristida bipartite	*A. bip*
Aristida congesta	*A. con*
Aristida diffusa	*A. dif*
Aristida junciformis	*A. jun*
Bothriochloa insculpta	*B. ins*
Bothriochloa radicans	*B. rad*
Bracchiaria eruciformis	*B. eru*
Cenchrus ciliaris	*C. cil*
Chloris virgata	*C. vir*
Cymbopogon plurinodis	*C. plu*
Cynodon dactylon	*C. dac*
Digitaria eriantha	*D. eri*
Digitaria monodactyla	*D. mon*
Enneapogon cenchroides	*E. cen*
Eragrostis biflora	*E.bif*
Eragrostis curvula	*E. cur*
Eragrostis lehmanniana	*E. leh*
Eragrostis palens	*E. pal*
Eragrostis racemosus	*E. rac*
Eragrostis rigidior	*E. rig*
Eragrostis superba	*E. sup*
Eragrostis trichophora	*E. tri*
Fingerhuthia africana	*F. afr*
Heteropogon contortus	*H. con*
Melinis repens	*M rep*
Panicum coloratum	*P. col*
Panicum maximum	*P.max*
Schmiditia pappophoroides	*S. pap*
Setatria verticillata	*S. ver*
Setaria nigrirostris	*S. nig*
Setaria sphacelata	*S. sph*
Themeda triandra	*T. tri*
Tragus berteronianus	*T. ber*
Urochloa agropyroides	*U. agr*
Urochloa mozambiscensis	*U. moz*

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