



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
MAFIKENG CAMPUS

**THE EXTENT OF WOODY PLANT INVASION IN
SELECTED AREAS OF THE FORMER MOLOPO
MAGISTERIAL DISTRICT**

BY:

Khumoetsile Stephen Molatlhegi

Student Number: 16094905

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Supervisor: Prof. P.W. Malan

TABLE OF CONTENTS

ABSTRACT

CHAPTER 1: INTRODUCTORY BACKGROUND

1.1. Introduction	1
1.2. Problem statement	4
1.3. Land degradation	5
1.4. Causes of land degradation	8
1.4.1. Natural causes of land degradation	8
1.4.2. Agricultural and human practices causing land degradation	9
1.5. Soil degradation	10
1.5.1. Human causes of soil degradation	11
1.6. Vegetation degradation	12
1.7. Dissertation presentation	12
1.8. Aims and objectives	13

CHAPTER 2: STUDY AREA

2.1 Introduction	14
2.2 Geology and soil types	17
2.3 Climate	19
2.3.1. Rainfall	20
2.3.2. Temperature	21
2.4. Vegetation	22

CHAPTER 3: INVASION OF WOODY SPECIES

3.1. Introduction	24
3.1.1 Background	24
3.1.2 Relationship between grasses and woody plants	32
3.2. Methodology	33
3.2.1 Technique used	35
3.2.2. Materials used	36
3.3. Results and discussion	37
3.3.1. Bush densities in different survey sites	37
3.4. Conclusion	71

CHAPTER 4: SOIL ANALYSIS

4.1. Introduction	81
4.2. Methodology	86
4.3. Soil pH	86
4.4. Mineral demands essential for plant growth	92
4.5. Organic carbon	94
4.6. Nitrogen	99
4.7. Phosphorus	102
4.8. Potassium	106
4.9. Sodium	107
4.10. Exchangeable sodium percentage (ESP) and the sodium adsorption ratio (SAR)	109
4.11. Calcium	111
4.12. Magnesium	113
4.13. Resistance	115

4.14. Soil texture	116
4.15. Cation exchange capacity	118
4.16. Electrical conductance	120
4.17. Conclusion	121

CHAPTER 5: SOCIAL SURVEY

5.1. Introduction	125
5.2. Material and methods	128
5.3. Results and discussion	128
5.3.1. Demographics	128
5.3.2. Infrastructure	129
5.3.3. Financial information	131
5.3.4. Agricultural information	132
5.3.4.1 Livestock farming	132
5.3.4.2. Crop farming	136
5.4. Conclusion	137

CHAPTER 6: GENERAL DISCUSSION AND RECOMMENDATION

6.1 General discussion	140
6.2 Recommendation	144

REFERENCES	146
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ACKNOWLEDGEMENTS	188
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APPENDIX

Appendix 3.1

Appendix 3.2

Appendix 5.1

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ABSTRACT

THE EXTENT OF WOODY PLANT INVASION IN SELECTED AREAS OF THE FORMER MOLOPO MAGISTERIAL DISTRICT

BY:

Khumoetsile Stephen Molatlhegi

Supervisor: Prof. P.W. Malan

Faculty of Agriculture, Science and Technology

Department of Biological Sciences

North-West University

Master of Science (Biology)

The value of grazing land may be completely destroyed by invading woody species (Donaldson, 1967), and their eradication may cost more than the land is worth. At consultative workshops in 1997 and 1998, participants considered the invasion by woody species to be a problem in 42 % of the magisterial districts, particularly in the North West, Northern Cape, Eastern Cape and Limpopo provinces. According to Hoffman & Ashwell (2001), 50 % of communal districts and 38 % of commercial districts are affected.

According to Ebersohn *et al.* (1960), woody plant invasion in the Molopo Area is a problem and over one million morgen of veld in the area has been invaded by *Acacia mellifera*. This is highlighted in this study, whereby *Acacia mellifera* is prominent in 4 survey sites out of 10. Other prominent woody species include *Dichrostachys cinerea*, *Prosopis*

CHAPTER 1: INTRODUCTORY BACKGROUND

1.1 INTRODUCTION

Woody plant invasion (bush encroachment) is the increase in tree density of natural grasslands (Bothma, 1996; Smit, 1999; Hoffman & Ashwell, 2001). It is considered by farmers to be a serious problem in the world and also in large areas of South Africa, particularly in savanna regions (Scott, 1967; Smit, 1999; Archer & Boutton, 2001; Malan *et al.*, 2001).

The present condition of the woody component of savanna areas reflects a change in the structure rather than in botanical composition. This phenomenon is primarily due to the exploitation of forests for fire wood and overgrazing (Tainton, 1981). Land-use history (e.g. livestock grazing and fire wood collection), rather than environmental factors appear to be the most important determinants of the extent and rate of bush encroachment (Anonymous, 2001 a).

Approximately 80 % of the total population of Southern Africa reside in rural areas and depend on agriculture to a greater or lesser extent (Crowley, 1985). Arid or semi-arid areas have a rainfall of approximately 150 mm per annum (Bothma, 1996) and are not suitable for crop farming. Therefore, people living in these areas, are mostly subsistence cattle farmers. Most subsistence cattle farmers lack the knowledge of sustainable farming and they seem to degrade the environment due to their farming practices.

High population densities are found in communal areas of the former homelands like Bophuthatswana (Hoffman & Ashwell, 2001). Official statistics suggest that between 1960 and 1980, the population of rural areas in South Africa increased from about 4.5 million to 11 million people (Hoffman & Ashwell, 2001). Large areas of these former homelands are used for communal farming (the land belongs to people and not to the individual). Therefore, most communal farmers do not take responsibility of maintaining the land for sustainable production (Anonymous, 2003).

The farmers keep large numbers of animals, which exceed the number, which the veld can sustain. Scholes and Walker (1993) revealed that, keeping large numbers of grazers in the absence of browsers, causes the reduction of the grass layer and increase tree seedling recruitment which consequently leads to the invasion of woody species.

According to Sola (2001), people who are living in poverty, facilitate forest and woodland degradation (through fire wood collection) in southern Africa. Poor households are dependent on fuel burning for energy and this has implications for their health (exposure to excessive smoke decrease lung functioning, leads to lung cancer and causes asthma attacks) (Anonymous, 2003). The woody component of the areas near the poor households gets reduced and facilitates increase in herbaceous vegetation, uncovered patches and reduction in grass production (Sola, 2001).

Woody plants and grasses in southern African rangelands appear to compete primarily for water and it is found that, because of a deep penetrating root system of woody plants, they are consistently stronger competitors for water (Scholes & Walker, 1993). This competition encourages bush encroachment, especially in arid and semi-arid areas.

High woody plant densities, especially in the arid savannas suppress the grass cover and thus reduce grazing capacity (Anonymous, 2001 a). Veld degradation in the savannas is facilitated by natural factors like droughts (Anonymous, 2001 a). This veld degradation can be reduced if more farmers understand the environmental management principles. Teaching local farmers about sustainable farming is the most effective method, which can enhance sustainable use of natural resources.

An ecosystem consists of biotic and abiotic factors which are interdependent and which are all essential for the preservation of life in a particular area. A disturbance or change in any form of an ecosystem has a ripple effect on the whole system and can lead to a reduction and some times the extinction of some species (Bothma, 1989).

The invasion of grasslands by woody species takes place at the expense of grazers, but with a balance between grazers and browsers, this problem may be limited (Bothma, 1996). In the long term, the absence of browsers can be detrimental to grazers. This means that there will be no food for grazers and the production number of grazers will be reduced (i.e. absence of browsers and presence of grazers will lead to bush encroachment, resulting in lower grass production).

Woody species in the study area are predominantly thorn bushes (see Chapter 3). This is also ensuring that there will be an increment of bushes in the area, because of defence mechanisms used by woody plants against browsers (Bothma, 1996).

1.2 PROBLEM STATEMENT

Woody plant encroachment has been widespread in grassland and savanna ecosystems of Africa (Archer *et al.*, 2000). This encroachment jeopardizes biodiversity and threatens the sustainability of pastoral, subsistence and commercial livestock grazing (Rappole *et al.*, 1986).

According to Hoffman *et al.*, (1999) and Hoffman & Ashwell (2001), woody plant invasion is the most serious veld degradation issue in the North West Province (Figure 1.1).

Cattle farming has received most of the blame for the perceived degradation problem, but at the same time has most to lose, because declining primary productivity translates to declining secondary production (De Ridder & Breman, 1993).

Data presented by Fourie *et al.* (1987), Skarpe (1990) and Perkins (1991), for the Kalahari, Dye and Spear (1982) and Bosch (1989) for elsewhere in southern Africa, show that in recent years, woody biomass productivity has increased at the expense of palatable grass species.

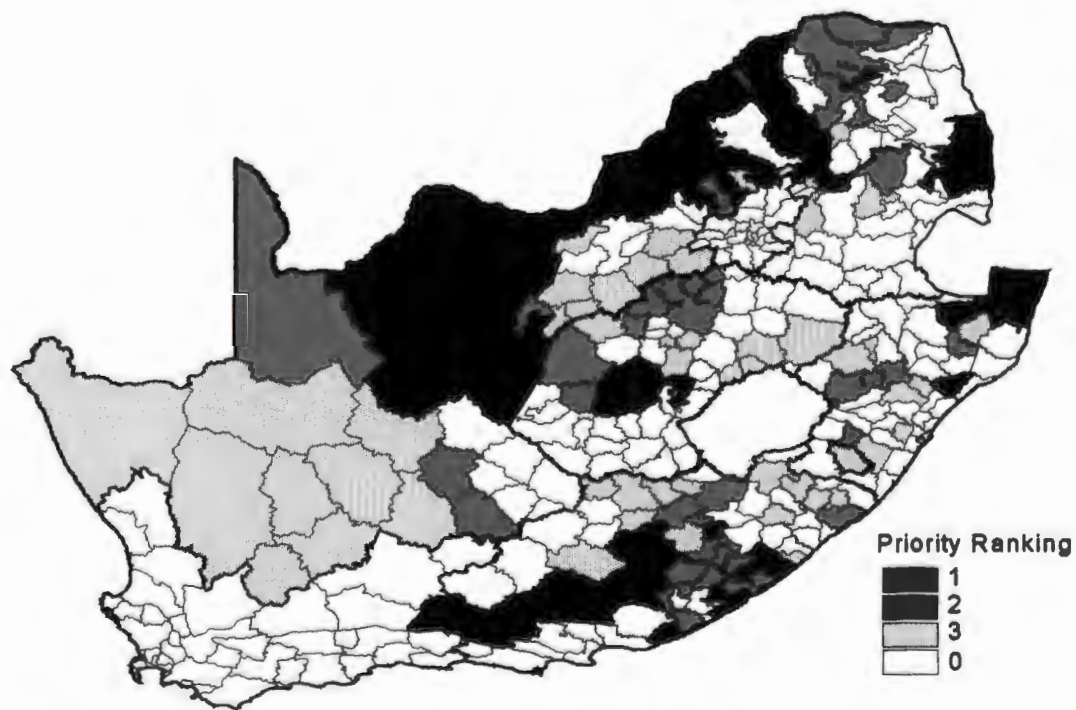


Figure 1.1: Location of the 154 Magisterial Districts. Workshop participants perceived bush encroachment to be first, second or third order veld degradation priority (from Hoffman & Ashwell, 2001).

Woody plant invasion decreases the grass production and reduces the grazing capacity of the veld. It suits the increase in the number of browsers, which can be maintained by the veld (Bothma, 1989).

In the long term, retrogression will affect biodiversity, which may result in the creation of a genetically malfunctioning ecosystem (Acland, 1971). Barnard & Newby (1999) indicated that, communal areas are much degraded as compared to commercial rangelands.

Little is known about the rates of and dynamics of bush encroachment or its impact on the fundamental ecological processes related to nutrient cycling and biodiversity (Archer *et al.*, 2000).

1.3 LAND DEGRADATION

Land degradation, more specifically desertification, is an issue of concern for rural communities, farmers and natural resource managers, who experience these effects first hand (Hoffman & Ashwell, 2001). This study will add to the information and data available in South Africa on the extent of woody plant invasion in grasslands and could aid in the development and implementation of control measures.

Land degradation is defined as the loss of biological or economic productivity of an area caused primarily by human activities (UNCCD, 1995). Land degradation takes on many forms, including urban development on productive agricultural lands, bush encroachment, alien plant invasion of grazing lands, desertification and pollution of ground and surface water resources. According to Hoffman & Todd (1999), land

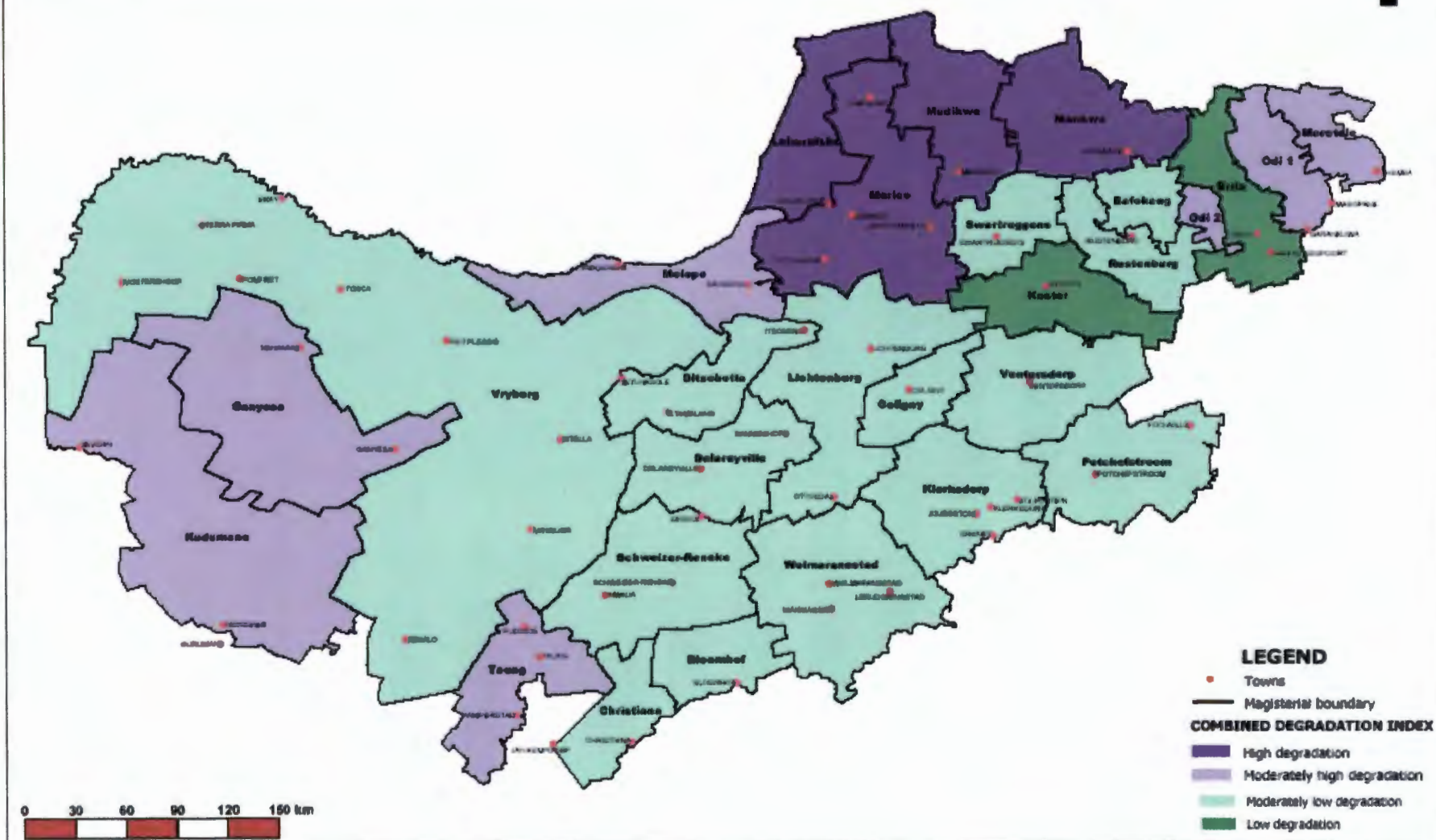
degradation in the Molopo Magisterial District is moderately high (Figure 1.2).

Degraded land supports fewer crop and animals (Hoffman & Ashwell, 2001). In order to maintain productivity under degraded lands, farmers need either to obtain more land or to farm more intensively by investing in irrigation and machinery and using supplementary feeds, fertilizers and pesticides. This is not possible for communal or subsistence farmers as they lack sufficient funds to afford the cost of supplements. It is therefore essential to lay emphasis on veld restoration and maintenance in communal or rural areas. This means, there should be more research development in communal areas (i.e. the research finding will enable extension officers to inform the communities about sustainable and productive agricultural practices which are affordable or cost effective).

Clearing of woody plants provides higher initial stands of grasses and a more dense population than sowing into regularly grazed rangelands (Richter & Meyer, 2001). The suppressive effect of woody plants on grass production and grazing capacity is often considered the major reason why clearing of woody plants is viewed as an important management option.

Veld mismanagement by man is responsible for the retrogression of established grasslands, which subsequently leads to changes in biodiversity such as a decline in grass species composition and invasion of woody and weedy species (Crowder & Chedda, 1982).

Land degradation extent per magisterial district



Source: Hoffman & Todd 1999

Figure 1.2: Land degradation extent per magisterial district in the North West Province (DACET, 2004).

According to Du Toit (1972); Skarpe (1990); Teague & Smit (1992); Scholes & Walker (1993); Milton & Dean (1995) and De Vreede (2000), factors contributing to bush encroachment are as follows:

- Absence of browsers and presence of grazers only;
- absence of competition between the grass and tree layers resulting from the deterioration of grass layer by drought and human disturbance; and
- presence of grass feeding insects.

Woody plant invasion decreases the grass cover production per hectare and thus reduces grazing capacity. The reduced grass cover eventually leads to increased soil erosion (Donaldson, 1967; Bothma, 1989).

Bothma (1989) found that in arid bushveld areas, bush encroachment is accompanied by a decrease in basal cover and a change in the species composition of the grass layer. Perennial grass species in particular, are replaced by annual species.

Grazing, especially overgrazing, reduces vegetation cover, which leads to the increase of evapotranspiration and the reduction of plant biomass production by 75 % (Snyman & Fouché, 1991). It is thus important that a balance between grazing animals and carrying capacity of land should be reached.

1.4 CAUSES OF LAND DEGRADATION

There are two factors facilitating the process of land degradation:

- Natural causes, and
- Agricultural or human causes.

1.4.1 NATURAL CAUSES OF LAND DEGRADATION

It is estimated that 82 % of the land (i.e. 68 million hectares of veld) available in southern Africa for agricultural purposes can only be effectively utilized by grazing ruminants (Snyman, 1998). The cyclic nature of annual precipitation and unreliable distribution of the seasonal rainfall of southern Africa, cause long, extensive droughts and shorter seasonal droughts (O'Connor & Bredenkamp, 1997).

Rainfall is the most important limiting environmental factor that determines grassland production in arid and semi-arid areas (Snyman, 1998). It is therefore necessary that the sustainable utilization of a grassland ecosystem must emphasize the efficient use of water. Rainfall in the Molopo District is restricted to the summer months of December to February (Figure 2.6).

1.4.2 AGRICULTURAL AND HUMAN PRACTICES CAUSING LAND DEGRADATION

Farmers cannot control rainfall, but can directly or indirectly influence the effects of rainfall, since grassland condition is mainly influenced by management practices (Snyman, 1999).

Steep slopes and highly drought prone areas are not preferable to be cultivated at all, but most farmers cultivate such areas as a result of lack of knowledge. It is the primary reason why South Africa experiences soil degradation and low soil fertility (Snyman, 1999).

Fertilizers are costly in terms of energy resources to produce, and continued high rates of use, lead to environmental problems like river pollution (Young, 2001). Poor farmers simply cannot afford the high cost of fertilizers and other purchased inputs, nor do they have the capital to take on the risk, which these inputs involve.

Soil and land are finite resources and irreplaceable in the short to medium term (Hoffman *et al.*, 1999). Poor management practices, causing the reduction in soil quantity and quality, lead to the depletion of soil reserves. Continued long term exploitation without replacement is not sustainable and is well recognized in South Africa (Hoffman & Ashwell, 2001).

In the past, it was thought that South Africa's soils were sensitive and fragile, that climate and topography predispose the country to soil erosion. The most influential factor in land degradation is "poor" farming

methods and land husbandry by both commercial agriculturalists and subsistence farmers (Hoffman *et al.*, 1999). Most farmers in the study area are communal farmers and do not own land of their own. This leads to a “non-care” attitude towards land degradation in general.

1.5 SOIL DEGRADATION

The cost of soil degradation in South Africa was estimated at nearly R2 billion during the 1992 / 93 financial year (Hoffman & Ashwell, 2001). Soil degradation in the Molopo Magisterial District is considered to be moderate (Figure 4.1, Chapter 4).

Soil degradation affects plant growth, thus rendering a particular area of land unproductive (Hoffman & Ashwell, 2001). The various forms of soil degradation cost the country billions of rands per annum due to reduced productivity and clean up costs (e.g. to neutralize the effects of acid rain on soils in Mpumalanga costs the region about R25 million per annum (Hoffman & Ashwell, 2001)).

Soil erosion, especially on arable lands, bears the most significant degradation cost largely as a result of sedimentation of dams and associated water purification. Additional costs include the loss of soil fertility, water logging and sedimentation.

1.5.1 HUMAN CAUSES OF SOIL DEGRADATION

Agricultural activities such as improper ploughing methods, use of heavy agricultural machinery and application of fertilizers have the greatest impact on soil degradation with consequent modification of plant diversity in an area. Soil compaction, which usually results from poor cultivation practices (e.g. cultivating wet soils), increases the resistance of soil penetration by plant roots, emerging seedlings and limits oxygen and carbon dioxide exchange between the roots zone and the atmosphere. Compaction also reduces the rate of water infiltration into the soil, which may change the soil moisture status and consequently accelerates surface run-off (Yayock *et al.*, 1988).

Poverty and reliance on natural resources for energy, food and construction materials have also contributed to soil degradation. Overstocking and inappropriate irrigation facilitate soil erosion and salination (Bothma, 1996; Hofman & Ashwell, 2001). Lack of education and extension services are factors contributing to extensive soil erosion. It is therefore important to ensure that farmers and rural communities are informed about soil degradation and degradation in their areas and the effects thereof.

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.

1.6 VEGETATION DEGRADATION

Overgrazing of rangelands implies excessive use of forage by herbivores which result in biotic and abiotic components of an ecosystem being changed and cannot be recovered within ecological time (Conner, 2002). Heavy grazing causes a decline of grass production in the long run (Bothma, 1996). Many palatable grasses and soil organisms lack adaptation to cope with extensive livestock grazing and will thus decline with time (Bothma, 1996). Figure 3.1 (Chapter 3), shows the severity of veld degradation in the study area.

Severe grazing removes herbaceous vegetation, reduces plant litter and destroys a biological crust that protects the soil from wind and water erosion (Pyke, 2001). If these impacts are severe enough, critical thresholds of ecosystem function may be exceeded which will irreversibly alter water availability, energy and nutrient supplies and eventually cause ecosystem degradation.

1.7 DISSERTATION PRESENTATION

In this presentation, 9 reference sites were identified as affected by woody plant invasion. These sites were compared to a benchmark site (site 10) in terms of woody plant invasion as well as nutrient status and chemical characteristics of the soil (Refer to figure 2.2). The woody plant invasion is discussed in chapter 3, while the results of soil analysis is discussed in chapter 4. A social survey was also undertaken in the study sites and the benchmark. These findings are discussed in chapter 5. A

complete reference list (of all referred literature) follows at the back of this thesis.

1.8 AIMS AND OBJECTIVES

- ❖ To determine the extent of woody plant invasion (bush encroachment) in agricultural rangelands in the former Molopo Magisterial District.
- ❖ To analyze the nutrient status of the soil, in relation to woody plant density.
- ❖ Conduct a social survey in order to determine the points of view from communities, regarding their environment.
- ❖ To construct a temporal inventory on land degradation for the Molopo Magisterial District (North West Province) and make the data available for nature conservators and governmental sectors on land restitution.

CHAPTER 2: STUDY AREA

2.1 INTRODUCTION

The study area is the former Molopo Magisterial District and it is situated north-west of Mafikeng, in the North West Province (Figures 2.1 & 2.2). In the new dispensation (i.e. after the 1994 elections) the former Molopo Magisterial District is renamed Central District and is sub-divided into Mafikeng and Setla Kgobi local municipalities (Figure 2.3). The area is located in the Savanna Biome (Rutherford & Westfall, 1986). Figure 2.2 indicates the location of the 9 survey sites as well as the reference site (benchmark, site 10).

Approximately 50 % of the surface area of Africa is covered by savanna vegetation, making it the most extensive of all the biomes (Scholes & Walker, 1993). The South African savanna represents the southernmost extremity of this vegetation type and covers approximately one third of the country. According to Tainton (1999), the Savanna Biome includes sweet and sour savannas, differentiated according to the quality of the grass component during the dormant season. As a generalisation, sweet savannas occur in arid environments and / or on fertile soils, whereas sour savannas occur in the more humid areas and where soils are infertile (Tainton, 1999).

The Savanna Biome may also be distinguished on the basis of the palatability of the material produced by the woody layer. "Palatable savannas" are generally dominated by microphyllous (small-leaved) species (e.g. *Acacia* spp.) whose leaves are not well defended against

browsers by secondary plant metabolites such as tannin (Tainton, 1999). “Unpalatable savannas”, on the other hand, are characterised by broad-leaved woody plants (e.g. *Euclea*), which have well-developed chemical defence mechanisms. The former are generally thorny and occur on fertile, often high-clay content, soil derived from shale, dolomite or basic igneous parent material. The latter are found on infertile, often sandy soils derived from sandstone or acid igneous parent material (Tainton, 1999).

Savannas have developed in the more tropical areas of South Africa, where rainfall is seasonal and high mean temperatures are experienced (Bothma, 1996). The Savanna Biome consists of scattered and relatively low woody plants and a well developed grass cover. This is not the case in the study area, in which the woody plants are dense, making it difficult for animals to move. Grass cover in all the survey sites (Figure 2.2) is limited.

According to the Department of Agriculture, Conservation, Environment & Tourism (DACET, 2004), the North West Province has four major ecological zones:

- The Highveld in the south-east,
- Bushveld in the north-east,
- Middleveld as a narrow zone between the Highveld and the Bushveld, and
- Kalahari desert in the west (Molopo Magisterial District).

The North West Province is land “locked” and surrounded by Gauteng and Limpopo provinces in the east, Northern Cape in the west, the Free State in the south and shares an international border with Botswana in the north (Figure 2.1). The vegetation of this area is described as Kalahari Plain Thorn Bushveld (Low & Rebelo, 1996) and is characterized by undulating to flat sandy plains at 1000 m altitude (Donaldson, 1967). Hoffman *et al.* (1999) as well as Hoffman & Ashwell (2001) identified the former Molopo Magisterial District as one of worst communal districts in South Africa in terms of woody plant invasion (bush encroachment) (See Chapter 3).

The North West Province is predominantly rural, with 60 % of the population living in rural areas and it is one of the poorest provinces in the country (Hoffman & Ashwell, 2001). The agricultural sector of the province is contributing 13 % of the GDP and 18 % of the employment (Department of Agriculture, Conservation, Environment & Tourism, DACET, 2002). Crops such as maize, sunflower and peanuts are produced extensively on the fertile plains of the central region, where the study area is located.

In the Savanna Biome, there is a balance between woody plants and the grass component (Bothma, 1996). When the grass cover deteriorates, the shrub layer can become more competitive, eventually leading to bush encroachment. The dry season and the accompanying dry grass stratum, creates a favourable condition for fires. Fire plays an important role in the development and maintenance of savannas. Where there is no fire or burning of veld, the increment of woody plants intensifies and reduces the grass component of the area (Bothma, 1996).



Source: DACET, 2004. North West Province: State of the environmental report

Figure 2.1: Location of the North West Province in southern Africa.

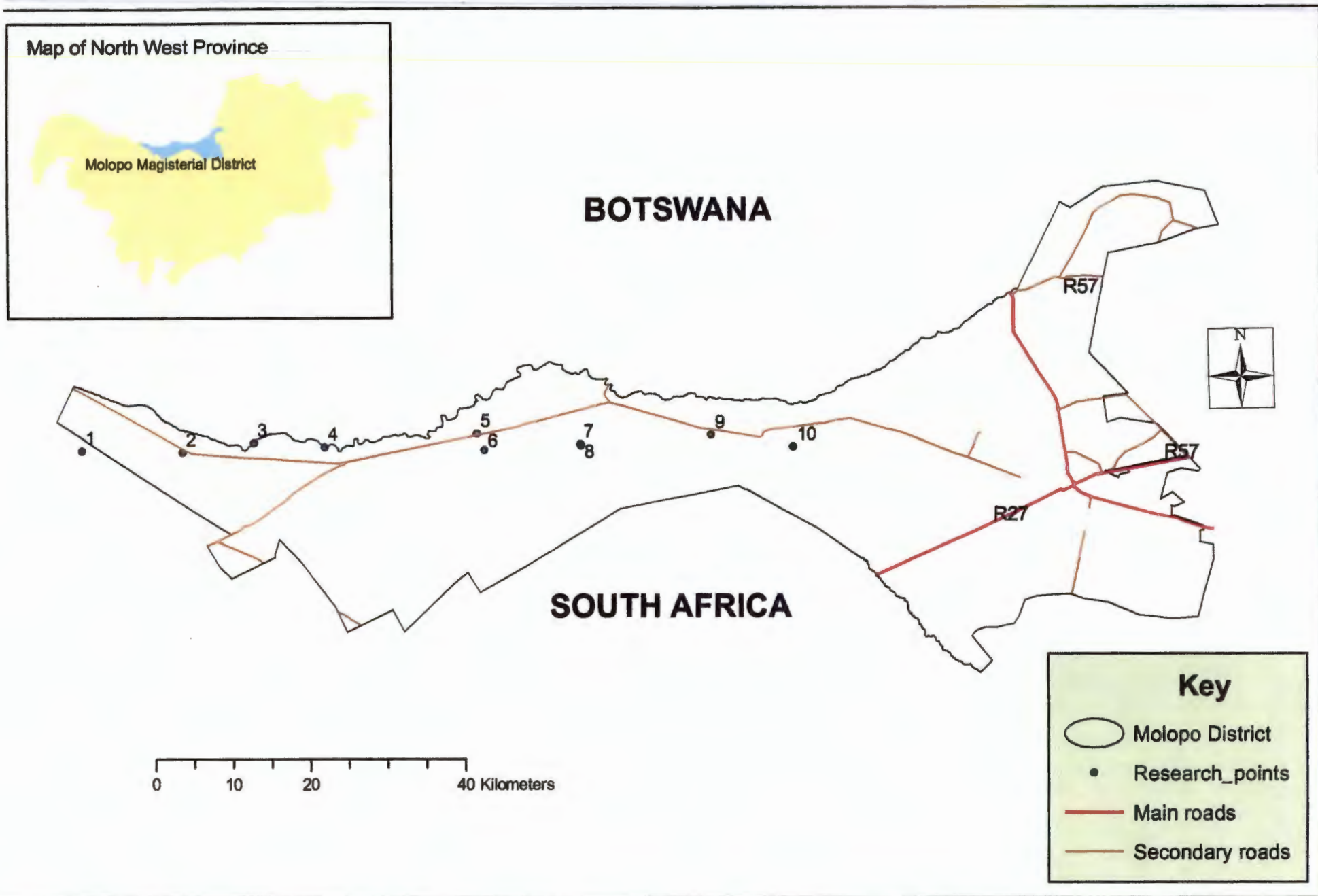


Figure: 2.2. Location of study sites in the Molopo Magisterial District .

North West Province: District and local municipalities



Source: Municipal Demarcation Board 2002

Figure 2.3: New districts of North West Province replacing the old magisterial districts of the former Bophuthatswana homeland (DACET, 2004).

According to Bothma (1996), savanna regions of South Africa are best for game ranching, since there is a large diversity of vegetation to support a large diversity of grazers and browsers. This biodiversity is currently under threat, due to the intensity of woody plant invasion. The invasion by woody plants in grasslands facilitates the growth of woody species (e.g. *Acacia* spp.) and eventually a decline of the herbaceous component.

2.2. GEOLOGY AND SOIL TYPES

In the semi-arid regions of South Africa, there is a good correlation between geological formations, soil types and plant communities (Bothma, 1996). This means that the soils have the same minerals, which are found in the rocky layers. The reason is that, the rocks break down into dust as a result of weathering and thus form soil. Therefore, the available soil minerals influence plants, growing in the particular area.

According to Tainton (1999), smaller rock particles weathered from the rocks, contain chemical constituents, which are adsorbed (attached) to the surface of soil particles. Water leaches chemicals out of the soil to greater depths or are taken up by plants. The portion taken up by plants is eventually returned to the soil in the form of organic matter.

The soil in the study area is deep sandy to loamy-sand of aeolian origin and is underlain by calcrete (Low & Rebelo, 1996). The sandy soils of the area are described as Kalahari sand. These sands are extremely low in organic matter and mineral elements (Donaldson, 1967). In places where

the sand is underlayed by a calcareous substratum, the soil is shallow and rich in lime (Donaldson, 1967).

The presence of deep soils explains the susceptibility of the area to invasion by deep-rooted woody plants, since these soils are more likely to be moistened to greater depths (Donaldson, 1967). Although the soils vary in colour, the texture appears to be the same, consisting of coarse and fine sand particles (Donaldson, 1967). The colour of the sand varies in tint from deep red, through pinkish and yellowish to pale grey. The grey to grayish-white soils are generally associated with dry sandy watercourses and contain limestone. The red sand, which consists of quartz grains, is coated with a red pellicle of iron oxide (Donaldson, 1967). The effects of wind, moisture, plant material and most probably lime, can therefore be assumed to be the main agencies responsible for the great variability in the soils of the study area (Donaldson, 1967).

The rock types in the area are Adesitic and Dolomite. These rocks are hard and essential for the prevention of soil erosion (Low & Rebelo, 1996). Soils that develop from igneous rocks such as dolerite and andesite are poorly leached, have a relatively high pH (Figure 4.3; Chapter 4), and consequently produce more palatable grazing (Bothma, 1996).

The soil types vary greatly in terms of fertility and texture (Hoffman & Ashwell, 2001) and their ability to absorb, retain and redistribute water. These factors make certain soils more susceptible to degradation by waterlogging, salination, wind and water erosion.

The most important characteristics of soil are colour, texture and structure (Bothma, 1989). Soil colour is attributed to different forms of iron in the soil, the parent rock from which it has developed and the amount of organic material in the topsoil (Bothma, 1989).

Red-yellow apedal soil type is prominent in the study area (Figure 2.4). This soil type has freely drained soils (sandy soils) and the soil colour is red and yellow.

Red soil usually indicates good drainage and aeration (Bothma, 1989). According to Agricultural Supportive Systems Specialist Services (1997), yellow and red soils an area without water tables.

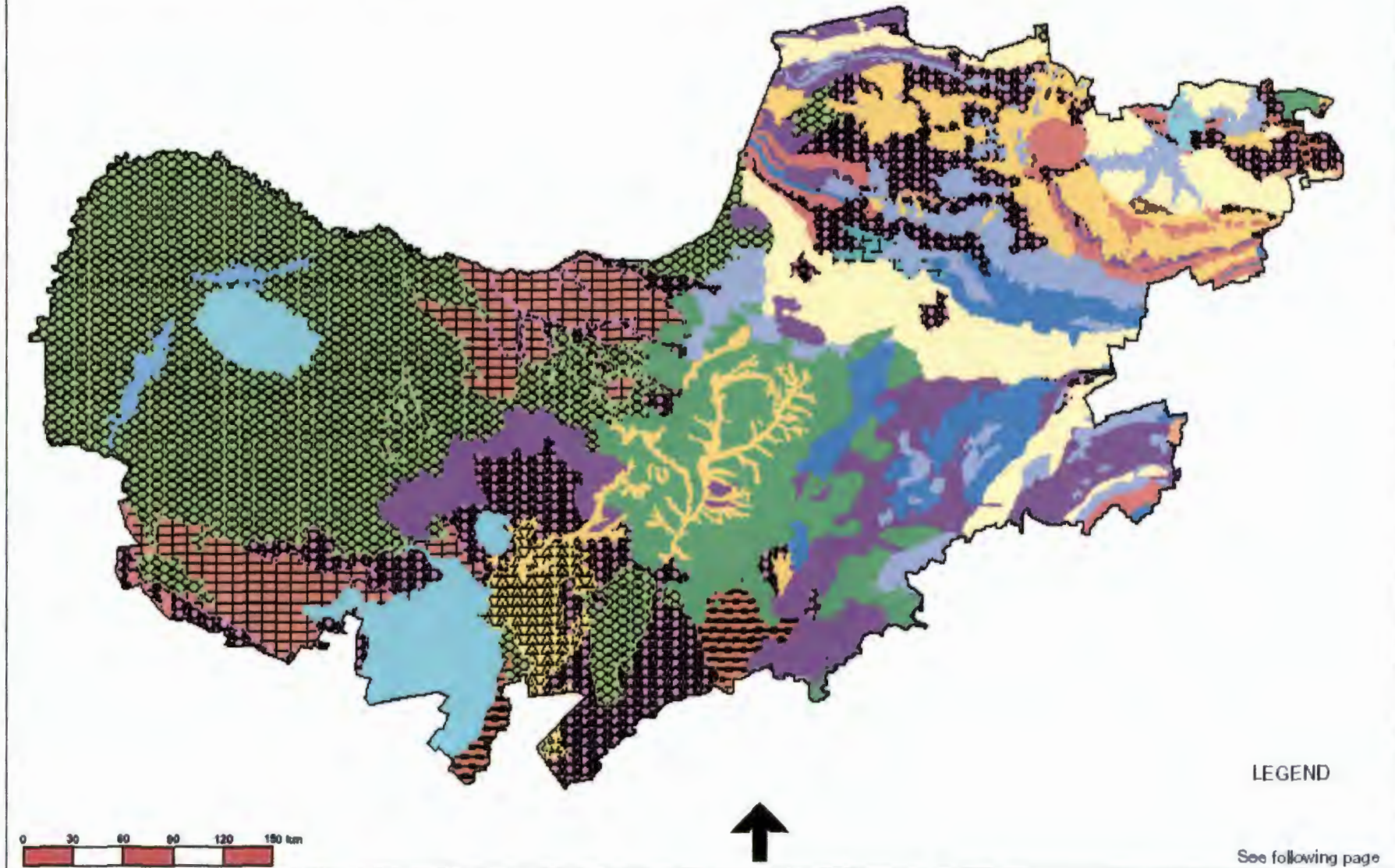
Soil with a high clay percentage has a better water holding capacity and nutrient composition than areas with a high sand percentage (Bothma, 1989). Soils in study area consists of clay particles less than 15 %.

2.3 CLIMATE

Climate alters the physical environment in ways that directly affects living organisms. Changing temperatures and water availability conditions are likely to induce stress in vegetation and plant species diversity and may encourage mobile organisms to alter their distribution in the medium to long term.

Climate changes will possibly cause a gradually increasing pressure on the tolerance limits of native species. According to Richardson *et al.* (1999), this stress (caused by climatic changes) in native species could

North West Province: Soil types



North West Province: Soil types

LEGEND

	Glenrosa and/or Mispah forms (other soils may occur), lime generally present in the entire landscape
	Glenrosa and/or Mispah forms (other soils may occur), lime rare or absent in the entire landscape
	Glenrosa and/or Mispah forms (other soils may occur), lime rare or absent in upland soils but generally present in low-lying soils
	Miscellaneous land classes, rocky areas with miscellaneous soils
	Miscellaneous land classes, very rocky with little or no soils
	One or more of: vertic, melanic, red structured diagnostic horizons, undifferentiated
	Plinthic catena: dystrophic and/or mesotrophic; red soils not widespread, upland duplex and marginalic soils rare
	Plinthic catena: dystrophic and/or mesotrophic; red soils widespread, upland duplex and marginalic soils rare
	Plinthic catena: eutrophic; red soils not widespread, upland duplex and marginalic soils rare
	Plinthic catena: eutrophic; red soils widespread, upland duplex and marginalic soils rare
	Prismatic and/or pedocutanic diagnostic horizons dominant. In addition, one or more of: vertic, melanic, red structured diagnostic horizons
	Red-yellow apedal, freely drained soils, red, high base status, < 300 mm deep
	Red-yellow apedal, freely drained soils, red and yellow, dystrophic and/or mesotrophic
	Red-yellow apedal, freely drained soils, red and yellow, high base status, usually < 15% clay
	Red-yellow apedal, freely drained soils, red, dystrophic and/or mesotrophic
	Red-yellow apedal, freely drained soils, red, high base status, > 300 mm deep (no dunes)
	Red-yellow apedal, freely drained soils, yellow, high base status, usually < 15% clay

Figure 2.4: Soil types of the North West Province (DACET, 2004).

favour the success and spread of alien plant species like *Prosopis* spp. (see Chapter 3).

The fluctuations of climate and the pressure exerted by the herbivores are the most important components of annual variation in grazing / browsing capacity in the savanna. According to Hoffman *et al.* (1999), it is impossible to control the climate and prevent natural catastrophes. Therefore, a ranch manager must pay special attention to other factors, which can be controlled (e.g. reduction of stocking rate).

2.3.1 RAINFALL

According to Tainton (1999), rainfall is the factor which most clearly determines the distribution and potential productivity of plant communities in South Africa.

The rainfall in the North West Province varies significantly from the more mountainous and wetter eastern region, which receives a mean annual rainfall of 400 mm - 600 mm (DACET, 2004), to the western parts which receive 200 mm – 300 mm per annum (Figure 2.5). The mean annual rainfall of the study area ranges from 300 mm – 500 mm (Figure 2.5). The drier semi-desert plains of the Kalahari in the west receive less than 300 mm of rainfall per annum (DACET, 2002). According to Donaldson (1967), the average annual rainfall of the Molopo Area during 1954-1961 was 566.8 mm. In the period, 1989-2003 (15 years), the average annual rainfall was 672.5 mm (Department of Geography, NWU). This average rainfall readings are typical for grassland or savanna vegetation (Crowder & Chedda, 1982).

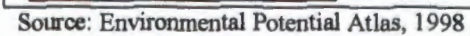


Figure 2.5: The mean annual rainfall of North West Province (DACET, 2004).

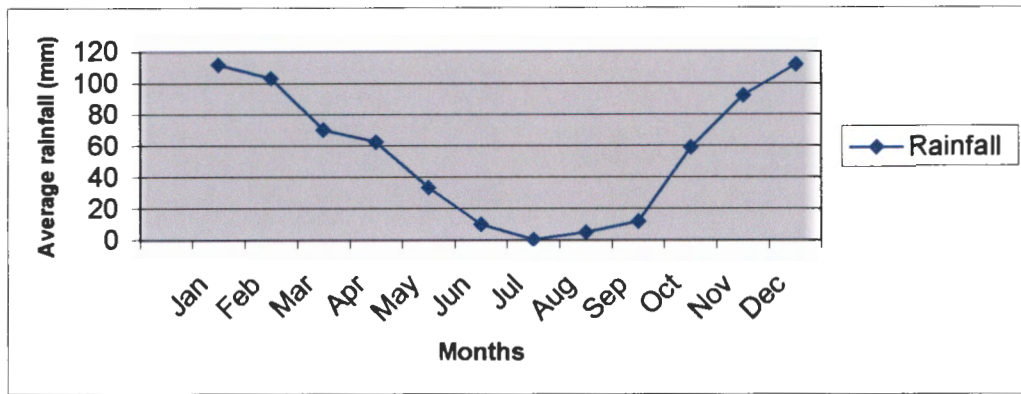


Figure 2.6: Average monthly rainfall of the former Molopo Magisterial District from 1989-2003 (Department of Geography, NWU, 2004).

There average rainfall during the summer months is as high as 105 mm and as low as 15 mm during winter months (Figure 2.6).

2.3.2 TEMPERATURE

Temperature is the most important factor enhancing plant growth and regulates the photosynthesis and transpiration processes (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. According to Jenny (1930), the organic matter content in soil is determined by rainfall and temperature. Rainfall increases the plant growth and hence the volume of residues to be broken down. An increase in temperature stimulates bacterial activity and thus the breakdown of organic matter.

The study area is semi-arid, characterized by very high day temperatures (often 42 °C) during summer months, with winter months being much

cooler (often - 9 °C) (Donaldson, 1967 and Low & Rebelo, 1996). According to Figure 2.7 the average monthly maximum temperatures were above 30 °C and the average minimum monthly temperatures were below 5 °C for the period of 1989-2003. Kalahari Plain Thorn Bushveld experiences dry northwesterly winds, which occur mainly during the spring and summer months (Low & Rebelo, 1996).

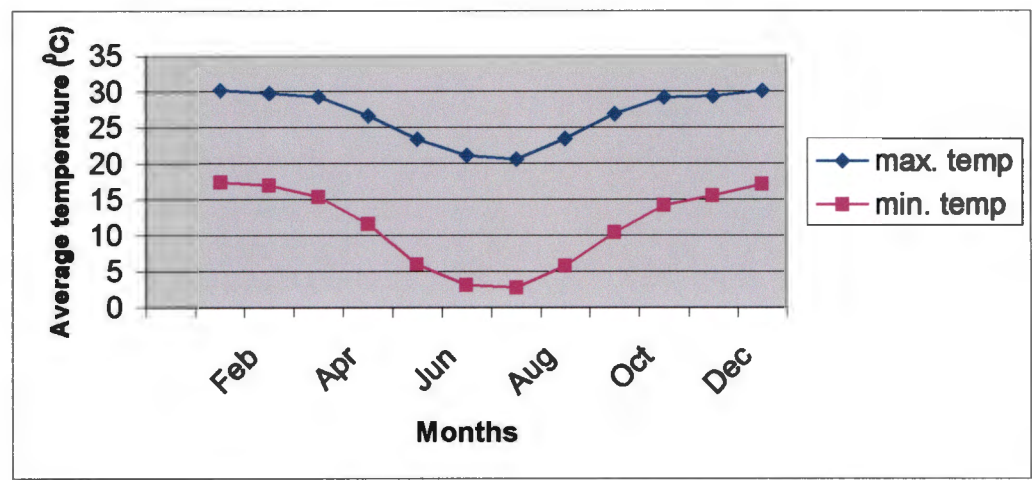


Figure 2.7: Average maximum and minimum temperatures of the study area from 1989 to 2003 (Department of Geography, North West University, 2004, Mafikeng Campus).

According to Figure 2.7, the hottest months of the year are January and December (average maximum temperature 30.2 °C, for the year 1989-2003) and the coldest month being July at average minimum temperature of 2.8 °C (i.e. for the period of 1989-2003).

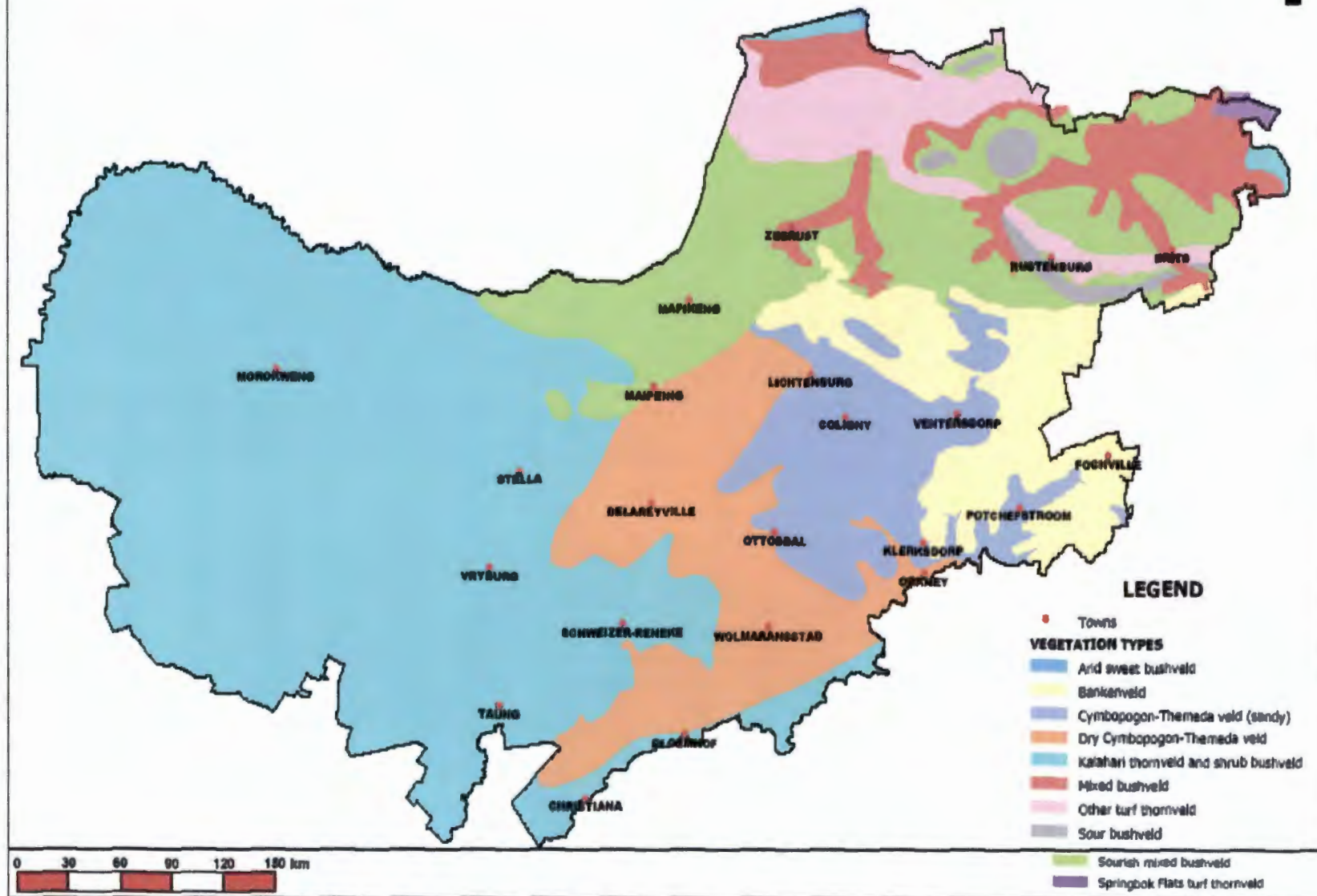
2.4 VEGETATION

Overgrazing, especially during dry years and selective grazing during wet seasons has led to the declining of the climax grass, *Antheophora pubescens* and the appearance of undesirable species such as *Aristida congesta* and *A. stipitata* in the Molopo Area (Donaldson, 1967).

According to Low & Rebelo (1996), the low rainfall, sandy plains and overgrazing influence the structure of vegetation. A fairly well developed tree stratum with, *Acacia mellifera*, *A. erioloba* and *Boscia albitrunca*, along with scattered *Terminalia sericea*, characterizes this vegetation type. The shrub layer is moderately developed and individuals of *Acacia hebeclada* and *Grewia flava* dominate this layer. The grass layer is made up of *Eragrostis lehmanniana*, *Stipagrostis* and *Aristida* species (Low & Rebelo, 1996).

According to the DACET (2004), vegetation types in the Molopo Magisterial District are Kalahari thornveld and shrub bushveld and Sourish mixed bushveld (Figure 2.8). The management of this vegetation type has bearing on both grass and shrub components (Bothma, 1996). Overutilization of grass layer leads to bush encroachment while underutilization has no detrimental effect.

North West Province: Vegetation types



Source: Environmental Potential Atlas 1999.

Figure 2.8: Vegetation types of the North West Province (DACET, 2004).

CHAPTER 3 INVASION OF WOODY SPECIES

3.1 INTRODUCTION

3.1.1 BACKGROUND

An association between grazing of livestock and increased woody plant abundance has often been found (Buffington & Herbel, 1965; Mandany & West, 1983; Van Vegten, 1983; Skarpe 1991; Busso 1997).

Grazing by livestock can result in the reduction of aboveground biomass and belowground biomass, which enhance woody plant establishment and growth (Bothma, 1996; Hoffman & Ashwell, 2001). This is because the seeds of trees can grow even in open and sunny conditions, unlike the seeds of palatable grasses (e.g. *Panicum maximum*). Heavy grazing can lead to the development of bare ground openings, which may encourage the increase of woody plant seedling survival and growth.

The value of grazing land may completely be destroyed by encroaching woody plants (Donaldson, 1967). The eradication of woody plants may eventually cost more than the land is worth. The influx of European farmers into the Molopo Area since 1945 (Donaldson, 1967) facilitated the invasion of woody plants in the area. This is encouraged by the mismanagement of veld by the people, like sinking of boreholes, ring fencing of farms, the elimination of veld fires and over utilization of palatable grasses for a period of more than twenty years (Donaldson, 1967).

In the past years, the balance between grazing land and the number of cattle was maintained by the loss of cattle due to diseases and epidemics such as rinderpest (Wrigley, 1981). An improved veterinary service with inoculation against certain diseases has led to an increase in livestock numbers, grazing in restricted areas. The effects of overgrazing are that the most sought after species are grazed out, leaving gaps in the cover, which are colonized, by species of lower acceptability not so severely grazed. Continued overgrazing removes most of the acceptable (palatable) grass species, which are lost, and the pasture is reduced to bare ground with annual species, and turfs of unacceptable coarse grasses like *Sporobolus* spp. (Wrigley, 1981).

Changes from savanna to woodland, in many cases, appear to result from reduced competition by herbaceous biomass due to reduction in biomass and vigour (Buffington & Herbel, 1965; Mandany & West, 1983; Van Vegten 1983; Van Auken & Bush, 1989). Woody plants, particularly leguminous species are very valuable in savanna grazing areas. Their fruits and foliage are nutritious and often high in phosphate (Wrigley, 1981). They are well adapted to the savanna environment and improve soil nitrogen content (See chapter 4).

The increase of woody plant density in savanna areas is the result of overgrazing by livestock and species competition (Hobbs & Mooney, 1986; Hurt, 1999). An increase in plant species densities facilitates the shortage of soil nutrients and water. Therefore, plant species compete for available soil nutrients. Grasses have a shallow root system while woody species have both shallow and deep root systems. Woody species out compete grasses for water and available soil nutrients as a result of a

well-developed root structure. This competition leads to the total elimination of grasses. According to Donaldson (1967), *Acacia mellifera* has a shallow root system and increases in density where there is heavy grazing.

According to Moleele (2001), overgrazing causes the transformation of a grass-dominated vegetation into a woody species dominated vegetation. This process is known as bush encroachment. Mandany and West (1983) found that grazing, and not climatic changes, is responsible for a shift from savanna to woodland. They observed that savanna protected from grazing was maintained, whereas nearby grazed savanna developed into woodland.

Even though many scientists believe that invasion by woody species into savanna grassland resulted from overgrazing (Mandany & West, 1983; Hobbs & Mooney, 1986; Hurt, 1999), Ward (2005) disagrees. According to Ward (2005), invasion by woody species (bush encroachment) is also widespread in areas where there is a single soil layer and where grazing is infrequent and light. According to Teague & Smit (1992) and Smit *et al.*, (1996), reduced livestock densities in years with below-average rainfall, have failed to reduce bush encroachment. This convinced Ward (2005) that the causes of woody plant invasion are poorly understood.

All veld types in South Africa are subjected to invasion by certain grass species, forbs, shrubs or trees (Bothma, 1989). Invasion usually occurs due to natural or artificially caused disturbances. The latter implies wrong grazing management and improper irrigation. According to

Bothma (1989), the factors influencing bush encroachment are rainfall variability, human and animal pressure and land-use patterns.

Overgrazing in the arid and semi-arid savannas of South Africa has led to the wide spreading of degradation over the past several decades. Generally, unpalatable woody species have gradually replaced grass forage and shrubs in a process locally termed “bush encroachment” (Hudak & Wessman, 2001). Malan *et al.* (2001) stressed that low species richness and low succession status of the species in an area are ascribed to the degradation of grasslands and to bush encroachment.

Woody plant invasion has been widespread in grassland and savanna ecosystems of Africa (Archer *et al.*, 2000 a). This encroachment jeopardizes biodiversity and threatens the sustainability of pastoral, subsistence and commercial livestock grazing (Rappole *et al.*, 1986).

The invasion of grasslands by woody species is a serious process, causing veld degradation in the North West Province (Hoffman *et al.*, 1999; Hoffman & Ashwell, 2001). 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 African savanna vegetation had been dominated by woody species (Department of Environmental affairs and Tourism, 1999).

Cattle farming has received most of the blame for the perceived degradation problem, but at the same time has most to lose, because declining primary productivity translates to declining secondary production (De Ridder & Breman, 1993).

Findings by Fourie *et al.* (1987), Skarpe (1990) and Perkins (1991), in the Kalahari and Dye & Spear (1982) and Bosch (1989) for elsewhere in southern Africa, show that in recent years, woody biomass productivity has increased at the expense of palatable grasses.

The leaf shoot tips and fruits of many woody plants are palatable and nutritious. Therefore, bush encroachment increases the carrying capacity for browsers (Bothma, 1989). This does not compensate for the loss in grass production and cover, which eventually lead to increased soil erosion. The invasion by woody species in arid areas causes the change in species composition of the grass layer (Bothma, 1989). Annual or biannual grasses replace perennial palatable grass species (Bothma, 1989).

In the long term, retrogression in the form of woody plant invasion, will affect biodiversity, which may result in the creation of a genetically malfunctioning ecosystem (Acland, 1971). Barnard and Newby (1999) indicated that communal areas are much degraded as compared to commercial rangelands. Degradation, which is prevalent in the communal areas, is facilitated by the misuse of natural resources (e.g. high stocking rates) by the community members (Tainton, 1981).

Veld degradation is considered to be moderately high in the study area (Figure 3.1). The community members need to be informed and taught the techniques on how to manage the environment. In communal areas where trees occur, the trees are often utilized as firewood.

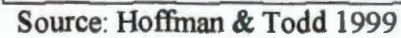


Figure 3.1: Veld degradation severity per magisterial district in North West Province (DACET, 2004).

According to Hoffman & Ashwell (2001), a decline of grazing lands in communal areas resulted from land degradation. Exploitation of natural resources to meet nutritional, medicinal and housing needs and to generate much needed income has led to the depletion of resources (DEAT, 1999). This has resulted in a range of land degradation types, including soil erosion, pasture degradation and eventually bush encroachment. On average, communal districts lost about three times as much grazing land as compared to commercial farming areas. According Rodger & Twine (2002), the overuse of natural resources and general human disturbance have a severe impact on the vegetation in communally managed areas. Socio-economic factors such as poverty and the lack of infrastructure contributed to the problem of land degradation (Rodger & Twine, 2002).

It is widely believed that overgrazing and other human impacts on the environment in communal ranches are greater than in commercially ranches areas in Africa (Archer *et al.* 1989, Behnke & Abel, 1996). This is largely due to the fact that communal land is not individually owned and has poor management strategies (Ward *et al.*, 2000). Farmers do not individually own the land in the study area but it belongs to the tribe (community). This situation ultimately leads to deterioration of the land, because nobody takes care of the land or takes responsibility if anything goes “wrong” (fire etc.). Tapson (1993), however, stressed that communal pastoralism in many areas is under the control of village committees or elders, and thus there is some management of stock in spite of an absence of individual ownership of land. Communities dependent on common property resources have adopted various institutional arrangements to manage these resources with varying

degrees of success in achieving sustainable use (Berkes *et al.*, 1989). Communal farming is evident in the study area, with almost all the farmers in a particular area, farming together to sustain their households (Chapter 5).

Producers on communal land have broader livelihood strategies than commercial land owners (beef farmers) (Tainton, 1999). The latter, aims to make a profit from meat production, while livestock production by the communal farmers may only be a small part (Tainton, 1999). In addition, livestock are kept for multiple reasons including draft power, security, milk and meat. They, therefore aim to maximise animal numbers per area and focus on the maintenance and survival of these animals.

Little is known of the rates and dynamics of encroachment or its impact on the fundamental ecological processes related to nutrient cycling and biodiversity (Archer *et al.*, 2000 b). Therefore, more research on woody plant invasion needs to be undertaken in order to understand the effects of invasion on biodiversity and nutrient cycling. According to McCulley *et al.* (2004), evidence of deep root nutrient uptake by woody species in arid and semi-arid systems is lacking. They suggest that deep roots play a major role in nutrient capturing and storage.

According to Freckman & Virginia (1989) and Canadell *et al.* (1996), the processes important for nutrient availability occur deep in the soil profile, including decomposition and weathering. Mesquite (*Prosopis* spp.) for example, relies mainly on lateral roots for water and nutrients absorption, depends on deep growing roots during drought and competes

successfully with grasses by using soil moisture in subsoil layers (Ansley *et al.*, 1991).

It is now well known that savanna ecosystems are complex ecosystems which are not at equilibrium and that they shift readily between different states in response to drought, grazing pressure, vegetation changes and soil degradation. Savannas do, however show some degree of resilience because of their complexity and biodiversity, but degradation occurs when they are perturbed beyond their ability to recover (Westoby *et al.*, 1989; Behnke *et al.*, 1993; Scholes and Walker 1993; Hodgson & Illius, 1996; Reij *et al.*, 1996).

Qualitative information about effects of overgrazing on vegetation is crucial for planning grazing regimes in order to achieve specific goals such as optimizing resource production of livestock and conserving local biodiversity (Binondini & Manske, 1996; Pickup, 1996).

According to and Bothma (1989) and Barnard & Newby (1999), woody plant invasion may occur in two ways, namely:

1. The invasion of woody species in areas where they originally did not occur. In most cases, the invading woody species may be referred to as alien species. *Prosopis velutina* is an example of such species and originates from Mexico and Argentina, but it is currently found in most areas of South Africa (Henderson, 2001).
2. The increase in the density of woody species in the existing natural bush veld. In this instance, the invading woody species is

originally found in the area but not in large numbers. *Acacia mellifera* is a good example of an invading woody species.

3.1.2 RELATIONSHIP BETWEEN GRASSES AND WOODY PLANTS

Heavy grazing reduces grass production and leads to reduced water and nutrient uptake by the grass layer, therefore, more resources become available for woody plant growth (Tolsma *et al.*, 1987; Skarpe, 1990).

Variation in competitive effects is based on plant size (Goldberg, 1987; Miller & Wener, 1987; Gaudet & Keddy, 1988; Mitchell *et al.*, 1993). The growth of herbaceous plants growing under tree canopies is suppressed by roots of trees (i.e. probably as a result of competition for resources) (Skarpe, 1991). Grasses are generally superior competitors within their rooting zone and the trees have little effect on reducing grass production in this zone (Knoop & Walker, 1985).

Previous studies suggest that woody plants may have larger competitive effects than grasses, but this may simply be caused by the higher shoot mass of shrubs and hence greater reduction in light availability (Wilson, 1998). Grasses may be superior competitors for soil resources like water and nitrogen as a result of their extensive, fine root morphology (Newman, 1973; Elliott & White, 1989; Glover *et al.*, 1989; Aerts *et al.*, 1991; Mitchell *et al.*, 1993). Smit (1999) however, stressed that woody species such as *Acacia mellifera*, compete directly with grasses due to a shallow root system.

Negative competitive interaction between woody and herbaceous plants may involve available soil water as the primary determinant of dry matter production (Dye & Spear, 1982) and has been reported worldwide (Australia: Walker *et al.*, 1986; Harrington & Johns, 1990; North America: Scifres *et al.*, 1982; Bozzo *et al.*, 1992; Southern and Eastern Africa: Scholes, 1987). This means, the herbaceous and tree components of savanna vegetation should suppress each other, but the results have been variable (Tainton, 1999).

Trees also may have positive effects on grass growth. Stuart-Hill *et al.* (1987) have argued that the net result of the negative and positive interactions of woody plants on grass production is dependent on tree density. Established trees create sub-habitats, which differ from the open habitat and which exert different influences on the herbaceous layer (Kennard & Walker, 1973; Kellman, 1979; Smit & Swart, 1994). Hagos and Smit (2005) reported that invasion of *Acacia mellifera* leads to soil nutrient enrichment on poor sandy soil in the semi-arid southern African savanna.

3.2 METHODOLOGY

According to Teague *et al.* (1981), measuring the number of plants by species, plant size and vertical distribution of life canopy, are used to determine potential productivity of available, browseable material and the competitive influence of the woody plants on grass productivity.

Tree equivalents (TE) are used to give a measure of total canopy volume (Tainton, 1981). According to Smit (1989), 1 TE is equal to 1 tree of 1.5

meters tall. Thus 2 TE is equal to a 3 meter high tree etc. These units can also be used to predict the productivity of useful available forage and to assess changes in the vegetation for any given objective. Regarding the woody component, long-term monitoring is aimed at measuring the number of woody plants by species, plant size and vertical distribution of its life canopy (Tainton, 1981).

According to Tainton (1999), the concept of “browse unit (BU)” was developed to estimate the browsing value of a savanna. It represents the total length of palatable trees and shrubs within 1.5 m of the soil surface (the browsing height of goats). Browse unit is derived by adding together portions of all palatable trees and shrubs within the 1.5 m stratum (Tainton, 1999).

One of the functions of the canopy of woody plants is to provide a structure on which the photosynthetic activities of the plant can take place. Different species have different light requirements. Certain species are able to establish and grow under low light conditions while others require high levels of insolation. The density and spacing of the plants can therefore be manipulated to either exclude or encourage certain species, depending on their light requirements (Tainton, 1999). The diameter of canopies of woody species at different height classes was measured. This will give an accurate estimation of the above-ground cover of woody species at the different height classes.

In this study, 9 survey sites were selected and compared to a benchmark site. A benchmark is described as an example of a site with vegetation that is considered to provide the highest possible sustained animal

production (Tainton, 1981). The benchmark site of the study area is marked survey point 10, site 10 or Disaneng (2) (Chapter 3) and is situated at the Disaneng Dam Area.

The selection of a benchmark is subjective and it should be in an area where there is grazing. The benchmark is not selected according to favoured features of the specific land unit (e.g. soil depth and moisture availability). There is no evidence of overgrazing in the benchmark site and the vegetation is in “good” condition. According to Wilson (1984), vegetation communities are dynamic entities with both temporal and spatial heterogeneity in which both quantity and composition fluctuates in response to continuous and current disturbances (e.g. climatic variation, fire, drought, grazing etc.). This phenomenon invalidates the use of reference areas such as benchmarks of original or ungrazed vegetation, because such benchmarks can no longer be assumed to be stable (Wilson, 1984).

3.2.1 TECHNIQUE USED

The technique for describing woody vegetation composition and structure in inventory type classification ordination and animal habitat surveys (Coetzee & Gertenbach, 1977) was used to quantify woody species.

Square quadrants were used. A quadrant is a square with the center at the cross and divided by the cross into four quarters (Coetzee & Gertenbach, 1977). The quadrant size is determined independently at each sampling site for each tree height class. The quadrants are enlarged to the required size in the following steps: $10\text{ m} \times 10\text{ m} = 100\text{ m}^2$, which is the minimum

size; 20 m x 20 m; 30 m x 30 m; 40 m x 40 m; and 50 m x 50 m (i.e. 0.25 ha).

A rope was used to construct a rectangular cross with four equal arms of 25 m length, calibrated at 5 m intervals by long visible poles. For each height class, four test squares were determined, one in each of the quadrants delimited by the cross.

The total density (expressed as TE/ha) of woody species for each height class (0.5 m, 1 m, 1.5 m, 2 m, 3 m, 4 m, 5 m and 6 m) was then determined in each quadrant.

The canopy diameters were measured at different height classes through the use of a measuring tape. All the sampled information was recorded on a field data sheet (Appendix 3.1). Plant density is referred to as the number of plants, which occur in each unit area (Barbour *et al.*, 1987; Kershaw & Looney, 1985).

3.2.2 MATERIALS USED

Soil auger

Soil collecting bags

Measuring tapes

Measuring poles

Data collection sheets

GPS apparatus

Soil samples were sent to the Institute for soil, climate and water of the ARC for nutrient and chemical analysis (See Chapter 4).

3.3 RESULTS AND DISCUSSION

3.3.1 BUSH DENSITIES IN DIFFERENT SURVEY SITES

A total of ten (10) sites were identified (Figure 2.2), where woody plant invasion is prominent. The Disaneng Dam Area (survey site 10) was used as a benchmark site. According to Tainton (1999), a benchmark represents an area of veld that is in optimum condition for sustained livestock production. The area is not encroached and in “good” condition.

The Disaneng Dam area represents an area, similar in vegetation structure and soil types than the various survey sites. Bush densities in various surveyed sites were compared to the benchmark site (reference site).

SITE 1: (Disaneng 1)

According to Moore & Odendaal (1987), a bush density of 200 TE / ha has no effect on grass production, but would decline with a further increase in bush density. Therefore, reduced grass production will eventually decrease livestock production in bush encroached areas. This is then affecting the lively hood of especially communal communities.

The most abundant woody species in this site (Figure 2.2, Chapter 2) were *Acacia erioloba*, *A. mellifera*, *Dichrostachys cinerea*, *Ehretia rigida*, *Grewia flava* and *Rhus dentata* (Figure 3.2). The density of *Acacia mellifera* was above 1000 TE/ha (Figure 3.2), which is recommended by Bothma (2002) for tree removal. According to

Donaldson (1967), the immediate approach to woody species invasion is that of eradication of undesirable woody species. The removal of woody species will ensure that the veld condition will improve. This will encourage desirable grass species to grow, improve production and eventually ensure economic returns.

The cyclic nature of annual precipitation and the unreliable distribution of the seasonal rainfall of southern Africa, cause droughts in certain regions (O'Connor & Bredenkamp, 1997). The occurrence of droughts in this area reduces the grass layer, facilitates the increase of annual unpalatable grasses and thus increases density of woody plants.

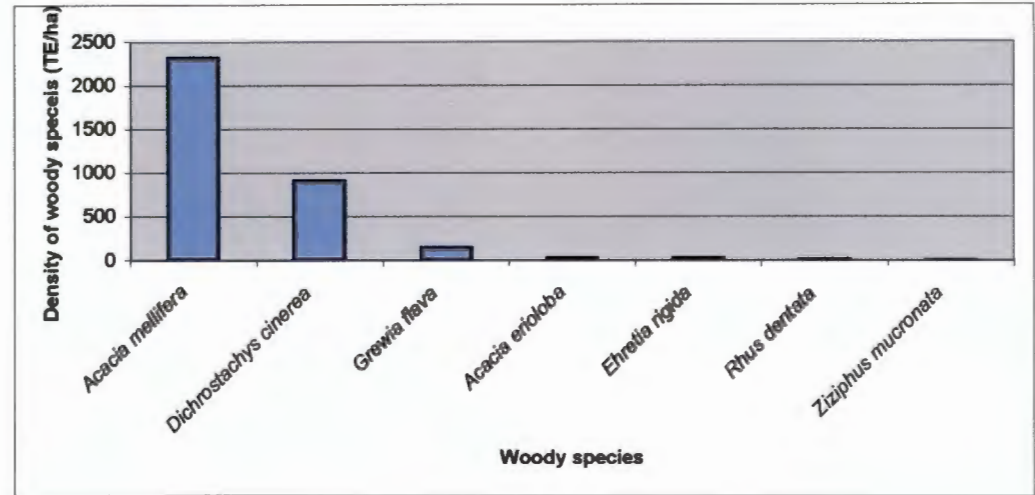


Figure 3.2: Density of different woody plant species in Disaneng (1).

Acacia mellifera (2 314 TE/ha, Figure 3.2) and *Dichrostachys cinerea* (909 TE/ha) represented the most abundant woody encroachers in this site (Figure 3.2). According to Donaldson (1967), one *Acacia mellifera* tree of 2.5 m high, transpires 64.8 kg of water per day (8 hours).

Therefore, 1 tree equivalent (1 TE) will transpire 38.9 liters of water per day. The transpiration of *Acacia mellifera* alone in this site will thus be 90 024 liters of water per day (According to the information supplied by Donaldson (1967)). The penetration of rainwater through the canopy of *Acacia mellifera* is found to be less when compared to rainwater, which penetrates through the canopy of *Terminalia* species (Donaldson, 1967).

According to Donaldson (1967), the transpiration rate of *Acacia mellifera* is four to eight times higher than that of *Terminalia* species and exceeds that of individual grass plants by approximately 190 to 800 times. This is the reason why there are few grass species in areas where *Acacia mellifera* is abundant (Donaldson, 1967).

Woody species with a maximum height of 2 meters had a total canopy diameter of 10 000 m/ha. This represents a considerable wider canopy regime than woody species within the same height class in the reference site (Figures 3.3 & 3.12). At 2 meters height, most browsers are able to reach and feed on edible material of plants.

Woody plants within a certain height class, do not necessary have the widest canopies at the highest point. According to Smit (1999), it depends on the browseable height of the trees as well as the browsers themselves.

Hagos and Smit (2005) stated that woody species, especially *Acacia* spp. are canopy restricted. This implies that woody species are generally not growing beneath canopies of other woody species, but will rather expand in an “outward” direction. Smit & Swart (1994) stated that tree-on-tree

competition is species specific and canopy “intolerant”, thus indicating that woody species, especially *Acacia* spp. will expand and thicken rather develop beneath currently existing trees.

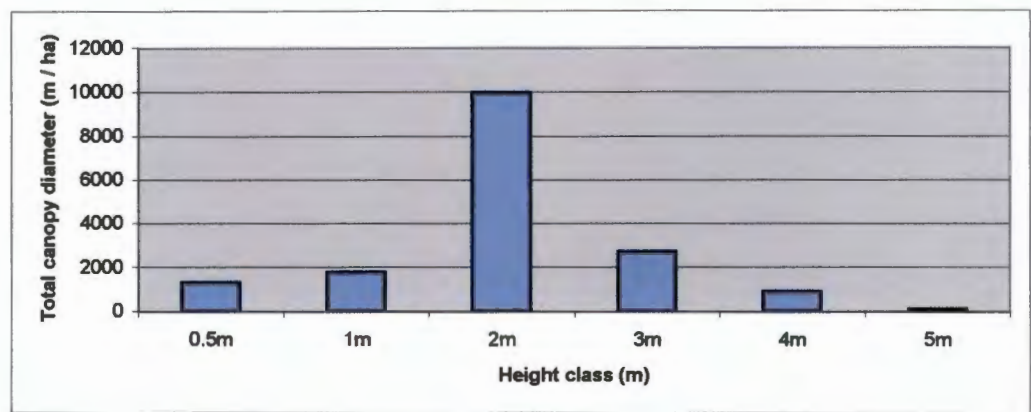


Figure 3.3: Canopy diameter of woody plants at different height classes in Survey point 1 (Disaneng 1).

SITE 2 (Phitshane 1)

According to FAO (2005), *Terminalia sericea* grows well in open woodlands or as a dominant or co-dominant woody species in mixed deciduous forests. This species thrives in a range of soil types, moisture conditions and drainage conditions, as long as light is not a limiting factor (FAO, 2005). It also thrives in deep sandy soil with moderate rainfall (Coates Palgrave, 1990).

Terminalia sericea (3 191 TE/ha) and *Dichrostachys cinerea* (808 TE/ha) were locally the most abundant woody species (Figure 3.4). This site had a higher species variety than the benchmark site (Figure 3.20). Woody

species found here include *Acacia mellifera*, *Dichrostachys cinerea*, *Rhus dentata*, *Terminalia sericea* and *Ziziphus mucronata* (Figure 3.4).

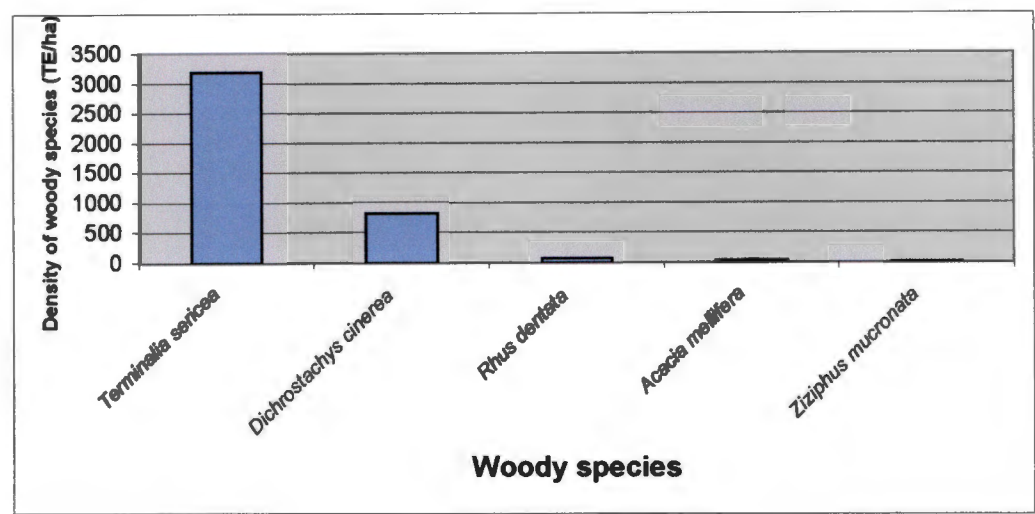


Figure 3.4: Woody plant composition and density in Phitshane (1).

Terminalia sericea forms dense thickets that when cut or burnt becomes weedy, thus preventing the growth of grasses (FAO, 2005). In this study, grasses are found to be growing well under *Terminalia sericea*. *Aristida congesta*, *A. diffusa* and *Eragrostis lehmanniana* were the most prominent grasses present. *Terminalia sericea* does not possess thorns and it is thus possible for cattle to move frequently between trees. *Terminalia sericea* improves the soil condition by draining waterlogged soils, shading out weeds and enriching impoverished soils (FAO, 2005). The branches of *Terminalia sericea* can be cut and placed where there is extensive soil erosion. These branches will be able to reduce excessive removal of fertile topsoil.

Terminalia sericea is an enigmatic bush encroaching species because it does not possess thorns and is said to be highly palatable to browsers and in particular to cattle during the dry seasons (personal communication with farmers in the study area). Among African people, this tree has a wide variety of uses. Local inhabitants use a decoction of the roots to cure diarrhoea (personal communication with local inhabitants). Local farmers use branches of *Terminalia sericea* to make fencing posts. This is confirmed by Coates Palgrave (1990). *Terminalia sericea* is adapted to drought and moderately adapted to saline soils.

Kroques (2005) reported that between 1947 and 1990, shrub cover in the Hlane National Park in Swaziland increased from 2 % to 34 % with *Dichrostachys cinerea* contributing to 81 % of the encroachment in 1997. *Terminalia sericea* and *Dichrostachys cinerea* often occur in dense stands and thus out-compete other woody species for available space and soil nutrients. The roots of savanna woody plants extend well beyond their projected crown radii (Wu *et al.*, 1985) and will thus be able to extract water from extensive depths.

Terminalia sericea has positive effects on grass production (i.e. this woody species does not inhibit the growth of grasses under its canopy) at low bush densities (Meyer, 2000). From these results, it shows that increased bush densities of this species have minimal impact on botanical composition of the herbaceous layer, but suppress further herbaceous production. According to Brock *et al.* (1978), the understory vegetation is distributed into zones with taller grass species beneath the canopies of *Terminalia* spp. and short grass in the interspaces.

Ziziphus mucronata, commonly known as buffalo thorn, is a woody species with the lowest density in this site, recording 13 TE/ha (Figure 3.4). *Ziziphus mucronata* is widespread in South Africa and occurs in deciduous woodlands where it grows up to a height of 9 m (University of Pretoria, 2005). It is drought and frost resistant and is a popular garden tree (Coates Palgrave, 1990).

Plants with a maximum height of 2 meters had the widest canopies (Figure 3.5) and are at a height, reachable to most browsers. This is similar to the height class and canopy diameter of woody species in the benchmark site (Figure 3.21), even though in the benchmark, the broadest canopy diameter is represented by 0.5 m high woody plants. In this site, browsers can be used to control woody species expansion.

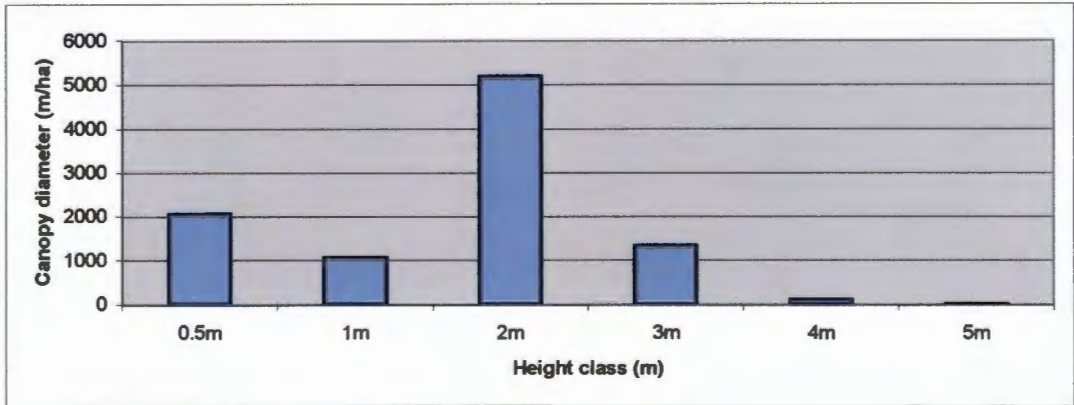


Figure 3.5: Canopy diameter of woody plants at different height classes in Phitshane 1 site.

According to Donaldson (1967), the transpiration rate of a single *Terminalia sericea* tree of 2.8 m high is 16.6 liters water per day. This means 1 tree equivalent (1 TE = 1 tree of 1.5 m high) transpires 8.8 liters

of water per day. Therefore, the transpiration rate of *Terminalia sericea* (3 190.5 TE/ha, Figure 3.3) in this site will be 26 481 liters of water per day (According to calculations done by Donaldson (1967)). It is thus clear that bush clearing will improve the water balance of the soil.

SITE 3 (Phitshane 2)

Terminalia sericea (3 062 TE/ha) was the only dominant woody species (Figure 3.6) in this area. Other woody species present included *Dichrostachys cinerea*, *Grewia flava* and *Tarchonanthus camphoratus* (Figure 3.6).

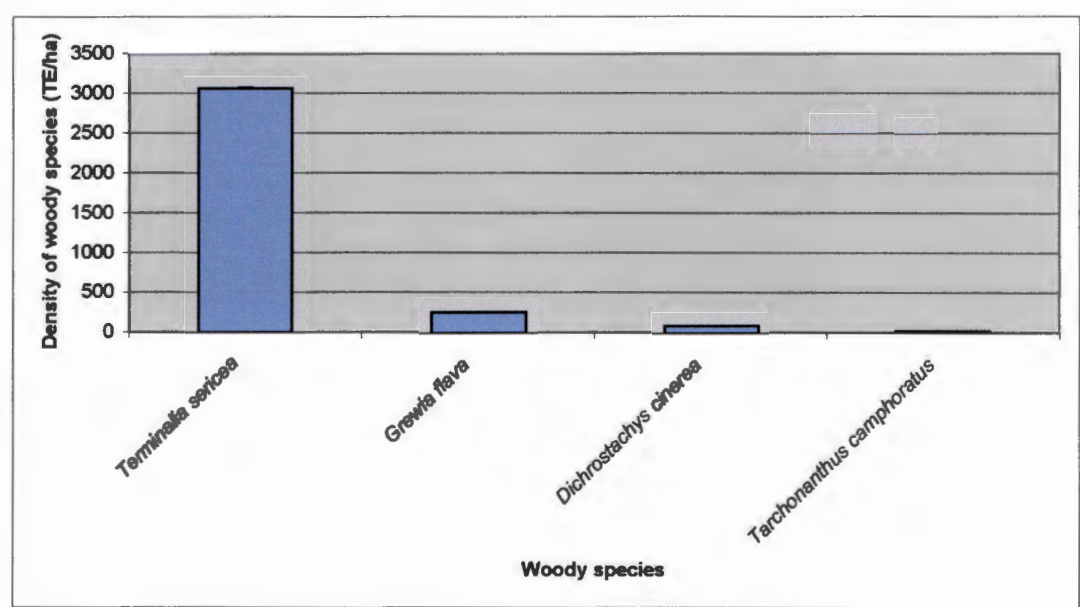


Figure 3.6: Density of woody species in Phitshane (2).

The increase of woody plants is the major concern for livestock farming in the southern Kalahari savanna (Tews *et al.*, 2005). *Terminalia sericea* is an encroaching woody species and because it does not possess thorns,

herbivores can walk freely during grazing. This species is said to be palatable (Katjiua, 2005), but cause a significant decline in range productivity where encroachment occurs (Katjiua, 2005).

Olar-Adams & Egunjobi (1992) estimated that in the case of *Terminalia* spp., leaf litter contributed more than 97 % of the nutrients returned to the soil. This takes place through the defoliation process. According to Katjiua (2005), cattle browse on *Terminalia sericea* during the dry season (winter). This browsing of cattle on *Terminalia sericea* is facilitated by reduced forage during winter months. According to Katjiua (2005), the palatability of *Terminalia sericea* encourages animals to browse on its leaves.

According Figure 3.7, woody species with a maximum height of 3 m had the broadest total canopy diameter at 1 375 m/ha. The measurement of canopy diameter can be used to determine the potential productivity available, browseable material and the competitive influence of the woody plants on grass productivity (Tainton, 1981).

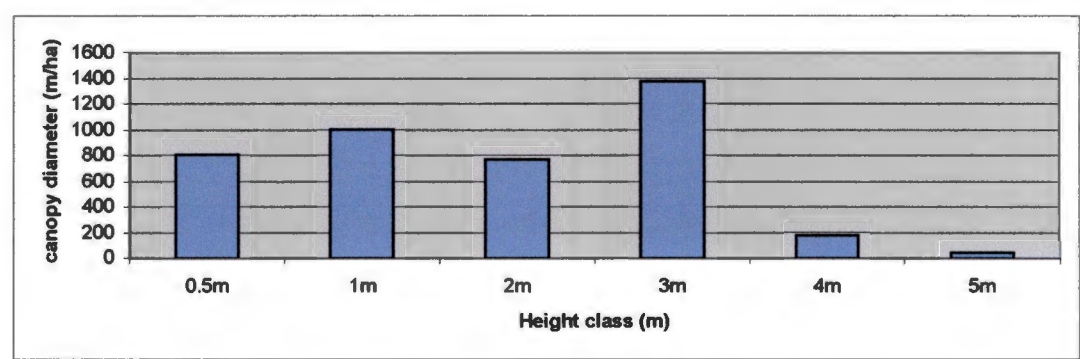


Figure 3.7: Canopy diameter of woody plants at different height classes in survey site 3 (Phitshane 2).

Water losses from the soil take place through the leaves of plants (Smith, 1990) and leaching. In the presence of sufficient moisture, leaves remain turgid with their stomata fully open. This permits an easy inflow of carbon dioxide, but at the same time permits a large leakage of water (Smith, 1990). *Terminalia sericea* occurred at a density of 3 062 TE/ha locally (Figure 3.6). According to Donaldson (1967), this means that the transpiration (loss of water through the leaves) rate of *Terminalia sericea* in this site will amount to 25 421 liters of water per day. Extensive loss of soil water and reduced rainfall leads to drought and impede the improvement of plant composition (Snyman, 1999). This, eventually will lead to reduced grass species development (Snyman, 1999).

SITE 4 (Selosesha 1)

Acacia erioloba and *A. mellifera* were the most prominent woody species recorded in this site (Figure 3.8). This site had a lower woody species composition than the benchmark (reference) site (Figure 3.20), recording only two woody species (Figure 3.8). This illustrates that woody plant invasion limits the plant composition of the invaded area. This is revealed in Figure 3.8 whereby there is a lower species diversity but a high plant density recorded. The competition among woody species causes *Acacia mellifera* to be predominant and reduce plant biodiversity (Donaldson, 1967).

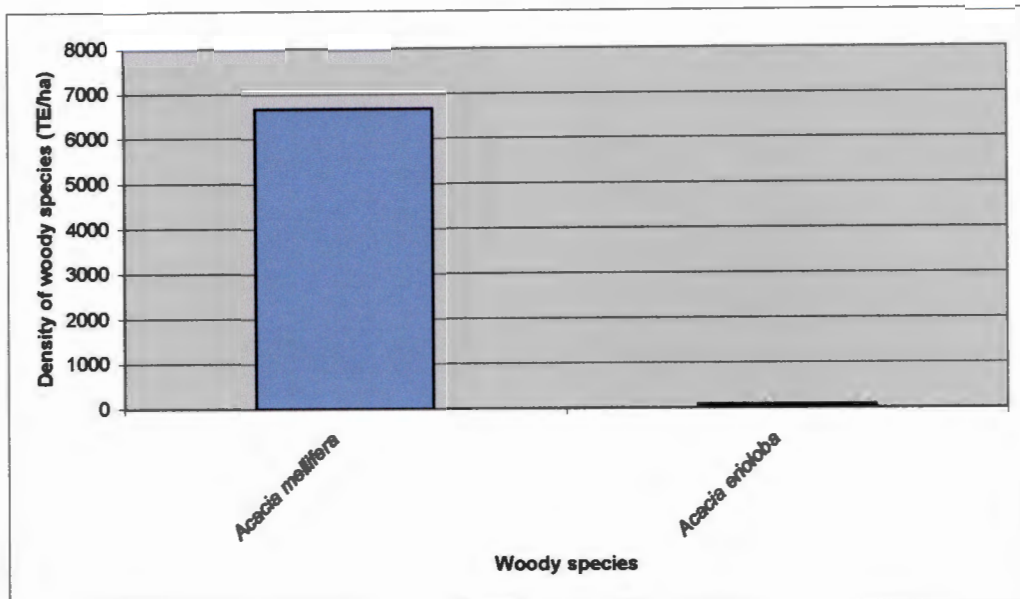


Figure 3.8: Densities of woody species in Selosesha (1).

Acacia species have the ability to compete for both surface and deep horizontal soil nutrients and water, because they have both a deep taproot- and a lateral root system (Rutherford, 1980). This effective lateral root system utilizes the same reservoir of water that grasses draw their moisture from (Donaldson, 1967). Therefore, grass production becomes reduced.

According to Bothma (1996), reduced grass production leads to a reduction in grazing capacity. This means that farmers have to reduce the stocking rate or face the risk of experiencing fodder shortages, which may result in livestock losses. The profitability of farming is reduced due to poor grass production and therefore the sustainability of livestock farming becomes affected.

Acacia mellifera is a deciduous tree, which grows up to a height of 7 m, with a round to spreading and much branched crown (Fagg, 1991; Venter & Venter, 1996). It often forms dense thickets. The flowering season is from September to November and produces fruit from January to April.

This woody encroacher occurs in dry thornveld (Donaldson, 1967), wooded grasslands and woodlands. It grows commonly in brackish soils and Kalahari sands (Venter & Venter, 1996). *Acacia mellifera* facilitates the loss of water in the soil to the atmosphere through transpiration. In this survey site, the transpiration rate of *Acacia mellifera* is estimated at 259 364 liters of water per day. This is according to the calculations done by Donaldson (1967). Transpiration is directly related to the amount of available moisture in the soil (Donaldson, 1967). This means, that if there is high moisture in the soil, there will be a high transpiration rate.

Acacia mellifera has a shallow, but “aggressive” root system, limiting the growth of grasses (Donaldson, 1967; Venter & Venter, 1996). Field observations also revealed that grasses are limited beneath the canopies of *Acacia mellifera* (Donaldson, 1967). When *Acacia mellifera* is left unattended to encroach in an area, it spreads to form impenetrable thickets, and depletes the growth of the herbaceous stratum. This was previously observed by Donaldson (1967) in the Molopo Magisterial District. The grass sward of this site was limited to only *Aristida congesta* and *Eragrostis lehmanniana*.

According to Bothma (1996), a high tree density (higher than 1000 TE/ha) is detrimental to the growth of palatable grasses. *Acacia mellifera* is of important economic value (Venter & Venter, 1996), if it is not in

high density. It is used as a valuable fodder tree on cattle and game farms in semi-arid areas. The leaves, young twigs, flowers and pods are very nutritious with a high percentage of raw protein and make an excellent stock and game feed (Venter & Venter, 1996). The stems are used for making axe, pick and instrument handles. The dry wood of *Acacia mellifera* can be used as fencing posts, which are termite and borer-proof (Donaldson, 1967; Fagg, 1991). However, there were only few examples observed where local farmers used *Acacia mellifera* (fence - and kraal building).

Woody plants within the 0.5 m – 2 m height classes contributed most to the total canopy regime, with the largest being woody plants, having a maximum height of 1 m (Figure 3.9). No trees within the 6 m height class were observed locally (Figure 3.9). This implies that plants within browsing height of goats (Tainton, 1999) have the widest canopies. The introduction of goats into this area to control woody plants is thus advisable.

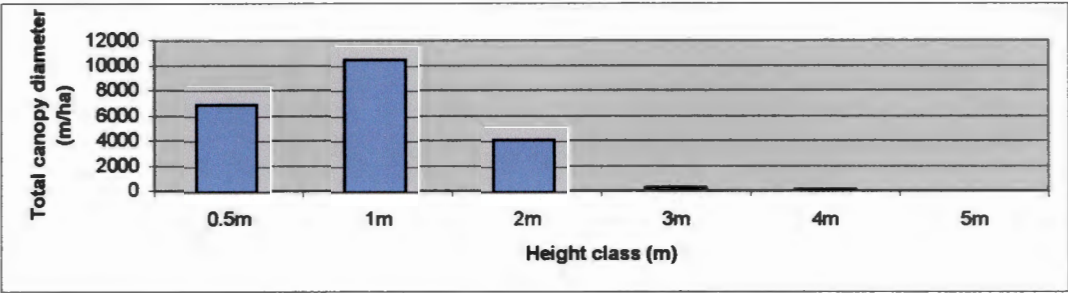


Figure 3.9: Canopy diameter of woody plants at different height classes in Sešosha 1.

According to Skarpe (1990), *Acacia mellifera*, with its shallow roots, is favoured by an increase of water availability in the topsoil as well as overgrazing of the grass sward. However, trees are able to make more effective use of deep water than are grasses (Stuart-Hill, 1985). Knoop (1982) observed that on a site dominated by *Acacia* species, large numbers of seeds germinated and survived when cleared of vegetation, but few were found in an uncleared area.

There is much difference in the growth of grasses in relation to the density of woody species in a particular area. Research has shown that the complete removal of trees leads to a substantial increase in grass production (Donaldson & Kelk, 1970; Walker *et al.*, 1986). This was also found by Jameson (1967), Teague *et al.* (1981), Dye and Spear (1982), Scifres *et al.* (1982), Moore & Odendaal (1987), Harrington & Johns (1990), Scanlan & Burrows (1990) and Richter (1991). Donaldson & Kelk (1970) found that grass yield did not decline linearly with increasing tree density.

Grass yields declined rapidly as tree density increased to 350 mature *Acacia mellifera* trees per hectare, there after yields declined slowly (Donaldson & Kelk, 1970). The growth and subsequent size that any individual tree can attain is a function of the abundance of resources to which it has access, such as water and nutrients (Tainton, 1999). *Acacia mellifera*, having shallow and deep roots will thus be an effective competitor in densely encroached savanna areas (Tainton, 1999).

Tree-on-tree competition is species specific (Tainton, 1999). In some, establishment is unaffected by a tree canopy while in others,

establishment is limited to “between canopy encroachments” (Smith & Goodman, 1986). Many *Acacia* species, including *Acacia mellifera*, fail to establish under a canopy of established individuals, irrespective of its density.

Figure 3.9 reveals that woody species within the 1 m and 0.5 m height classes had the widest canopies. Tree thinning will result in a drastic and immediate change in the competition regime, which will largely, control the growth and structure of the plant community (Tainton, 1999). The resulting gaps will lead either to increased growth of neighbouring individuals or to the establishment of new individuals (Teague & Smit, 1992).

SURVEY POINT 5 (Selosesha 2)

Dichrostachys cinerea (4 876 TE/ha) and *Acacia hebeclada* (1 330 TE/ha) are prominent woody species in this site (Figure 3.10). Other woody species include *Acacia erioloba*, *A. mellifera*, *Grewia flava* and *Rhus dentata* (Figure 3.10). Selosesha (2) has a higher woody species composition when compared to the benchmark site (Figure 3.10 & 3.20).

This area was dominated by *Dichrostachys cinerea* (Figure 3.10). This species occupies a diverse range of habitats (Donaldson, 1967; Venter & Venter, 1996), including woodland at high and low altitudes, forests margins and grasslands and grows on all soil types (Venter & Venter, 1996).

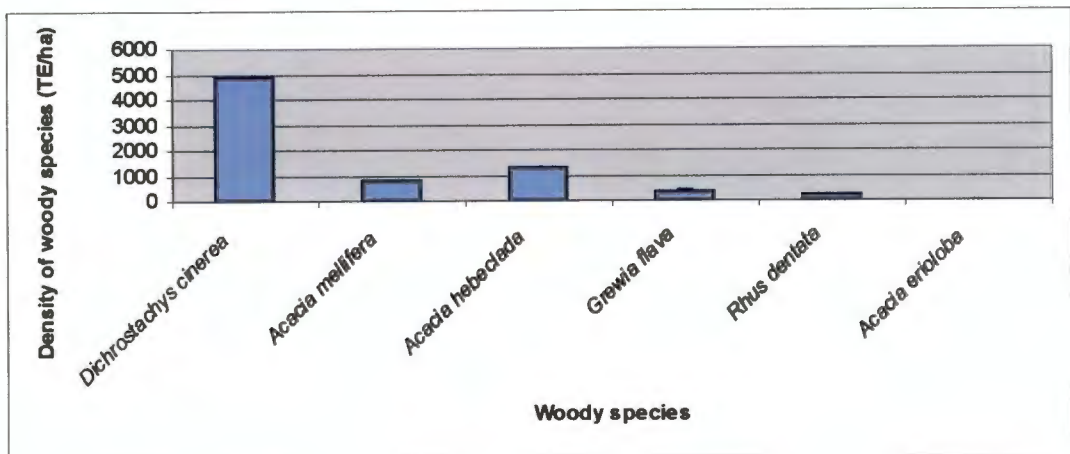


Figure 3.10: Densities of woody plants in Selosesha (2)

Dichrostachys cinerea is a semi-deciduous to deciduous tree (Venter & Venter, 1996), which grows up to 7 m high and has an open crown. It has wood with yellow sapwood and hard, deep red-brown heartwood. The tree flowers from October to February and bears fruit from May to September (Venter & Venter, 1996). Rutherford (1980) found that the roots of *Dichrostachys cinerea* often extend well beyond the canopy's ground projected area.

This plant invades rapidly on overgrazed, trampled soil and on old lands where the grass cover has been reduced (Venter & Venter, 1996). According to Venter & Venter (1996), it is difficult to eradicate *Dichrostachys cinerea* as it shoots again (coppice) from portions of roots or remaining stumps. Mechanical and chemical control measures can be used to eradicate this plant.

Severe soil disturbance may encourage the establishment of large numbers of seedlings of *Dichrostachys cinerea* (Tainton, 1999). This

may result in time in a woody community, which is more dense than the original community. Therefore, mechanical methods are not generally recommended to control *Dichrostachys cinerea* (Tainton, 1999).

The author noticed that local inhabitants use wood of *Dichrostachys cinerea* for fencing posts. The wood of *Dichrostachys cinerea* is durable, termite resistant and may last up to 50 years. The wood is also an excellent fuel, producing very hot coals that last for a long time and produces good quality charcoal (Venter & Venter, 1996).

Plant roots depend on leaves for both sugars and hormonal growth, while leaves depend on roots for supply of water from the soil (Kozlowski, 1971). Plants within the 2 m height class had the widest total canopy diameter, followed by plants within the 3 m height class (Figure 3.11). This shows that in this site, woody species reachable to browsers has a broad canopy cover. Therefore, browsing animals can be used to control the invasion of woody plants, although soil disturbance will enhance development of *Dichrostachys cinerea* seedlings.

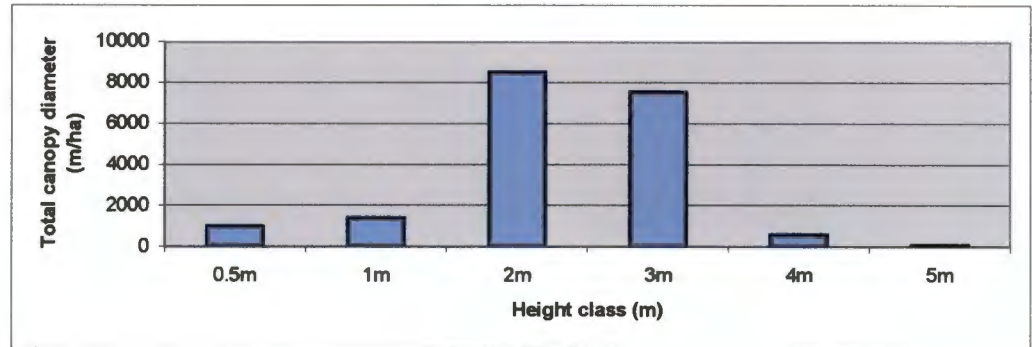


Figure 3.11: Canopy diameter of woody plants at different height levels in (Selosesha 2).

According to Smith (1990), the loss of water through plant leaves, continues as long as moisture is available for absorption by roots. This also depends on whether the amount of energy striking the leaf is enough to supply the necessary latent heat for evaporation process to take place (Smith, 1990).

SITE 6 (Tshidilamolomo 1)

Woody encroachers were represented locally by *Acacia mellifera* and *Grewia flava* with *Acacia mellifera* dominating (Figure 3.12). *Acacia mellifera* was absent in the benchmark (Figure 3.20). *Acacia mellifera* has a shallow root system and out competes grasses for water and soil nutrients (Smit, 1999). According to Donaldson (1967), grasses are limited beneath the canopy of *Acacia mellifera*. Therefore, the density of this species needs to be controlled, either chemically or mechanically (i.e. biologically-animals are unable to move through, because of the thorns of this woody encroacher).

The consequences of thickets for biodiversity are not clear (Ward, 2005). Bush thickets are often monospecific, for example *Acacia mellifera* in the Kalahari, and represent a lower woody plant diversity (Smith, 2002). The abundance of *Acacia mellifera* ensures less availability of water to grasses and will thus lead to the elimination of palatable grasses.

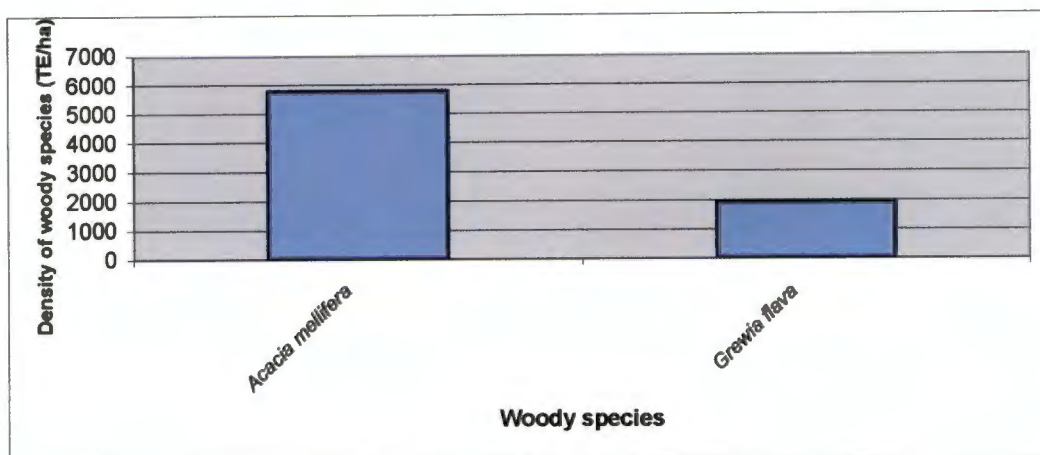


Figure 3.12: Density of woody species in Tshidilamolomo (1).

The density of *Acacia mellifera* in this site causes the loss of about 225 503 liters of water per day due to transpiration. According to Skarpe (1990), the increase of the shallow rooted *Acacia mellifera* and *Grewia flava* in the savanna is favoured by an increase in water availability in the surface soil, following overgrazing of the grass layer. A large number of seeds of *Acacia* species were found to germinate and survive where the vegetation was cleared, with few in the uncleared areas. Grasses beneath *Acacia mellifera* trees and between canopies are limited. Donaldson (1967) stressed that the deep sandy soils of the Molopo Area can be regarded as being more favourable for the establishment of woody plants, especially *Acacia mellifera* from seed than areas with a denser stand of grasses and a heavier soil type. Skarpe (1990) also illustrated that *Acacia mellifera* seedlings establish themselves with great difficulty in a dense grass sward and that either fire or competition from grasses or both may considerably retard the thickening up of *Acacia mellifera*. According to Donaldson (1967), the chief causes of the failure of woody plants to survive the seedling stage would therefore include drought or absence of

moisture in the root zone, lack of success in competition with grasses and damage by other causes such as veld fires.

Grewia flava is a source of food to animals (Tews *et al.*, 2005), because of the high quality leaf and young twig material (Groenewald *et al.*, 1967). However, signs of animals eventually browsing this species were limited. This facilitates seed dispersal and invasion of this species in grasslands. Tews *et al.*, (2005) recommended that the management of *Grewia flava* invasion in rangelands should be practiced through the use of frequent fires. To implement this, a dense grass stand is needed.

The maximum height of woody species locally was 3 meters (Figure 3.13). *Acacia mellifera* trees within the 2 m height class, had a total canopy diameter of 9 650 m/ha (Figure 3.13). These wide canopies had a negative influence upon grassland development (Smit, 1999), beneath these trees.

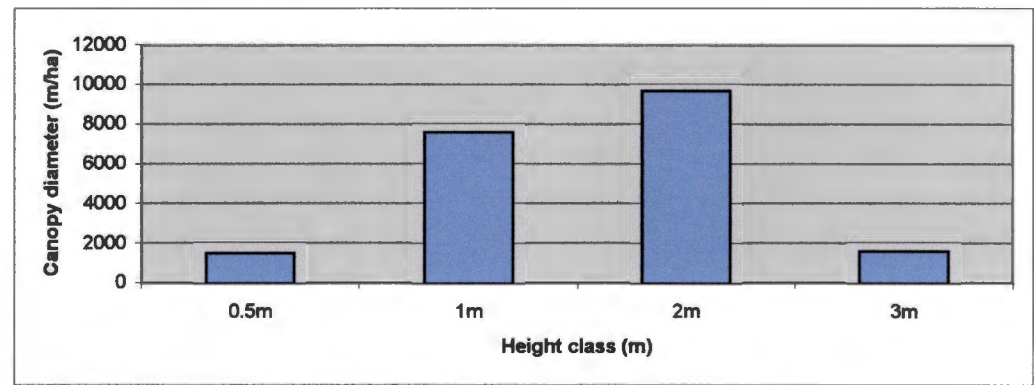


Figure 3.13: The canopy diameter of woody species at different height classes in Survey point 6 (Tshidilamolomo 1).

SITE 7 (Masamane 1)

Acacia erioloba, *A. mellifera*, *Dichrostachys cinerea* and *Grewia flava*, were the most prominent woody species in this site with *Acacia mellifera* the sole dominant (Figure 3.14). Woody plant density locally exceeds the density in the benchmark. Increased woody plant density decreases the potential grazing capacity by as much as 331 % in the Molopo Thornveld (Richter *et al.*, 2001).

According to Richter *et al.* (2001), bush encroachment has an adverse influence on the density and production of the grass component, but not on species composition. Fluctuations in seasonal rainfall appear to be the most important factor governing changes in the species composition of the grass component.

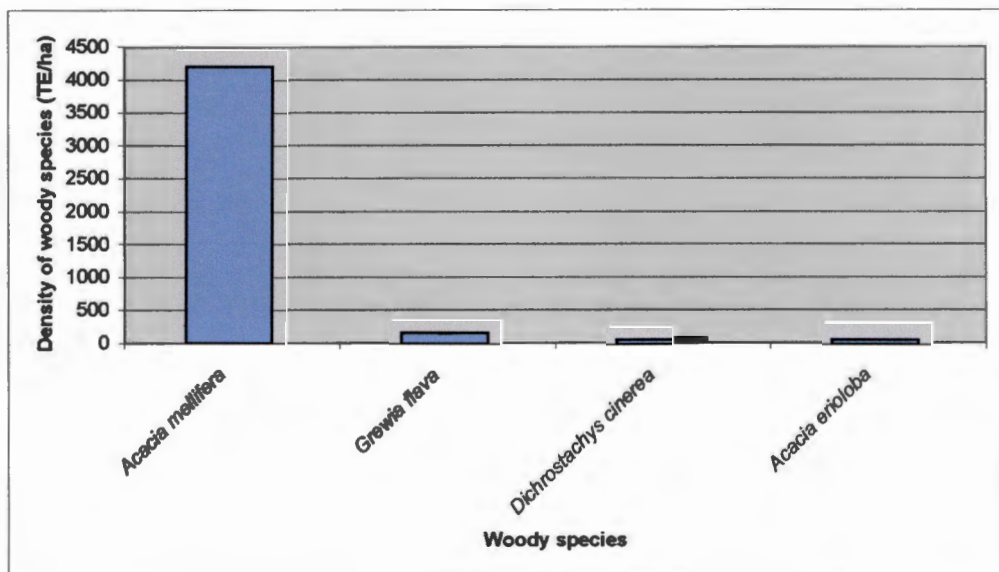


Figure 3.14: Density of woody species in Masamane (1).

The density of *Acacia mellifera* in this site was 4 210 TE/ha (Figure 3.14) and the transpiration rate 163 761 liters of water per day (according to the calculations by Donaldson, 1967). The high rate of transpiration leads to the reduction in soil water availability (Kozłowski, 1971). This means plants will therefore compete more intensively for soil water. According to Hurt (1999), woody species out compete grasses for water and thus result in reduced grazing capacity. This is also confirmed by Skarpe (1990), in which it was found that the density of shallow rooted trees increased with an increase in soil water. This is especially evident following overgrazing of the grass layer. Ward (2005), indicated that, it is not only overgrazing which causes woody species invasion, but also other factors such as soil texture and moisture. The sandy texture of local soils (Refer to Chapter 4, Figure 4.17) leads to the infiltration of water well below the reach of grasses (See later).

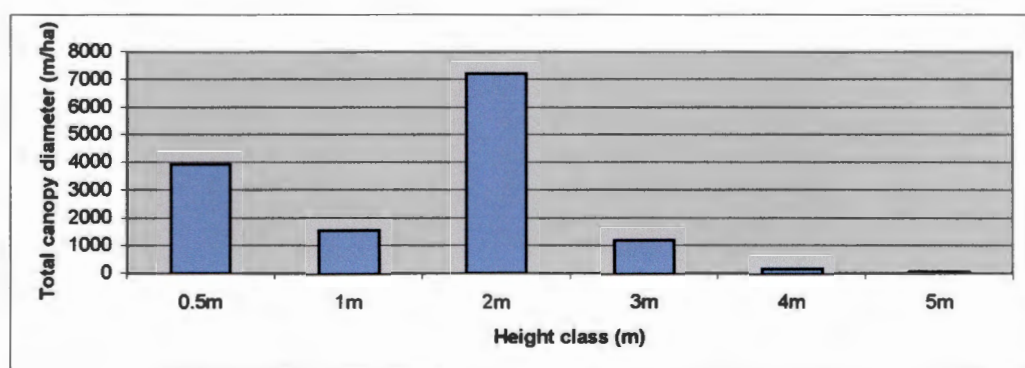


Figure 3.15: Canopy diameter of woody species at different height classes in Masamane 1.

Plants within the 2 m height class had the widest canopies (Figure 3.15). These plants are reachable to most browsers (Bothma, 1996) and the introduction of browsensing herbivores should be considered locally.

SITE 8 (Masamane 2)

This site (See Figure 2.2, Chapter 2) had a higher woody species composition compared to the benchmark (Figures 3.16 & 3.20), having a woody plant density of 2 990 TE/ha. *Acacia hebeclada*, *A. mellifera* and *Dichrostachys cinerea* were the most prominent encroachers in this area (Figure 3.16).

Other woody species present included *Acacia erioloba*, *Diospyros lycioides*, *Grewia flava*, *G. occidentalis* and *Terminalia sericea* (Figure 3.16), with *Acacia erioloba* also being found in the benchmark site (Figure 3.20).

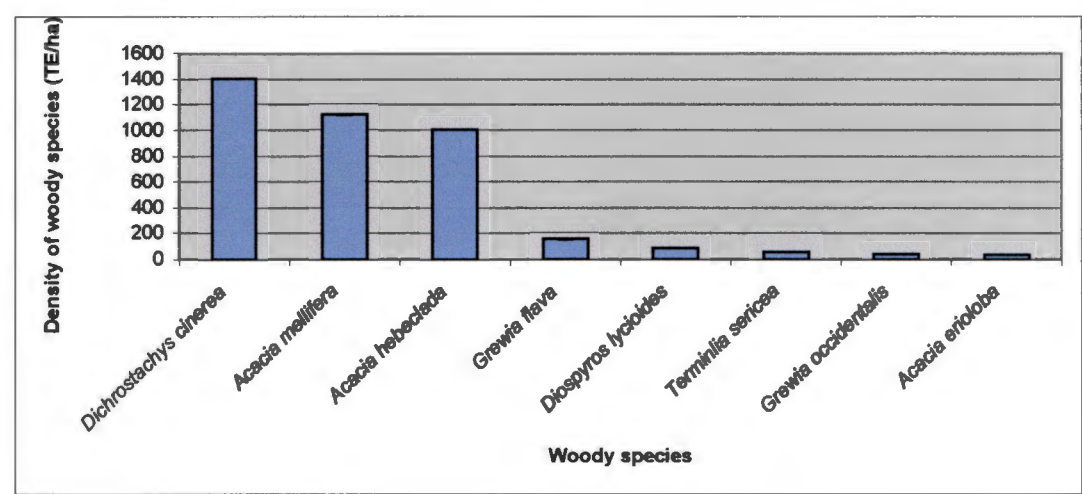


Figure 3.16: Woody composition of Masamane (2).

Dichrostachys cinerea recorded the highest density at 1 400 TE/ha (Figure 3.16). This thorny shrub is considered to be an aggressive woody invader (Bothma, 1996). It is difficult to eradicate this species as it shoots again from different portions of the roots. Therefore, chemical control measures can be used during the eradication process. According to Venter & Venter (1996), cattle and game relish the palatable pods that drop to the ground, thus contributing to seed dispersal. The pods and seeds do not contain hydrocyanic acid, thus minimizing the chance of poisoning animals (Venter & Venter, 1996).

According to Donaldson (1967), woody and bushy plants of the Molopo Area can be classified according to their mode of seed dispersal and manner of invasion into grasslands, in two main groups respectively, referred to as the blackthorn group and the camelthorn group. The blackthorn group (multi stemmed) includes species such as *Acacia mellifera* and *Dichrostachys cinerea*. The second group of plants consists of single stemmed trees such as *Acacia erioloba*, *Boscia albitrunca* and *Terminalia sericea*.

General characteristics of the blackthorn group include the following (Donaldson, 1967):

- (i) a characteristic increase of plants around the parent plant, giving an effect of clumps or thickets of plants with a contagious type of distribution during the initial stages of colonization;
- (ii) sparseness or complete absence of grass plants within and immediately outside the crown spread of the plants;

- (iii) except for *Dichrostachys*, flowering is restricted to Spring;
- (iv) the pods and seeds of both are easily dislodged from the plant and either fall on the soil underneath the plant or are blown or fall away from the plant. The pods and seed are therefore only accessible to animals for a relatively short period. Although the pods and seed are taken by animals, the relatively papery and leather-like pods appear to be less palatable than those of plants belonging to the camelthorn group.

The total canopy diameter of woody species with a maximum height of 0.5 m was the broadest, recording more than 6 000 m / ha (Figure 3.17). This is indicative of fierce intraspecies competition (Smit, 1999).

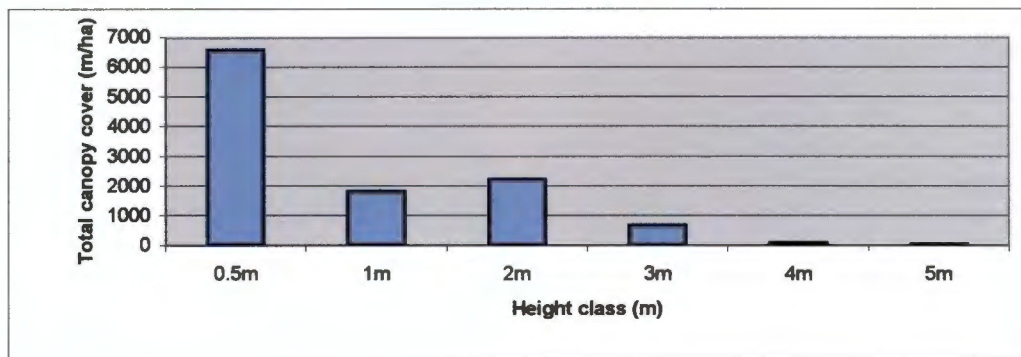


Figure 3.17: Canopy regime of woody plants at different height levels in Survey Point 8 (Masamane 2).

Plants in semi-arid and desert regions tolerate drought by reducing the leaf area of the canopy by dropping the leaves during periods of extreme water stress and developing new leaves at the onset of rain (Smith, 1990). This response usually results in decreased production. Some plants

maintain some of their photosynthetic capacity by increasing photosynthetic activity in green stems.

SITE 9 (Tshidilamolomo 2)

Prosopis velutina (6 165 TE/ha), *Acacia hebecclada* (799 TE/ha), *Grewia flava* (750 TE/ha) and *Rhus lancea* (118 TE/ha) were the most prominent woody species in this site (Figure 3.18) with *Prosopis velutina* being dominant.



Figure 3.18: Densities of woody species in Tshidilamolomo (2).

The total density of woody plants recorded in this site was 8 927 TE/ha (Figure 3.22). This site is more densely encroached than the benchmark site (Figures 3.18 & 3.20) and was located near the Molopo River, bordering South Africa from Botswana (Figure 2.1, Chapter 2). This is because the woody species in the benchmark site are not considered to be invaders (Bothma, 1996), while the woody species locally, especially the exotic *Prosopis velutina* and *Grewia flava* are invaders (Appendix 3.2).

The higher woody plant density in Tshidilamolomo 2 is facilitated by the inter-species competition, whereby the invader species (*Prosopis velutina*) out competed other woody species for available space. The dominance of *Prosopis velutina* (Figure 3.18) shows that woody plant invaders lead to the reduction in plant diversity.

Brown (1999) found that *Prosopis* spp. has the potential to occur in areas with low resource availability and livestock grazing pressure. *Prosopis velutina* invaded at least 18 000 km² of the low-lying alluvial plains and the seasonal watercourses of semi-desert areas (Milton *et al.*, 1999). The habitat in this site is similar to the habitat described by Brown (1999) and Milton *et al.* (1999). The soil is dry and stony and has a higher Ca and Mg content (Figure 4.9, Chapter 4) than other surveyed areas predominated by different species (e.g. *Dichrostachys cinerea*).

Prosopis spp. has increased abundantly in recent years (Brown, 1999). This may be because of its capability to regenerate within two (2) weeks of germination (Scifres & Hahn, 1971), tolerance of repeated top removal during its first growing season (Weltzin *et al.*, 1998) and tolerance of hot fires by its second and third year of growth (Wright *et al.*, 1976).

Reductions in fire frequency and intensity, accompanied by continuous heavy livestock grazing, allowed the establishment of *Prosopis* spp. (Baisan & Swetnam, 1990; Savage & Swetnam, 1990; Covington & Moore, 1994).

According to Brown & Gubb (1986), Harding & Bate (1991) and Steenkamp & Chown (1996), *Prosopis* spp. invades actively in the

Savanna Biome. They also found that *Prosopis* spp. increases the biomass, change the native vegetation structure, decrease pasture productivity, out compete native plants and reduce diversity of dung beetle assemblage.

According to Bothma (1996 & 2002), an increased bush density in grasslands has negative effects on grass production (i.e. lower the production of grasses). This is because there is a reduction of available soil moisture as a result of the excessively high transpiration rate of woody species. Grass growth beneath *Prosopis velutina* is limited. This means that invasion by *Prosopis* spp. reduces grass production. According to Bothma (1996), woody plant species reduce grass production by as much as 90 % in a Savanna ecosystem. *Aristida congesta* and *Eragrostis lehmanniana* were the only grasses present.

The maximum height of *Prosopis velutina* trees locally was 4 meters (Figure 3.19). The total canopy diameter at the 2 m height class was the broadest, representing 7 050 m/ha (Figure 3.19).

According to Watts *et al.* (1989), adult *Prosopis* spp. are not palatable and are not browsed by animals (with the possible exception of new regrowth sprouts). This woody species provides cover for many wildlife animals and insect species (cutworm and twig girdler) which are dependent on *Prosopis* for food (Watts *et al.*, 1989).

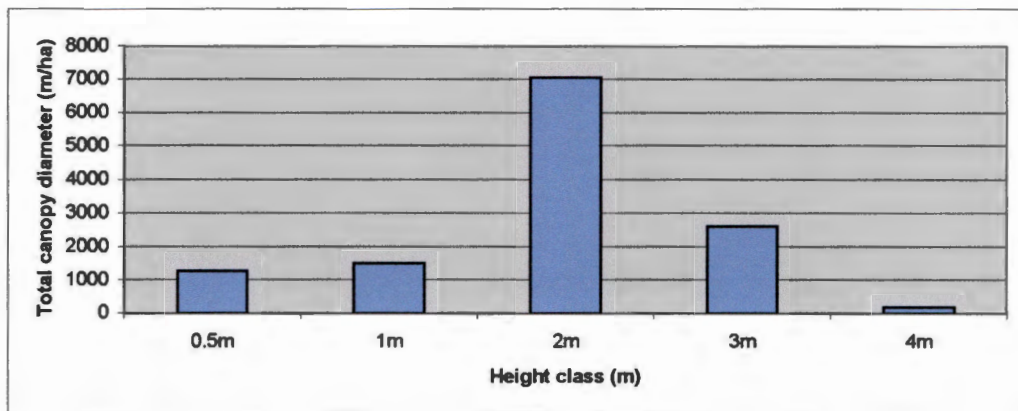


Figure 3.19: Canopy diameter of woody plants at different height levels in Tshidilamolomo 2.

According to Versfeld *et al.* (1998), invasive alien plants are using as much as 6.7 % of the country's water runoff. Clearing the invasive plants is a good investment, simply to prevent water losses (Hosking & Du Preez, 1999) and failure to clear stands of invading woody plants will result in exponential increases in the costs of clearing as catchments areas become further invaded.

Prosopis forms a real threat to indigenous vegetation and livestock farming, primarily due to the suppressive effect of bush encroachment on the productivity of the herbaceous component of veld leading to the lowering of biodiversity (Henderson & Harding, 1992). This multi-stemmed and thorny tree/shrub forms impenetrable thickets, causing limited access to grazing animals. It also has a negative effect on grass production.

According to Henderson & Harding (1992), *Prosopis* uses great amounts of water and can influence the hydrology of an area, especially in arid

and semi-arid regions. Le Maitre (2000), stressed that a single *Prosopis* tree can use up to 930 mm of water per annum with an average of 350 mm – 500 mm per annum. This is because of its very effective root system. Phillips (1963) found roots of *Prosopis* to a depth of 50 meters. Harding & Bate (1991), however found roots of *Prosopis* up to a depth of 12 meters, but will vary from area to area depending on the soil texture. The water use by *Prosopis* is estimated to be 192 million m³ per year (about 1 100 mm per year) for a dense stand (an area with bush density higher than 1000 TE/ha, Bothma, 1996).

According to Coetsee (1993), dense stands of *Prosopis* are drought resistant, but invasion usually takes place in areas such as riparian areas and flood plains. *Prosopis* have an exceptional ability to extract moisture from the soil. Invasion by *Prosopis* is a common phenomenon in communal areas. It is especially riparian areas that are under threat. According to Coetsee (1993), the pods of *Prosopis* are a good source of protein for cattle and goats. The author noticed farmers gathering pods in dense stands to feed their cattle. According to them, the pods are “good” as feed. This will eventually contribute to the distribution of the seeds. The pods have a sweet taste and it was noticed by the author that the children are also chewing the pods. They also are thus contributing in the distribution of the species, by spitting out the hard seeds wherever they go.

Because of the scarcity of available land, the pods of *Prosopis* are often the only alternative source of protein. The pods have a sweet taste, but the testa of the seed is very hard and is not easily destroyed. Man and animal thus form important agents in seed dispersal. According to Jacoby

et al. (1990), cattle favour the distribution of mesquite (*Prosopis*) pods. Large percentage of the seed remains viable through the animal's digestive tract (Jacoby *et al.*, 1990). Cattle should be prevented from grazing creeping mesquite infested areas when pods are present on the trees (McPherson *et al.*, 1988, Jacoby *et al.*, 1990).

SITE 10: (Benchmark)

According to Tainton (1981) and Bothma (1996), a benchmark site is a site, which has “excellent” veld condition and provides sustained animal production. The benchmark site is not fenced, but the vegetation is in “good” condition. It represents the vegetation that is suspected to be have been prominent, prior to large-scale settlement.

Acacia hebeclada and *A. tortilis* were the only declared invaders (Appendix 3.2) in this site. The most prominent woody species were *Acacia hebeclada* and *A. erioloba* (Figure 3.20). Other woody species present locally included *Acacia tortilis* and *Ziziphus mucronata* (Figure 3.20).

According to Figure (3.20), *Acacia erioloba* is the second most prominent woody species (Figure 3.22) in the benchmark. *Acacia erioloba* is an evergreen to semi-deciduous tree, growing up to 20 m tall. It flowers from July to September and bare fruits from December to April (Venter & Venter, 1996). It grows in dry woodland along dry riverbeds where underground water is present and on sandy loam and Kalahari deep sand (Venter & Venter, 1996).

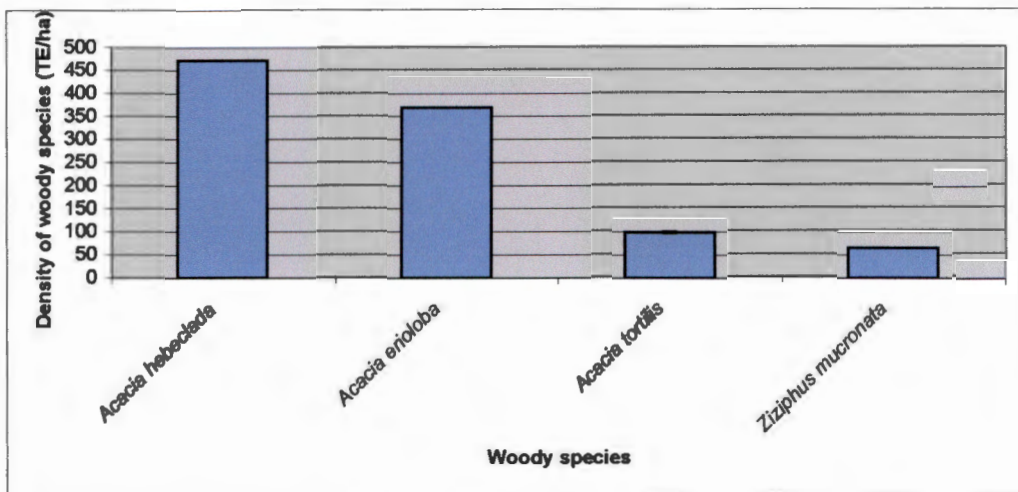


Figure 3.20: Densities of woody species in Disaneng 2 (Benchmark).

Economically this woody species is used for livestock browsing. According to Venter & Venter (1996), the sweetish pods are excellent fodder and are highly nutritious (pods have 11.4 % crude protein, seeds yields up to 33 % crude protein and 3.3 % fat, while the shell of the pod yields 1.2 % fat). Cows feeding on the pods show an increase in milk production (Venter & Venter, 1996).

Woody plants within the 0.5 m height class had the widest canopy diameter representing 1 380 m/ha (Figure 3.21). This indicates that this site is in an early stage of desertification. In this site, browsers can be use to control or reduce the density of woody species. This biological control method is relevant because browsers can reach the edible plant material at 2 m – 3 m height.

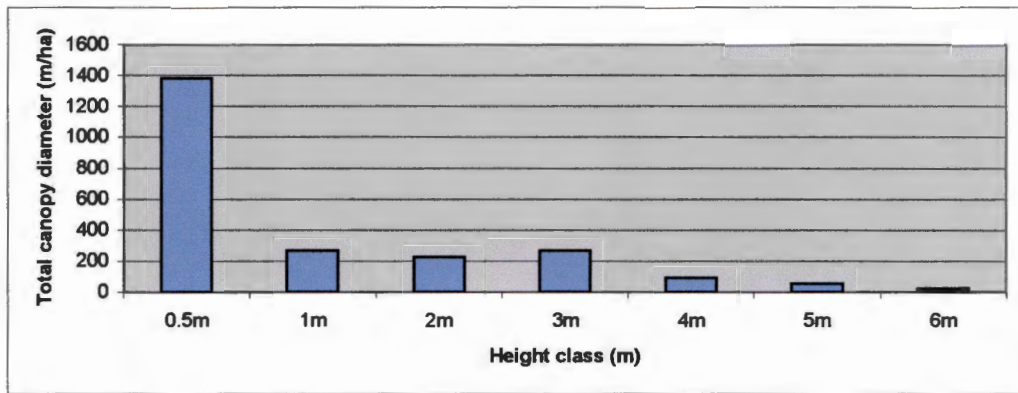


Figure 3.21: Canopy diameter of woody plants in the benchmark.

The low woody plant density (Figure 3.22) indicates that it can provide the highest possible sustained animal production. *Aristida diffusa*, *Eragrostis lehmanniana*, and *E. rigidior* were the most prominent local grasses.

According to Snyman (1999), grassland in “good” condition does not only deliver a higher production than degraded veld, but also has significantly higher total crude protein and water use efficiency than grassland in a “poor” condition.

The woody plant density in different surveyed sites in the Molopo Magisterial District, ranges from 1 007 TE/ha (Benchmark site) to 8 927 TE/ha (Figure 3.22).

During observations, it was noticed that *Acacia mellifera* is the most prominent and frequently observed woody encroacher. This findings correlate to the results of Donaldson (1967).

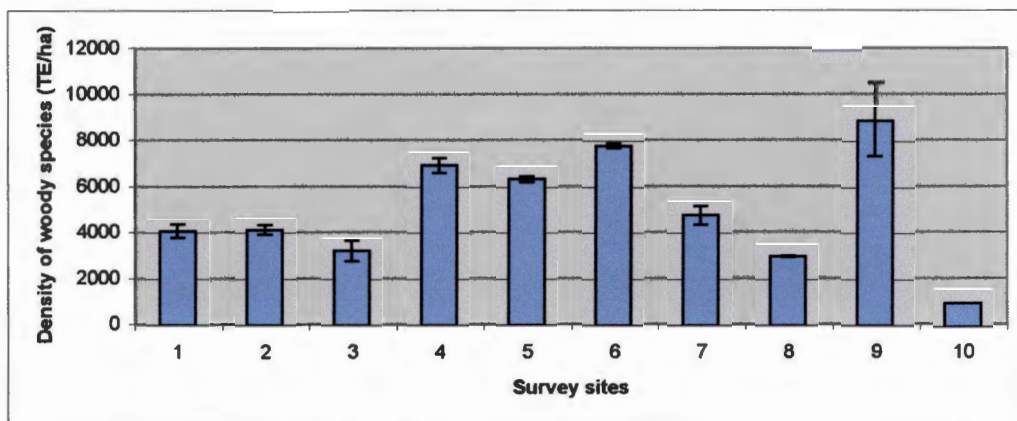


Figure 3.22: Woody species densities in the study area.

The woody plant density in the benchmark represented the lowest density of all the surveyed sites (Figures 3.22). This gives the reason for choosing Disaneng Dam area as the benchmark site. The low (1 007 TE/ha) woody plant density in the benchmark site, indicates that it is still in a “good” state of producing grass, essential for grazing.

According to Anonymous (2001 b), there is a reduction in soil moisture availability accompanying woody plant invasion. The increase in woody plant density reduces water evaporation (Aguiar *et al.*, 1996). The influence of woody plant invasion 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 West Provinces, 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. Woody plant density had an adverse influence on the density and production of the grass component. According to Richter *et al.* (2001), a woody plant density of 2 500 TE/ha decreased the potential grazing

capacity by as much as 33 %, 149 % and 58 % in Molopo Thornveld, Mixed Vaalbos and Eastern Grass and Bushveld respectively.

3.4 CONCLUSION

In cases of increased bush invasion, there are no other alternatives but to eradicate or reduce the number of undesirable woody plants (Bothma, 1996).

It is evident that bush encroachment in the survey area is made of trees with height ranging from 0.5 m to 2 m. Thus browsers will be able to reach the browseable material and may be used to control the invasion of these woody species.

Attempts to restore productivity in rangelands by passive management (withdrawal of livestock) and active intervention (browsing, burning clearing, reseeding and cultivation) have been successful in savanna areas (Milton & Dean, 1995). In savannas, bushes invade rangelands rapidly, but because of the long lifespan of woody plants, this encroachment is slow to reverse itself through self-thinning (Scholes & Walker, 1993).

There is no measurable improvement in species composition, which could be detected in 15 to 50 years after livestock removal (Fairall & Le Roux, 1991; Stokes, 1994). Farming with a combination of cattle and goats is more productive than cattle alone in savanna rangelands (Stuart-Hill, 1987). Continuous browsing, combined with burning, prevents further increase of woody species (Bothma, 1996). Scholes & Walker

(1993) pointed out that, this increase of woody plants is short lived. Most chemical treatments take two to three years to have full effect, due to plants using their reserves to stay alive after treatment (Bothma, 1989).

Before any woody plant control programme is embarked on, two alternative approaches to the problem of increasing tree density in savanna areas need to be assessed. One approach is to adapt the livestock system to the existing vegetation. Where tree densities are high and the woody plants are palatable, browsers should form an important component of the livestock system (Tainton, 1999).

The second approach is to modify the vegetation to suit a specific livestock system and particularly a system based on grazing animals, especially where the vegetation has been greatly modified by past management practices. Here, since the establishment of woody plants is normally a continuing process in savanna areas, control cannot be achieved with a single thinning operation. Planning and implementation therefore need to be ongoing. Where this option is adopted in areas with a high tree density, the first operation should be the drastic one of thinning down to some predetermined density, after which a post-thinning management programme will be needed to keep the area open (Tainton, 1999).

According to Tainton (1999), making any decision on the most appropriate procedures to use when controlling woody species invasion, one has to consider two conditions:

i) ecological responsibility, and

ii) economic viability.

Tree thinning practices which do not comply with these objectives may lead to severe soil erosion and reduced production through, for example, a replacement of good forage species by largely unpalatable species and may, in the long term, result in a more serious tree density problem than existed prior to the initial thinning treatment (Tainton, 1999). Before any tree clearing operation is initiated, the programme must be carefully planned. Hagos and Smit (2005) stressed that the positive effect of woody plants on soil nutrient status must be taken into consideration when a bush clearing programme is planned. Hagos and Smit (2005) suggested selective thinning of *Acacia mellifera* trees, thus reducing the grass – tree competition, while retaining some of the beneficial effects of the trees in terms of soil enrichment.

Bothma (1989), Milton & Dean (1995) and Bothma (1996), found that there are four methods of controlling the invasion of woody species:

1. Mechanical methods

Heavy machinery or implements are used, with which woody plants are removed completely. According to Bothma (1996), mechanical methods imply the use of machinery or implements and even manual methods (e.g. stem burning, hacking or digging out). These methods are characterized by disturbance of the soil layer, where the grass layer is damaged and the re-growth of certain woody species is stimulated.

2. Chemical method

The knowledge of different arboricides and how they work is of great importance (Bothma, 1996). This will ensure the correct selection of arboricides, considering the high cost and effectiveness of the chemicals under different climatic and soil conditions. Arboricides can be divided into two broad groups: (i) arboricides applied to the soil (e.g. Molopo GG, Bushwacker, Molopo SC), and (ii) arboricides applied directly to the plants like, Tordon Super and Garlon (Milton & Dean, 1995 and Bothma, 1996).

In arid areas, the cost of chemical control usually exceeds the benefit and value of the land per hectare (Bothma, 2002). The aerial application of herbicides in the Molopo River region of the Kalahari resulted in a 700 % increase in grass production and a four-fold increase in grazing capacity within three years (Bothma, 2002). The woody plant density decreased from 3 000 plants per hectare to between 200 and 400 plants per hectare (Bothma, 2002).

3. Biological control measures

Biological control of woody species involves the application or manipulation of natural factors that control the composition of savannas (Milton & Dean, 1995; Bothma, 1996).

When considering veld utilization, it is important to focus on the utilization of both the grass and woody layers. To control woody species invasion successfully by means of utilization, it is essential that the grass

layer should not be over utilized (by cattle), whilst the tree layer should be browsed severely by goats (Bothma, 1996).

Where bush thickening has already taken place, it is generally accepted that effective bush control cannot be obtained with browsing by goats alone. Effective bush control with goats can only be successful if the woody plants are completely within the browsing reach lower than 1.5 meters and standard fencing implemented to restrict the movement of goats (Tainton, 1981; Bothma, 1996). To ensure that the goats primarily utilize the woody plant component, the stocking rate must be based on the amount of available palatable browsing material within a specific camp (Tainton, 1981).

4. Fire

Fire can be used as a management tool in controlling undesirable woody plants (Tainton, 1981; Hoffmann & Ashwell, 2001). However, it is clear that in most cases fire does not kill off the trees (Bothma, 1996). This is because fire kills the top part of trees, and then these trees may re-grow (coppice). Bothma (2002) indicated that, the mortality rate inflicted on woody plant species by fire varies from 1.3 % to 33 % in arid savannas. A mean mortality rate of 15 % was recorded for *Acacia mellifera* following grass fires (Bothma, 2002). Tainton (1999) however stressed that a good sward is essential to implement fire control.

According to Bothma (1996), there are two types of fire to be used for controlling invasion of woody species. These are:

- (i) head fires (burns with the direction of the wind), and
- (ii) back fires (burns against the wind).

Tainton (1981), Bothma (1996) and Hoffman & Ashwell (2001) found that there are several factors that should be considered when choosing the method for controlling invasion of woody species in grassland areas:

- (i) density of woody species,
- (ii) growth form of the dominant tree species,
- (iii) size (age) of the majority of plants,
- (iv) size of the area affected,
- (v) production potential of the area, and
- (vi) financial position of the farmer or researcher.

Clearing of 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 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).

Land ownership and use, have always played an important role in shaping the political, economic and social processes of the country. Increased abundance of woody plants in grasslands and savannas has significant socio-economic and environmental implications on the land that have been predominantly used for livestock grazing (Fisher, 1950; Simpson, 1977; Brown, 1999; Hoffman & Ashwell, 2001).

Mugasi *et al.*, (2000), found that bush encroachment on pastoral rangelands has caused some economic losses through reduced levels of animal productivity, increased mortality rates, increased farm variable costs and reduced gross margins. Reduced agricultural production results in further worsening of poverty, increased rural-urban migration and loss of biodiversity (Ponniah, 1998).

It is costly to control woody plant invasion in grasslands (FAO, 1998). Du Toit (2002), found that the cost of treatment using herbicides such as Graslan (Molopo 200 GG) ranges from R 97.00 to R 117.00 per hectare. According to Skarpe (1991) it was found that vegetation recovers after droughts and even during droughts, following the stoppage of grazing or browsing. Less seem to be known of the progressive changes in the grass layer (Skarpe, 1991).

It is predicted that, the degraded vegetation will follow a progressive succession back to the original vegetation once the disturbance has stopped. This is under the assumption that the system is still limited by the factors causing the disturbance (Walker, 1979). Destruction of woody species provides higher initial stands of grasses and more dense population than sowing into regularly grazed rangeland. The suppressive effect of invasive woody species on grass production and grazing capacity is often considered the major reason why clearing of woody plants is viewed as an important management tool (Richter & Meyer, 2001).

Poverty and environmental degradation go hand in hand because poor people cannot afford to take proper care of the environment, since they

have no alternative but to use environmental resources unsustainably for their survival (Sola, 2001). The provision of electricity to the rural households would, to some extent, diminish the direct impact on the environment.

It is a matter of urgency that attempts should be made to halt and eradicate bush encroachment. Research on sustainable use of rangelands, rangeland rehabilitation and alternatives to ranching has to be prioritized in South Africa.

Inadequate planning has contributed to the collapse of many indigenous management systems recently. This is because of the combined pressure of population growth and limited access to land (De Vreede, 2000). Today, the main issue is not only that land degradation should be prevented, but also should be reversed wherever possible.

There is a need for more research on determining the real magnitude of environmental losses caused by bush encroachment and the possible implications on the livestock sector and national economy. Continuing deterioration of the vegetation is at present probably one of the largest agricultural problems in southern Africa (Bosch, 1988). Bosch (1988) described the initial stage of degradation as a change from palatable to unpalatable communities.

Radical changes are also continuing to occur in the Savanna Biome. A large portion of formerly good grazing areas is today relatively unproductive because of dense bush encroachment (Donaldson, 1967).

Widespread tree - and shrub invasions in vegetation types that previously had a low tree cover have radically altered habitats for animals. This is shown by the major changes in distributions of many bird species, including species that invaded the southwest parts of South Africa from adjacent biomes in response to increased tree cover (MacDonald, 1986). Educating members of the public in understanding the complexity of the problem, and thus enabling them to judge the merits of control programmes will enhance reduction in the invasion of woody species.

Moisture availability is a key factor limiting plant growth and vigour and a strong positive relationship between rainfall and the degree of invasion could reasonably be expected. Degradation of riparian habitats due to inappropriate land-use practices has also facilitated invasion as these zones, are naturally prone to invasions (Henderson & Wells, 1986; Rowntree, 1991; Pysek & Prach, 1993).

One of the issues that are currently widely debated is that of applying commercial carrying capacity norms to communal rangelands (Dikeni *et al.*, 1996). Commercial beef farmers aim to make a profit from meat production. They manage the rangeland by controlling animal numbers and applying grazing management systems (e.g. rotational resting) to avoid degradation of the grass resource. By contrast, producers on communal lands have much broader livelihood strategies, of which livestock production may only be a small part. In addition, livestock are kept for multiple reasons including draft power, security, milk and meat (See Chapter 5). They, therefore aim to maximize animal numbers per area and focus on the maintenance and survival of those animals (Dikeni *et al.*, 1996).

It is now recognized that an universal “norm” of carrying capacity is meaningless in a system that are not related to production objectives (Dikeni *et al.*, 1996). However, if maximizing the animal numbers form one of the main objectives of management, care needs to be taken to ensure that the range is not badly stressed. One of the problems in addressing degradation is the lack of information on whether degradation is occurring. A major research gap exists on the long-term quantitative biological and economic effects of high stocking rates under communal systems (Tapson & Rose, 1984; Dikeni *et al.*, 1996).

In order to halt woody plant invasion in communally managed rangelands in the Molopo Area, the co-operation of local communities is essential. They are the major stakeholders and managers of these rangelands, and should thus take the responsibility of rehabilitation upon themselves. It is thus of importance to determine the extent of woody plant density in order to do future planning on rehabilitating these target sites.



CHAPTER 4 SOIL ANALYSIS

4.1 INTRODUCTION

Soil is the weathered superficial layer of the earth's crust that typically is made up of decomposed and partly decomposed parent rock material with associated organic matter in various stages of decomposition (Handreck & Black, 1999; Bothma, 2002). Soil is the natural medium in which the roots of plants grow and it is extremely slow to form (Jordaan, 1998). From soil, the plant absorbs water and solutes necessary for its continued well-being (Weier *et al.*, 1974).

According to Van der Watt & 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 plants, when other growth factors, such as light, water, temperature and physical conditions of the soil, are favourable.

The biotic component may recover after being disturbed for a long period. In contrast, the abiotic component, especially soil, if subjected to accelerated erosion, fertility loss and structural alteration. These changes are usually irreversible in ecological time (Biot, 1993; Milton *et al.*, 1994). The soil degradation in the study area is moderately high (Figure 4.1). This means that the land-use practices must be monitored in order to prevent continuous soil degradation.

Soil erosion is a natural process, which cannot be prevented, but it can be limited to acceptable levels (Bothma, 1996). Erosion and deposition by



Figure 4.1: Soil degradation extent per magisterial district (DACET, 2004).

Figure 4.1: Soil degradation extent per magisterial district (DACET, 2004).

North West Province: Broad soil potential



Source: North West Province Department of Agriculture – Potchefstroom

Figure 4.2: Broad soil potential of North West Province (DACET, 2004).

the agents of wind and water are responsible for transportation of soils from one location to another. According to Hoffman & Ashwell (2001), sandy soils are more permeable to water, and therefore less likely to erode due to water than clay soils. According to Figure 4.2, the soil of the study area was subjected to wind erosion due to low percentage of clay.

Exploitation of natural resources to meet nutritional, medicinal, housing, energy, construction needs and generation of income has led to the depletion of resources and the occurrence of land degradation types (e.g. soil erosion, invasion of woody plant species and deforestation) (DEAT, 1999). Most magisterial districts in the North West Province have shown an increase in land-use intensity for grazing lands over the last ten (10) years (Hoffman & Todd, 1999). Invasion of indigenous woody plant species is recognized as an indication of veld degradation in South Africa (Hoffman & Todd, 1999).

Invasion of exotic woody species possesses a severe threat to plant and animal diversity. This is enhanced by greater use of water, change of nutrient cycling and reduction of light penetration in areas covered by exotic woody plants when compared to areas with indigenous vegetation (MacDonald, 1989; MacDonald & Richardson, 1986). Donaldson (1967) found that the calculated relative transpiration of a single blackthorn plant is between four to eight times greater than that of the other woody plants present (*Terminalia sericea*, *Boscia albitrunca* and *Grewia flava*). *Acacia mellifera* is the most prominent woody species in this area (See Chapter 3). This means there is a greater use of water by plants in the area and this may change current species composition.

Human alterations of hydrology (underground water pumping and surface water diversions) and climate influence terrestrial vegetation (Snyder *et al.*, 1998). In semi-arid and arid regions, this impact led to the change of riparian species composition (Stromberg & Patter, 1990).

The availability of light, water and nutrients are major determinates of plant community structure and function (Midwood *et al.*, 1998). In arid and semi-arid ecosystems, availability of soil moisture drives primary production and influences nutrient dynamics. Plant communities are comprised of species with various adaptations for acquiring and conserving soil moisture. When water requirements, phenology and rooting patterns are similar, competitive exclusion may occur and when they differ, species may coexist (Midwood *et al.*, 1998).

Walter (1971), Walker & Noy-Meir (1982) and Eagleson & Segarra (1985), presume that in woody and shrub savannas, woody plants and grasses are coexisting by partitioning the soil water resources vertically. Le Roux *et al.* (1995) and Scholes & Archer (1997), however do not support this hypothesis. These inconsistencies reflect that a variety of factors, including the amount of rainfall as well as the seasonality, soil texture, soil depth and disturbance (fire, grazing, browsing) can affect species interactions (Midwood *et al.*, 1998).

According to Meyer *et al.* (2002), soil degradation is more prominent in communally managed areas than in commercially managed areas. Soil degradation is correlated with high human and animal density, which characterises the rural areas (Garland *et al.*, 1999). According to Schwabe

(2004), 20 % of land in South Africa is degraded. This degradation is mainly in the former homelands and self-governing territories.

The cause of land degradation is often a consequence of many people being forced to live in relatively small areas. The people overuse the natural resources in order to sustain themselves. According to Schwabe (2004), overgrazing is the pervasive cause of soil degradation. In Africa, overgrazing causes 49 % of soil degradation mainly in arid and semi-arid regions (Schwabe, 2004).

Plants need nutrients to grow and deficiencies or excesses of mineral elements can determine the nature of vegetation (Singer & Munns, 1999). Plants get carbon, oxygen and hydrogen from air and water, but all the other nutrients come from the soil (Singer & Munns, 1999). It is thus important to analyse the soil for nutrient status. The nutrients required in large quantities (macro nutrients) are carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), sulphur (S), potassium (K), calcium (Ca), and magnesium (Mg). Nutrient deficiency is the condition in which a plant is getting nutrients so slowly as to limit growth or impairs a significant attribute of quality (Moore *et al.*, 1998; Singer & Munns, 1999).

Soil influences our whole environment. For example, plants are influenced by acid rain, but many soils react with acid rain, reducing its acidity and protecting water quality (Singer & Munns, 1999). All uses of soil alter the soils, just as soil properties affect the use of natural resources. Proper management means matching the soil with a use that will minimize damage to the soil (Singer & Munns, 1999).

For over 100 years, physiologists have been studying the mineral nutrients of plants. Extensive investigations have been carried out to determine which nutrients are essential for plant growth and what effects are produced in the plant when a particular essential nutrient is lacking (Weier *et al.*, 1974). Smit (1999), also cited the effects of *Acacia mellifera* on soil and noted an increase of nitrogen under tree canopies.

According to Young, (2001) trees improve the soil in the following ways:

- increase addition of top fertile soil,
- reduce losses from the soil,
- improve physical, chemical and biological conditions of soil;
- stabilize runoff and soil erosion,
- promote more closed nutrient cycling,
- maintain soil organic matter, and
- increase nutrient inputs, through nitrogen fixation and uptake from deep soil horizons.

Acacia nilotica, *A. tortilis* and *Ziziphus* spp. are principal trees that have been employed for soil improvement in savannas (Webb *et al.*, 1984; Von Carlowitz, 1986; Young, 1989; Von Carlowitz *et al.*, 1991 and Mac Dicken, 1991). According to Skarpe (1991), trees have other important roles in savannas and are desired for a variety of purposes, such as shade (for human and animals), wood for fuel, fibre, construction and for fodder.

Smit & Swart (1994) and Hagos & Smit (2005) found that soils beneath both leguminous and non-leguminous trees are richer in nutrients (% total

N, % organic C, Ca, K and Mg), than between tree canopies. According to Smith (1996) and Smit (1999), soil under tree canopies has higher concentrations of nitrogen, soil organic matter, phosphate and exchangeable cations like potassium (K^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}) compared to soil from open areas. The nutrient concentrations and pH are usually higher under tree canopies, whilst electrical resistance is the lowest under canopies. There is a significant higher concentration of exchangeable cations under non-leguminous trees, rather than under leguminous trees (Smit & Swart, 1994).

4.2 METHODOLOGY

Two soil samples were collected per site. The samples collected in one site were then mixed to one composite soil sample. The composite soil samples were sent to the Institute for soil, climate and water of the ARC for nutrient and chemical analysis.

4.3 SOIL pH

Soil pH is a measure of acidity or alkalinity of the soil and is defined as the negative logarithm of the hydrogen ion concentration (Fitzpatrick, 1990). Soil acidity or alkalinity has a considerable influence on nutrient availability. Most major nutrients are considered to be easily available to plants within the pH range of 5.5 – 7.5 (Ahn, 1993).

Generally, soil pH of about neutrality is associated with large amounts of exchangeable calcium and some magnesium in the soil (Fitzpatrick, 1990). Singer & Munns (1999), found that there is a positive relationship between pH and exchangeable Ca in the soil. This was evident in soils of

survey sites 6 and 9, whereby the pH was 7.91 and Ca contents 3 292 mg / kg (site 6), and in survey site 9 where the pH was 8.08 while the Ca contents was 2 371 mg / kg (Figures 4.3 & 4.13).

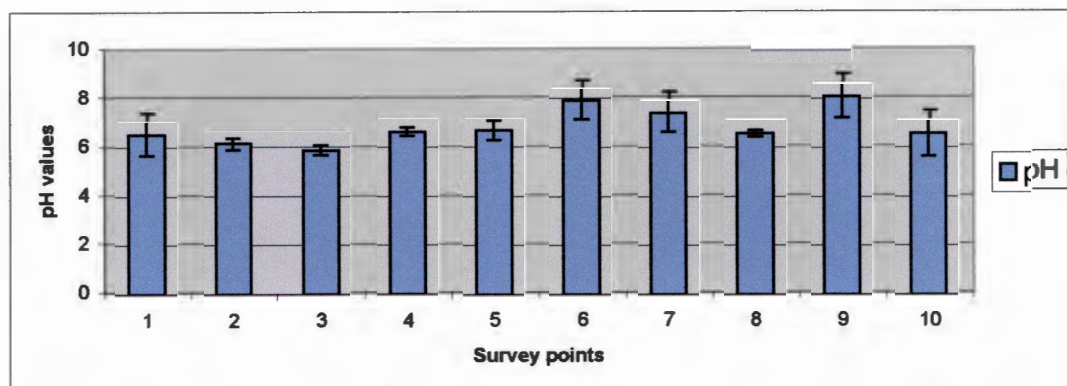


Figure 4.3: The pH of the soil in the study area.

According to Figure 4.3, the soil pH of the surveyed sites varied between 5.86 (site 3) and 8.08 (site 9), with soil pH in most of the survey sites ranged from 6.12 to 6.7 (Figure 4.3), which is considered to be neutral (Table 4.1). Therefore, the soil pH in the study area was moderately acid to moderately alkaline. This was also supported by Hagos & Smit (2005). Soils with a pH between 6 and 7 can support almost any vegetation. However, cation exchange can decrease the pH of soil to as low as 3 (Moore *et al.*, 1998).

There is a negative correlation between pH and electrical resistance (Smit, 1999). This is reflected in Figures 4.3 and 4.16. Smit (1999), found that higher soil pH enhances the availability of exchangeable cations, such as K^+ , Ca^{2+} and Mg^{2+} .

An increase in pH facilitates an increase in cation exchange capacity (CEC) (Foth & Ellis, 1988). This means that the CEC of the soil is pH dependent. As the soil pH increases, the OH^- concentration increases and facilitates the formation of water and increase in negative charges.

Table 4.1: Simple classification of pH (Fitzpatrick, 1990; Anonymous, 1997).

Extremely acid	: < 4.5
Very strongly acid	: 4.5 – 5.0
Strongly acid	: 5.1 – 5.5
Moderately acid	: 5.6 – 6.0
Slightly acid	: 6.1 – 6.5
Neutral	: 6.6 – 7.3
Slightly alkaline	: 7.4 – 7.8
Moderately alkaline	: 7.9 – 8.4
Strongly alkaline	: 8.5 – 9.0
Very strongly alkaline	: > 9.0

The leaching process, which takes place in acid soil, causes soil nutrients like K, Ca, and Mg to be deficient (Singer & Munns, 1999).

Acidity of a soil influences the physical properties of the soil, the availability of certain minerals to plants and also the biological activity. It thus strongly influences plant growth (Bickelhaupt, 1993; Weier *et al.*, 1974).

According to Weier *et al.* (1974), soil pH affects the availability of plant nutrients in three ways:

- in an acid soil, hydrogen ions (H^+) replace other cations (like K^+ , Ca^{2+} , and Mg^{2+}), allowing the nutrient ions to be easily leached from the soil;
- the solubility of plant nutrients (e.g. nutrients, like calcium and magnesium, increase in solubility as pH increases); and
- plant growth indirectly, by suppressing bacterial growth at the extremes of pH levels (i.e. at pH level 3 and pH level 8).

According to Hagos & Smit (2005), the mean soil pH in semi-arid region is moderately acidic. This is expected in the leached sandy soils (Hagos & Smit, 2005). Hagos & Smit (2005), found that soil in encroached semi-arid regions has a lower soil pH than in the open. This means that bush encroachment affects the soil pH of an area.

Acid soil can be improved by the application of lime (calcium hydroxide or calcium carbonate), which tends to neutralize the acid while alkaline soils may be improved by the addition of sulfur or ammonium sulfate (Weier *et al.*, 1974).

Acidity is an important contributing factor in the availability of plant nutrients, but many chemical compounds, found in strong acidic solutions of soil, cause toxicity (Courtney & Trudgill, 1984). Strongly acid soils (see Table 4.1) result in the precipitation of phosphorus by colloidal fractions, forming insoluble aluminum and ferric compounds that are toxic to plants (Simpson, 1983; Landon, 1991).

In most cases, alkaline soils are found in arid regions (Singer & Munns, 1999) and have high levels of nitrate in the solution, but little reserve N because of poor plant growth and the resulting lack of humus. Soils with a pH of 5.5 or lower inhibit plant growth. Roots are commonly the first organs to show injury (stunted growth), owing to acid or lack of calcium. Stunted or injured roots are unable to absorb nutrients like phosphorus from the soil (Singer & Munns, 1999).

According to Singer & Munns (1999), different soil pH levels have a negative impact on soil minerals as listed below:

- a) $\text{pH} < 5$: Al and Mn toxicity, Ca and Mo deficiency.
- b) $\text{pH} < 5.5$: Mo, Zn, K and S deficiency.
- c) $\text{pH} > 7.5$: Salinity, Zn and Fe deficiency.
- d) $\text{pH} > 8.5$: Sodidity, salinity, Zn, and Fe deficiency.

The most common deficiencies of N and P are likely to exist, regardless of the pH (Singer & Munns, 1999).

Base saturation influences the palatability of the vegetation (Jordaan, 1998). This means, the higher the base saturation, the more palatable is

the veld. However, high base saturation of over 100 % is undesirable for plant growth. This means the soil in survey sites 6 and 9 are not suitable for plant growth, because it had a base saturation above 100 % (Figure 4.4). The soil of the benchmark had a base saturation of 58 %, which is within the acceptable range (see Table 4.2).

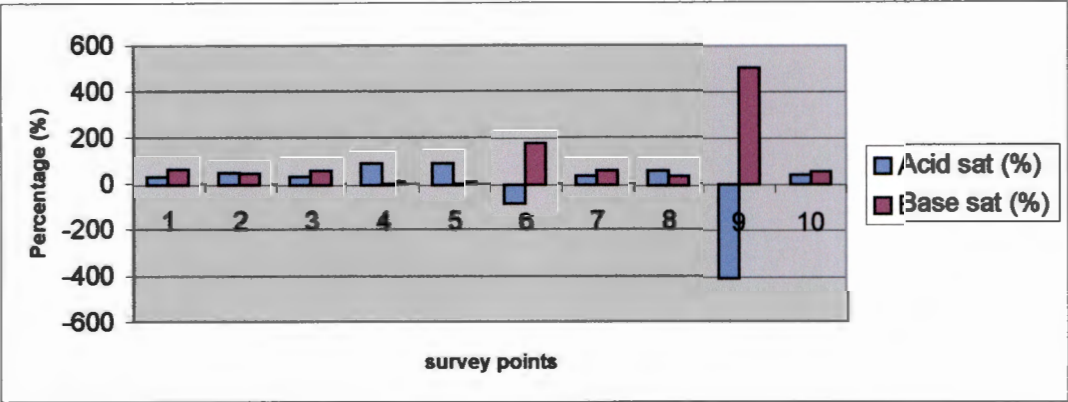


Figure 4.4: Acid and base saturation of soil in the study area.

The term “base” refers to the percentage (%) of cation exchange capacity (CEC) occupied by Na, K, Mg, Ca, persists as an index of soil acidity (Singer & Munns, 1999). Base saturation is nearly 100 % in neutral and alkaline soils (Singer & Munns, 1999) and becomes less than 100 % in acid soils.

According to Borman *et al.* (1989) the acceptable range of acid saturation in soil is 5 % – 15 %. This means the soil in the study area had an acid saturation, which is not suitable for plant growth (Figure 4.4).

Table 4.2: Acceptable limit of soil indicators (Adapted from Borman *et al.*, 1989).

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

Soils in survey sites 6 and 9 had an acid saturation below 0 % (Figure 4.4). Hydrogen and aluminum tend to dominate very acid soils, both contributing to the concentration of H^+ in the soil (Foth & Ellis, 1988).

Soils with pH above 7 are considered basic and those of 5.6 and below are acid (Smith, 1996). In this study, the soil pH in most sites was above 5.6 and 7 (Figure 4.3), indicating the soils to be basic (Smith, 1996).

4.4 MINERAL ELEMENTS ESSENTIAL FOR PLANT GROWTH

The readiness, with which soil supplies nutrients to plants, depends on how much of the nutrient the soil contains (Singer & Munns, 1999). An increased amount of nutrient in the soil increases the concentration in solution, the speed of replenishment of the nutrient in solution and the nutrient's mobility in the soil. Therefore, nutrient availability increases (Singer & Munns, 1999).

According to Handreck & Black (1999), plants utilize essential elements (nitrogen, sulphur, phosphorus, potassium, calcium, magnesium and iron), in four basic ways:

- (a) The elements may form part of the structural units, such as carbon in cellulose or nitrogen in protein;
- (b) elements may be incorporated into organic molecules important in metabolism, like magnesium in chlorophyll or phosphorus in ATP;
- (c) elements may function as enzyme activators (e.g. magnesium in glucose degradation during the process of respiration); and
- (d) essential elements help to maintain the osmotic balance (e.g. potassium in guard cells).

The low fertility of soil may be inherent or caused by leaching or soil erosion. It is known that, low soil fertility is often more of a limiting factor for plant growth than low and irregular rainfall (Handreck & Black, 1999).

The mechanism of soil enrichment beneath tree canopies remains largely unexplained (Smit & Swart, 1994, Hagos & Smit, 2005). Leaf litter from fallen leaves has been mentioned as a possible source (Stuart-Hill *et al.*, 1987; Belensky *et al.*, 1989).

Kellman (1979) concluded that mineral nutrients, concentrated beneath neotropical savanna trees, could not have been derived from weathering at depth and that they must have been derived from the capture of precipitation inputs. Stem-flow represents another source of mineral input into soil (Potter, 1992). The occurrence of N-fixation, due to

microbial activities in the soil under leguminous trees, also remains a possible source of soil enrichment (Felker & Clark, 1982; Högberg & Kvarnström, 1982; Högberg, 1986).

The base richness of the parent material is initially important in determining soil fertility, but biological activities are important in the creation and maintenance of localised areas of enhanced soil fertility (Smit, 1999). Woody species and especially leguminous woody plants, like *Acacia* species, are important in establishing areas of enhanced soil fertility (Hagos & Smit, 2005). Most comparative studies that involved *Acacia* species, showed that soil enrichment under their canopies is higher than under non-leguminous woody species (Smit, 1999). Soil under canopies often exhibits a higher pH value and lower electrical resistance (Smit, 1999). Hagos & Smit (2005), however, reported a lower soil pH of encroached areas than in the open. The pH values were lowest close to the stem and increase further away (Hagos & Smit, 2005).

With regard to soil nutrients, evidence exists that the type of grass species (e.g. in nutritive soils where there is availability of palatable grasses while in infertile soils unpalatable grasses dominate) changes with changes in soil nutrient status (Grunow *et al.*, 1970; Donaldson *et al.*, 1984).

4.5 ORGANIC CARBON

The carbon content of the soil tends to be low when compared to nitrogen (N) content in soils dominated by leguminous plants (Foth, 1990). However, the carbon content of soil in the study area was higher than the

soil nitrogen content (Figure 4.5). Leguminous woody species (*Acacia mellifera*) were prominent in site 6 (See Chapter 3), where the organic carbon in the soil was highest (0.64 %) compared to nitrogen content (0.061 %) (Figures 4.6 & 4.7). It is thus evident that the soil organic carbon content is higher than the soil nitrogen, even in soils covered by non-thorny woody species such as *Terminalia sericea* (Figures 3.4 & 3.6, Chapter 3).

The soil carbon content of survey sites 1, 4, 6, and 9 was higher than that of the benchmark (Figure 4.6). This is due to the high density of leguminous woody species (Figure 3.22, Chapter 3). The abundance of organic matter beneath tree canopies and the rate of decomposition ensure the increase in soil organic carbon (Foth, 1990).

The organic matter of the soil is derived from decomposing plant and animal material (Weier *et al.*, 1974; Bellows, 2001). Trees and shrubs shed their leaves, twigs, bark and fruits and their roots die off. This dead plant and animal material decompose in the soil and form organic matter. Organic matter improves the physical condition of most soils, especially those with much clay (Weier *et al.*, 1974). The gradual decomposition of organic matter in the soil continually liberates mineral elements that are essential for plant growth (e.g. sulphur, phosphorus, and nitrogen).

According to Bellows (2001), the balance between the amount of carbon and nitrogen determines whether soil organisms will release or immobilise nutrients. Populations of soil organisms are enhanced by soil that is not compacted and has adequate air and moisture.

The C:N of the soil provides an indication of the adequacy of N for heterotrophic organisms (mineralizers) and the amount of nitrogen that will appear as excess nitrogen (Foth & Ellis, 1988).

In general, soil with a C:N ratio between 20 and 30 has enough nitrogen to satisfy the needs of the decomposers (Foth, 1990; Singer & Munns, 1999). Soil with higher ratios produces a temporary period of nitrogen deficiency for plant growth. The soil in the study area had a C:N ratio between 8 and 13 (Figure 4.6). This means there is no soil nitrogen deficiency in the study area, but the present C:N ratio cannot satisfy the needs of the decomposers.

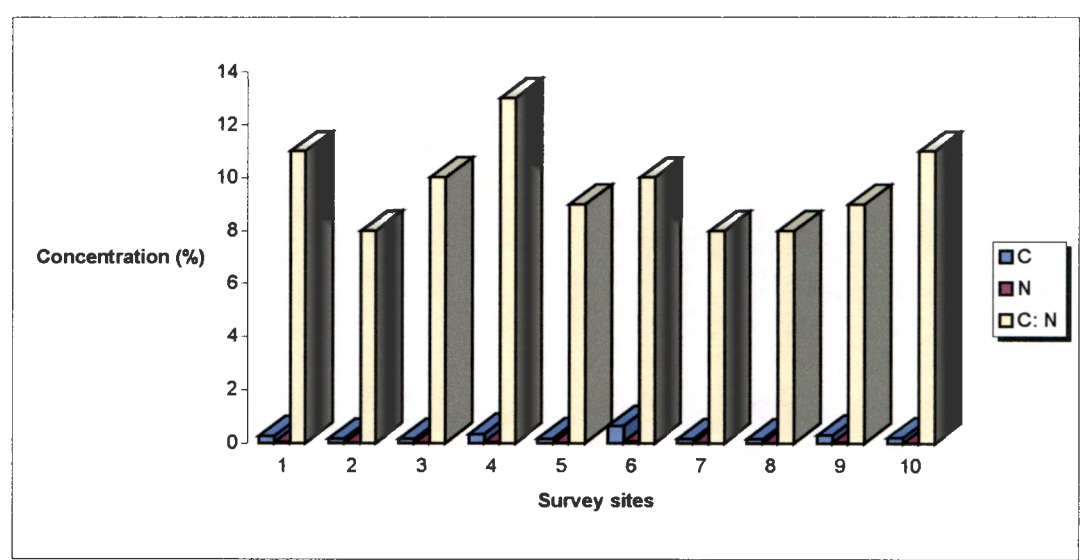


Figure 4.5: Chemical composition of soil.

When soil organic matter is in sufficient amounts, it improves the soil water holding capacity, increases CEC and improves soil structure (Ahn, 1970; Buckman & Bray, 1969; Nye & Greenland, 1960; Jordaan, 1998).

The organic carbon content of soils in survey sites 1, 4, 6 and 9 was higher than that of the benchmark soil (Figure 4.6). It is also evident that the density of woody species in the same sites was higher than that of site 10 (Figure 3.22, Chapter 3). This correlates with the findings of Smit and Swart (1994) and Smit *et al.* (1996).

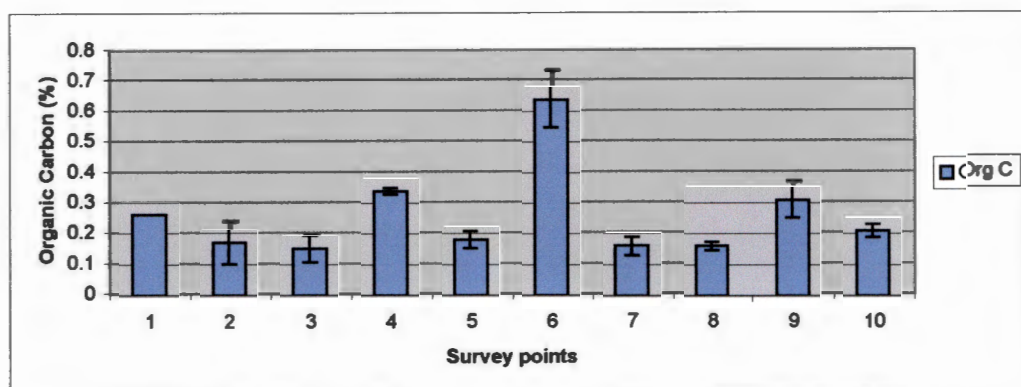


Figure 4.6: Organic carbon of soil in the study area.

According to Archer & Boutton (2001), grazing, fire and their interactions affect carbon dynamics in rangelands. The organic carbon content in the soil in Tshidilamolomo 1 (site 6) (Figure 4.6) was higher than in the soil of Disaneng Dam Area (benchmark). This resulted from a high density of *Acacia mellifera* in Tshidilamolomo 1 (Figure 3.12, Chapter 3). This is in accordance with Smit (1999) who found that there is an increased organic carbon in the soil under the leguminous species than under non-leguminous species. Hagos & Smit (2005), also found an increased organic contents under tree canopies than in open areas.

The organic carbon content of the soil in the study area can be rated as “very low” according to Metson (1961) (see Table 4.3). The organic C is used for the prediction of water holding properties of the soil (Salter & Williams, 1969). Jordaan (1998) discovered that, when the amount of organic carbon is known, the amount of soil organic matter (SOM) could be predicted. The SOM is known for improving the soil structure and soil water holding capacity (Jordaan, 1998).

Table: 4.3 Broad ratings of organic carbon measurements (Adapted from Metson, 1961).

Organic C content Walkley method (% of soil by weight)	Rating
➤ > 20	➤ Very High
➤ 10 – 20	➤ High
➤ 4 – 10	➤ Medium
➤ 2 – 4	➤ Low
➤ < 2	➤ Very low

The use of land by human is often inducing changes in plant composition. These changes in vegetation are geographically widespread and result in alterations of global nutrient cycles (Boutton, 2002). Livestock grazing has the potential to change ecosystem structure and alter carbon storage in plants and soil. When there is reduction of vegetation density or cover, resulting from human practices or overgrazing by livestock, the soil becomes exposed or uncovered. This, then leads to the reduction of soil nutrients caused by leaching or removal of fertile topsoil through the process of erosion.

According to Boutton (2002), moderate grazing strongly increases the proportion of carbon in the soil. This is because, in moderately grazed areas, the soil is not exposed to crusting, nutrient leaching and soil erosion.

4.6 NITROGEN

Nitrogen derived from the atmosphere or dead tissues is transformed by bacteria in the soil into ammonia and nitrate, which are taken up by the plant roots (Fitzpatrick, 1990; Landon, 1991; Ahn, 1993). Nitrates are the main form of nitrogen used by plants.

Reduction or deficiency of N can occur in all soils due to leaching of ammonia and nitrate (Fitzpatrick, 1990). According to Table 4.4, the N content of the soil in all the survey sites was very low. The low N content is influenced by the chlorides in the soil and the leaching of nutrients in sandy soil (Metson, 1961).

Table: 4.4 Ratings of nitrogen measurements (Metson, 1961).

N content (Kjeldahl method) (% of soil by weight)	Rating
> 1.0	Very high
0.5 – 1.0	High
0.2 – 0.5	Medium
0.1 – 0.2	Low
< 0.1	Very low

Nitrogen is required by plants in amounts that are relatively large when compared to their needs for other nutrients. The growth of crops is thus more often limited by nitrogen deficiency than by deficiency of any other nutrient. Excess nitrogen can adversely delay maturity of crops (Ahn, 1993).

According to Singer & Munns (1999) and Moore *et al.* (1998), nitrogen supply often limits both soil microbes and plant growth. This is realized when the N is tied up in the large molecules and too little of it is in available forms (ammonium and nitrates).

According to Smit & Swart (1994) and Hagos & Smit (2005), the soil nitrogen content is higher beneath tree canopies than in open areas. These findings of Smit & Swart (1994) are positively related to the results presented in Figure 4.7. The soil of site 3 (Phitshane 2) was the only site, having a lower nitrogen content than the soil of the benchmark site (Figure 4.7).

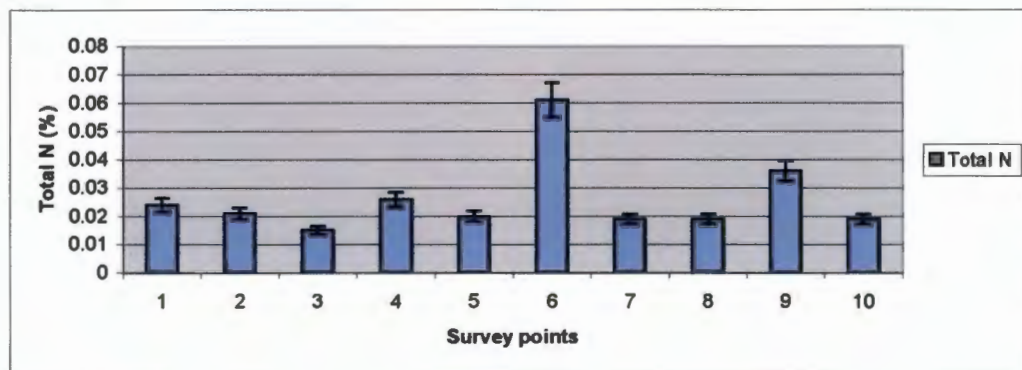


Figure 4.7: Nitrogen content of soils in the study area.

The soil nitrogen content, of the study area ranged from 0.015 % - 0.061 % (Figure 4.7). There was a positive relationship between organic C and total N (Figures 4.6 and 4.7). Thus, when N increased, organic C also increased. This is evident in sites 6 and 9. According to Archer (2001), invasion of unpalatable woody species into rangelands is a global problem, because excess soil C and N accumulate during woodland development. Soil nitrogen content accumulates relatively faster in woodland than C (Archer, 2001).

Losses of nitrogen are greatest on calcareous soils or when the pH is above 7.0 (Traynor, 1984). The soils of survey points 6 & 9 had a pH above 7 (Figure 4.3) and a high N content, as compared to the benchmark site (Figure 4.7). This resulted from high bush densities in these areas (Figure 3.12, Chapter 3). Therefore, the findings of Traynor (1984) do not correlate with the results in these sites (Figure 4.3). However, the percentage of nitrogen in the soil of the benchmark site (survey point 10), positively correlated with the pH (Figures 4.3 & 4.7) and therefore, is in accordance with the findings of Traynor (1984).

Soil in site 6 (Tshidilamolomo 1) had a higher N content, compared to the soil of the benchmark (survey site 10), even though leguminous woody plants dominated in these sites (Tshidilamolomo 1 and Disaneng 2). This is the result of larger densities of woody encroachers in site 6 (Figure 3.22, Chapter 3).

Macronutrients are used by plants in relatively large amounts and include nitrogen, phosphorus, potassium, calcium, and magnesium (Foth, 1990).

Nitrogen availability in the soil is controlled mainly by materialization and immobilization. It is added to soils by fixation and an appropriate amount is lost annually by denitrification. The dominant form of available nitrogen is nitrate, which is readily moved to roots by mass flow and lost from soil by leaching and denitrification (Foth, 1990).

Plants use nitrogen for the formation of proteins and genetic material (Bellows, 2001). Grazing animals that consume these plants use some of the nitrogen for their own growth and reproduction. The remaining proteins return to the soil in the form of urine and manure.

4.7 PHOSPHORUS

According to Smith (2002), savanna rangelands of southern and western Africa have shown that phosphorus is depleted in grazing lands. In the Kalahari Savanna of Botswana, phosphorus loss has been extensively found in areas subjected to 40 years of livestock use. As the normal content of soil phosphorus is very low in the Kalahari, any further loss may be enough to cause livestock malnutrition. The rising of pH, resulting from liming acid soils, increases the phosphorus availability in phosphorus deficient soils (Whiteman, 1980).

Phosphorus is tightly bound in acid soils that contain high concentrations of iron and aluminium (Bellows, 2001). Active calcium in neutral to alkaline soils also forms tight bonds with phosphorus. Therefore, the availability of phosphorus in acid soil can be increased through the application of lime.

In alkaline calcic soils, the phosphate is associated with calcium carbonate and its solubility will increase if the pH drops toward neutrality. In neutral or acid soils, the phosphate content is associated with Fe (Moore *et al.*, 1998).

Nutrient availability in the soil is influenced by a range of climatic and soil factors (Ahn, 1993). A rough (course) sandy soil texture facilitates the leaching of soil nutrients during high rainfall. When water rises to the soil surface, it brings nutrients with it and these may be left at or near the soil surface when that water evaporates (Ahn, 1993).

Plants require large amounts of nitrogen, phosphorus and potassium (Moore *et al.*, 1998). As a result, these are the nutrients most likely to be deficient in soil.

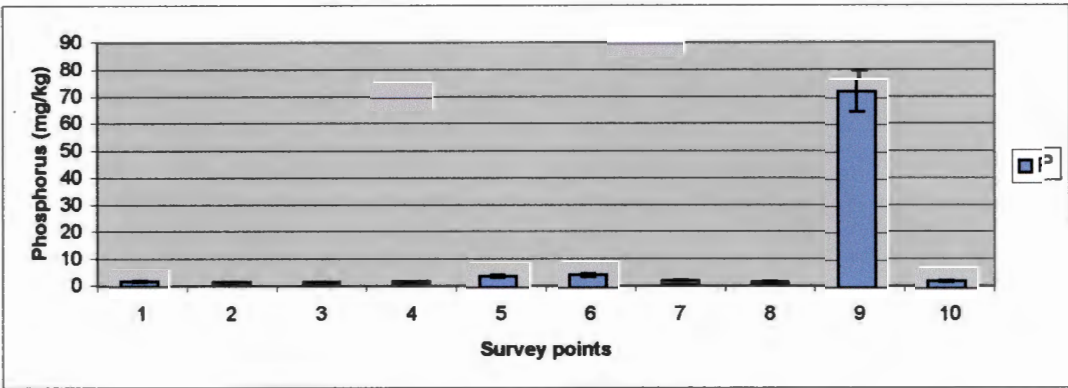


Figure 4.8: Phosphorus quantities in study sites.

Deficiency of phosphorus is caused by increased calcium in the soil (Fitzpatrick, 1990; Foth, 1990). Soil in site 9 had the highest content of phosphorus (Figure 4.8), and higher calcium content when compared to

the benchmark site (Figure 4.13). This reflects a positive relationship between calcium and phosphorus.

According to Fitzpatrick (1990) and Foth (1990), soil pH below 5.5 increases the deficiency of phosphorus, while raising the pH to 5.5 or 6.5, reduces the deficiency of phosphorus. The pH of soils in the study area was above 5.5 (Figure 4.3), with the phosphorus content being 72.30 mg/kg (site 9) (Figure 4.8) at a pH of 8.08 (Figure 4.3). Phosphorus originates from apatite weathering. Soil pH affects phosphorus fixation and therefore, phosphorus availability (Foth, 1990). Erosion and water runoff lead to the movement of phosphorus through the cracks and channels in the soil to artificial drainage systems or natural rivers (Bellows, 2001). The truth of Foth's (1990) finding was revealed in survey site 9 (Figures 4.3 & 4.8), where increased pH showed an increase in phosphorus. The soil of the benchmark recorded a pH of 6.54 with the phosphorus content of the soil 2.38 mg/kg (Figures 4.3 & 4.8). The effect of pH on P content of the soil is thus clear.

According to Moore *et al.* (1998), neutral soils are phosphorus deficient, than soils that are naturally acid or alkaline (Figure 4.8). Alkaline soils are evident in arid climates and are also found in the study area (Figure 4.3).

Plant growth and organic matter accumulation in the soil result in the conversion of a significant amount of apatite phosphorus into organic phosphorus (Foth, 1990). The loss of phosphorus in the soil occurs as a result of plant removal through grazing (Whiteman, 1980).

In acid soils, phosphorus released by dissolution of apatite is gradually converted into ion and aluminum phosphates. Eventually, in intensively weathered soils, rich in iron and aluminum oxides, phosphorus becomes least available (Foth, 1990). Agronomists have long regarded phosphate application as being useful in promoting a good root system (Ahn, 1993).

According to Traynor (1984) there are a number of factors that have a strong influence on the chances of getting a crop “response” from phosphorus:

- a) phosphorus moves more easily and is taken up more easily in moist soils;
- b) phosphorus is more soluble and plants can take up phosphorus more easily as temperatures increase; and
- c) phosphorus is most available to plants at pH 6.5 to 7.0. If pH gets too low, phosphorus can be held tied up by the metallic elements (iron, zink etc.), that are much more active in acid soils. If pH gets much above 7.0, phosphorus can be tied up by calcium and magnesium.

Addition of sulfuric acid or acidifying materials may improve availability of phosphorus in the soil, but it may be impossible to reduce the pH to below 7.2 on highly calcareous soils. Manure, particularly poultry manure, can be a good supplemental source of phosphorus (Traynor, 1984).

4.8 POTASSIUM (K)

Exchangeable potassium will be available in soil with a low CEC (Ahn, 1993). This means that there is a positive correlation between CEC and exchangeable K.

Potassium is a limiting factor in plant growth and absorbed by the plant as K^+ . Potassium is absorbed by the plant in relatively large quantities, and probably second in amount in many cases only to nitrogen (Ahn, 1993). It influences the uptake of other elements and affects both respiration and transpiration (Fitzpatrick, 1990). Deficiency of K is usually the result of leaching and continuous cultivation practices.

Compacted or poorly aerated soil would be a candidate for K deficiency (Traynor, 1984). Excessive potassium is not directly toxic to woody plants, but have adverse effects. A high potassium content in the soil, leads to the deficiency of magnesium (Traynor, 1984; Smith, 2000). This corresponds with the results found in the soil of survey site 6, which had a high potassium content which suppressed magnesium content in the same area (Figures 4.9 & 4.15). The benchmark has the lowest content of both potassium and magnesium compared to the soil of survey site 6 (Figures 4.9 & 4.15).

The potassium content of the soil in the benchmark was lower than that in the majority of the other sites. Sites 4, 6 and 9, especially site 6, had high potassium content in the soil (Figure 4.9)

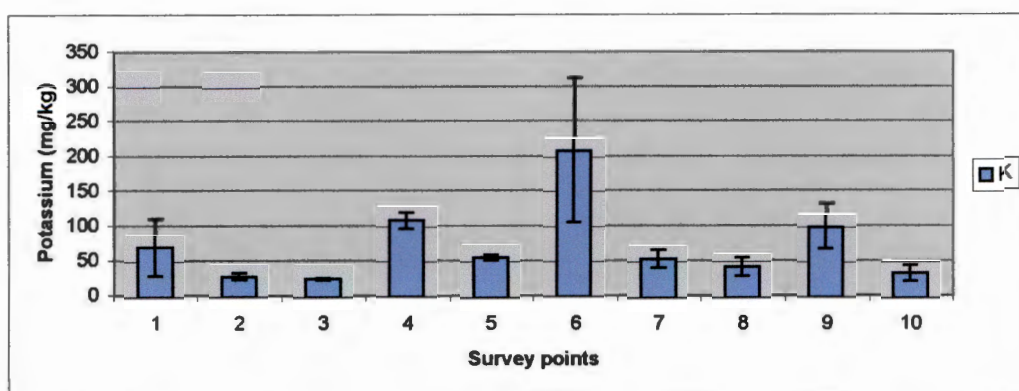


Figure 4.9 Potassium content of soil in the study area.

Potassium, like all plant nutrients, is recycled through plant uptake, animal consumption and manure deposits (Bellows, 2001). The application of fertilizer nitrogen increases the potassium uptake by grasses if soil has an adequate supply of potassium (Bellows, 2001).

4.9 SODIUM (Na)

Sodium is one of the adsorbed cations (Na^+), considered exchangeable on negatively charged soil colloids (Foth, 1990). Sodic soils have been called “alkali soils” (Foth, 1990). They are non-saline and have an adsorbed or exchangeable sodium percentage (ESP) of 15 % or more (Foth, 1990).

Sodium is available to plants when the pH is in the range of 8.5 – 10 (Foth, 1990; Singer & Munns, 1999).

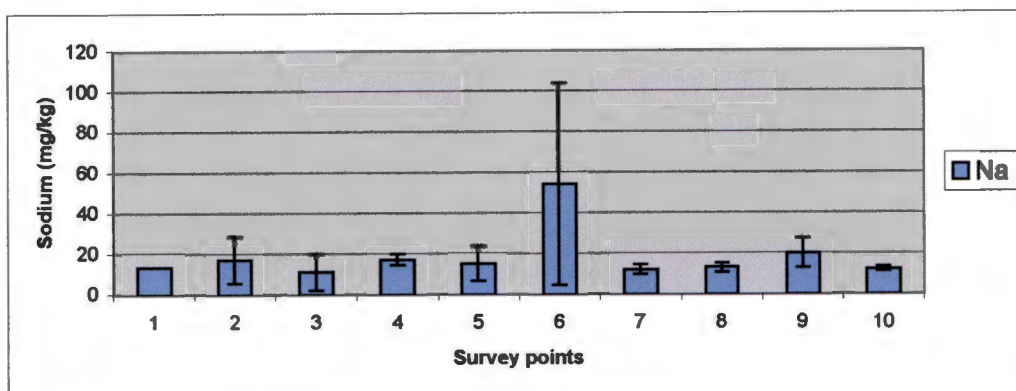


Figure 4.10: The amount of sodium in the soil of different sites.

In the study area, only soils in survey sites 6 and 9 were close to this pH range with pH of 7.91 – 8.08 (Figure 4.3), respectively and the sodium content of soil in the same survey points being 54 mg/ kg and 20 mg/ kg respectively (Figure 4.10). This means the sodium in the soils of sites 6 and 9 were readily available to plants. Soil of the benchmark site (survey point 10) also showed a positive relationship between pH and Na (Figures 4.3 & 4.10).

Soil with excess sodium content is difficult to till and crusting may inhibit seeding emergence. This soil is also reducing the calcium and magnesium content in the soil (Foth, 1990; Singer & Munns, 1999). This does not relate to the results found in the study area (Figures 4.10 & 4.13), thus the soil in survey site 6 and site 9 had a high Na content compared to other survey sites and high calcium and magnesium content.

Sodic and alkaline soils are most common in areas with low rainfall, high evaporation and limited drainage, which promote accumulation of salts from incoming water (Singer & Munns, 1999). Poor soil permeability

due to sodicity and micronutrient deficiencies, associated with a high pH, limits plant growth (Singer & Munns, 1999).

When the soil sodium content is 10 % or higher when compared to total exchangeable cations, the soil is said to be sodic (Singer & Munns, 1999). Soil in which salts of Ca and Mg are more abundant than Na salts is known as sodic soils. Sodic and saline soils are usually alkaline. The pH is commonly 8.3 – 8.5 and approaches 10 in sodic soils (Foth, 1990).

4.10 EXCHANGEABLE SODIUM PERCENTAGE (ESP) AND SODIUM ADSORPTION RATIO (SAR).

According to Singer & Munns (1999), the ESP (exchangeable sodium percentage) is the exchangeable Na, expressed as a percentage of the total exchangeable cations. The SAR (sodium adsorption ratio) is the modified ratio of Na to other major cations, Ca and Mg (Singer & Munns, 1999).

The soil's ESP and SAR are positively related, because exchangeable cations in soil are nearly in equilibrium with each other. Critical values for ESP vary from 5 % - 15 %, depending on soil salinity (Singer & Munns, 1999). The ESP of soil in the study area was below 5 % (Figure 4.11) and had sufficient ESP. An ESP of 15 % is often regarded as the boundary between sodic and non-sodic soils (Singer & Munns, 1999).

The exchangeable potassium percentage (EPP) of soil in site 9 (Figure 4.11) was above the acceptable range (Table 4.2). This means potassium is out-competing other available ions (e.g. magnesium and calcium ions)

in the soil for uptake. The EPP of the soil in the benchmark was within the acceptable range at 3.71 % (Figure 4.11).

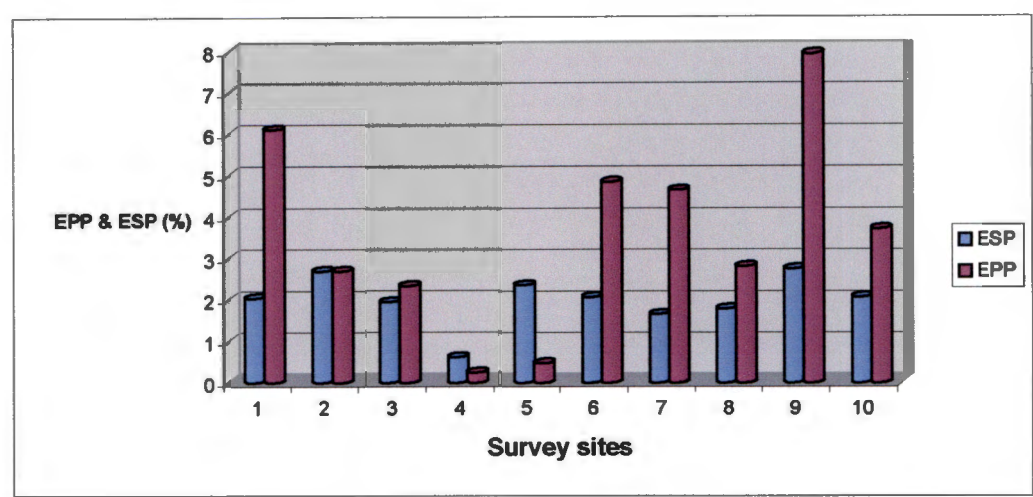


Figure 4.11: EPP and ESP of soil in study area.

The SAR of soil takes into account that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions (Macvicar *et al.*, 1977). Alkali soils are associated with SAR greater than 4, which indicates a sodium hazard (Bornman *et al.*, 1989).

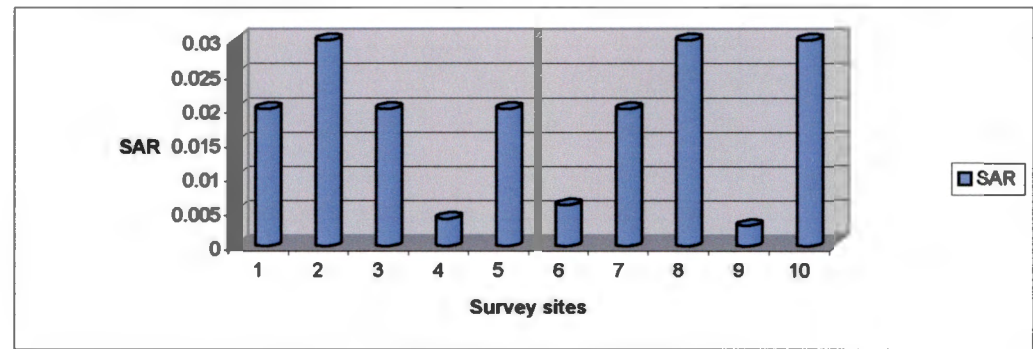


Figure 4.12: SAR of soil in the study sites.

The SAR of the soil in all the survey sites, including the benchmark was below 1 (Figure 4.12), which indicates that there is no sodium hazard in these soils.

4.11 CALCIUM (Ca)

Calcium is an essential element for all higher plants and is absorbed by plants as Ca^{2+} . Calcium is normally the dominant exchangeable cation in most soils, but the amounts become progressively less in more acid soil (Ahn, 1993). Calcium is a major ingredient of plant cell walls and is important for root development (Smit, 1999).

There is a positive relationship between pH and Ca, that is, an increase in pH leads to an increase of calcium content in soil (Whiteman, 1980). Calcium and magnesium are components of liming material used to increase soil pH and thus reduce soil acidity (Bellows, 2001). This relationship is evident in sites 4, 6 and 9 (Figures 4.3 & 4.13). According to Whiteman (1980), the cations, including calcium, decrease as pH decreases.

Calcium content of soil in the study area was the highest of all the other soil nutrients (Figure 4.13). Soils of sites 2 and 3 had the lowest Ca contents of 124 mg/kg (Figure 4.14). According to Olar-Adams & Egunjobi (1992), soil under canopies of *Terminalia sericea* contains nutrients in the following sequence, namely $\text{Ca} > \text{N} > \text{K} > \text{Mg} > \text{P}$. Site 3 was dominated by *Terminalia sericea* (Figure 3.6, Chapter 3). The

findings registered in Figure 4.13, thus correlates with those of Olar-Adams & Egunjobi (1992).

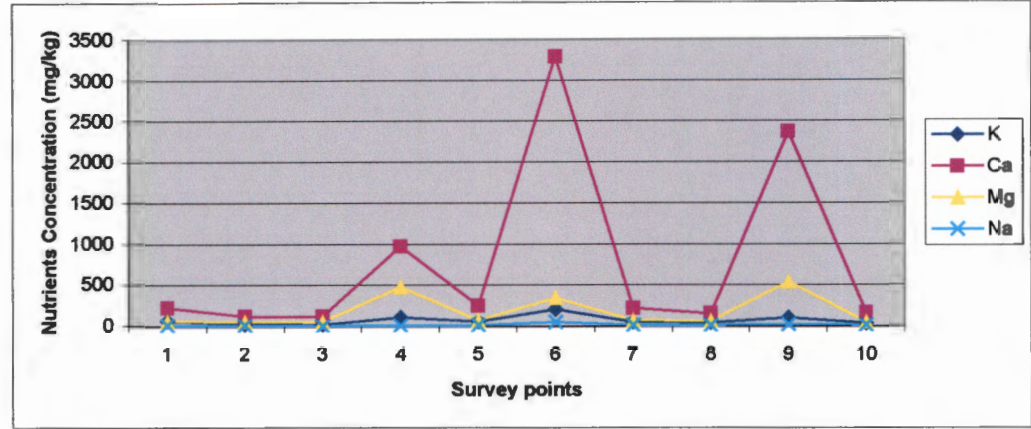


Figure 4.13: Illustration of different soil nutrients in soils in the study area.

Sites 4, 6 and 9 had high bush densities (Figure 3.22, Chapter 3). Soils in these sites thus recorded high calcium contents (Figure 4.14). These results are positively correlated to the results of Smit & Swart (1994), in which higher soil nutrients are found in soils beneath tree canopies. The benchmark site had a lower density of woody species as well as a lower soil calcium content, compared to Selosesha 1, Tshidilamolomo 1 and Tshidilamolomo 2 (Figure 4.14).

Structural differences in the leaves of leguminous (microphyllous) and non-leguminous (broad-leaved) trees present a possible source of difference in soil nutrient contents, the latter being subject to further dispersal by wind (Olar-Adams & Egunjobi, 1992).

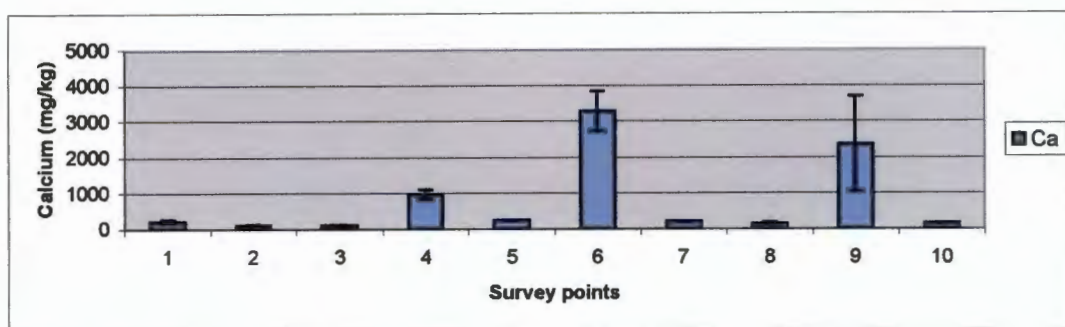


Figure 4.14: The amount of calcium in the soil of the different sites.

Some important calcium minerals include calcite, dolomite, gypsum and feldspar (Foth, 1990). Calcium salts are abundant in arid soils, and cause the soils to be alkaline. This was evident in the study area (Figure 4.13).

Calcium is rarely deficient for plant growth. Such a deficiency occurs usually in intensively weathered soils. Increasing the calcium concentration enhance biological activity in the soil (Bellows, 2001). Magnesium is sometimes deficient in plants, growing in acid and sandy soils with a low cation exchange capacity (Foth, 1990).

4.12 MAGNESIUM (Mg)

Magnesium is active in enzyme systems and forms part of chlorophyll (Foth, 1990; Singer & Munns, 1999). Deficiency of magnesium causes premature defoliation of plants and animals feeding on such vegetation develop hypomagnesaemia (reduced magnesium level in animal blood) (Foth, 1990; Singer & Munns, 1999). Important magnesium minerals include dolomite, biotite and olivine (Foth, 1990).

The dominant exchangeable cation in tropical savanna soils is calcium (Ca^{2+}) followed by magnesium (Mg^{2+}) (Ahn, 1993). These findings are in line with the findings in the study sites, where Mg was found to be the second most prominent nutrient following Ca (Figure 4.13). When soils are subjected to increased leaching, both exchangeable calcium and exchangeable magnesium are removed (Ahn, 1993).

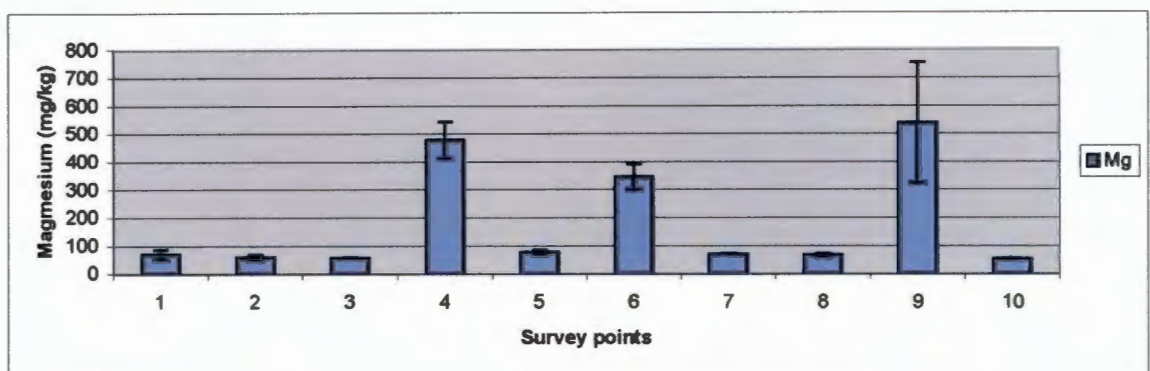


Figure 4.15: Magnesium contents of soils of the study area.

Soils in Tshidilamolomo 2 (survey site 9) had a magnesium content of 537 mg/kg, compared to the soil of the benchmark with a magnesium content of 54 mg/kg (Figure 4.15). Smit (1999) and Hagos & Smit (2005) indicated that, the magnesium contents of soils under tree canopies of woody species is higher than in soils of non-encroached areas.

Magnesium is rarely deficient in plants growing in acid and sandy soils with a low cation exchange capacity (Foth, 1990). The presence of Mg deficiency in a crop may not only be associated with low magnesium content in the soil, but also with the presence of large Ca:Mg ratios above 5:1 (Landon, 1991).

4.13 RESISTANCE

High resistance in soil implies a reduction in soil moisture availability accompanying woody plant invasion (Anonymous, 2001 a). This correlates with the findings in the study area. According to Foth & Ellis (1988), soil water and soil pH are positively related. Survey site 3 had a low soil pH (Figure 4.2). This shows that this site had a low soil moisture content.

Soil resistance ranges from 300 ohm – 500 ohm in clay soil to thousands or millions ohms in sand or limestone (Anonymous, 2001). Sandy soils were evident in the study area (Figure 4.17). The soil resistance ranged from 1 100 ohm – 23 000 ohm (Figure 4.16). The high resistance indicates that the local soil has poor water holding properties (Ahn, 1993) and results from sandier soil texture and reduced soil moisture.

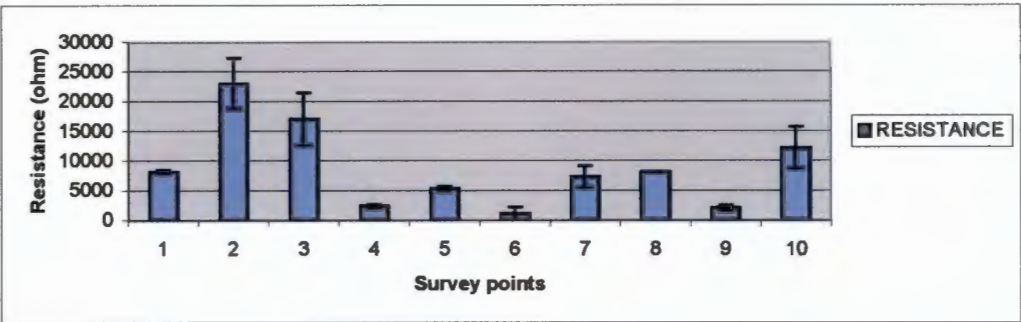


Figure 4.16: Resistance of soils in the study area.

The resistance of the soil in sites 4 & 6 were 2 400 ohm & 1 130 ohm respectively, which was low, compared to the soil in the benchmark site (Figure 4.16). This is due to a lower sand percentage (80.94 % & 74.62

%), in these sites. The sand percentage of the soil in the benchmark was measured at 89.9 % (Figure 4. 17).

4.14 SOIL TEXTURE

Soil texture is the relative proportion of sand and clay in the soil. It is a fundamental soil property which in practice the farmer can do little to modify (Ahn, 1993).

There are various types of soil texture, and the most referred to are, sand, clay and silt. Sandy soil is extremely gritty, not smooth, not sticky or plastic, and does not form cohesive balls (i.e. balls collapse easily). The higher the percentage of sand in the soil, the greater the pore spaces between soil particles. These pore spaces are responsible for aeration and water drainage (Jordaan & Thiart, 1998). Savannas are water-limited for at least part of the year as the climate is characterised by the alternation of a dry and rainy period (Frost *et al.*, 1986). The amount and distribution of rainfall, infiltration and evaporation, determine the soil moisture regime of a particular region (Frost *et al.*, 1986). Permeable soils like sands under wet climates favour trees while soil with high water-holding capacity and arid conditions are disadvantageous to trees (Scholes & Archer, 1997).

According to Bornman *et al.* (1989), clay fractions are the sources of negative charges in soil. Therefore, a high percentage of clay in the soil increases the CEC of the soil. This was evident in the soils of Selosesha 1 (site 4) and Tshidilamolomo 1 (site 6), in which the clay content and CEC was higher than in the other sites, including the benchmark (Figures

4. 17 & 4.18). The EC of the soil correlates to the CEC (Moore & Wolcott, 2001).

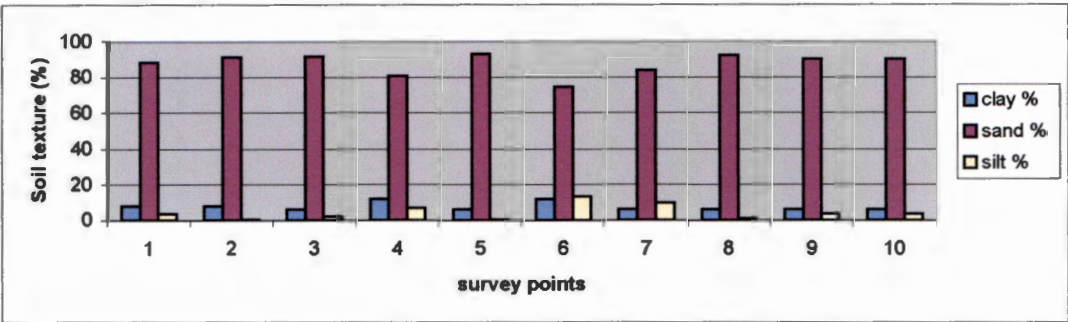


Figure 4.17: Soil texture in the study area.

Silt soils are not gritty, are extremely smooth and silky, very slightly sticky and plastic, forms moderately cohesive balls and show slight degree of polish. Clay soils are neither gritty nor smooth, are extremely cohesive and have high degree of polish (Foth & Ellis, 1988).

Soils with severe leaching (sandy soil) are more likely than are neutral soils to be deficient in K, Ca, Mg or S (Singer & Munns, 1999; Moore *et al.*, 1998). Leaching occurs in acid soils without clay or humus to retain nutrients and that encourages deficiency of tightly held nutrients such as Zinc or Boron. In soil with little vegetation, humus accumulates to provide reserves of N and S (Moore *et al.*, 1998; Singer & Munns, 1999).

According to Foth & Ellis (1988), soils with a fine texture have a slower K diffusion rate as compared to coarse textured soils with the same water content. This means that the high sand percentage of soil in all the survey sites ensures high K diffusion (Figure 4.17).

4.15 CATION EXCHANGE CAPACITY (CEC)

CEC of the soil refers to the amount of negative charges on the clay and humus (colloids) in a specific soil (Foth & Ellis, 1988; Bornman *et al.*, 1989; Fitzpatrick, 1990; Anonymous, 2001 b). Traynor (1984) refers to CEC as the total amount of cations held exchangeably by a unit mass of soil. Organic matter and clay fractions are the sources of most negative charges.

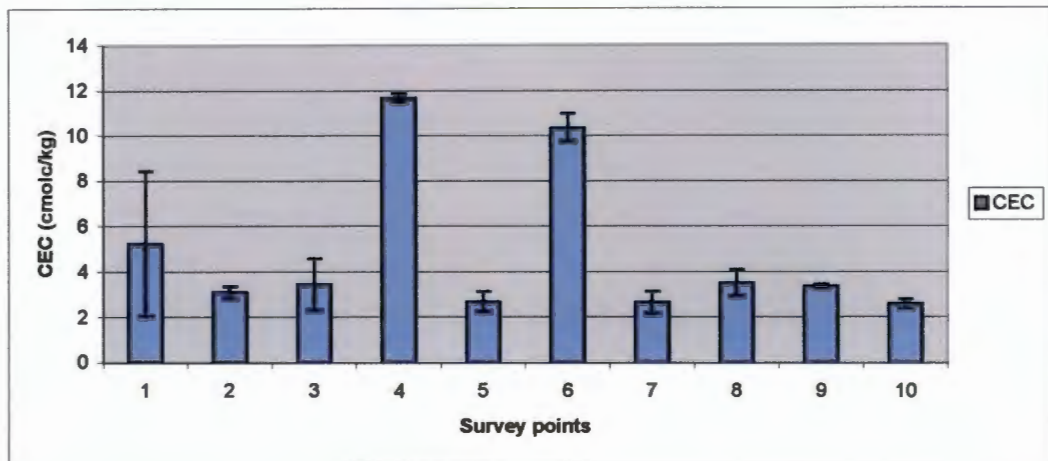


Figure 4.18: CEC of the soils in study area.

Based on the strength of positive and negative charges in the soil, one can produce a sound soil nutrient treatment plan for growing vegetation (Harris, 2001). According to Fitzpatrick (1990), the negative charges in the soil are directly related to soil pH. At acidic pH levels, the CEC was low but increases as the pH rises. Soil CEC could be expected to increase up to 50 % if the pH was changed from 4.0 to 6.5 and nearly double if the pH increases from 4.0 to 8.0 (Harris, 2001). The pH of the soil in site 4 is

neutral (Refer to Table 4.1 and Figure 4.3). The soil in site 6 recorded a pH of 8.5, which is regarded as strongly alkaline (Table 4.1). The CEC of the soils in these two sites (sites 4 and 6) was similar, recording 11.45 cmol/kg and 11.15 cmol/kg respectively (Figure 4.18).

To some extent, cations “compete” with each other for uptake by plants (Ahn, 1993). According to Harris (2001), in most instances the calcium content in the soil is higher than the sodium content in the same area. This explains why Ca and Mg were present in larger quantities in soil than Na and K. Particular attention is given to the ratio between exchangeable magnesium and exchangeable potassium in the soil. Since a high level of Mg suppresses the uptake of K, a ratio of 2:4 is considered generally to be satisfactory (Ahn, 1993). In the study area, soil in Selosesha 1 (survey site 4) and Tshidilamolomo 2 (survey site 9) (Figure 4.13 & 4.15), had a ratio of 5 (Mg):1 (K) and reflect low potassium availability. In the benchmark, the Mg:K was 4:2 (Figures 4.13).

According to Figure 4.18, the soils of the different survey sites had a higher CEC compared to that of the benchmark site. This is in accordance with findings by Foth & Ellis (1988) and Harris (2001) in which soil pH increases lead to an increase in CEC of the soil. Sandy soils need more frequent and small applications of fertilizer in order to maintain the nutritive requirements of plants from the soil. This is because there is high nutrient leaching in sandy soil (Harris, 2001).

4.16 ELECTRICAL CONDUCTANCE (EC)

The ability of soil to transmit or conduct an electric current is known as electrical conductance (Doerge *et al.*, 2002). According to Singer & Munns (1999), EC is the accepted measure and criterion of salinity.

The EC of soil also correlates with the CEC - the higher the EC, the higher the CEC will be (Moore & Walcott, 2001). This was not evident in the soil of site 9 (Figures 4.18 and 4.19), but can clearly be seen in sites 4 and 6. The soils of the benchmark had an EC that is positively correlated with the CEC (Figures 4.18 and 4.19). Moore & Wolcott (2001) indicated the same correlation. The EC of the soil is influenced by interaction of soil pore continuity, water content, salinity level, soil depth and temperature (Doerge *et al.*, 2002).

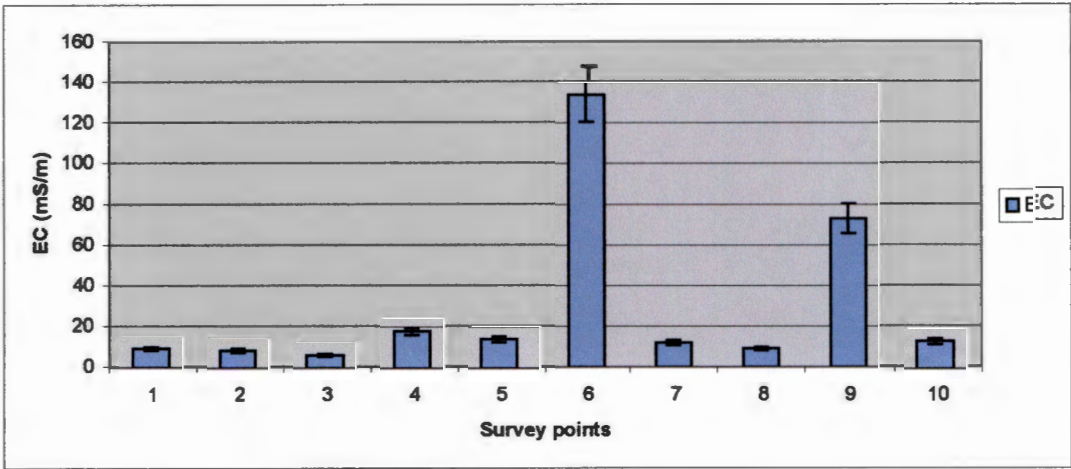


Figure 4.19: The EC of soil in the study area.

According to Hartsock *et al.* (2002), there is a close correlation between soil texture and EC. Soils of the benchmark (survey site 10) and

Tshidilamolomo 2 (survey site 9) had similar soil textures (Figure 4.17) but the EC of the soil in both sites was different (Figure 4.19). The difference was facilitated by higher soil pH in site 9 as compared to the benchmark (Figure 4.3). Foth & Ellis (1988) also found that increase in soil pH facilitates the increase in CEC. Therefore, an increase in soil CEC, leads to an increase in soil EC (Moore & Wolcott, 2001).

Soils with a high CEC are potentially fertile (i.e. the soil can hold larger amounts of cations), thus indicating that soils with a high CEC and base saturation imply fertile soils unless when it is saline or contain toxic heavy metals (Smith, 1996).

4.17 CONCLUSION

Biotic and climatic factors are interrelated. Animals living in the soil influence the soil development by breaking down plant materials and facilitate decomposition. Humans also influence the soil through their daily activities of agriculture, urbanization, grazing management and forestry.

According to McLelland (2000), water infiltration rate depends mainly on soil texture. Sandy soil has large pore spaces through which water move quickly and easily. The study area was predominantly covered by sandy soils and thus, having a low soil water retention capacity.

The widely accepted theory explaining bush encroachment is the two-layer soil-water hypothesis (Wiegand *et al.*, 2005). Here, water is the limiting factor and it is assumed that grasses use only topsoil moisture

and nutrients, while woody plants use subsoil resources (Walker *et al.*, 1981). When grasses are removed by heavy grazing, grass roots will extract less water from the topsoil layer, thus allowing more water to percolate into the subsoil where it becomes available for woody plant growth (Wiegand *et al.*, 2005).

The fact that many bush-encroached areas are heavily grazed means neither that grazing causes encroachment nor that Walter's model (the model states that grasses typically outcompete trees in open savannas by growing fast and intercepting moisture from the upper soil layers, thereby preventing trees from gaining access to precipitation in the lower soil layers where their roots are mostly found) is correct (Ward, 2005). Bush encroachment is widespread in areas where there is a single soil layer and where grazing is infrequent and light. We thus need to move away from observational studies and these single-factor explanations (Ward, 2005). Ward (2005) suggests that, if we are to understand the causes of bush encroachment, we need mechanistic models to guide us, and multi-factorial experiments to tease out the interactions among causal factors.

Soils associated with woody plant invasion in this study had a higher nutrient status than in non-encroached areas. This is confirmed by Smit & Swart (1994) and Hagos & Smit (2005). It was also evident in soils of survey sites 4, 6 and 9 (Figure 4.13), which had higher contents of calcium, magnesium and potassium compared to sites with lower woody plant densities (i.e. lower than 6 900 TE/ha) (Figure 3.22).

Plants provide a protective cover and are thus important to prevent soil erosion (Enviro Facts, 1999). The prevention of soil erosion requires

political, economical and technical changes in South Africa. Political and economic changes should address the distribution of land in South Africa and the possibility of incentives to encourage farmers to manage their land sustainably (Enviro Facts, 1999). Aspects of technical changes include avoiding of overgrazing, encouraging biological diversity, planting different types of plants and conservation of wetlands or drainage areas (Enviro Facts, 1999).

Soil conservation in agriculture reduces soil erosion, prevent the depletion of soil nutrients and restore soil nutrients to their natural levels. Soil conservation can be achieved through keeping soil covered by vegetation at all times.

According to Hoffman & Ashwell (2001), soil and veld degradation are more significant in communal areas than in commercial farming areas. This is associated with the high level of poverty in these areas. Soil degradation also appears more strongly correlated with high human-animal and settlement densities, which characterise the rural communal areas, where unemployment is prevalent.

The principal determinants of savanna structure and functioning are soil moisture, soil nutrients, herbivory and fire (Huntley, 1982, Bourliere & Hadley, 1983; Skarpe, 1992;). Soil moisture, soil texture and soil nutrients are the key environmental variables as they regulate the productivity and relative abundance of savanna vegetation (Knoop & Walker, 1985; Ward, 2005).

Soil is a finite resource, and it is therefore essential to manage it sustainably. A greater investment of effort is needed in the communal areas to develop locally appropriate soil conservation programmes. These programmes will have to take cognizance not only of biophysical conditions in the worst affected areas, but also of political and economic factors that have contributed in large measures to the problem. If soil degradation is to be reversed, the people most directly affected by it must be involved in developing solutions that take into account of their aspirations, needs, knowledge and experience (Hoffman & Ashwell, 2001).

In spite of large livestock losses in communal areas during droughts, livestock numbers have shown no obvious directional change (Tainton, 1999). The grazing system in communal rangelands closely follows the cropping cycle (Tainton, 1999), where the cattle are removed away from the crop fields to graze in the rangelands.

Management of communal rangelands is a dynamic and challenging process. Farmers are not owners of the land and thus do not take responsibility upon themselves to “take care” of the veld and soil conditions. It thus can be concluded that communal land tenure leads to overstocking and resource over-exploitation, thus leading to the “tragedy of the commons” as described by Hardin (1968).

CHAPTER 5 SOCIAL SURVEY

5.1 INTRODUCTION

Growing demand on scarce resources and the pollution generated by rising living standards of the relatively affluent, degrade the environment (Musinguzi, 2002). People who are poor and hungry will often destroy their immediate environment in order to survive. They will cut down forests, their livestock will overgraze and they will overuse marginal land (Musinguzi, 2002).

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.

Most Africans, regard cattle as a source of economic and social status; hence they prefer quantity rather than quality (Musinguzi, 2002). Therefore, as demand for agricultural land grows and grazing land reduces, poverty becomes rampant, leading to the worsening of environmental degradation.

Rural development has been identified as a key strategic activity for government intervention, to create sustainable rural livelihoods and alleviate poverty (Smuts, 2001). This will ensure that migration of

people, living in rural areas, to urban sentra is limited. Improvement of the livelihood of people, living in rural villages, by constructing grazing camps and regulating grazing patterns (rotational grazing etc.), will reduce evident overgrazing in grazing lands.

The knowledge of natural resources of an area and methods of farming are essential in conducting any agricultural research. This includes the correct selection of crops, correct utilization of soil and general farming systems and will eventually lead to long-term sustainability and reduction of environmental degradation (Smuts, 2001).

According to Tainton (1999), communal rangelands are defined as areas where agriculture is largely subsistence and where rangelands are communally owned and managed. In South Africa, these areas are comprised of the previous homelands and constitute approximately 12 % of the country (Tainton, 1999). Communal farming is reported to support a quarter of South Africa's human population (De Bruyn & Scogings, 1998). As the study area is located within communal land, it is thus necessary to evaluate the perceptions of these inhabitants towards their natural environment.

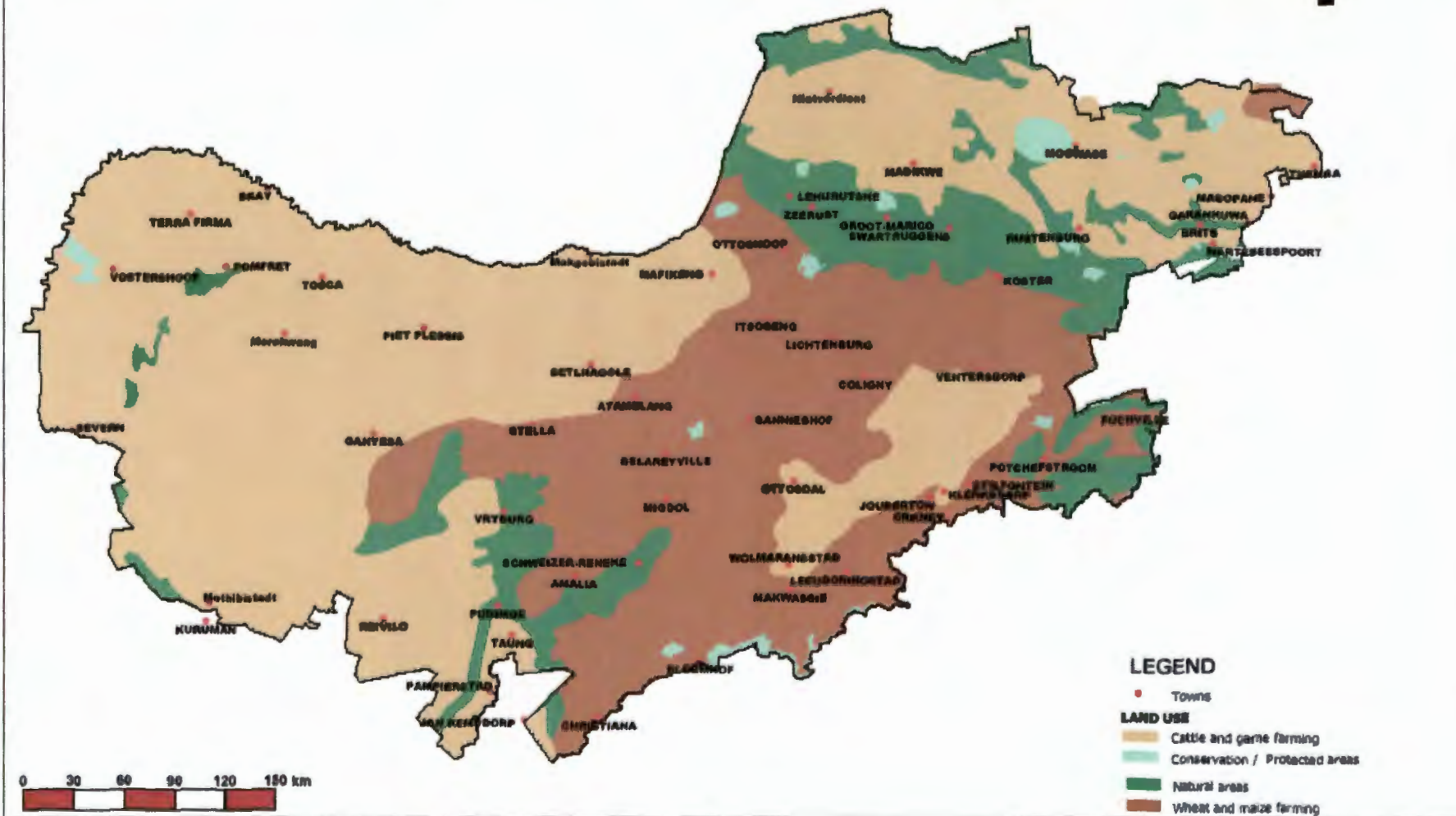
Livestock production is a major component of Southern Africa's rural agriculture (Rocha *et al.*, 1991). Cattle and game farming are identified as the major land uses in the Molopo Magisterial District (Figure 5.1). Livestock products (meat and milk) provide food for home consumption and are sources of income (Rocha *et al.*, 1991). For many small-scale farmers, livestock represent a form of capital that is easily converted to cash (Rocha *et al.*, 1991; Nell, 1998; Moorosi, 1999) and provide drought

power and manure. The productivity of these systems is generally relatively low (Muchena *et al.*, 1997; Spio, 1997). Data on the socio-economic and management characteristics of small-scale farming systems is essential in order to plan and implement effective development strategies (Schwalbach *et al.*, 2001).

In the past, research on land degradation focussed on understanding the physical impacts on soil, vegetation and agricultural potential, while it is probably the social effects that have broadest implications on land degradation (Hoffman & Ashwell, 2001). Land degradation in rural areas causes urbanization, which results in social disruptions, poverty and increased crime rate (Hoffman & Ashwell, 2001). Women and children remain in degraded rural areas without husbands and fathers to support their families. Children become criminals once they realize that they do not have food or clothes (i.e. they start stealing goods and sell it in order to buy themselves food). Over the past ten years, it is discovered that there is a moderate change (increase) of land (grazing lands) use intensity in the Molopo Magisterial District (Figure 5.2). The majority of these farmers are subsistence farmers. They farm on a communal basis which implies that land belongs to the community and individual farmers do not own land of their own.

According to Tainton (1999), participatory rural appraisal (PRA) is a process that is used to develop approaches and methods to make research more relevant to the needs of people. Participation empowers people and gives them a sense of ownership.

North West Province: Main Land Uses



Source: Environmental Potential Atlas 1998

Figure 5.1: Main land uses in the North West Province (DACET, 2004).

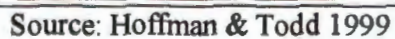


Figure 5.2: Land use intensity changes over the past 10 years – grazing lands (DACET, 2004).

5.2 MATERIAL AND METHODS

A total of 15 households (two respondents per household) in the selected villages (5 households each in Disaneng, Selosesha and Tshidilamolomo) had been interviewed through the use of a questionnaire (Appendix 5.1).

5.3 RESULTS AND DISCUSSION

5.3.1 DEMOGRAPHICS

The South African population is estimated at about 40.6 million people (Statistics South Africa, 2001). North West Province is regarded as the sixth highest populated province with 3.4 million residents and constitutes 8.3 % of the total population of South Africa. This province has an annual population growth of 3.1 % (Statistics South Africa, 2001).

According to Statistics South Africa (2001), there is a higher number of young people in Tshidilamolomo and Disaneng Villages, when compared to older people. This correlate to the findings by the Department of Agriculture, Conservation, Environment & Tourism (DACET) (2004), in which it was stated that the population of the North West Province is “relatively young”. There is a higher percentage of teenagers and more than 33 % of the total population is younger than 14 years old (DACET, 2004). According to the 1996 population statistics in Tshidilamolomo and Disaneng Villages, males and females between 1 and 20 years are in the majority (Statistics South Africa, 2001).

The migration of people to urban sentra is due to people searching for a better lifestyle (i.e. looking for employment in towns). The North West Province has 34.9 % of people living in urban areas and 65.1 % living in rural areas (Statistics South Africa, 2001).

Information on the age structure is important in order to make an assessment on the ability of inhabitants to contribute to the household income by any means of physical labour (Appendix 5.1). In this survey, 42 % of respondents were males, of which 83 % were older than 60 years of age. The mean age of the male respondents was 68 years. The mean age of female respondents was 59 years. Only 40 % of female respondents were older than 60 years.

The average number of household members in this study area was 6, of which the mean number of children per household was 4. An average of 80 % of the children of respondents were unemployed. According to the respondents, their children do not help financially in the household. Twenty seven percent (27 %) of children who were employed, did not assist their parents financially, as they had their own families and stay in urban areas.

5.3.2 INFRASTRUCTURE

According to figure 5.3, most of the respondents indicated that they relied on public for transport and donkeys for traveling (transport) purposes.

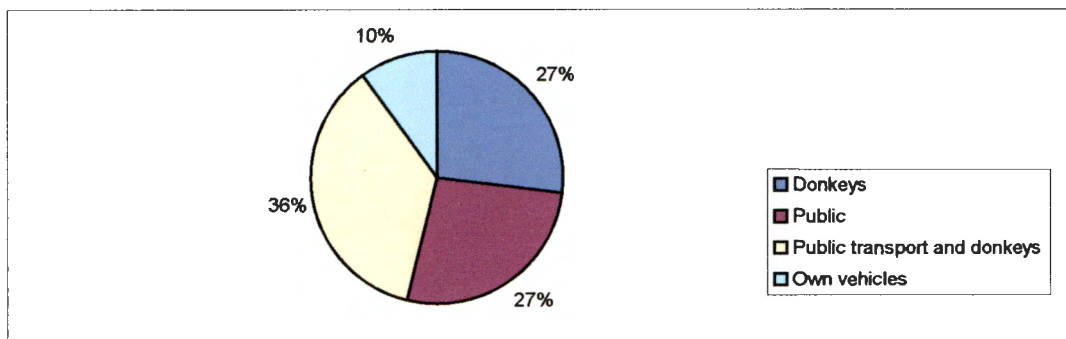


Figure 5.3 Means of transport in the study area.

The majority of farmers in the selected areas were keeping donkeys solely for transport purposes. Generally, donkeys were not used for consumption purposes.

The majority of people got water from boreholes (pumps). The water pumps in different villages were distributed with the help from the local government. Almost 90 % of the villagers did not pay for water services, while the remaining 10 % stated that they started recently to pay for these services. The payments are mainly for remuneration of the generator operator and for servicing the generator when broken. The water from the pumps is used for both household purposes and drinking by livestock.

There are schools in all survey sites, which were rated to be “good” by the respondents. It is revealed by only 10 % of the respondents who said the schools produce “bad” results (i.e. there is a high failing rate of students). This is mainly due to teachers who are staying far from schools and arrive late for work.

Health services are available in villages or in neighboring villages. The respondents complained about shortages of ambulances at the clinics. The respondents indicated that the shortage of ambulances led to the death of members who were critically ill or injured.

5.3.3 FINANCIAL INFORMATION

According to DACET (2004), the economy of the North West Province is relatively small, with 4.9 % contribution to the South African national Gross Domestic Product (GDP).

Only 36 % of local farmers were full-time farmers, while 36 % relied on government grants (pension) and 28 % were unemployed (Figure 5.4). Through the questionnaire (Appendix 5.1), it was revealed that, 10 % of the pensioners were part-time farmers.

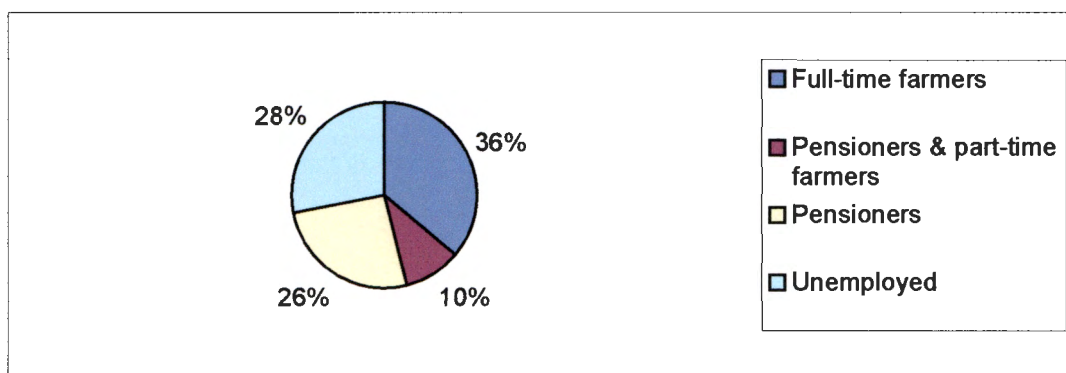


Figure 5.4: Financial backgrounds of participants in study area.

Poverty itself “pollutes” the environment (Musinguzi, 2002) and thus creates environmental stress because poor people make more use of natural available resources. According to Fraser & Mabusela (2001), the

effort to strengthen rural economy and improve livelihoods of people, living in rural areas, has not been successful. This is facilitated by lack of community commitment or participation and poor planning.

Cattle hold a higher social value as a symbol of status and indirectly as a source of investment (Fraser & Mabusela, 2001). In the communal areas, members of the community regard an owner with a large number of livestock as economically sound. According to Arntzen (1998), communal farmers sell their animals at lower prices, but they are also producing at lower cost and fewer uncertainties.

5.3.4 AGRICULTURAL INFORMATION

5.3.4.1 LIVESTOCK FARMING

For thousands of years, livestock provided security and all the essentials of animal origin to the indigenous people of the entire sub-Saharan continent (Musinguzi, 2002). Raising livestock is an age-old tradition and indeed forms part of the cultural heritage of rural lifestyle in many countries on this subcontinent up to the present time.

The livestock production in the selected survey sites was characterized by cattle, goats, donkeys, sheep and poultry (Figure 5.5). The number of cattle owned per household in the study area (Molopo Magisterial District) ranged from 3 to 50. These are small numbers when compared to the findings of Schwalbach *et al.* (2001). Schwalbach *et al.* (2001) found that the number of cattle owned by households in the Mopaene-

Rustenburg area (North West Province) varies from 5 to 149 and had a normal distribution with a mean of 29 head of cattle per household.

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 tradition societies, common property resources are managed carefully and are conserved (Warren & Agnew, 1988).

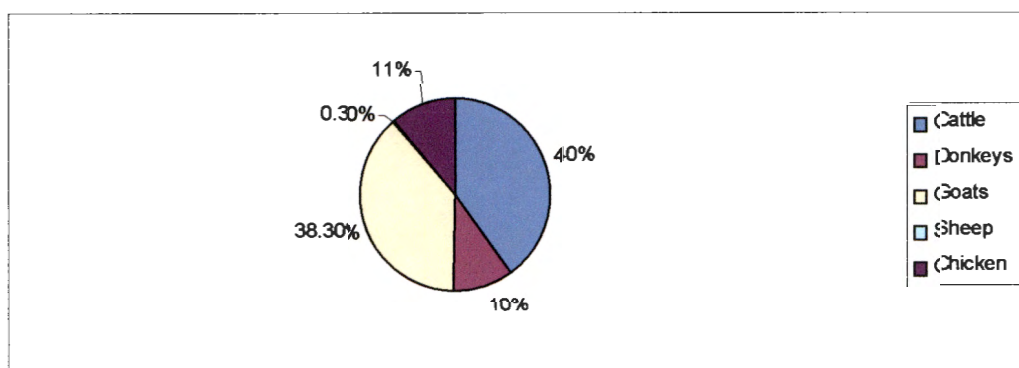


Figure 5.5: The occurrence of animals in the study area.

Moorosi (1999) reported that the average herd size in Thaba' Nchu and Botshabelo were 11 and 7 respectively. Nthakeni (1996) reported a mean of 8 head of cattle per farmer in Venda, while Bembridge (1984) estimated the mean herd size in the Transkei (Eastern Cape Province) to be 6 cattle. The results obtained in this study area correlate with the finding of above-mentioned researchers in different areas of South Africa. Cattle farmers own an average of 12 animals per household. This mean is revealed from the answers given by the respondents.

Cattle and goats were predominant livestock in the surveyed sites (Figure 5.5). According to Stuart-Hill (1985), the mixture of grazers and browsers promotes more effective utilization of both browse and herbaceous plants. In this area, it is evident that this combination of grazers and browsers is not effective (Chapter 3).

Breeding females constituted the majority of the herds, which is in agreement with results of other studies in South Africa (Seobi, 1980; Dreyer *et al.*, 1999; Moorosi, 1999; Sieff, 1999; Schwalbach *et al.*, 2001). According to the respondents, most farmers keep one bull with a large number of cows. Other farmers keep cows only and rely on bulls from other farmers for breeding.

Schwalbach *et al.* (2001) found that the stocking rate in Rustenburg area is 9.7 LSU/ha, which is higher than 0.2 LSU/ha recommended by Tainton (1999). Overstocking has a negative impact on pasture and soil resources and represents a potential threat to the sustainability of small-scale cattle farmers. Overstocking is common in other small-scale cattle farming communities (Mopane-Rustenburg District; Botshabelo-Thaba' Nchu District) in South Africa (De Villiers, 1998; Dreyer *et al.*, 1999; Moorosi, 1999; Schwalbach *et al.* 2001). This is also evident in the Molopo Magisterial Area.

Rocha *et al.* (1991), Wilson (1995), Nell (1998), Moorosi (1999) and Schwalbach *et al.* (2001), indicated that most of small-scale farmers keep cattle mainly for cash related purposes. Schwalbach *et al.*, (2001) noted that 91 % of farmers keep cattle for economic gain. The respondents in the study sites revealed that, only 5 % of farmers in the study area, keep

cattle for prestige and 5 % for lobola (bridal dowry) purposes (Figure, 5.6). Farmers in the study area were keeping livestock for reasons like lobola (dowry), emergency needs, cash (money), security (bank on hoof) and prestige (Figure, 5.6). According to Schwalbach *et al.* (2001), the small-scale farmers in the North West Province (particularly in the Rustenburg region) are more commercially orientated, than others in southern Africa, where home consumption, prestige, and lobola are given as more important reasons for farming with cattle than are cash related reasons.

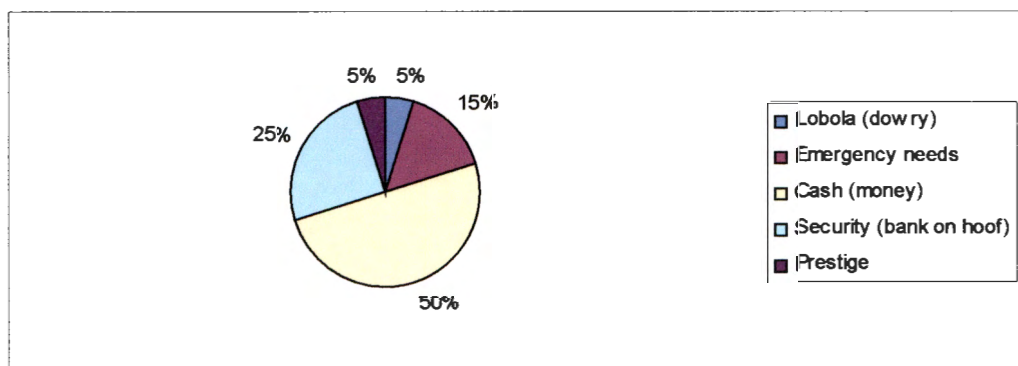


Figure 5.6: Reasons for selling cattle in the Molopo Magisterial District.

According to the respondents, on average 2 calves and 2 young goats die during birth per household. The participants indicated that diseases (e.g. dystocia, heartwater and butulism) and increasing drought caused these deaths.

Respondents indicated that animals are kept for meat (47 %), leather (15 %), milk (11 %) and egg (26 %) production. In the study area, people sell animals on auctions and also by hand. They sell animals according to the

number and not by weight. On average 3 cattle per household are sold in per annum. The livestock is kept on communal land on which there are no grazing camps. This facilitates overgrazing which leads to increased encroachment by woody species. There is no veld management (camp system etc.). Cattle herders are young boys (12 – 14 years) and often as young as 10 years.

Eighty two (82 %) percent of respondents, acknowledged that overgrazing is a problem in their area. They believe that overgrazing results from an increased number of farmers and their livestock. The other 22 % believed that shortage of grazing land is the sole reason for overgrazing. They said that the shortage of grazing land is due to white farmers occupying tribal land. Ninety-one percent (91 %) of the respondents did not think that there is any solution to the problem of overgrazing and increased bush density. The villagers receive advice on farming methods twice a month from the Department of Agriculture.

5.3.4.2 CROP FARMING

According to the responses, it was revealed that only 27 % of the farmers in this area were crop farmers. The most prominent crops included maize, peanuts, groundnuts and different types of vegetables, especially potatoes. According to their comments, this area is not suitable for crop farming due to reduced rainfall and droughts experienced in the Molopo Magisterial District. Sixty six percent (66 %) of the crop farmers plant maize for self-subsistence. Crop farmers use donkeys to till the soil. The reason is that, using donkeys are cheaper than hiring or buying a tractor. Therefore, this is also encouraging farmers to keep large numbers of

donkeys. According to the majority of the respondents, the number of donkeys is a problem in this area. There are too many donkeys and they too contribute to the overgrazing of the grasses in the grazing lands.

Most farmers 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 best time for ploughing. The unreliability of rain leads to the bad quality of crops.

5.4 CONCLUSION

Rural communities depend on common property resources and have adapted different management strategies to ensure success in achieving sustainable use of natural resources. This success is largely dependent on the effectiveness of the tribal authorities and emerging range management institutions.

According to Musinguzi (2002), communities “abuse” land because they regard it as a commodity belonging to them. When people see land as a commodity, which belongs to them, they may begin to love, respect and start to manage natural resources sustainably. The past failures of how to solve the problem of environmental degradation have been attributed to lack of consultation and involvement of rural people (Tainton, 1999).

New conservation policies are based on the principle that the land belongs to the people who are part of the environment and also apart

from it. Therefore, the inhabitants of that land must participate in developing and managing their natural resources.

Governments should realize that they couldn't solve environmental problems on their own. They should involve the communities, if the world is to achieve true ecological sustainability and solve the current environmental crisis (Hoffman & Ashwell, 2001), especially in communally managed areas.

The communal farmers must be recognized, empowered and their lives have to be changed by restructuring social and economic structures of agriculture and land. This will enable the communities to participate in the decision making processes, affecting them. Cattle farmers in communal areas have much broader livelihood strategies, than keeping cattle solely for beef production (Tainton, 1999). They keep livestock for multiple reasons including draft power, security, milk and meat production. Therefore, communal farmers aim to maximize animal numbers per area and focus on the maintenance and survival of those animals (Tainton, 1999). Because cattle is regarded as an "African bank" (Tainton, 1999), farmers will continue to overstock the rangelands with livestock. Communal farmers should thus be empowered to ensure that they have alternative ways of paying and trading.

According to Tainton (1999), the past failures of development initiatives to solve the problems of environmental degradation have been attributed to the lack of consultation and development of the rural population. Community development is a process that emphasizes learning,

participation and action (Chambers, 1983). This process of community development is directed towards improved socio-economic livelihoods.

Governments need to formulate policies that would require the promotion of sustainable socio-economic development (Musinguzi, 2002). This will lead to eradication of poverty and ensure food and energy security as well as improving living and habitat conditions of rural people.

CHAPTER 6 GENERAL DISCUSSION AND RECOMMENDATION

6.1 GENERAL DISCUSSION

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

- ❖ To determine the extent of woody plant invasion (bush encroachment) in agricultural rangelands in the former Molopo Magisterial District.
- ❖ To analyze the nutrient status of the soil, in relation to woody plant density.
- ❖ Conduct a social survey in order to determine the points of view from communities, regarding their environment.
- ❖ To construct a temporal inventory on land degradation for the Molopo Magisterial District (North West Province) and make the data available for nature conservators and governmental sectors on land restitution.

The extent of woody species invasion and nutritive status of the soil were surveyed in order to meet the aims of this research.

Woody plant invasion is the dominant indicator of land degradation, and it is recognized as a serious problem through out Sub-Saharan Africa

(Hoffman *et al.*, 1999). The reason is that, it reduces the capacity of large grazing areas, by transforming habitats and reducing the species diversity. According to Hoffman *et al.* (1999), the North West Province is amongst the worst areas invaded by woody species. This is revealed in chapter 3.

It is evident that the main cause of woody plant invasion in the study area is man's interference with nature (i.e. lack of veld management skills by members of the community). Other causes of woody plant invasion are as follows:

- the absence of periodic veld fires which would have killed many small and some large woody plants;
- overgrazing and the reduced competition of grass to the seedlings of woody species; and
- increased spread of seed by livestock.

Woody species invasion decreases grass production and therefore the grazing capacity of the grazing land (Hoffman & Ashwell, 2001). This, then affect the livelihood of the rural communities.

The woody plants *Acacia mellifera*, *A. hebeclada*, *Dichrostachys cinerea*, *Grewia flava*, the exotic *Prosopis velutina* and *Terminalia sericea* were prominent in the study area and are also declared indicators of bush encroachment (Appendix 3.2). *Prosopis velutina* is an exotic woody species (Henderson & Harding, 1992), and was prominent especially along the Molopo River (Chapter 3). This woody species possesses a threat to indigenous vegetation and livestock farming (Henderson & Harding, 1992). Thus, forming impenetrable thickets that limit access to

grazing animals. According to Figure 3.22 (Chapter 3), the lowest density (1 007 TE/ha) of woody species was found in the benchmark site (Disaneng 2), while the highest density (8 927 TE/ha) was in survey site 9 (Tshidilamolomo 2), where *Prosopis velutina* was evident.

Acacia mellifera was the most prevalent encroacher in the study area (Chapter 3). It was present in seven surveyed sites. It suppresses grass growth (Smit & Swart, 1994) and thus has an influence on the grazing capacity of the land. This is due to high transpiration rate of *Acacia mellifera*, which exceeds that of individual grass by approximately 190 to 800 times (Donalson, 1967). According to Smit & Swart (1994), *Acacia mellifera* also out competes, grasses for available soil nutrients and water. This is due to the shallow root system of this woody species.

The general distribution of woody plants is not particularly limited by the soil structure, soil texture and parent material from which soil has derived (Acocks, 1953). It would appear that, in areas of similar rainfall, woody plants show preference for edaphic conditions of the habitat (Acocks, 1988).

The soils in the study area were sandy (Figure 4.17, Chapter 4). According to Figure 4.17, the minimum sand percentage in the study area was 75 % (survey site 7) and the maximum was 93 % (survey site 5). Sandy soils were generally leached, have a low water holding capacity and are low in soil nutrients (Singer & Munns, 1999).

The soil nitrogen content of 0.02 % - 0.06 % found in the study area, indicated that the soil had a low nitrogen content (Table, 4.4, Chapter 4).

The low soil nitrogen resulted from the leaching of ammonia and nitrate (Fitzpatrick, 1990). This is due to the high sand percentage in the study site.

According to Donaldson (1967), the soil of Molopo Area is characterised by light calcareous sandstone, which is rich in lime. Bellows (2001) also found that calcium and magnesium are components of liming material, which are used to increase soil pH. The abundant soil calcium and magnesium contents (Figure 4.13) caused the soil in the study area to be alkaline (Figure 4.3).

The soils of the Molopo Area were low in phosphorus (Chapter 4), except soil of survey site 9 (Figure 4.8). This reduced soil phosphorus content facilitated increased density of woody species, which suppressed grass growth. Reduced soil phosphorus in the study area was due to the leaching effect of sandy soil.

According to UNEP (1997), phosphorus loss has been found to be extensive in areas subjected to 40 years of livestock grazing, in the Kalahari savanna of southern Africa. After the removal of grasses by grazing, mixed grass-shrub vegetation grow on soil that had a higher concentration of phosphorus, whereas the density of woody species increase on soil with a lower phosphorus content (UNEP, 1997).

The soil resistance in the survey sites ranged from 1 100 ohms to 23 000 ohms (Figure 4.16). This depends on the percentage of sand in an area. Thus, a high sand percentage of the soil increases soil resistance (Anonymous, 2001).

Communal farmers contributed to the degradation problem in the study area. They do not own land and thus do not take any responsibility of rehabilitating the land. Communal farmers in the study area are poor and need to farm to be self sustainable. They generally do not have any formal education and farming seems to be the only option to sustain themselves.

Communal farmers use their livestock as means to pay and trade. The more livestock they have, the better for them, irrespective of the effect on the environment.

6.2 RECOMMENDATION

Increased woody plant invasion in communal rangelands of the study area, indicates that, the density of woody species must be reduced and effectively monitored, in order to reduce land degradation. Factors to be considered in paving ways to reduce land degradation in the study area are:

- public participation must be encouraged at all levels and efforts to combat land degradation must be better coordinated. This especially involves participation from the communal and commercial farming sectors;
- agricultural extension services in the area need to be strengthened to ensure that land degradation is reversed;
- strong conservation ethics must be encouraged amongst local farmers;

- grazing camps must be established. Thus, fences must be erected and maintained regularly to ensure controlled grazing;
- government intervention schemes and policy documents (e.g. National Grazing Strategy and drought subsidy schemes) must be implemented.
- invasive woody plants in the study area must be controlled;
- selective thinning of *Acacia mellifera* is advisable, thus reducing the grass-tree competition, while retaining some of the beneficial effects of the trees in terms of soil enrichment (Hagos & Smit, 2005); and
- chemical control is advisable in all the sites.

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APPENDIX 3.1

Woody species composition structure

Survey size

Height (m) class	Survey		Test Measurements				Notes
	Size	Area	1	2	3	4	
5-6							
4-5							
3-4							
2-3							
1-2							
0.5-1							
0-0.5							
Standing							

Survey site:-----

Date: _____

Name: -----

Grids: -----

[illegible]

APPENDIX 3.2

List of declared indicators of bush encroachment according to CARA
(Conservation of Agricultural Resource Act, 1983).

BOTANICAL NAME	COMMON NAME
<i>Acacia caffra</i>	Common hook-thorn
<i>Acacia erubescens</i>	Blue thorn
<i>Acacia fleckii</i>	Plate thorn
<i>Acacia hebeclada</i>	Candle thorn
<i>Acacia luederitzii luederitzii</i>	False umbrella thorn
<i>Acacia luederitzii retinens</i>	Belly thorn
<i>Acacia mellifera</i>	Black thorn
<i>Acacia nilotica</i>	Scented thorn
<i>Acacia tenuispina</i>	Fynthorn
<i>Acacia tortilis</i>	Umbrella thorn
<i>Asparagus spp.</i>	Wild asparagus
<i>Combretum apiculatum</i>	Red bush willow
<i>Dichrostachys cinerea</i>	Sickle bush
<i>Diospyros lycioides</i>	Blue bush
<i>Dodonaea angustifolia</i>	Sand olive
<i>Grewia bicolor</i>	Bastard raisin bush
<i>Grewia flava</i>	Velvet raisin bush
<i>Grewia flavescens</i>	Rough leaved raisin
<i>Lopholaena coriifolia</i>	Broad-leaved fluff bush
<i>Strychnos madagascariensis</i>	Black monkey orange
<i>Tarchonanthus camphoratus</i>	Camphor bush
<i>Terminalia sericea</i>	Silver cluster

APPENDIX 5.1



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
MAFIKENG CAMPUS

Questionnaire: Communal Farming

Dept: Biological Sciences

[Questions: Personal=9, Infrastructure=11, Finance=7, Agriculture=25, Environment=14, Total=66]

1. Personal Information

- 1.1 [Male or Female respondent]
- 1.2 How old are you?
- 1.3 What is your highest qualification?
- 1.4 Are you married?
- 1.5 How old is your wife / husband?
- 1.6 How many children do you have?
- 1.7 Where do the children stay?
- 1.8 How old are they? (1 st).....
- (2 nd).....
- (3 rd).....

Do they in any way contribute to the household and / or income? Explain

.....

.....

2. Infrastructure Information:

- 2.1 What means of transport do you use?
- 2.2 If using horses, donkeys etc: Are you keeping them for transport purposes?
Explain.....
-

2.3 Is transport a “problem” in the village? Explain.

.....

.....

2.4 Where do you get water from?

2.5 Do you pay for the water? How much and in what format?

.....

.....

2.6 What are you using the water for?

2.7 Do you have a vegetable garden?

2.8 What are you using the vegetables for?

.....

2.9 Are there schools in or near the village?

2.10 How do you rate these schools?

.....

2.11 Do you have any access to medical / hospital / clinic facilities?

.....

.....

3. Financial Information

3.1 Are you a full-time farmer?

3.2 If not, what other occupation do you have?

3.3 Do you get a pension from the government?

3.4 Do you save money on a regular basis?

3.5 Do you have access to banking facilities?

3.6 What is your major source of expenses?

.....

.....

3.7 How do you pay for these expenses? Explain

.....

.....

.....

4. Agricultural Information



4.1 What are you farming with and why?

.....
.....

4.2 How many animals do you have?

.....
.....
.....
.....

4.3 What is the major purpose of farming?

.....
.....
.....

4.4 How many animals die at birth?

.....
.....
.....

4.5 What is the major reason of these deaths?

.....

4.6 What (part) of the animals are you using for self-consumption? [meat, skin, eggs etc]

.....
.....
.....

4.7 Do you participate in livestock sales?

4.8 If "yes", How often?

.....

4.9 Do you sell on auctions or out of hand? Explain.

.....
.....

4.10 How many animals do you sell/year?

.....
.....

4.11 Do you sell per animal or per weight? Explain.

.....

.....

.....

4.12 Do you have a camp system?

.....

.....

4.13 Do you practice rotational grazing in your area?

4.14 For how long and when do you rest these camps?

.....

.....

4.15 Is overgrazing a problem in the rangelands?

4.16 If "yes": Who are responsible and why?

.....

.....

.....

4.17 Is there a solution for the problem of overgrazing in the rangelands? Explain.

.....

.....

.....

4.18 Do you get any assistance or advice from the Department of Agriculture?

.....

4.19 If "Yes": How often and in what format? Explain.

.....

.....

.....

4.20 Do you dip, vaccinate and / or drench your livestock? If yes: How often?

.....

.....

.....

.....

4.21 Is the above-mentioned the decision of the community or yours as an individual farmer?

.....

4.22 Do you own land of your own or does it belong to the community?

.....

4.23 If the land belongs to yourself: Do you take special steps to rehabilitate / monitor the general condition of the rangelands? If "yes" explain these steps.

.....

4.24 If the land belongs to the community: Do the community members have structures to rehabilitate / monitor the general condition of the rangelands? Explain.

.....

4.25 Do you see other farmers in the area as a threat to your farming prospects or do you learn from each other? Explain.

.....

5. Environment

5.1 How do you value land, rangeland and the natural area?

.....

5.2 What, in your opinion, are the most important shortcomings in the area?.....

.....

 5.3 Is desertification a problem / concern in your area?

5.4 Elaborate on point 5.3.

5.5 Do members in the community / village have a common concern on the general state of the environment?

5.6 Do these members often (how often?) meet to discuss the general concerns in the rangelands?

5.7 If the members / community meet: Do these meetings take place on a regular basis?

5.8 If and when these meetings take place: Do you involve the Department of Agriculture and / or chief?

5.9 Do you consider these meetings as "fruitful"? Explain.

5.10 Did the rangelands become more degraded over the years? Explain

.....
.....

5.11 What or who, in your opinion, is responsible for the degrading of the
rangelands?

.....
.....
.....

5.12 What do you suggest must be done to improve the general state of the
rangelands?

.....
.....
.....

5.13 Who, in your opinion, must be responsible for improving the rangelands?
Explain why.

.....
.....
.....

5.14 In your opinion, does the government have a responsibility to rehabilitate these
rangelands? Explain.

.....
.....
.....

THANK YOU FOR YOUR PARTICIPATION