The evaluation of bush thickening in two management systems in three districts of the North West Province in South Africa: A LandCare Initiative

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Abstract

The evaluation of bush thickening in two management systems in three districts of the North West Province in South Africa: A LandCare Initiative

The problem of land degradation is something that can not be ignored in this day and age. A food shortage as a result of desertification is a reality in especially, the African continent. One of the factors contributing to the problem of land degradation, is bush thickening. Bush thickening leads to the reduction of the grazing potential of natural rangelands. This has a direct effect on the cattle production and thus on the human livelihoods itself. Bush thickening usually occurs in areas that were exposed to over grazing in the past. The North West Province is the sixth largest province of South Africa. Nine (9) of the 28 magisterial districts of this province are considered to have a severe bush thickening problem.

Several programmes have been initiated in South Africa to address the land degradation problem in order to make the land users more aware of the problem and to get involved in more sustainable natural resource management practises. Such an initiative is the LandCare program in South Africa, introduced by the National Department of Agriculture. LandCare has five themes, of which VeldCare is mainly based in the North West Province. This involves, amongst others, bush thinning, clearing or the total eradication of undesirable woody and/or alien plants to improve the grazing potential of rangelands.

The clearing of the bush can be achieved by direct or indirect practices. Direct practices are when bush is eradicated by chemical or mechanical methods, whereas indirect practice focus more on the stocking rate and management of livestock, to prevent bush thickening. The indirect rangeland management practices were introduced together with awareness creation programmes in this study. Through this project, communities are given the opportunity to participate and take charge of the degradation problems in their region. LandCare therefore also focuses on education, training and capacity building of the land users in the rural areas.

Three magisterial districts in the Western Region of the North West Province namely Ganyesa, Kudumane and Taung were identified by the Provincial Department of

Agriculture to be monitored on account of their project development at the time. All three magisterial districts are subdivided into three Agricultural Development Centres (ADC's). These ADC's are again divided into a number of Field Service Units or FSU's. Benchmark sites were selected in certian FSU's for this study. The study sites were chosen to represent both the Morafe Ranches and Communal managed systems. The Morafe Ranch and communal management systems in the Ganyesa magisterial district were Water-Fouché and Austrey respectively. In the Kudumane magisterial district, the Morafe Ranch systems were studied at the Heuningvlei study site. No communal managed rangeland system was monitored in this district, as there were no woody species in the vicinity of the exclosure plots used in this study. The Morafe Ranch system in the Taung magisterial district was at the Orange Grove study site and the communal managed rangeland was at the Ipelegeng study site. The data of the Ipelegeng study site however is unpresentable. The reasons are fully discussed in Chapter 4.

In the study areas, several benchmark plots were selected that would represent the vegetation and management systems of the region. At the benchmark, an exclosure was erected. The fenced-in area would serve as a control to demonstrate the effect resting would have on a rangeland, while the outside of the exclosure normal grazing practise occurred. The aim was to determine the extent of bush thickening at the selected benchmark study sites, and how it will change both under the current grazing regime (outside the exclosure) and during resting (inside the exclosure) in the two management systems (Morafe Ranch and communal managed system).

Quantitative surveys were carried out over a two year period to determine the structure and composition of the woody species. The average percentage of the woody species was calculated for the past three sampling periods (April 2001, December 2001 and May 2002). Although a two year period (three seasons) is much too short to detect any changes in the structure and composition of the woody component, the data and results will serve as good baseline data for long term monitoring and management projects. The benchmark sites are also used as demonstration plots that contribute to the awareness and training of the land users as part of the LandCare initiative.

The vegetation sampling methods included the belt transect method, 2 x (4 x 100 m) or 5 x (4 x 40 m), depending on the size and shape of the exclosure. Each woody species rooted in the 4m belt was noted as well as the structure class it occurred in. Five height classes were noted, namely: less than 0.5 m, 0.5 – 1 m, 1 – 2 m, 2 – 3 m, 3 – 4 m and higher than 4 meters.

The environmental factor, rainfall, had the most influence on the slight changes that occurred in the species composition and structure of the woody vegetation. The rainfall data of the past five years could be considered as above average. It had a significant impact on the germination of seedlings of woody species, and thus influenced the less than 0.5 m height class the most.

A major drawback to the data collection was the sampling practises, as different people participated in each sampling event. Some of the species such as *Grewia flava*, which has a multi stemmed growth form, was noted as one individual during one survey and in other cases as several individual plants. This caused much distortion in especially the density data and contributed to the fact that the results between sampling events and seasons could not be clearly correlated with each other.

The data collected is represented as a percentage of the woody species for each benchmark site, inside and outside the exclosure. The species that were present in a more than 5 % abundance, as well as the structure classes, were represented in bar graphs. To give more perspective on the woody species data, the tree equivalents per hectare (TE/ha) per structure class, as well as the total tree equivalents, were calculated for each study site and survey period.

The dominant height class was the less than 0.5 m. The tree equivalent per hectare data show the 1 – 2 meter height class to have more influence on the herbaceous data at the study area.

A species that was found in most of the benchmarks was *Grewia flava*. The reduction in the grazing area might be significant, due to the growth form and large canopy cover of *G. flava*. Although *Acacia mellifera* was present in all the benchmark sites with more deep sandy soils, such as the Water-Fouché -, Austrey -, Heuningvlei – and Ipelegeng study sites, the presence of *A. hebeclada* seems to be greater problem leading to bush thickening. *Acacia hebeclada* was more abundant than *Acacia mellifera* in most cases.

The attitude towards the LandCare projects in each of the communities improved as the data was analysed and results presented to the land users, agricultural officers and the communities, a task which is often neglected in feedback sessions by scientists. Feedback to the communities therefore forms an integral part of such a long term study.

As mentioned, the study period was too short to determine any significant differences in woody species composition, but it has contributed considerably to the awareness and capacity building of all stakeholders.

If future data collection is done, it is essential that the surveyors should be thoroughly trained beforehand in the identification of woody species, especially the seedlings of the different *Acacia* species, as well as the sampling procedures, to avoid problems in the data analysis and results. Woody species should be noted as multi- or single stemmed to eliminate the problem of perception differences of different surveyors. Sampling methods can also be improved on in future.

All in all, this LandCare project can be viewed as a success story. Despite some drawbacks, a lot was learned about the different natural resource management systems.

Opsomming

Die evaluasie van bosvedrigting in twee bestuurs stelsels in drie distrikte van die Nooredwes Provinsie in Suid-Afrika: 'n LandCare Inisiatief

Die probleem met landdegradasie is iets wat nie langer geïgnoreer kan word nie. Probleme soos voedsel tekorte, as gevolg van verwoestyning is 'n werklikheid, veral in Afrika . 'n Kleiner faktor wat tot die groot globale probleem van landdegradasie bydra, is bosverdigting. Bosverdigting lei tot die vermindering van die produksie van natuurlike weiveld. Die verminderde produksie van voer het 'n direkte invloed op alle grasvreters, en dus op die mens se voedselvoorsiening. Bosverdigting kom gewoonlik voor in gebiede wat aan oorbeweiding bloodgestel was. Die Noordwes Provinsie is die sesde grootste provinsie in Suid-Afrika en nege van die 28 landrosdistrikte van die provinsie word beskou as areas met 'n aansienlike bosverdigtingsprobleem.

Verskeie programme in Suid-Afrika, wat die probleem van land degradasie aanspreek, is geïmplimenteer om die grondgebruikers bewus te maak van meer volhoubare bestuurs-praktyke. Een van hierdie programme is die LandCare program wat deur die Nasionale Departement van Landbou in Suid-Afrika bekend gestel is. Die LandCare program bestaan uit vyf temas, waarvan die VeldCare tema hoofsaaklik in die Noordwes Provinsie uitgevoer is. Die VeldCare program fokus, onder andere, op die uitdunning, verwydering of die totale uitwissing van ongewensde houtagtige- of indringer plante om die weidingskapasiteit van natuurlike weiding te verbeter. Die verwydering van ongewensde houtagtige plantegroei, kan of deur direkte metodes, of indirekte metodes, bewerkstellig word. Direkte metodes, behels die gebruik van chemiese en meganiese beheermetodes om die ongewenste houtagtige plante te verwyder, terwyl indirekte metodes meer op veelading en bestuur van lewende hawe konsentreer, om bosverdigting of bosindringing te verhoed. Die indirekte natuurlike weidingbestuursmetodes, was deur middel van bewuswordings programme geïmplimenteer. Deur hierdie projek het gemeenskappe die geleentheid gekry om aktief deel te neem aan die oplossings, om die degradasie probleme in hulle omgewing te verminder en/of te voorkom. Die Land Care inisiatief is dus toegespits op die onderrig, opleiding en kapasiteitsopbouing van die grond gebruikers in plattelandse gebiede.

Drie landrosdistrikte in die Westelike streek van die Noordwes Provinsie, naamlik, Ganyesa, Kudumane en Taung is deur die Provinsiale Departement van Landbou, geïdentifiseer om gemoniteer te word, op grond van die vordering wat die VeldCare projekte aan die begin van die studietydperk getoon het. Al drie hierdie distrikte is verder opgedeel in drie Landbou Ontwikkelings Sentrums (Engels: "Agricultural Development Centers" of "ADC's") wat op hulle beurt weer in 'n aantal Veld Dienseenhede (Engels: "Field Service Units" of "FSU's") opgedeel is. Dit is in die "FSU's" wat die uitsluitings persele geleë was. Die studiegebiede is gekies om beide die "Morafe Ranches" en kommunale weidingsisteme ("Communal grazing") te verteenwoordig. Die "Morafe Ranch" in die Ganyesa distrik is in die Water-Fouché studiegebied geleë en die kommunale weiding in die Austrey studiegebied. In die Kudumane distrik is slegs die "Morafe Ranch" tipe sisteem, in die Heuningvlei studie gebied ondersoek, aangesien die kommunale weidingsisteem slegs uit grasvelde bestaan het en daar dus geen houtagtige komponente was om te bestudeer nie. Die "Morafe Ranch" in die Taung distrik is in die Orange Grove studiegebied geleë, met die kommunale weidingsisteem in die Ipelegeng studiegebied. Die data van Ipelegeng gaan egter nie in diepte bespreek word nie. Die redes vir die besluit word duidelik in Hoofstuk 4 gedokumenteer.

Verskeie veldverwysings persele is in elke studie gebied gekies om die plantegroei en bestuursmeganismes van die veld te verteenwoordig. Binne elk van die verwysingsareas is daar 'n uitsluitingsperseel uitgesit. Die toegespande gebied dien as die kontrole om die invloed van rus op die natuurlike weiding te demonstreer, terwyl gewone beweidingspraktyke aan die buitekant van die uitsluitingsperseel beoefen is. Die doel was om die omvang van bosverdigting in die verwysingsareas vas te stel, hoe die samestelling sal verander onder die gewone weidingsbestuur buite die uitsluitingsperseel asook die vasstelling van wat sal gebeur met gereelde rus binne die uitsluitingsperseel in die twee bestuurssisteme ("Morafe Ranch" en die kommunale weidingsisteem).

Kwantitatiewe opnames is oor 'n periode van twee jaar uitgevoer om die struktuur en samestelling van die houtagtige spesies vas te stel. Die gemiddeld van die houtagtige spesiesamestelling sowel as die struktuur is vir drie opnametydperke (April 2001, Desember 2001 en Mei 2002) bereken. Hoewel 'n twee jaar periode, met drie opnames te kort is om 'n verskil in houtagtige spesies waar te neem, sal die resultate van die studie as goeie basislyninligting vir langtermynmonitering en bestuursprojekte dien. Die

verwysingsareas kan ook as demonstrasiepersele, wat tot die bewusmaking en opleiding van die grondgebruikers, as deel van die LandCare inisiatief, dien.

Die plantegroei opnametegnieke sluit die belttransek metode in. Dit is of twee maal (4 x 100m) of vyf maal (4 x 40 m), afhangende van die grootte en vorm van die uitsluitingsperseel uitgevoer. Elke houtagtige spesie wat in die 4 m belt transek gewortel was, is genoteer, sowel as die hoogteklas waarin dit voorgekom het. Vyf hoogteklasse is gebruik, naamlik minder as 0.5 m, 0.5 – 1 m, 1 – 2 m, 2 – 3 m, 3 – 4 m en hoër as 4 meter.

Die reënval het die grootste invloed op die waarneembare verskille van die spesiesamestelling en struktuur gehad. In die algemeen kan die reënval van die afgelope vyf jaar as bo gemiddeld bestempel word. Dit het bygedra tot die groot getal saailinge wat die minder as 0.5 m hoogteklas sterk beïnvloed het.

Die feit dat verskillende persone aan die opnames deelgeneem het by elke opnamegeleentheid, het die konsekwentheid van die opnames negatief beïnvloed. Sekere spesies soos *Grewia flava*, wat 'n meer stammige groeivorm het, is deur sommige individue by een opnamegeleentheid as een bos beskryf, terwyl 'n ander dit as 'n aantal enkel stammige plante of individue genoteer het. Dit het daartoe bygedra dat, veral die spesiedigtheidinligting, oor die studietydperk nie met mekaar vergelyk kon word nie.

Die inligting wat versamel is, is as 'n persentasie van die houtagtige spesies vir elke verwysingsarea, binne en buite die uitsluitingsperseel bereken. Die spesies wat gemiddeld meer as 5 % oor die drie opnames voorgekom het, is in ag geneem en grafieke voorgestel. Boomekwivalente per hektaar is vir elke hoogteklas, asook die totale boomekwivalente vir elke studiegebied per hektaar vir elke opname bereken, om meer perspektief op die bosverdigtingstatus in die studiegebied te verkry.

Die dominante hoogteklas was die minder as 0.5 m hoogteklas. Indien daar na boomekwivalente gekyk word, het die 1 – 2 meter hoogteklas 'n groter invloed op die graslaag gehad.

'n Spesie wat die meeste in die veldverwysingspersele voorgekom het, was *Grewia flawa*. Die smaaklike houtagtige spesie kan, as gevolg van die groeivorm en groot

kroonbedekking, 'n noemenswaardige invloed op die vermindering van beskikbare weiding hê. Hoewel *Acacia mellifera* in die meeste veldverwysingspersele met diep sanderige grond (byvoorbeeld die Water-Fouché-, Austrey-, Heuningvlei en Ipelegeng studiegebiede) voorgekom het, het die teenwoordigheid van *Acacia hebeclada* 'n groter bydrae tot bosverdigting gelewer en was die spesie ook baie meer vollop as eersgenoemde spesie.

Die gesindheid van die grondgebruikers, landboupersoneel en die gemeenskappe het verbeter, soos wat die data geanaliseer en resultate aan hulle gekommunikeer is. Terugvoering is in die verlede gewoonlik afgeskeep, maar dit is weereens as 'n integrale deel van 'n gemeenskapsgebasseerde projek bewys. Dit verbeter ook die sukses van so 'n langtermyn projek.

Soos reeds genoem was die studieperiode, te kort om enige betekensvolle verandering in spesiesamestelling en struktuur van die houtagtige plante te verkry. Die resultate het tog sinvol tot die bewuswording en kapasiteitsopbouing van al die rolspelers bygedra.

Die individue wat by soortgelyke toekomstige opnames betrokke gaan wees, moet deeglik opgelei word in die identifisering van veral saailinge van verskillende *Acacia* spesies, asook opnametegnieke. Dit sal die data-analisering en resultate positief beïnvloed. Verder moet houtagtige spesies as enkel- of meerstammige spesies genoteer word. Daar kan ook verbeterings aan die opnametegnieke aangebring word.

As alles in oënskou geneem word, kan die spesifieke LandCare projek as 'n suksesverhaal beskou word. Ten spyte van sekere probleme in die opnames, is daar baie geleer oor verskillende natuurlike hulpbron bestuursisteme.

Chapter 1

Introduction

1.1 Introduction

The human population has become more aware of the deterioration of the environment in the past decade. The rapid population increase over the world has been recognised as one of the main reasons for land degradation. High population densities put stress on natural resources (Snyman, 1999; Van Rooyen, 2000; Taddese, 2001). To put South Africa into perspective of the global problem of rapid population increase, the following aspects should be considered: The South African population was estimated at 42 835 000 in 1998 and the projection for 2010 is 47 503 000. The world population increase is estimated at 15.7 % per year, whereas South Africa has an average estimated population increase of 16.3 % per year (South African Maps, 2002). This might not seem much, but each individual has a basic need for food, water and shelter. The stress is thus, again put back on the natural resources.

Human induced stress is found to be more harmful to the environment than naturally induced disturbances (Kozlowski, 2000). Catastrophic, but avoidable human-induced stresses on the environment, include deforestation, uncontrolled fire, pollution and overgrazing, which also leads to the degradation of the soil properties (Kozlowski, 2000). Land degradation not only impacts negatively on food production, loss in productivity and the climate change, but the economy and stability of societies are also affected. Loss of resources often results in political unrest, especially, in the poorer and underdeveloped countries (UNEP, 2000). Many of these harmful effects can be reduced by the correct environmental management strategies, such as, continuous production of the products and services by the sustainable utilisation of the natural resources. To identify strategies of sustainable utilisation, long term research and close collaboration between biologists, social scientists, economists and regulatory government agencies, is necessary (Kozlowski, 2000).

During the 1992 United Nations Conference on Environment and Development (UNCED), also known as the Rio Conference, three environmental problems that are of global significance, were identified (Hoffman *et al.*, 1999; Hoffman & Ashwell, 2001). These issues included the loss of the biological diversity, global climatic change and desertification (Hoffman & Ashwell, 2001). Desertification was defined by the United Nations Convention to Combat Desertification (UNCCD) as: "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities" (Hoffman & Ashwell, 2001).

Livestock production, as one of the main agricultural practises in South Africa, has a large impact on the biodiversity and desertification of the country. More than 80 % of the total area of South Africa is used as grazing, be it natural rangeland or planted pastures (Snyman & Fouché, 1991; Hoffman & Ashwell, 2001). This makes livestock production the dominant form of land use in this country. The influence of livestock on the environment may be considered from numerous points of views. Livestock may out compete other native animals or may alter the environment to such an extent that some plant species may be lost due to over utilisation (Blackburn & De Haan, 1999). The effect of overgrazing on the plant community has far reaching results. It does not only effect the condition of the vegetation, but also the soil condition. Due to a loss in vegetation cover, soil crusting, reduced water infiltration, enhanced surface runoff and decreased soil water availability for plants occur (Snyman & Fouché, 1991; Hoffman *et al.* 1999; Manzano & Návar, 1999; Snyman, 1999; Van der Westhuizen *et al.* 1999; Snyman, 2000a; Snyman, 2000b).

The climate and changes in climatic patterns also influence the process of degradation and desertification. Not only does climate, especially the rainfall pattern, determine the existence of certain vegetation, but it also has a great influence on the recovery rate of disturbed vegetation. If the South African climate is taken into consideration, it is evident that this country is prone to desertification, as it has an arid climate with a rapid increasing population (Hoffman *et al.* 1999). According to the UN definition of "affected drylands", which states that if a dryland has a ratio of mean annual rainfall to potential evapotranspiration of 0.05 to 0.65, nearly 91 % of South Africa can be considered to be arid or semi-arid. Seventy one per cent (71 %) of the commercial farming areas and 29 % of the communal farming areas are situated in these regions

(Hoffman *et al.*, 1999; Hoffman & Ashwell, 2001). The main restrictive factor determining plant production in a semi-arid or arid environment is moisture and it has been extensively proven that a rangeland in good condition has a better effective rainfall utilisation than a rangeland in poor condition (Snyman & Fouché, 1991; Snyman, 1999; Van der Westhuizen, 1999; Snyman, 2000a; Snyman 2000b). Figure 1.1 illustrates the factors influencing land degradation (Hoffman & Ashwell, 2001). It is clear that land degradation is an interplay between climatic, human and environmental impacts which have a detrimental affect on the water soil and vegetation resources.

Of the 1 219 080 km² of South Africa, 116 190 km² is taken up by the North West Province. The North West Province consists of 9 % of South Africa and is the sixth largest province of this country. The total population of the province is approximately 3.9 million, thus 8 % of the total population of South Africa (1996 population census). Sixty five per cent (65 %) of the people live in the rural areas previously known as the Bophuthatswana homelands. The grazing land of the communal areas were generally perceived to be approximately two times as degraded as those of the commercial farming lands (Hoffman *et al.*, 1999). The North West Province is one of the poorest provinces in the country with a Gross Geographical Produce (GGP) of only R 3 964 as opposed to the average of R 6 498 of the other provinces (Mangold & Kalule-Sabiti, 2002). It is one of the most unbalanced regions in the world with 38 % of the people unemployed. More than 50 % of the women are unemployed and 30 % of the adults living in the North West Province are still illiterate (Mangold & Kalule-Sabiti, 2002).

The North West Province has the fourth highest land degradation index of all the provinces in South Africa. Amongst the degradation problems, soil degradation in the North West Province is also rated fourth in South Africa i.e. very high if compared with other provinces in this country. It is apparent that soil degradation is 30 % higher in the communal farming areas as opposed to the commercial farming areas (Mangold & Kalule-Sabiti, 2002).

The soil degradation index as well as the vegetation degradation index is a measurement to relate certain phenomenon to each other and globally (Mangold & Kalule-Sabiti, 2002). This indexes help to identify the key driving forces that influence environmental change. When the state of the soil, vegetation or the combined degradation index of an area such as the North West Province is determined, the driving forces behind the current situation can be investigated. The impact of the current situation can be determined and a positive response can be seeked by engaging in environmental management, promoting sustainable utilization of natural resources. Figure 1.1 relates to the different impacts on the environment determining the state of the environment.

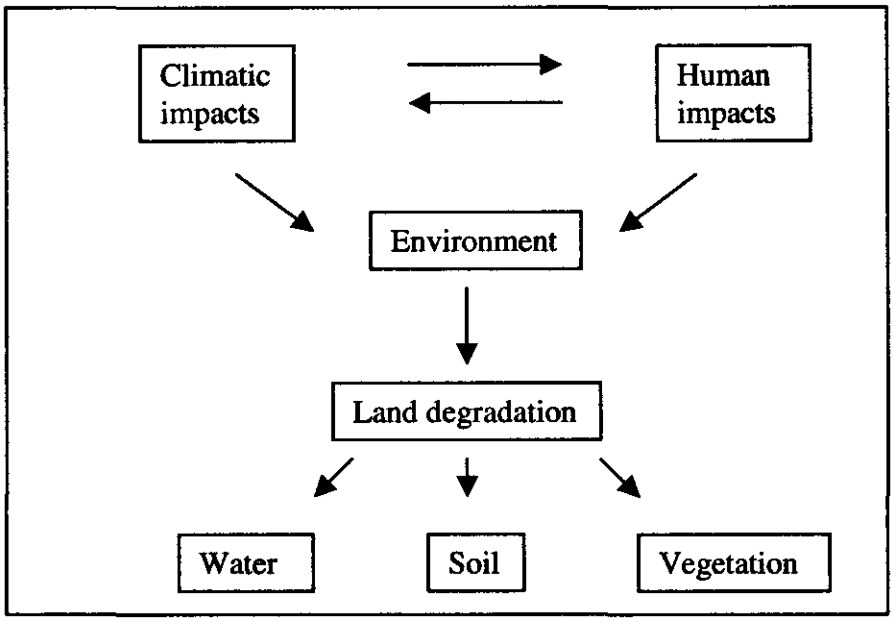

Figure 1.1: Environmental factors contributing to land degradation and the influence it have on the natural resources (adopted from Hoffman & Ashwell, 2001).

1.2 Degradation of agricultural lands

There are mainly two types of agricultural production systems in South Africa, namely livestock and crop production. In this study, the emphasis will be on livestock production on natural rangelands and, especially, the impacts of livestock production on the woody vegetation of a rangeland.

A rangeland is a natural or semi-natural ecosystem mostly characterised by indigenous, natural vegetation (Tainton, 1999). It is usually characterised by physical limitations such as low and erratic rainfall patterns, rough topography, poor drainage or extreme temperatures. Rangelands are usually not suitable for cultivation but mainly used for grazing by free ranging animals be it domestic or wild. Rangelands in savannas also provide the community with wood, fuel and construction material (Tainton, 1999). The definition by Harris *et al.* (1996) of different land-use capability classes, classifies a rangeland in capability class 5. This class is described as: "Land with severe limitations that restrict its use to pasture, forestry and recreation." The limitations mentioned could be one of the following: Poor or very poor drainage of the soil, steep slopes that have a severe risk of erosion or a severe climate. The rangelands in the North West Province, especially, the Western region, are exposed to severe climatic conditions with seasonal droughts (Smit, 2000).

Rangeland ecosystems in the arid and semi-arid regions are diverse, extensive and extremely vulnerable (Squires *et al.,* 1992). Rangelands, especially in arid environments are therefore easily degraded by injudicious management strategies.

Livestock farming is directly influenced by the condition of the rangeland, which in turn depend on the vegetative composition and the availability of good quality, palatable and nutritious fodder in the system. Severe limitations and challenges in the utilisation of a rangeland for sustainable livestock production consist as a result of the low production of vegetation in arid and semi-arid environments. The low vegetative production can be attributed to the nature of the erratic climate, especially rainfall and poor soil found in these regions (Snyman, 1999; Van der Westhuizen, 1999; Mugasi *et al.*, 2000).

Studies showed that in areas where rangeland degradation decreased, better farm planning, subsidies for conservation, better legislation, education and town planning, reduced stock numbers, and conversion to game planning were introduced (Hoffman *et al.*,1999).

Rangeland degradation can be classified in the following five categories and will be discussed under separate headings in more detail namely, soil degradation due to vegetation cover loss; bush thickening; invasive alien vegetation; deforestation and other forms of land degradation (such as pollution of natural resources) (Hoffman *et al.,* 1999; Hoffman & Ashwell, 2001).

1.3 Soil degradation

Soil degradation is one of the largest causes of desertification and is characterised by water erosion, chemical erosion or soil pollution, wind erosion and salinization of soil in arid areas (Hoffman *et al.*, 1999). Water logging of soil can also cause problems though it is not relevant to this study in an arid zone and will not be discussed further although this type of soil degradation is applicable to the agricultural sector.

Agricultural activities such as ploughing and the establishment of monocultures are one of the most contributing practices to soil degradation (Hoffman *et al.*, 1999). Ploughing removes the vegetation, which causes the soil to be exposed to wind and water, enhancing erosion. Vegetation can also be removed by over stocking or over grazing or development of settlements. The most severely eroded areas can be traced to agriculture especially to the cultivation of lands (De Bruin *et al.*, 1998; Hoffman *et al.*, 1999).

Soil erosion occurs in any ecosystem and only becomes a dilemma when the rate of erosion exceeds the rate of soil formation. Studies show that in most of the cases soil formation is 30 times slower than the loss in soil as a result of erosion (Hoffman *et al.*, 1999; Hoffman & Ashwell, 2001). The South African Regional Commission for Conservation and Utilisation of Soil (SARCCUS), which was founded to co-ordinate conservation activities, identified six categories of erosion and six categories of non-erosion forms of soil degradation (Hoffman *et al.*, 1999). These will be discussed briefly.

(1) ***Sheet erosion*** is the widest form of erosion and is also the most predominant form, especially in the communal managed areas (see 1.8) (Hoffman *et al.*, 1999). Raindrops detach soil particles, which are transported away by water. The removal of soil particles is fairly uniform. (2) ***Rills, gullies and dongas*** are grouped together as a single erosion form and are more predominant in the higher rainfall areas (Hoffman *et al.*, 1999). Factors, such as soil texture, the slope of the terrain and the type of land use, may contribute to rill, gully and donga formation. Rills are small furrows that develop due to water runoff. Gullies are deeper trenches worn by running water and dongas are ravines with steep sides (Hoffman & Ashwell 2001). (3) ***Soil compaction and crusting*** are predecessors of rill and gully erosion, and is also of significance in many rural areas,

which are mostly over stocked and over grazed (Hoffman *et al.*, 1999). (4) ***Wind erosion*** occurs in soils that are poor in nutrient status and have a clay content of less than 15 % (Hoffman & Ashwell 2001). This is the most prominent kind of soil erosion in the North West Province especially in the Vryburg district (Hoffman & Ashwell, 2001). A third of the North West Province is susceptible to wind erosion due to the sandy nature of the soil of this area (Hoffman & Ashwell 2001). (5) ***Salinization and water logging*** are of great importance in irrigated areas (Hoffman & Ashwell 2001). (6) ***Acidification, soil mining, and soil pollution*** are grouped together and are becoming a growing problem in especially the developed and industrialised areas (Hoffman *et al.*, 1999).

Figures released by the Department of Environmental Affairs in 1992 estimate that the removal of sediment by rivers amounted to 150 million tons per year (Van Wyk, 1985). The loss in soil due to erosion was estimated to be between 300 and 400 million tons per year for South Africa (Van Wyk, 1985). In order to prevent the loss of valuable topsoil by the different types of erosion or other soil degradation processes, it is important to manage the natural resources as sustainable as possible.

1.4 Invasive alien vegetation

The impact of the invasion of alien vegetation on the natural vegetation is another form of land degradation. Not only does alien vegetation compete with the natural vegetation and disturb the biodiversity and sustainability of an ecosystem, but it also has a measurable impact on the valued water resources of South Africa (Hoffman *et al.*, 1999). Invasive alien plants affect approximately 8.28 % of South Africa and are rapidly spreading (DWAF, 1998). The North West Province has a very low invasive alien plant status (between 0.1 to 5.0 %) and it seems as if this type of degradation is currently not causing a great threat to the sustainability of the ecosystem process in this area (DWAF, 1998).

Not all alien species are regarded as invasive. Only 15 % of the tree species introduced into South Africa are regarded as invasive (DWAF, 1998). These include woody species such as *Prosopis* spp., *Acacia mearnsii, Eucalyptus* spp. and *Opuntia* spp. It is important to note that invasion of alien plant species is not the same as bush thickening. The latter occurs when the natural vegetation becomes denser.

The reason why the North West Province is so lightly invaded by alien vegetation might be because of the lack in sustainable water resources in this arid environment (Mangold & Kalule-Sabiti, 2002).

1.5 Deforestation

The head of the World Bank (agricultural division) claimed in 1991 that 12 million acres of natural forests are being destroyed annually to develop cultivated lands for crop production. Deforested land is mainly being destroyed by soil erosion (Van Wyk, 1985). The heavy use of wood as fuel out competes the natural regeneration tempo of the trees by far, in most areas of South Africa. Rapid deforestation leads to soil erosion, silting up of rivers and the general depletion of soil nutrients. Deforestation also leads to the drying up of underground wells and ultimately the loss of clean drinking water (Ramphele, 1991).

Not only the health of the people collecting wood is negatively affected, but it is also very time consuming, when wood has to be gathered over long distances. Women walk very far and carry very heavy loads. The safety of the woman is also affected, as nobody can hear them calling if they are threatened, far from the village (Ramphele, 1991).

Although deforestation is a great problem especially in the communal areas of South Africa, it is currently not such a large problem in the North West Province. The North West Province has less of a deforestation problem because there is an annual surplus of wood of approximately 500 000 tons each year (Mangold & Kalule-Sabiti, 2002). Approximately 17 million people in 3.2 million households depend heavily on wood for fuel for cooking and heating in South Africa (Hoffman *et al.* 1999). An average family uses approximately three tons of wood per year (Ramphele, 1991; Mangold & Kalule-Sabiti, 2002).

1.6 Other forms of land degradation

Before the problem of bush encroachment and bush thickening is discussed, other forms of land degradation that can be mentioned include activities such as clearing land for crop production, development of settlements and pollution (Hoffman *et.al* 1999). These forms of degradation are often seen as a third order priority in some magisterial districts in this country (Hoffman *et.al* 1999). The fact that these types of degradation are not acknowledged does not mean that they cannot develop to be a problem in the North West Province. Environmental poisoning due to careless mining practices and dumping of toxic waste in poorer countries have received a lot of publicity the past few years (Ramphele, 1991).

The Kudumane district in the North West Province is known historically as an asbestos mining region. Education concerning the dangers of the asbestos mine dumps, that were left by mining companies, need to be conducted otherwise it could go the same route as in a settlement in KwaZulu Natal. This settlement plastered their houses and made bricks for public buildings from asbestos tailings with great health implications (Ramphele, 1991).

1.7 Bush thickening

The North West Province, where this study has been conducted, forms part of the savanna biome in South Africa (Rutherford & Westfall, 1994). One of the most common forms of land degradation in the savanna biome is bush thickening. Although some literature refers to bush encroachment and bush thickening as a similar phenomenon, it is not the case. Bush encroachment occurs when natural herbaceous vegetation become invaded by indigenous woody vegetation from forest fringes, while bush thickening is when the natural occurring woody vegetation in a savanna increases indefinitely (thickens) mainly as a result of overgrazing and climatic conditions (Rutherford & Westfall, 1994; Smit *et.al.*, 1996). Overgrazing reduces the herbaceous layer that control the woody composition by competing for soil nutrients, sunlight and, especially, soil moisture (Smit *et.al.*, 1996).

Many previously economically viable livestock properties are now non-profitable or often non-existent depending on the degree of bush thickening (Tainton, 1999). This phenomenon is of great importance seeing that two major industries of South Africa are situated and supported in this biome, i.e. cattle ranching and wildlife related tourism (Scholes & Walker, 1993). Nine (9) of the 28 magisterial districts of the North West Province have areas that are so severely encroached with bush that the land can not be reclaimed by farmers without desperate bush eradication measures (see Figure 1.2) (Mangold & Kalule-Sabiti, 2002).

Bush encroachment receives a first, second or third order in the rangeland degradation index (Archer *et al.* 2000). Under the primary or first order degradation, ecological factors promoting bush encroachment, such as rainfall and increased atmospheric CO_2 concentrations may have a negative effect (Archer *et al.* 2000). Secondary factors that promote bush encroachment are considered to be the decrease in endemic browsers, and replacement with cattle, the change in the fire regime, and the reduction in fuel by either over grazing or wood harvesting. Secondary factors are mainly human induced (Trollope, 1980; Ramphele, 1991; Hoffmam *et al.,* 1999)

The limitation of primary production due to bush thickening applies largely to approximately 38.5 % of commercial land and 50 % of communal lands. *Acacia* spp. are the greatest cause of bush encroachment and bush thickening in South Africa. Over the past three to four decades a 30 % increase in woody cover was observed in South Africa (Hoffman *et.al.* 1999).

The North West Province priority of bush thickening is very high, more than 50 % of the land is considered to be severely affected. (See Figure 1.2). The most invasive species either indigenous or foreign are *Acacia* spp., *Prosopis* spp., *Melia azedarah* and *Eucalyptus* species (Mangold & Kalule-Sabiti, 2002).

Woody vegetation itself is not a negative element in a rangeland system for it can serve as reserve feed in severe dry years. It is only when bush encroachment and later bush thickening occurs, where the woody component can be seen as a threat to primary production of the rangeland (Richter *et al.*, 2001).

Figure 1.2: The priorities of bush thickening in the North West Province as found by Hoffman and Todd, 1995. Nine (9) of the 28 magisterial districts are considered to be under severe bushthickened circumstances (Mangold & Kalule - Sabiti, 2002).

1.7.1 Possible ecological factors contributing to bush thickening and other forms of land degradation

Although there are many factors that can contribute to above-mentioned degradation only a few important factors will briefly be discussed. The physical environment has a great influence on the vegetation composition of a given site. The soil, climate, available surface water, interspecies competition, anthropogenic influences and physical plant characteristics all contribute to vegetation distribution and vegetation cover. The reasons for bush thickening are thus very diverse and complex and also differ from site to site because of topography, soil texture or nutrients or climatic differences. Even so, in most situations man has either directly or indirectly modified these savanna systems, which in many cases resulted in over utilisation and rangeland degradation (Tainton, 1999).

Primary determinants of vegetation distribution in the semi-arid region of the North West Province would typically be, wet summers and dry winters. The plant species composition can also be determined, with precipitation and with soil properties such as the soil nutrient status, pH, salinity and soil texture. The spatial distribution of the vegetation is usually determined by the soil moisture balance and thus the competition between plants for that available moisture (Teague & Smit, 1992).

Bush encroachment is thus area bound. Though some sites might be more susceptible to degradation due to soil type, humans can still manage it. Areas where population density is high, are always more susceptible to degradation no matter what the habitat might be. In other words the more different species there is the more intricate the system become and the more effect will be provoked by a single disturbance. Some of the possible causes of bush thickening will be discussed in more detail.

(a) Climate and Soil: Climate plays a vital role in the distribution of all the organisms on earth. Tropical plants, for example, can not tolerate drought, low humidity or frost. The amount of precipitation and the average temperatures of a region are not, however, as important as the timing and nature of precipitation (Moore *et al.*,1998). Some plant species shed their leaves for a period of dormancy when temperatures are too low or to reduce transpiration during dryer months.

Arid savannas, such as the study area, usually have eutrophic soils as a result of low rainfall and lack of soil leaching. The grass produced in these soils usually has a high nutrient status and is known as "sweet grass" to most farmers. These savannas are characterised by relatively high animal biomass and high levels of grazing and browsing herbivory, seeing that crop cultivation is not viable in an arid environment. As a result of high grazing levels, low plant biomass is usually observed (Teague & Smit, 1992). The organic matter content of the soil is usually low due to the high temperatures and low moisture levels that slow down the activities of the micro organisms, associated with decomposition of organic matter (Scholes & Walker, 1993).

Sandy soils, found almost in the whole Kalahari Thornveld (Smit, 2000) that also occurs in the study area of this thesis, are less limiting than clay soils in moisture availability to plants in the same climatic conditions. It is found however, that moisture is not kept so readily in sandy soil than in clay soil. The presence of rocks in the soil profile increases water infiltration to a depth that favours woody plants. This is because woody species have a much deeper root system than the grass component, in the savanna biome. Moisture at a shallower soil depth is more available to grass due to a shallower root system (Teague & Smit, 1992). The rooting patterns of the different vegetation will be discussed in depth under the sub-heading "Grass-Tree competition".

(b) Physical plant characteristics: There are numerous reasons why the woody component of a savanna is not utilised by livestock. The first might be that most livestock are grazers and mostly utilise the grass component of the given system. Cattle may turn to browsing but only if no grazing is left or if an additional nutrient supplement in their diet is needed (White, 1993; Smit *et al.*, 1996). The woody species that are mostly utilised during ultimate dry seasons in the Kalahari Thornveld are *Diospyros lycioides, Grewia flava, Boscia albitrunca* and even *Acacia hebeclada* (White, 1993).

The woody vegetation in the more arid environments has spines as defending mechanisms against browsing (Teague & Smit, 1992). Hooked spines seem to have a better defensive effect than straight spines (Smit *et al.*, 1996). Increased levels of tannin in *Acacia karroo* leaves were also observed as a defence mechanism against browsing (Teague & Smit, 1992).

Palatable woody species are very resistant to herbivory and recover fairly quickly after being utilised. Over-compensation by the plant, after browsing, can result in enhanced biomass production of the woody species (Teague & Smit, 1992). This may lead to an increased crown cover that will compete with the grass component for sunlight.

Other biological interactions such as tree size, leaf area, rainfall duration and intensity, also determine the competition between the vegetation in the Savanna (Teague & Smit, 1992).

The Grass – Tree competition, is one of these other biological factors. Different growth forms co-exist in the savanna because of the spatial and temporal separation and competition with regard to available resources (Teague & Smith, 1992; Tainton, 1999). The soil beneath the tree canopies has a higher nutrient status than that of soil in the open areas. The rooting patterns of the vegetation differ, as already mentioned. The grass cover and the density of the grass roots determine the depth of water infiltration into the soil. Grass utilise soil moisture much more rapidly and more efficiently than trees (Teague & Smit, 1992). It is clear that any factor that influences the tree component negatively will result in higher herbaceous productivity and vice versa (Teague & Smit, 1992; Tainton, 1999; Smit, 2000; Dye & Spear, 1982).

Grass can significantly control the seedling survival of the woody plants. They can shade the seedlings, to influence the photosynthesis and also compete better for the moisture in the topsoil (Teague & Smit, 1992; Smit *et al.,* 1996).

Poor grazing practices have a greater adverse effect on grass growth than on tree growth, especially during severe drought conditions. The woody species will increase more rapidly in a rangeland that has been over grazed (Tainton, 1999). Herbivory is a secondary determinant to competition that should not be ignored. Heavy grazing and browsing reduces the growth and reproduction of individual plants, which in turn influence competition outcomes and community composition of the vegetation (Teague & Smit, 1992).

Certain grass species, such as *Panicum maximum* that are very palatable and nutritious are usually associated with the shade of *Acacia* spp. due to high nutrient moisture regime around the stem of the trees. The net result of the negative and positive interactions on grass production is dependent on the tree density. The effect of natural tree densities can have a positive effect on the grass-tree interaction. Trees create sub-habitats that exert different influences on the herbaceous layer. Leaf litter influences the micro-environment and enriches the soil with organic carbon. Trees provide shading that reduces evaporation. Trees also redistribute rain (Tainton, 1999).

Inter-tree competition is another factor to be investigated as this influence the distribution of certain woody species. The larger the tree, the larger the area of resource depletion due to the cumulative extended root system between the trees. Inter-tree competition is species specific and many *Acacia* species fail to establish under a canopy of established individuals, irrespective of its species (Tainton, 1999).

A potential exists that African *Acacias* may facilitate the invasion of broad-leaved woody plants, leading to broad-leaved dominance in a rangeland (Tainton, 1999). Most broad-leaved evergreen woody plants compete more strongly with the grass component in a rangeland. The evergreen tree does not cease to utilise the available soil moisture during winter. Inter-tree competition benefit grass production on sandy soils, seeing that fewer seedlings of the same species will germinate in the vicinity of a large tree (Teague & Smit, 1992).

(c) Anthropogenic contribution to the bush thickening problem: From all the literature it is evident, that the potential of bush thickening and bush encroachment exists in each savanna system. (Trollope, 1978; Ramphele, 1991; Hoffmam *et al.,* 1999) All these systems have a bush and a grass component. It will depend on the type of external pressures exercised on the system whether a phenomenon such as bush thickening will occur.

Determinants of vegetation composition and cover that will have an affect on bush thickening can be either primary (climate and soil) or secondary (fire and the impact of herbivores). Secondary determinants can be modified and manipulated by management systems. Management practices such as the exclusion of fires, restriction of herbivore movement and controlling of the stocking density on a rangeland are necessary for sustainable utilisation (Tainton, 1999). Arid savannas can also be viewed as semi-deserts and are very vulnerable to grazing and therefore susceptible to degradation (Teague & Smit, 1992).

A good understanding of ecological functioning of a system is necessary to manage an ecosystem for higher productivity and sustainability achievements. The concepts of sustainability and resilience are of great extending importance. In other words: how and to what degree does a savanna change and will it recover to its former composition, function and productivity, after a certain impact, such as grazing has occurred (Teague & Smit, 1992; Tainton, 1999; Smit, 2000). Long term costs and benefits of a rangeland management practices can be calculated if these concepts are known (Teague & Smit, 1992).

(d) Fire: is more important in the humid savannas than in the semi-arid environments. Fires occur as surface fires during the dry season. The intensity of fires is dependent on many variables, such as the direction and speed of the wind, dry matter availability and humidity (Teague & Smit, 1992). Due to a lack of sufficient dry matter at the end of a dry season (winter) the intensity of fires in a semi-arid or arid environment is not as intense as fires found in the more humid and sub-humid areas of South Africa (Trollope, 1974; Trollope, 1978; Trollope, 1980). Fires in these semi-arid and arid environments only lead to the top kill of the woody species and after rain the plants show coppice re-growth (Trollope, 1974; Trollope, 1978; Trollope, 1980).

Browsing limitations have been drastically reduced as domestic livestock replaced natural browsers over a period of a few hundred years (Trollope, 1974; Teague & Smit, 1992). Domestic livestock usually consists of a wide variety of grazers, only "Boer goats" are primarily browsers (White, 1993).

Grazing pressure reduces both the growth rate and reproductive potential of individual plants and therefore influences the competitive relations among the different species. It was found that overgrazing of grass leads to the increased woody plant density and non-grazed and moderately grazed areas showed no consistent trend in bush increase (Trollope, 1974). The tree species with shallow root systems tend to increase. These are species such as *Acacia mellifera* and *Grewia flava* (Tainton, 1999). This is due to more moisture available to these plants as a result of reduced competition from the grass component.

Previously cultivated fields favour woody plants. This might be because of a lack in the grass seed bank and higher water infiltration depth in the soil (Teague & Smit, 1992).

(e) **In summary:** the consequences of bush encroachment, and bush thickening is the reduction of grazing capacity and decrease in grass production (between 40 – 90 %) (Tainton, 1999).

High density tree stands is poorly suited to grazers not only as a result of the reduced production of grass, but is also negative to browsers due to the relatively poor browse supplying characteristics of thickets (Tainton, 1999). Most of the shrubs have spines that are so close to each other that it becomes an impenetrable thicket. Only the outside branches can be utilised by browsers. A lot of feeding potential is lost due to inaccessibility to the inner leaves of the thicket.

Not only does the shading effect of bush thickets reduce the amount of grass in the vicinity but the animals that have to move around the thickets also trample the existing grazing (Teague & Smit, 1992).

A situation that was identified in connection with the land management and tenure systems such as Morafe Ranch (see 1.8) was that problems such as bush thickening would not be addressed if it would imply too large financial expenditure for the current non-free hold owner. The current owner does not see the use if no profit would be made in the time that the allocated plot still belonged to him.

1.7.2 Combating the problem of bush thickening

The eradication of bush in a rigorously thickened area can be done using one or a combination of the following control methods: mechanical, chemical or biological methods (Smit *et al.*, 1996). The mechanical method combined with chemicals is the most effective to achieve bush management practises with quick results. Mechanical control methods are expensive owing to the labour intensiveness and the equipment used in this method. Chemical control is more effective when using it in combination with mechanical control methods (Smit *et al.*, 1996). Biological methods such as the use of browsing animals might be comprehensively cheaper but is usually not as effective over a shorter time frame. The degraded rangeland does not recover within a time frame that is acceptable to the land users (Van Rooyen, 2000). Seasonal droughts limit the recovery tempo of a biologically treated area to a great extent. Impact of tree thinning may vary across different rangeland types (Tainton, 1999).

Bush control is an ongoing process as the establishment of woody plants is always in continuing progression in savanna areas. Treated camps (camps that was rested) should first be grazed during the dormant season to allow the grass to establish and produce seed. When the rangeland has recovered, it can be reintroduced into the normal grazing program. Animal numbers should be controlled, particularly that of selective feeders, such as cattle (Tainton, 1999).

Sites dominated by *Acacia* species showed large numbers of seed germination and survival when the vegetation is cleared but few were found in uncleared areas (Tainton, 1999). This means, that the tree–tree competition is much higher in uncleared areas. It also means, that follow–up work needs to be done, to ensure that the clear area does not become encroached again, and to ensure that the herbaceous cover can re-establish.

To illustrate the effectiveness of bush clearing projects, the following study conducted in Uganda is used to indicate that woody vegetation thickening is a major factor affecting livestock production. (Mugasi *et al.*, 2000) In this study, it was found that cleared ranches had 33 % - 53 % more vegetative yield than uncleared ranches. Differences of 1850 kg ha^{-1} to 2230 kg ha^{-1} of dry matter production in a cleared ranch compared to the 622 kg ha^{-1} to 1190 kg ha^{-1} of dry matter produced on an uncleared ranch were measured. (Mugasi *et al.*, 2000).

The heifers on ranches where bush eradication was applied reached puberty and calved earlier than heifers on bush thickened ranches. There was difference of 12 to 30 months to reach adolescence, as opposed to 24 to 36 months for heifers on the uncleared farms. The mean calving rate of the heifers was also higher with an approximate difference of

11 % (Mugasi *et.al.*, 2000). This may be due to the fact that the heifers on cleared farms received more nutrition.

The milk yield differed form 3.8 L $cow^{-1}d^{-1}$ on a bush cleared ranch to 2.4 L $cow^{-1}d^{-1}$ on an uncleared ranch. A marked annual gross income difference of approximately US $26 042 was observed between the two types of ranches (Mugasi *et al.*, 2000). Out of these studies the importance of a management system for a rangeland can be deducted and also the influence of bush on the primary vegetative production of the rangeland.

Studies where bush thickening in *Colophospermum mopane* dominated areas in South Africa also showed an increase in herbaceous vegetation if excess woody components were removed (Smit *et al.*1996). The suppressive effect of high densities of woody species was clearly seen. The effect of rainfall on the herbaceous cover did not differ considerably, but a clear increase in herbaceous cover was observed in plots that were cleared of bush from 50 % to 100 %. Plots that had a woody component covering 50 % of the plot were already viewed as being beyond a critical point where the woody species out compete the herbaceous layer. As a result the herbaceous production was lower in these plots viewed as being beyond critical point.

1.8 Land tenure

Degradation can be classified by the intensity and degree of a certain problem, be it any of the five previously mentioned categories (see 1.2). Nearly 80 % of the communal areas have a first, second or third order rangeland degradation priority (Hoffman *et al.*, 1999). Overgrazing by mostly cattle is the most to blame for the deterioration of natural rangeland in especially these areas (Hoffman *et al.*, 1999).

To conserve natural resources sustainable management needs to be implemented. Sustainable agricultural development results in a careful balance between the conservation of the fragile resources (in especially an arid or semi-arid area) that will meet the changing and growing needs of consumers (Squires *et al.* 1992; Snyman, 1999; Van der Westhuizen *et al.* 1999).

Management programs are of extreme importance to determine structure and reach the goal of the project. For land tenure to be successful it must have two goals in mind, namely:

1) the protection and conservation of the biophysical environment, and
2) the well-being of the people dependant on the rangeland production system (Squires *et al.*, 1992).

The main reason for rangeland degradation under the current land tenure system in the undeveloped and poverty stricken areas of South Africa can be described as follows: the land does not belong to the people. The fact that most of the people in communal lands are usually poor and they might never own their own land contributes to the negligence of the land and over utilisation of recourses. Land degradation is like a slow cancer eating away at the natural resources and when the symptoms finally show it is usually too late.

Communal land has often been described as unproductive, and investors would usually invest in a more productive area (Anon, 1999). Communal areas are usually characterised by regional poverty and vegetation degradation. It has long been described as the "tragedy of the commons" because property rights are the foundation of resource use in a sustainable manner (Anon, 1999).

The reason for overgrazing and over utilisation of resources in communal managed systems is individual benefit (Todd & Hoffman, 1998). The animal owner benefits over a short period of time by having a large number of animals, and the commons carry the cost of overgrazing over the long term (Todd & Hoffman, 1998; Hoffman & Ashwell, 2001).

Communal grazing is a system that allows animal production on a rangeland that provides access to all members of a community. These areas are usually restricted to the former homeland areas, when South Africa is being discussed (De Bruin *et al.*, 1998).

Land degradation has long been blamed on land tenure in South Africa and this country is not the only country where these problems exist (Manzano & Návar, 1999).

Countries such as Mexico, Ethiopia and even European countries have similar problems. Another problem with land tenure is the lack in infrastructure and regulations regarding the use of natural resources (Manzano & Návar 1999).

Communal rangeland management systems are more impartial than privately owned land. The emphasis on the rangelands is on the number of animals produced and not so much on the sale for the profit as on privately owned land. Animals in rural areas are kept for milk, meat, a form of insurance and investment (De Bruin *et al.*, 1998). Most of the people in the rural areas cannot acquire loans from the financial institutions and have to invest in a different form i.e. livestock. This leads to the deduction that the livestock of the farmer is his insurance for the future.

Rangelands might therefore carry two to three times more animals than the recommended carrying capacity. Animal numbers are only controlled by drought and disease and not really by marketing (De Bruin *et al.*, 1998).

In the past the government attempted to restrict livestock numbers in the Bophuthatswana homelands by introducing legislation, which was discarded and ignored as soon as it was implemented (De Bruin *et al.* 1998). The reason: The commons do not see the problem as to many animals on the land, but as too little land for the animals (Ramphele, 1991; De Bruin *et al.*, 1998). The previous legislation did not implement indigenous knowledge and relied on a one sided approach (Ramphele, 1991).

Although communal grazing is condemned as degraded and overgrazed rangelands, case studies in the Ciskei have shown that rangeland conditions are often surprisingly good (De Bruin *et al.* 1998). Acocks commented in the 1950's that communal land looked better than commercially owned farms. The reason for this might be the selective grazing of animals on commercial farms, where the stocking densities are not so high. The less palatable grass is left and may then out compete the palatable grass. The less palatable vegetation then dominates over the long term (De Bruin *et al.*, 1998). In the North West Province there are two land tenure systems currently in use in the Western region, namely Morafe Ranches and Communal Grazing.

1.8.1 Morafe Ranch management system

It is a common property system consisting of a management group or 'owner' group that has the right to exclude non-members. All the co-owners have a certain duty in the maintenance of the piece of land allocated to them (Anim & Van Schalkwyk, 1996).

When the farmers of a Morafe Ranch were interviewed, they explained that they receive a term of five years on which they can farm on the piece of land provided to them. After the term expires, they have to renew their non-freehold ownership. Morafe Ranch farmers are more interested in the marketing of livestock. Lower theft figures of cattle and fencing are experienced by Morafe Ranch farmers than in the communal farming areas. The main reason might be because farmers normally stay at the Ranches which creates a level of ownership and quality control.

The land, in a Morafe Ranch system is subdivided into sub-units of for example 1200 ha each. These sub-units are then subdivided further into four camps. A four camp rotational grazing system is then implemented where one of the four camps have to be rested for one entire year. The grazing capacity per unit for all the sites, is 10 ha/LSU (Large Stock Units), which means that not more than 120 LSU's (Large Stock Units) are permitted on a 1200 ha sub-unit. To obtain the right to a sub-unit, the potential farmer must apply at their Provincial Department of Agriculture, Conservation and Environment. Two or more farmers are appointed to a sub-unit. The total stock numbers on the sub-unit may not exceed the total long-term stocking rate. No sheep or goats are allowed on Morafe Ranches. The farmers are also compelled to sell their calves at an age of nine months. A levy of R22 per cow per year should also be paid to the tribal authority. The funds obtained in this manner are used for the maintenance of the Morafe Ranch infrastructure.

The theory is that this management system will better the rangeland condition and will educate farmers regarding rotational grazing, resting the rangeland and other management practices.

1.8.2 Communal Grazing management system

This is a non-property system, usually does not have a defined group of 'owners' and anyone in the community can utilise all the resources on the land. There is no property right at all. The group or community might however decide to exclude an individual on any grounds found reasonable by the grazing committee and tribal authority of the given area (Anim & Van Schalkwyk, 1996).

As mentioned, this system has long been blamed for degrading the land, as well as being unstructured. This is only partially true. The researchers were informed by the different communities that the communal managed systems that were studied have special grazing committees that consist of representatives of the whole community. This committee includes youths, elders, the headman, extension officers and some women. These committees meet at least once a month to discuss factors such as the health of the animals, breeding strategies, quality of the grazing and the rotation of the animals in the area allocated to a specific community.

1.9 LandCare in South Africa

This study conducted by the Potchefstroom University for Christian Higher Education focuses on the influence of grazing and how rangeland management effect the phenomenon of bush thickening in a savanna area. The Department of Agriculture, Conservation and Environment of the North West Province in South Africa has always been involved in agricultural practises in South Africa. The LandCare program that has been developed in Australia was introduced to South Africa in 1998 by the Department of Agriculture, Conservation and Environment (Thabethe, 1999). It is a program that promotes the management of water, plants and animals in a sustainable manner. Sustainability can only be accomplished if people share knowledge and understand the functioning of an ecosystem. LandCare focuses on "community based resource management", "integrated catchment management" or "stewardship". The program gives land users the chance to take charge of their own problems (Jordaan, 2001).

People have the greatest influence on their surroundings. Land degradation and water scarcity are serious issues in a desert margin country, such as South Africa. Land degradation is costing millions of rands each year in production losses alone, not to mention what it will cost to remedy it. If the cost of restoration of degraded lands, nutrient loss, research costs and the silting up of our waterways, are included, it adds up to several billion rands per year (Jordaan, 2001).

The National Department of Agriculture is a key role player in the development of South Africa as a nation, in providing adequate information about agriculture to the farming communities. This prevents land degradation and food shortages. Their vision is to increase the long-term productivity and ecological sustainability of the natural resources, and thus ensuring a future of the land's people within the agricultural sector (National Department of Agriculture, 2001). The program targets the farming community, of both the commercial to communal sector. LandCare is thus a community-based and government-supported approach to promote sustainable management and use of the natural resources in agriculture (Jordaan, 2001).

Why would the government implement community-based initiatives within provincial structures and involve strong private sector and civil society participation? South Africa's Constitution provides within the Bill of Rights that:

> *Everyone has the right to:*
>
> *a) an environment that is not harmful to his/her health or wellbeing; and*
>
> *b) have the environment protected, for the benefit of present and future generations through reasonable legislative and other measures that:*
>
> > *i) prevent pollution and ecological degradation;*
> >
> > *ii) promote conservation; and*
> >
> > *iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.*

Several treaties that have been signed by South Africa are also honoured by the LandCare initiative (National Department of Agriculture, 2001).

The objectives of the South African LandCare program are to:

- provide a framework for individuals, community organisation and the public and private sector, through partnerships to optimise productivity and sustainability of the natural resources through management, protection and rehabilitation;
- develop the capacity and skills of land users through education, knowledge sharing, information, participatory interaction for better access and management of resources;
- support institutional building at all levels of governance for improved communication, networking, financial and other support services;
- empower all people through knowledge and understanding to take the responsibility for the care of the environment;
- ensure as far as is practicable that resources are used at a rate within their capacity for renewal;
- maintain and enhance the ecological integrity of natural systems;
- minimise or avoid risks that lead to irreversible damage and
- maintain biodiversity (contribute towards the maintenance of biodiversity) (Jordaan, 2001).

The mission of the LandCare projects is to facilitate an enabling environment for the development and support of an integrated community. It addresses issues such as erosion, soil acidity and overgrazing (Thabethe, 1999).

The LandCare program has several themes to achieve the objectives, depending on the need of the specific community in the given province. The specific objective of the North West Province LandCare project is mainly the VeldCare program. This includes aspects such as:

- improvement of rangeland management through the implementation of different management systems;
- improvement of production and composition of the rangeland through improved bush control practises;
- improvement of the rangeland production and composition by limiting the stocking density on the rangeland;

- establishment of an effective LandCare program by giving the resource owners and users the responsibility for maintenance, management, improvement and sustainable utilisation of the resources and
- Monitoring and evaluation of the impact of the program on the resources, society and the economy of a given community.

(Jordaan, 2001).

Monitoring of the different VeldCare projects is of the utmost importance. It is necessary to monitor the projects to see whether there has been any improvement in the rangeland condition and an increase in primary vegetative production of the rangeland.

The VeldCare program involves, amongst others, bush thinning, clearing or total eradication of undesirable woody plants. The clearing of the bush can be achieved by direct or indirect practises. Direct practises are when bush is eradicated by chemical or mechanical methods, where as indirect practise focus more on stocking rate of livestock and other rangeland management systems (Jordaan, 2001).

It is important to base all LandCare projects on scientific sound principals. This will also assure a certain amount of quality control and accountability. These projects can only be evaluated if scientifically sound data, methodologies and results obtained over longer periods of time, is used. Setting up of references or benchmarks can assess parameters and references to measure any changes in rangeland condition, whether it has improved or degraded. These benchmark sites or areas can also be used as demonstration plots to promote more sustainable rangeland management practices in future. This calls for a high level of collaboration between the rangeland manager, researcher and the extension technology transfer services, to ensure most effective results. The tools that are needed should be specified from the start and the project should also be scientifically evaluated (Ffolliott *et al,* 1998). Scientifically based projects are more acceptable to institutions and can give better directions to future incentives for other projects in rural areas.

1.10 The importance of demonstration plots

As mentioned, the goal of demonstration projects is to illustrate how acquired research information and proposed technologies can aid and improve the application of sustainable management systems. By using demonstration projects, the relevant information is given in a visual way to the decision-makers of the region and is accessible to all levels of the community in an understandable format (Ffolliott *et al.*, 1998). Thirty percent (30 %) of the adults in the North West Province are illiterate and this calls for visual aid to promote sustainability (Mangold & Kalule-Sabiti, 2002). The motto "seeing is believing" would literally apply in this situation.

To accommodate the community, it is necessary to adapt the demonstration projects to a scale that is acceptable with regards to the temporal and spatial measures in the specific environment. This also promotes adoption and acceptance of the project. It is of great importance that any project is relevant to the people living in the region (Ffolliot *et al.*, 1998).

Practical applications of research and technologies are also represented by the demonstration projects. The benefits of the project should be clearly highlighted and the problems of the community directly addressed. The relevance and application method to their situation should be clearly stipulated. The aims and time scale should also be understood by all (Ffolliot *et al*, 1998).

The importance of effective communication in regards of the demonstration must not be under estimated. Key personnel, such as the researchers, policy and decision-makers from the top management, usually do not have direct contact on a community level at regular intervals. Key personnel are usually stationed away from the central government authorities, who could be more effective in mobilising their subordinates if given proper advice (Squires *et al.*, 1992).

If the parameters of sufficient planning and development of a relevant scaled demonstration project are followed, the results obtained by a certain project will have a much greater impact and will contribute to the acceptance of a "new" or other strategy as advised by the demonstration. The results must be given to all stakeholders involved to be used as a guideline for future projects of a similar nature.

Thus the co-operation between the different parties involved in any initiative, such as this LandCare project, learning opportunities for stakeholders can be created (Ffolliott *et al,* 1998). Researches need to realise that theoretical methods are not always practically applicable and communities need to realise that their problems are addressed and can be overcome.

There are four stages to the adoption of a project:

1) awareness about a certain problem and the severity of the situation should be created;
2) awareness generates interest in the problem;
3) awareness, in turn generates an understanding of the project and its way of functioning and
4) this leads to the most critical phase in the implementation of a project, the trail phase were a project will be adopted or rejected (Ffolliott *et al,* 1998).

Demonstration plots should be "on site" or "on farm" for better adoption by the land user.

Baseline surveys are of the utmost importance, for it provides a basis from were the project could be evaluated over a long period of time. Many authors have stressed the fragility of an arid and semi-arid system and the time it takes to recover form degradation. Changes in the vegetation in these climatic environments are very slow, mainly due to a moisture constraint.

Any long term monitoring project depends on very first-class baseline studies. Base line data is used to adapt management strategies, as the historical experiences that could have influenced the data, is also taken into consideration. This includes that during the base line surveys the indigenous knowledge of the local communities and their specific management systems are being incorporated.

Demonstration plots are usually small plots situated in a benchmark site. The role of the demonstration plot is to show a result of an application of some kind of management practice. The larger area of the benchmark site shows the actual current situation. People viewing the benchmark and demonstration plots can make their own deductions.

The use of demonstration plots in benchmark sites was therefore also needed in the application of this study.

1.11 Aims of this study

The aims of the study were to:

- identify the type of species and structure of the most important woody vegetation contributing to bush thickening in the study area;
- determine the extent of bush thickening to serve as baseline data for long term monitoring and management projects and
- Contribute to the awareness, education and training of land users and agriculturists as part of the LandCare initiative.

To achieve these specific aims listed above the following strategies were used by the Research group of the Pothcefstroom University for Christian Higher Education:

i) Educate and assist in the training of the technicians, extension officers, managers, team members and land users in different rangeland management systems.

ii) Advise in bush control practices, rangeland management, stocking density and carrying capacity.

iii) Show the benefits of resting the rangeland by the use of benchmark sites.

iv) Advise the communities responsibility of their resources and how to manage it sustainable.

v) Assistance in the monitoring and of interpretation of the data collected and data analysis.

vi) Assist in the application and standardisation of survey methods.

The chapters that will follow in the rest of the thesis are presented as follows:

Chapter 2: Study Area

Chapter 3: Material and Methods

Chapter 4: Results and Discussion

Chapter 5: Conclusion

Chapter 2

Study area

2.1 Rangeland management systems

As mentioned in the previous chapter, two types of rangeland management systems were identified for this study. The first is known as the Communal managed system and the second as the Morafe Ranch system. Anim and Van Schalkwyk (1996) refer to Communal managed rangelands as "Non-property" and Morafe Ranches as "Common property". Misconceptions in the terms have given rise to various disputes. These two systems were broadly discussed in Chapter 1 under section 1.8.

The use of exclosure plots erected inside benchmark sites at all the study sites will aid as illustration to the benefit of resting the rangeland. The exact layout and construction of benchmark sites will be discussed further in Chapter 3.

Improvement systems applied to the two rangeland management systems by means of several projects are financed through the LandCare programme of the National Department of Agriculture, Conservation and Tourism. The LandCare project was only implemented during 2000. At the moment, the entire infrastructure, such as fencing and chemicals for bush eradication is still provided by the Government through the LandCare program.

2.2 Study area description

The North West Province is 123 370 km² and the sixth largest province of South Africa (Hoffman & Ashwell, 2001) (see Figure 2.1). This province is sub-divided in three principal regions namely the Eastern-, Central- and Western regions in total there are 28 magisterial districts in the three regions (Mangold & Kalule-Sabiti, 2002). The study was conducted in the Western region of the Northwest Province, in

Figure 2.1: The location of the North West Province in South Africa.

the three magisterial districts of Kudumane, Taung and Ganyesa (see Figure 1.2, Chapter 1).

According to Hoffman *et al* (1999) the North West Province is described as having 57 % arid areas and 43 % semi-arid areas. This makes this area very susceptible to rangeland degradation.

This region is classified as part of the savanna biome and falls in the Kalahari Thornveld (veld type 16) (Acocks, 1988). According to Acocks (1988) it is subdivided into the Kalahari Thornveld Proper and the Vryburg Shrub Bushveld. Figure 2.2 illustrates the basic vegetation types found in the North West Province. All five the study areas fall in the Kalahari thornveld and shrub bushveld. Typical woody vegetation of this area includes *Acacia erioloba, A. hebeclada, Boscia albitrunca, Grewia flava, Lycium hirsutum* and *Rhigozum trichototum.*

This area has well defined seasons with little to no frost (Smit, 2000). Seeing that the study area has hot temperatures and low rainfall, it can be accepted that the rangelands consist of generally sweet veld. The soil type of the study area provides that the vegetation can recover very fast after sufficient rain.

2.2.1 Process for study site selection

The need for monitoring the success of a rangeland improvement project is not just important to science but vital for all land users and managers. The National Department of Agriculture identified the need for such research to form part of the LandCare program. The researchers had to establish and implement long term monitoring systems to evaluate the management project for one of the objectives of the LandCare program is to improve the management systems.

The LandCare meetings for the North West Province's Western region were held at Armoedsvlakte near Vryburg on an *ad hoc* basis. The meetings were attended by the Agricultural District Center managers (ADC managers), agricultural extension

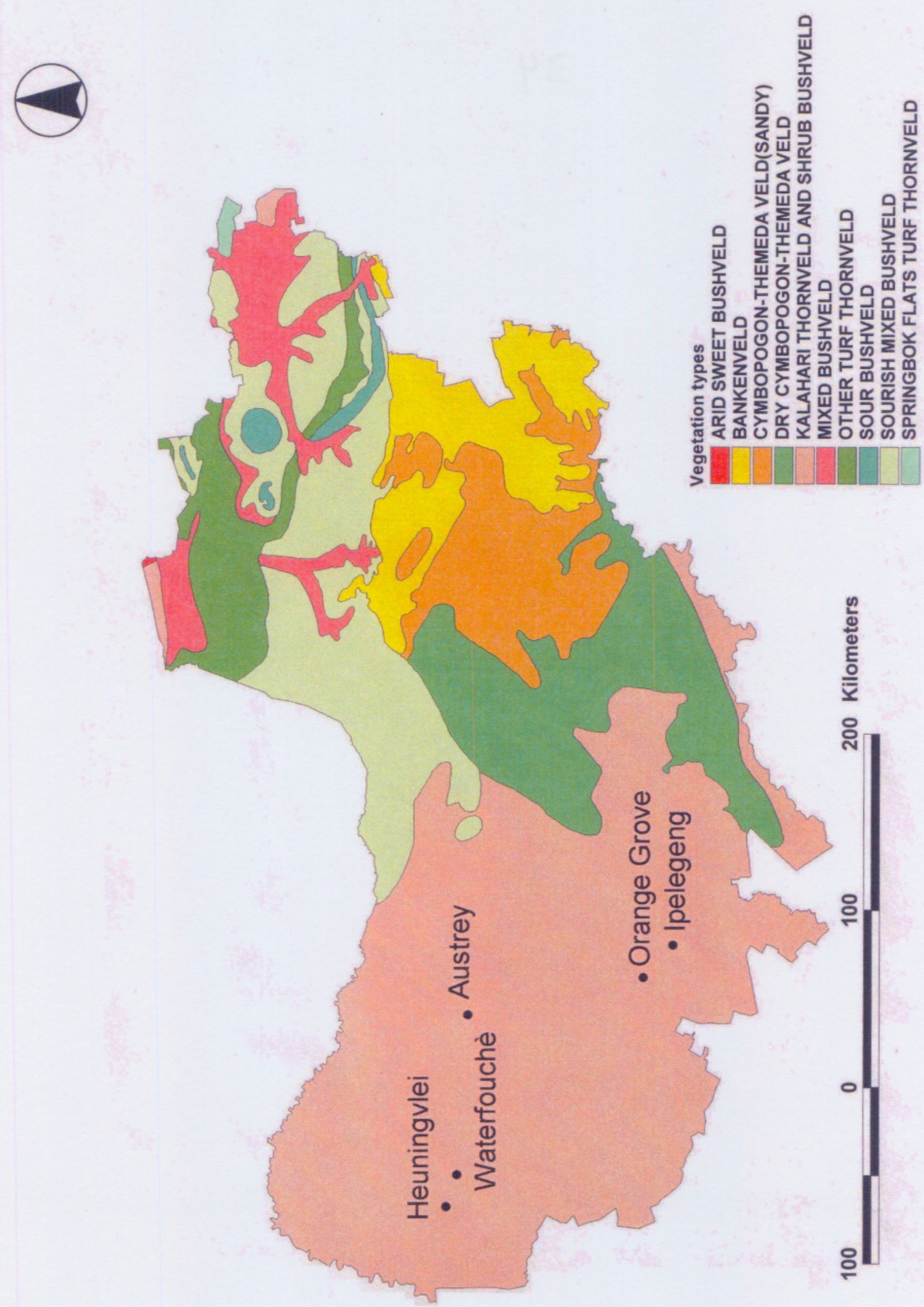

Figure 2.2: The broad vegetation classification of the North West Province and the location of the study area.

officers, technicians and specialists. The projects were discussed in detail to inform all participating stakeholders. Different study sites were identified in collaboration with the ADC managers, extension officers, technicians and farmers. An exclosure of 110 x 20 m or 50 x 50 m was erected at selected benchmark sites. The benchmark site represented the vegetation type of the area. The amount of benchmark sites set aside in each vegetation type will be discussed later in this Chapter. The benchmark sites was chosen by the project funding body and not by the researchers.

The exclosure plots were fenced to exclude any grazing by livestock. These plots would serve as a demonstration to illustrate the effect of resting on the rangeland condition. Where possible, the benchmark sites were selected on a gradient from good to poor rangeland conditions. This selection was however very subjective and carried out by the extension officers and land users of the local communities. The selection of the benchmark sites were mainly done according to distances from the watering points in order to get a range of different conditional states. The herbaceous component in the exclosure was grazed during the winter.

Each district were the study was carried out had both Morafe and Communal ranch management systems. The type of sampling methods and procedures were carefully planned in collaboration with the ADC managers, technicians, extension officers and the community. In January 2001 visits to the different sites where conducted which contributed to the first awareness objectives of the study.

Vegetation sampling were conducted during April 2001, the second sampling was done in December 2001 and the third in May 2002. Community participation was encouraged to promote awareness, training in surveying techniques and education in species identification during sampling procedures.

The three magisterial districts in the Western region of the North West Province, where this project was carried out, are subdivided into three Agricultural Development Centres (ADC's) each. The Ganyesa magisterial district is subdivided into the Ganyesa-, Pomfret- and Vryburg ADC, the Kudumane magisterial district into the Heuningvlei-, Glenred- and Seoding ADC and the Taung magisterial district into the Taung North-, South- and Central ADC.

Agricultural Development Centres are further divided into smaller Field Service Units or FSU's. The benchmark sites of this study, were situated at the following FSU's:

Ganyesa magisterial district

- Pomfret ADC
  - Driefontein FSU: Water-Fouché
- Ganyesa ADC
  - Tlagameng FSU: Austrey

Kudumane magisterial district

- Heuningvlei ADC
  - Heuningvlei FSU: Heuningvlei

Taung magisterial district

- Taung North
  - Moretele FSU: Orange Grove
- Taung Central
  - Ipelegeng FSU: Ipelegeng

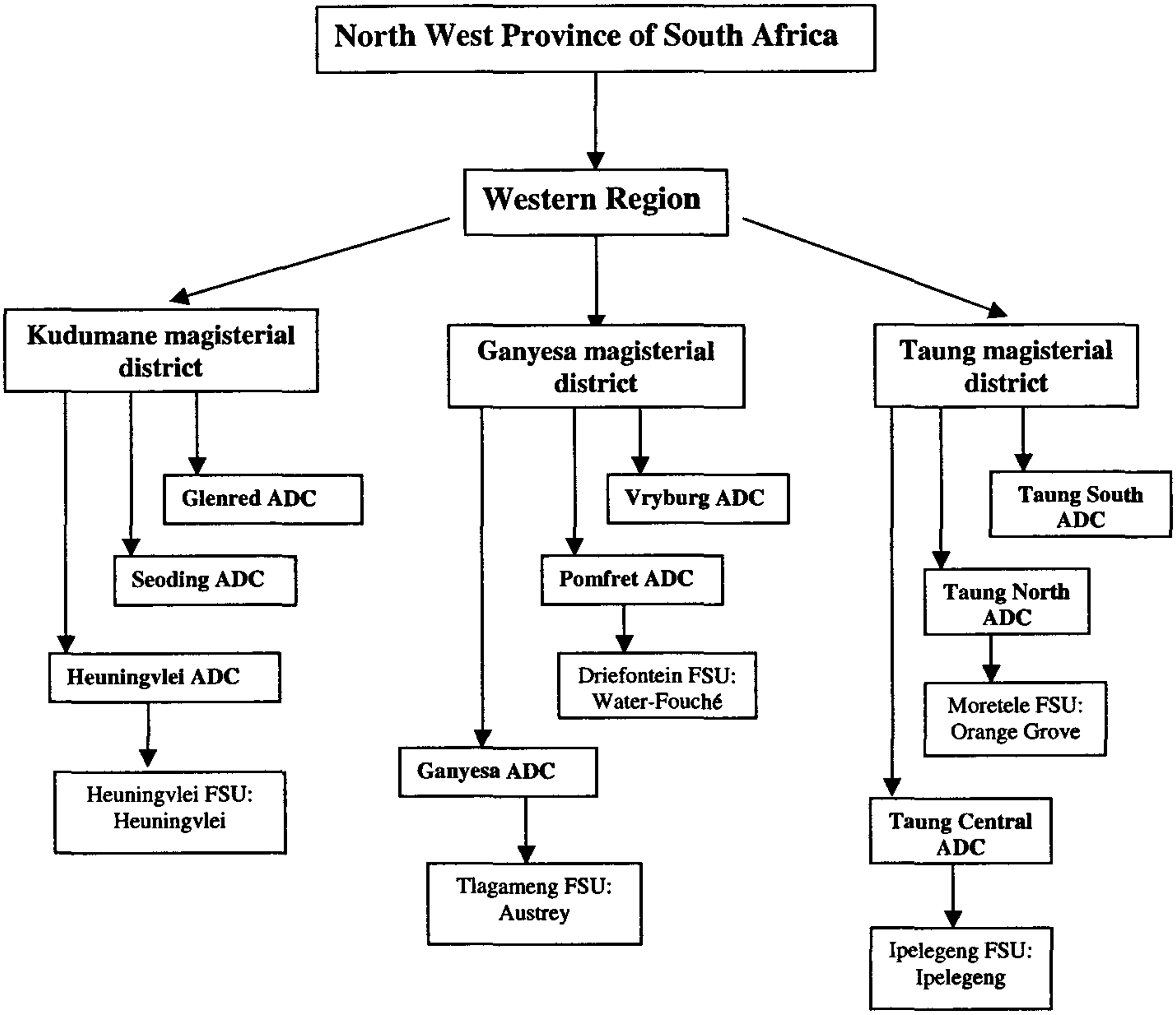

Figure 2.3: The diagrammatic representation of the division of the benchmark sites into different Agricultural Development Centres (ADC's) and Field Service Units (FSU's).

2.2.2 General characteristics of the study area

The most important abiotic characteristics found to influence the vegetation dynamics in the study area where soil and climate. Climate can be divided into primary and secondary factors, which determine the kind of weather that is going to persist in a particular region. The three primary factors determining weather are:

(1) the latitude of the site;

(2) the situation of the site in terms of the sea (is the site situated more to the East where wetter climates persists or is the site situated more to the West where dryer climates occur) and;

(3) the height above sea level (the higher the site is situated the colder the temperature).

Secondary factors are more confined to the general characteristics of the earth surface at the site, for example (1) soil type, (2) water, (3) rain, (4) snow and ice. The vegetation cover and topography, such as the situation in terms of hills, ridges and mountains also is an important factor determining vegetation composition (Smit, 2000).

Smit (2000) argues that the broad classification of Acocks is insufficient to determine the potential of a site and also to develop sustainable management programs for a given area. It is important to know what occurs at a specific site to determine the kind of management needed for the site.

The word "Kalahari" is derived from the Setswana word "Kgalagadi" meaning, "always dry" (Smit, 2000). The Kalahari is known to have a non-sustainable water supply and is characterised by extremely dry years (Smit, 2000). The main water source in this region are pans that collect water during the rainy season but due to the fast evaporation in that area, soon dry up (Smit, 2000; White, 1993). The regional rainfall isopleths of the North West Province are indicated in Figure 2.4. Part of the study area (Heuningvlei and Water-Fouché) fall in the 300mm – 400mm per annum rainfall isopleth where as the other part (Austrey, Orange Grove and Ipelegeng) fall in the 400mm – 500mm per annum rainfall isopleth according to the map supplied by the National Department of Agriculture.

Water is the main limiting factor for the vegetative production of any arid or semi-arid area (Snyman & Fouché, 1991). The drainage of the area is mainly along the Molopo-, Kuruman-, Harts- and Vaal River systems. Some springs and branches of the rivers also help with the drainage of the area. The Taung dam is one of the largest

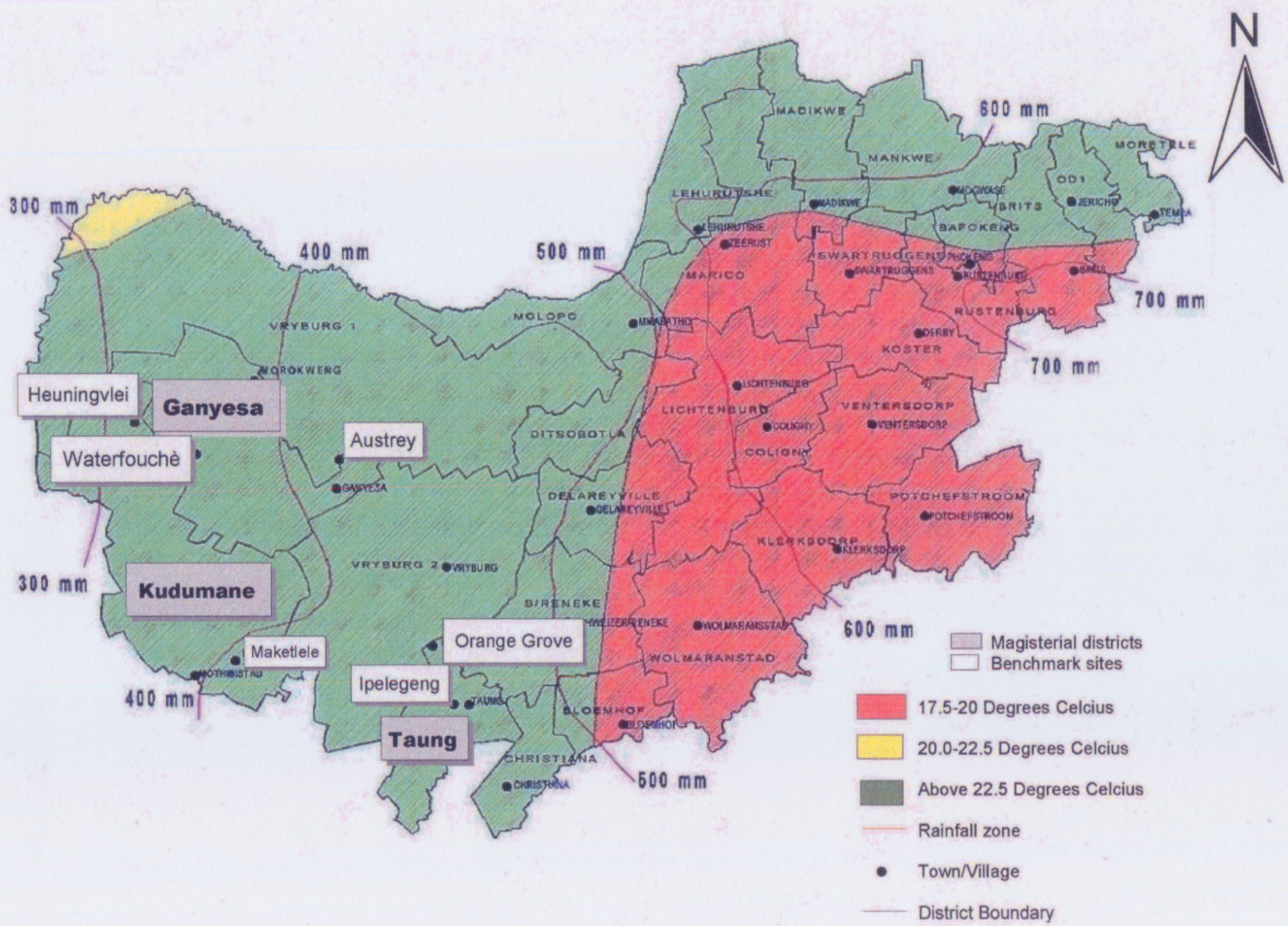

Figure 2.4: The regional average rainfall patterns and temperatures of the North West Province and the location of the study sites in each isopleth.

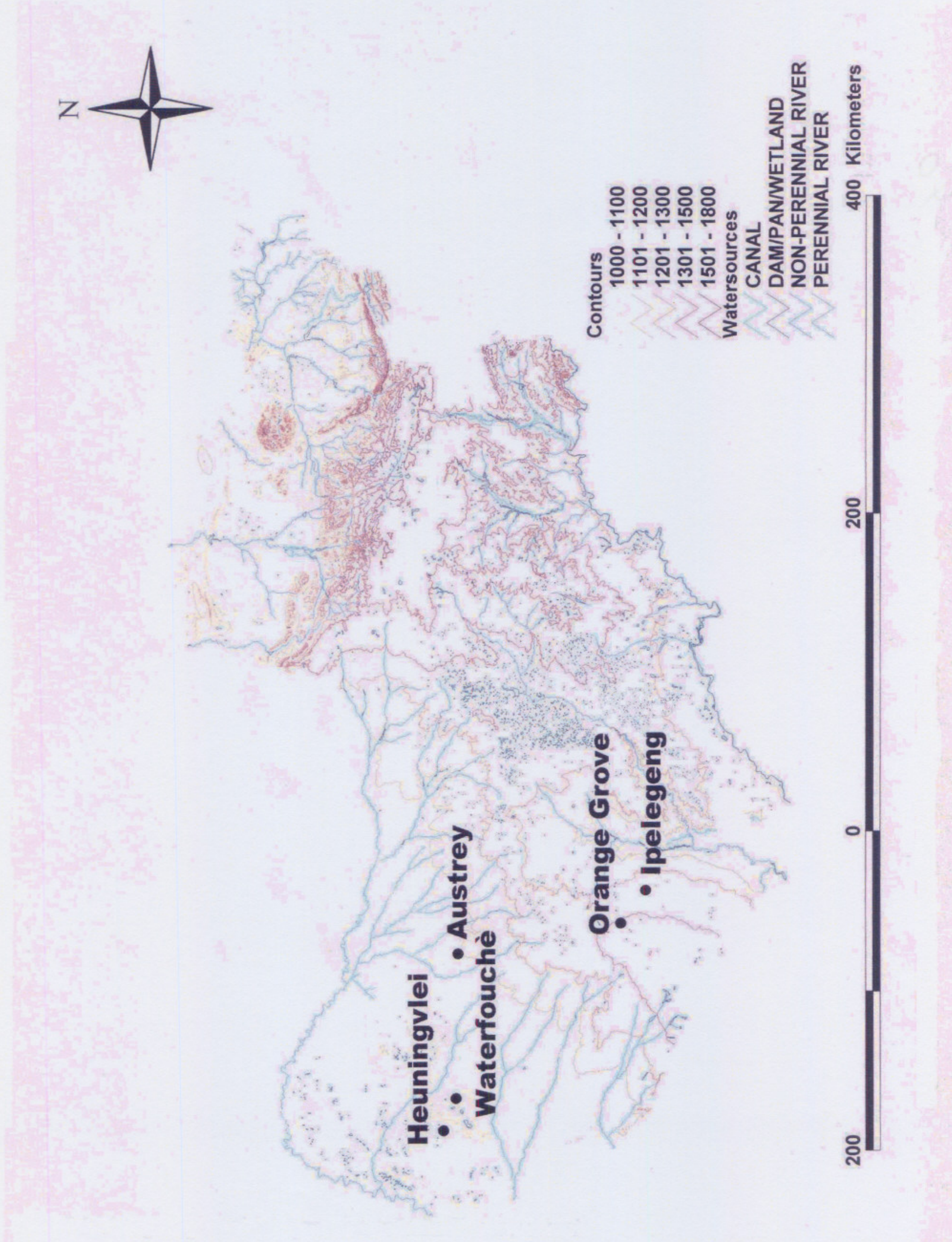

Figure 2.5: The topography and drainage of the North West Province and the location of the study sites.

water bodies in the area (Smit, 2000). The drainage and the topography of the North West Province are illustrated in Figure 2.5. The runoff of the precipitation is less than 1 % in the western region of the North West Province. This means that this area rely heavily on groundwater resources for the primary vegetative production. Due to the low rainfall and the lack of surface water, this area can be described as a semi-arid area with sufficient drainage. The amount of rainfall increases from West to East. Only the South Eastern side of the Kalahari can be described as an area with sufficient water (Smit, 2000). That is where the Ipelegeng study area is situated.

Changes in the rainfall pattern and the change into a more arid type of climate may contribute to the land degradation process, as a result of the scarcity of water over the long term. The temperature has also risen over the last ten to twenty years, mainly as a result of the so-called "greenhouse effect" (Hoffman *et.al.*, 1999).

The Kalahari starts north of the Orange River and continues northwards into Botswana and Namibia. It is a relatively flat, sand covered, semi-desert type of area. The red dunes in the North are one of the characteristics people think of when they hear the word "Kalahari" (Smit, 2000).

The sand deposits of the soil can be up to 20 to 30 meters deep and are deposited on a limestone rock table. Sand may not be the best growth medium for plants, but it does have the necessary potential to absorb and retain moisture (Smit, 2000). This moisture is usually retained in the upper six meters of the soil (Smit, 2000). Sandy soils have a relatively low nutritional status (Smit, 2000). Figure 2.4 illustrates the geology of the North West Province and Figure 2.6 the average soil depth of this Province. The Water-Fouché, Heuningvlei and Austrey study areas are situated on sand, whereas the Orange Grove and Ipelegeng study areas are situated on dolomite (Figure 2.7). The soil depths at the Water-Fouché and Austrey study areas are deeper than 750 millimetres (> 750mm), whereas the depths of the soil in the Orange Grove and Ipelegeng study areas are of less than 450 millimetres (< 450mm) and the Heuningvlei study area varies between 450mm – 750mm.

The soil of the Kalahari is not homogenous. Some soils have minimal development and are usually shallow on hard or degraded rock. Loam is usually present in this

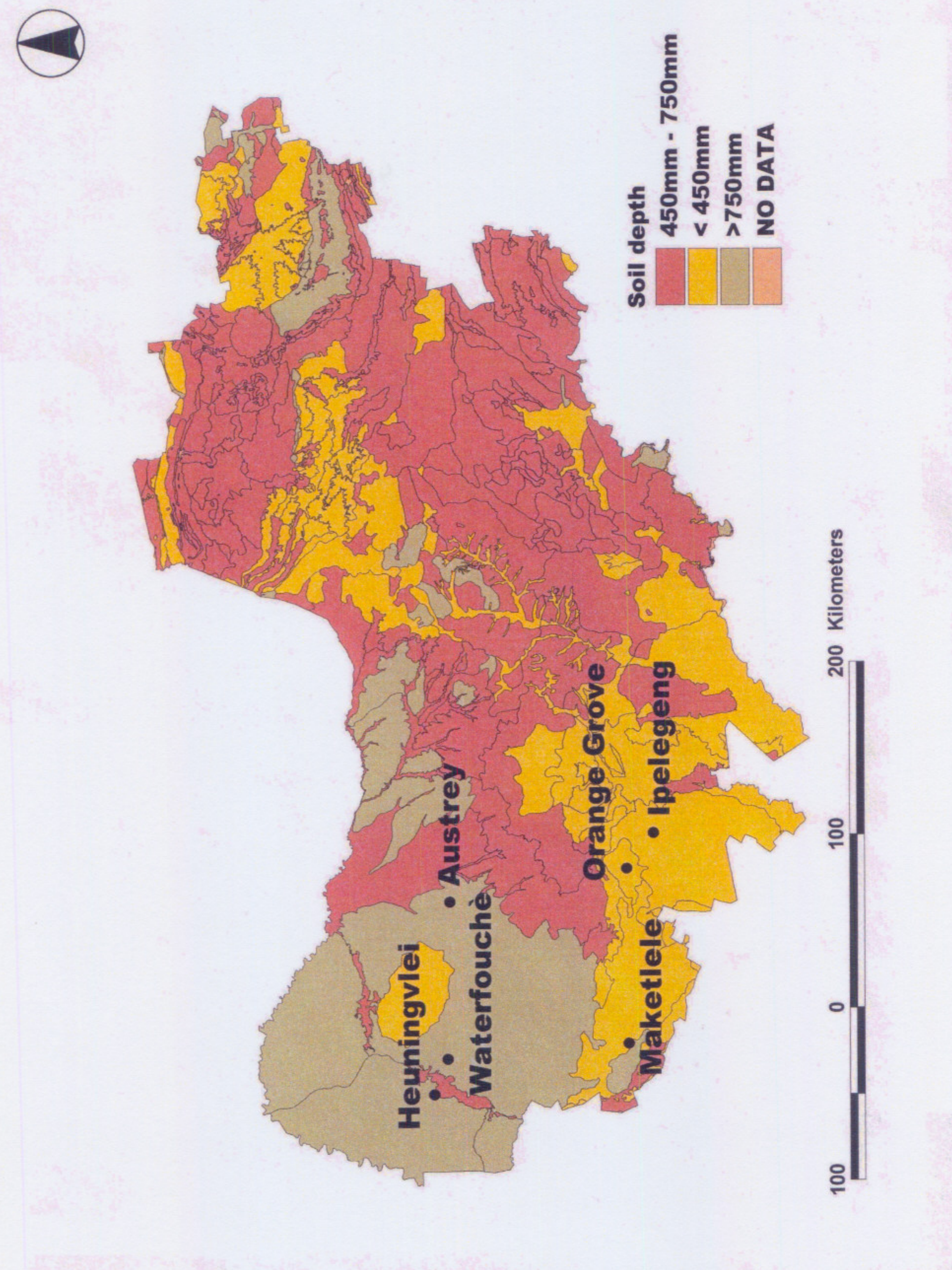

Figure 2.6: The average soil depth of the soil in the North West Province and the location of the study sites.

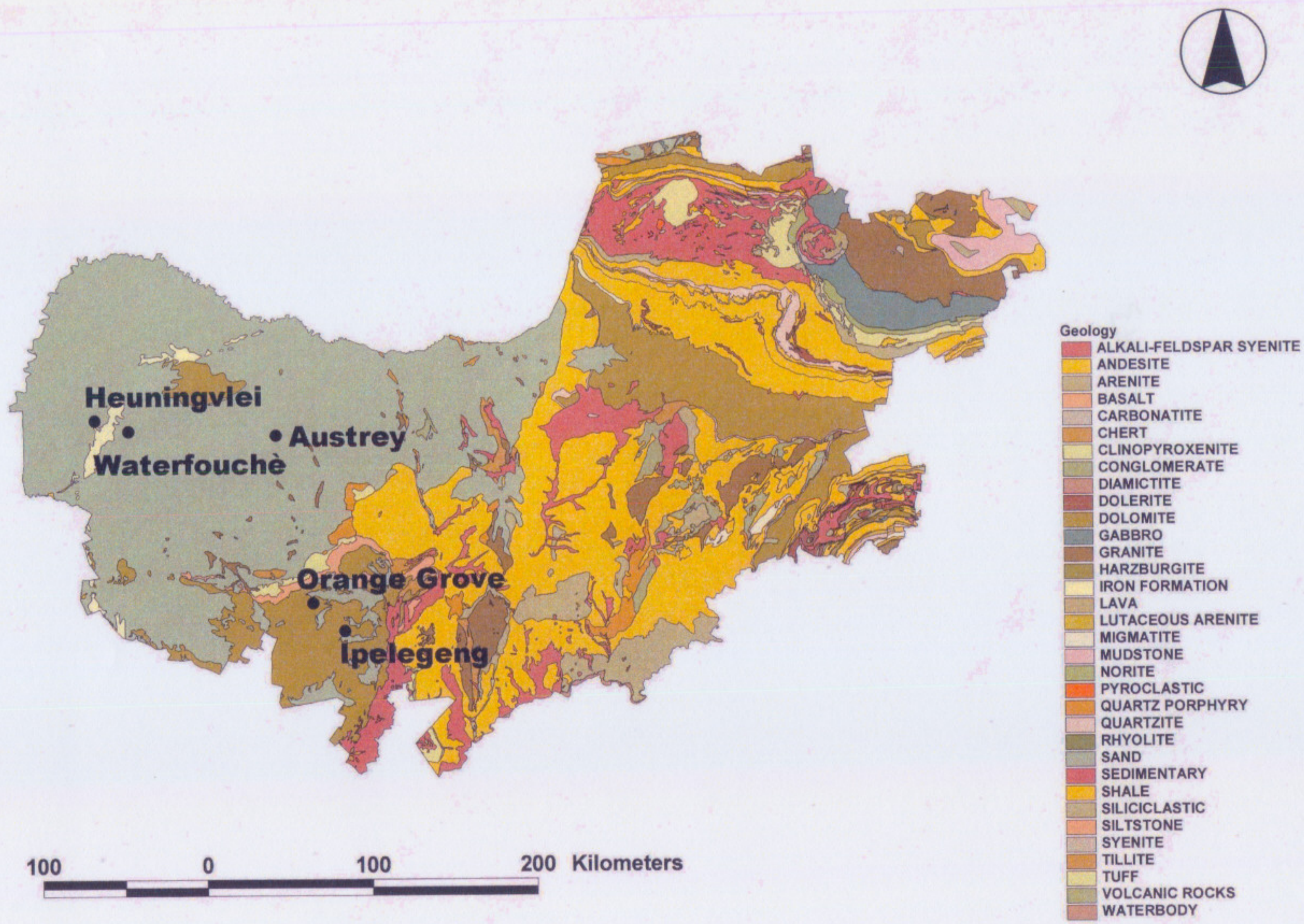

Figure 2.7: The geological composition of the North West Province and the location of each study site.

soil. The rest of the sites consist of red and yellow sandy soils. The soil has an alkaline quality due to the low rainfall (Smit, 2000). The average height above sea level of the Kalahari area is between 900 to 1200 meters (Smit, 2000). Most of the Kalahari consists of plains with a low relief form.

2.2.3 Study site description

2.2.3.1 Ganyesa magisterial district

In this district, two study sites occurred. The sites included Austrey site, which is an example of communal grazing system in the Ganyesa magisterial district site and the Water-Fouché which is an example of the Morafe Ranch system.

i) Location of study sites

The location of the two study sites in the Ganyesa magisterial district are given in Table 2.1.

Table 2.1: The location and type of management system of the Austrey and Water-Fouché benchmark sites situated in the Ganyesa magisterial district.

District	Site	Lat.	Long.	Management system
Ganyesa	Austrey	26°27'52"	24°10'35"	Communal grazing
	Water-Fouché	26°25'59"	23°28'59"	Morafe Ranch

<u>Austrey study site</u>

The Austrey study site is situated 80 km from Vryburg on the Toska road. The extension officer for this region is Mr. Kenneth Makwati, who assisted in all the vegetation surveys from April 2001 to May 2002.

The Austrey study site has four benchmark sites of which only three (Austrey 1, 2 and 4) were surveyed in April 2001. The reason for conducting the surveys this way was as a result of poor time management that resulted in a time constraint. All the sites were however surveyed during the second and third sampling periods in December 2001 and May 2001.

The Austrey benchmark sites has 110 m x 20 m exclosure plots which is not grazed by large herbivores except for some time in winter.

Water-Fouché study site

The Water-Fouché study site is situated near Morokweng, approximately 120 km from Vryburg. The extension officer for this region is Mr. Gert Namelang.

This study site has six benchmarks of 110 m x 20 m exclosure plots. The benchmark sites with exclosure were established in April 2001.

Only the Water-Fouché 1 benchmark were surveyed during April 2001 for that was the only benchmark with an exclosure at that time. Benchmarks one to six were surveyed during December 2001 and May 2002. Further reasons will be discussed in Chapter 4 and 5

ii) Rainfall for the Ganyesa magisterial district

The rainfall information for the Austrey study site was obtained from the Bryngwyn weather station which is situated 6.21 km East North East of the Austrey study site. The rainfall data for the Water – Fouché study site was measured at the Morokweng weather station and will be discussed later. The average long term rainfall measured at the Bryngwyn weather station over a 28 year period is 453 mm per annum (Figure 2.8). According to the long term rainfall data the wettest months of the year are from January to March. June, July and August are the driest months with a very low rainfall. The start of the growing season in September is characterised with an average of 12.3 mm rain (Figure 2.8).

Months that received well above average rainfall for the given time of year were November 2000 (122 mm), December 2000 (112.5 mm) and April 2001 (107 mm). The good rains in April 2001 could have had a significant impact on the seed germination of the woody vegetation (Figure 2.8). December 2001 (139.5 mm) and January 2002 (260.5 mm) were the two months for the second growth season that received well above average rainfall (Figure 2.8).

The average long term temperature for this site is 22.5°C.

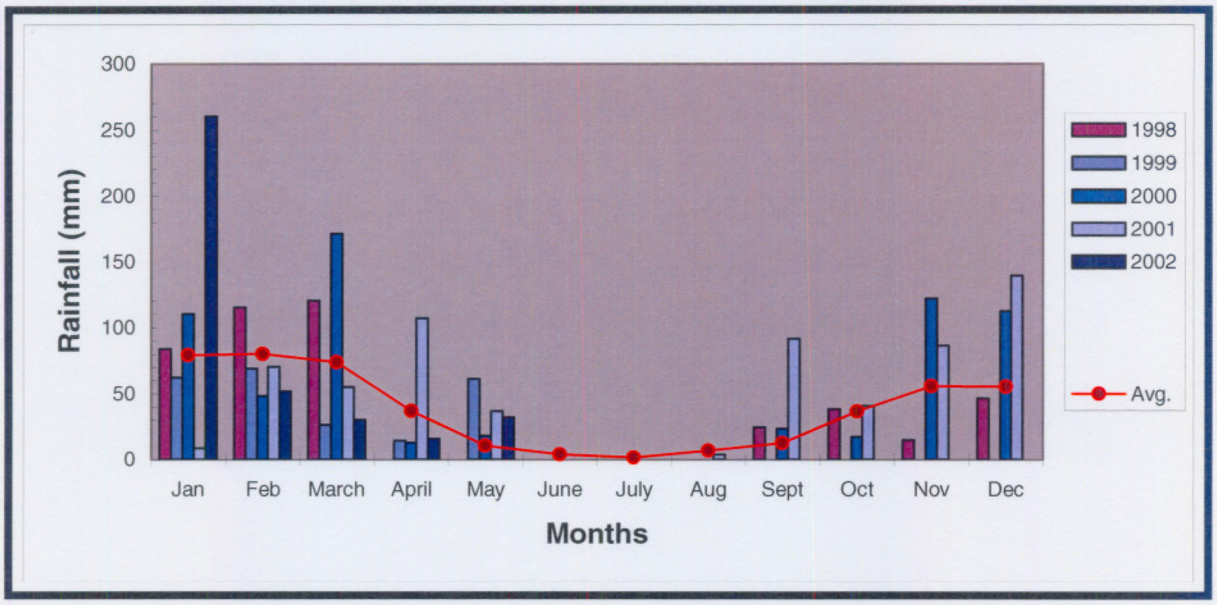

Figure 2.8: The average long term rainfall (mm) and the monthly rainfall (mm) from January 1998 to June 2002 as measured by the Bryngwyn weather station.

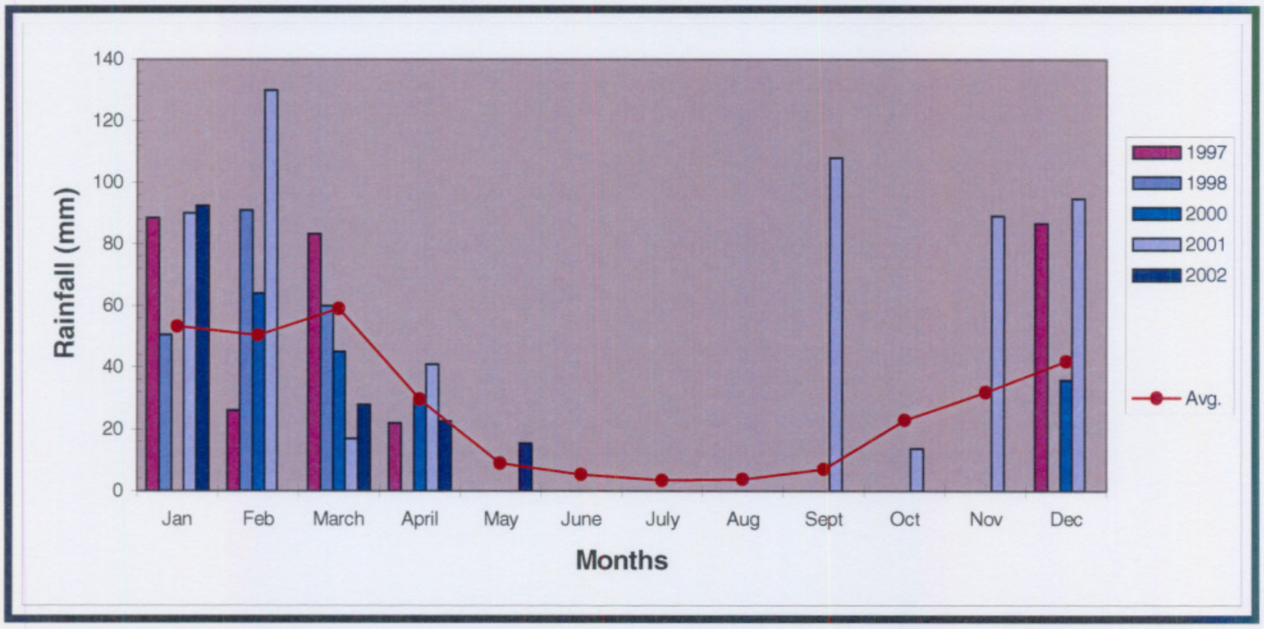

Figure 2.9: The average long term rainfall (mm) and the monthly rainfall (mm) from January 1997 to June 2002 as measured by the Morokweng Police weather station.

The Morokweng Police station weather station is situated 46.2 km East of the Water-Fouché benchmark site. In Figure 2.9 the average long term monthly rainfall calculated over a 28 year period is illustrated together with the monthly rainfall from January 1997 to June 2002. The total average long term rainfall for this region is 318 mm per annum. This is 135 mm less than at the Austrey study site. The months that should have the highest rainfall according to the long term statistics is January (53.3 mm) and March (58.9 mm).

The short term rainfall monitoring has been neglected at times but the following deductions can still be made. February 2000 (64 mm), March 2000 (45 mm) and April 2000 (30 mm) had sufficient rain for seedling germination and establishment. But this will be discussed in Chapter 4.

In September 2001 a record rainfall of 108 mm occurred. The area received rain every month from September until January 2002. Some rain fell during March (28 mm) and April (22.6 mm).

The average long term temperature for this region is 22.5°C.

iii) Soil and geology

Both the Austrey and Water –Fouché study sites are situated on deep sandy soil with a depth of more than 750 mm deep (Smit, 2000). The soil is a red-yellow apedal, well-drained soil with a clay content of less than 15 % and of the Hutton or Clovelley landforms. The geology is aelian sand of the recent age with few outcrops of tertiary Kalahari beds in the riverbeds (Smit, 2000).

iv) Topography

The Austrey and Water-Fouché study sites are relatively flat. Eighty per cent (80 %) of the surface of the area have a slope of less than eight per cent. The Austrey site is situated 1200 meter above sea level and the Water-Fouché site 1100 meters above sea level.

v) Vegetation

The whole study area is situated in the savanna biome (Rutherford & Westfall, 1994) in the Kalahari thorn veld (Acokcs, 1988). The Austrey study site is situated in the *Acacia erioloba – Acantosicyyos naudinalus – Dichrostachys cinerea* flats on the brim of the *Acacia mellifera - Rhigozum trichotomum – Stipagrostis uniplumes* sand plains (Smit, 2000). The Water-Fouché study site is situated in the *Acacia mellifera - Rhigozum trichotomum – Stipagrostis uniplumis* sand plains (Smit, 2000).

The vegetation at the Austrey site is characterised by *Acacia erioloba, Acacia mellifera, Acacia hebeclada, Grewia flava, Tarchonanthus camphoratus, Terminalia sericea* and *Ziziphus mucronata.*

The Water-Fouché study site is characterised by *Acacia haematoxylon, Grewia flava* and *Rhigozum brevispinosum.* This site also have two distinguishable vegetation types that will be discussed further in Chapter 4.

vi) Management

Austrey study site

The Austrey area is 5200 ha in size. A four camp grazing system was introduced by the LandCare program and the camps are 450 – 500 ha in size. The recommended grazing capacity is 12 ha/LSU and was communicated by the Provincial Department of Agriculture for the Western region. This is only an estimated figure by the extension officer. The community tries to keep the stocking rate at 14 – 16 ha/LSU.

The Austrey 1 study site is visually the most degraded of all four sites that were surveyed. The Austrey 2 study site seemed to be in a better condition than Austrey 1 and Austrey 4 has the best rangeland condition of all the sites. According to this information good management practises can be proposed and will be discussed later.

The community of the Austrey site has established a cattle committee that regulates the number of cattle on the ranch as part of the implementation of a rangeland management system of the LandCare program.

The theft of cattle and fencing material is a problem in the Austrey communal management system. Donkeys also seem to be in abundance in this area. The owners of the donkeys usually sell them if the grazing committee asks them to, but it is usually to their neighbour. The impact the donkeys have on the rangeland is thus not prevented.

Water-Fouché study site

The benchmark sites were selected on a gradient away from the cattle posts (i.e. more degraded near the cattle posts and under utilised further from the water points at the cattle posts). This gradient was not gradual but it was evident in the state of the vegetation that the sites near the cattle posts seemed to be overgrazed and in a more degraded state than the sites further away from water. Most of the farmers were born on this Morafe Ranch and do not experience theft or donkey problems.

A four camp grazing system is implemented where a 600 ha camp is divided in four. Not more than 60 head of cattle is allowed in a camp. A grazing capacity of 10 ha per LSU applied to the site.

2.2.3.2 Kudumane magisterial district

i) Location of study site

Only one study site occurred in this magisterial district. The site was located near Heuningvlei and is an example of the Morafe Ranch management system and the geographical location of the site is depicted in Table 2.2.

Table 2.2: The location of the Heuningvlei study site in the Kudumane magisterial district.

District	Site	Lat.	Long.	Management system
Kudumane	Heuningvlei	26°17'20"	23°10'53"	Morafe Ranch

Heuningvlei is situated 105 km West-Southwest of Morokweng and 120 km North of Hotazel. The Morafe Ranch is a further two hours travel on a two track dirt road. The benchmark sites were selected by the agriculturist, the extension officers and the farmers of the range. The sites were randomly selected and did not show certain conditional stages.

The person serving the duties of extension officer of Heuningvlei is Mr. Marcus Ndlapo.

The exclosure plot are 110m x 20m in size due to the structure of woody species and was only erected after the April 2001 surveys. There were three sites surveyed but only during December 2001 and May 2002.

ii) Rainfall for the Kudumane magisterial district

The weather station is situated at the Severn Police station, 45.31 km South West of the Heuningvlei study site. The monthly average long term rainfall and the monthly rainfall from January 1998 to June 2002 is depicted in Figure 2.10. The average long term rainfall of this weather station as calculated over a period of 29 years is 307 mm per annum. This area receives approximately the same amount of rain as the Water-Fouché study site (Morokweng Police station weather station). The highest rainfall months, according to the long term statistics are January (58.1 mm), February (52.5 mm) and March (51.5 mm). Thunderstorms are experienced during December to April. The average long term temperature is 22.5°C (Smit, 2000).

The growing season of September 2000 started with an average rainfall, except for December 2000, which had 24.5 mm below average. January 2001 also received a very low rainfall of 10 mm. April 2001 had an above average rainfall of 134.5 mm (Figure 2.10).

September and October 2001 were average rainfall months whereas November 2001 received an above average rainfall of 101.5 mm. January 2002 (84.5 mm) and February 2002 (91 mm) had a higher rainfall than the previous year but March and April 2002 did not experience much rainfall.

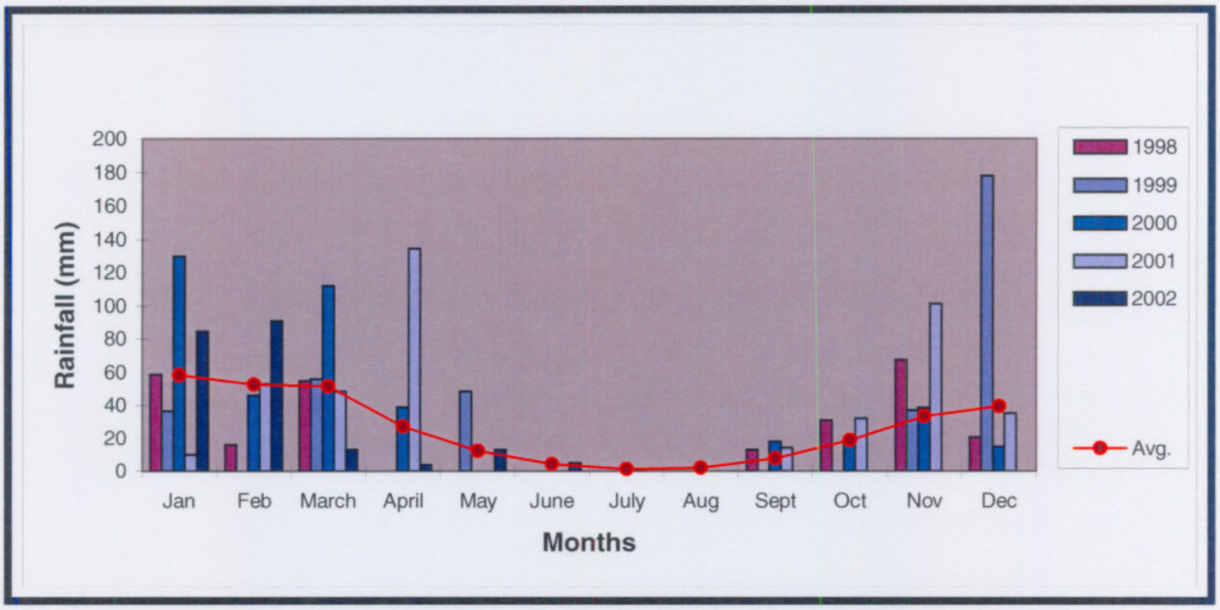

Figure 2. 11: The average long term rainfall (mm) and the monthly rainfall (mm) from January 1998 to June 2002 as measured by the Severn Police weather station.

iii) Soil and geology

Heuningvlei is situated on deep red-yellow apedale, well-drained sandy soil. Hutton or Clovelly form, near iron formations is also present in this area. The soil depth varies between 450 mm to 750 mm and consists of wavy to flat sand flats (Smit, 2000).

The geology of the area consists of red aeolian sand of recent age, a few outcrops of tertiary Kalahari beds (surface of limestone and silcrete) with jaspillte and baned iron stone of the Asbestos Hill formation of the Griquatown Group are also found (see Figure 2.6) (Mangold & Kalule – Sabiti, 2002).

iv) Topography

The Morafe Ranch is nestled between iron and asbestos containing hills. The ranch surface is very flat with a maximum incline of not more than five degrees.

v) Vegetation

Heuningvlei is situated in the *Acacia mellifera - Rhigozum trichotomum – Stipagrostis uniplumes* sand plains on the brink of the *Tarchonanthus camphoratus – Rhus tridactyla – Diheteropogon amplectens* vegetation of the Kuruman hills (Smit,2000).

According to Smit (2000) the typical woody species that could occur in this area is *Acacia mellifera, Acacia erioloba, Grewia flava, Ehretia rigida, Acacia hebeclada, Ziziphus mucronata* and *Lycium hirsutum.*

vi) Management

The Heuningvlei Morafe Ranch is divided in 1200 ha sub-units and is subdivided in 300 ha camps. A four camp system is implemented and two farmers have to share four camps. There can be more farmers on four camps but they have to stay in the norm with the cattle numbers. One camp in the system is rested for one year (see land tenure, Chapter 1).

There may be 120 head of cattle for the whole system thus 60 head for each farmer. Heuningvlei is currently still under the norm according to Mr. Ndlapo. A norm of 10 ha per LSU is thus applied. Only 12 farmers are part of this Morafe Ranch system. No sheep or goats are kept on the Heuningvlei Morafe Ranch. The farmers have a five year contract after which they have to reapply for the land. The farmers are all positive about the LandCare project and objectives of this study.

2.2.3.3 Taung magisterial district

i) Location of study sites

The separate locations of each study site in the Taung magisterial districts are depicted in Table 2.3.

Table 2.3: The precise location of the Orange Grove and Ipelegeng study sites in the Taung magisterial district.

District	Site	Lat.	Long.	Management system
Taung	Orange Grove	27°16'59''	24°27'00''	Morafe Ranch
	Ipelegeng	27°32'31''	24°46'48''	Communal grazing

Ipelegeng study site

At the Ipelegeng study site a communal grazing system is followed. Ipelegeng is situated 3 km West of Taung. The extension officer is Mr. M.J. Gabanakgosi who was in charge of the logistics of this site and had to assist in the co-ordination of sampling.

There are two benchmark sites on the Ipelegeng study site agreed upon. The exclosure plots was not yet erected when the first surveys were conducted. Experimental data plot of 100 m x 30 m was surveyed.

Ipelegeng consists of sandy red soils and the grazing areas in the range of 30 ha in size. A grazing capacity of 10 ha per LSU is applied to the Ipelegeng site.

Orange Grove study site

At this study site the Morafe Ranch system is applied. The area is situated approximately 70 km South of Vryburg in the Taung district. This site can only be reached by dirt road going through two villages. The exclosure plots are 50 m x 50 m in size due to the homogenous vegetation type in this area.

This study site differs from the other study sites due to the very shallow soil (10 cm to 30 cm) with underlying rock.

ii) Rainfall for the Taung magisterial district

Figure 2.11 illustrate the monthly long term rainfall and the monthly short term rainfall from January 1998 to June 2002. The climatic information was obtained from the Taung weather station. The Taung weather station is situated 4.68 km west of the Ipelegeng study site. The long term rainfall was calculated for the past 19 years. The total average long term rainfall is 440.4 mm per annum which is the highest of all the study sites. As a result of this higher rainfall, the vegetation at the Ipelegeng study site seems to be denser than at the other study sites.

The months that received the highest average rainfall according to the long term rainfall statistics is February (85.6 mm) though March seems to have received the most rainfall over the past five years.

The first growing season to be discussed started in September 2000. Though each month received some rain most was on average or below average. March 2001 did not receive any rain. The second growing season of this study started in September 2001 with high rainfall for most of the season except for December 2001 (35 mm) and April 2002 (4 mm).

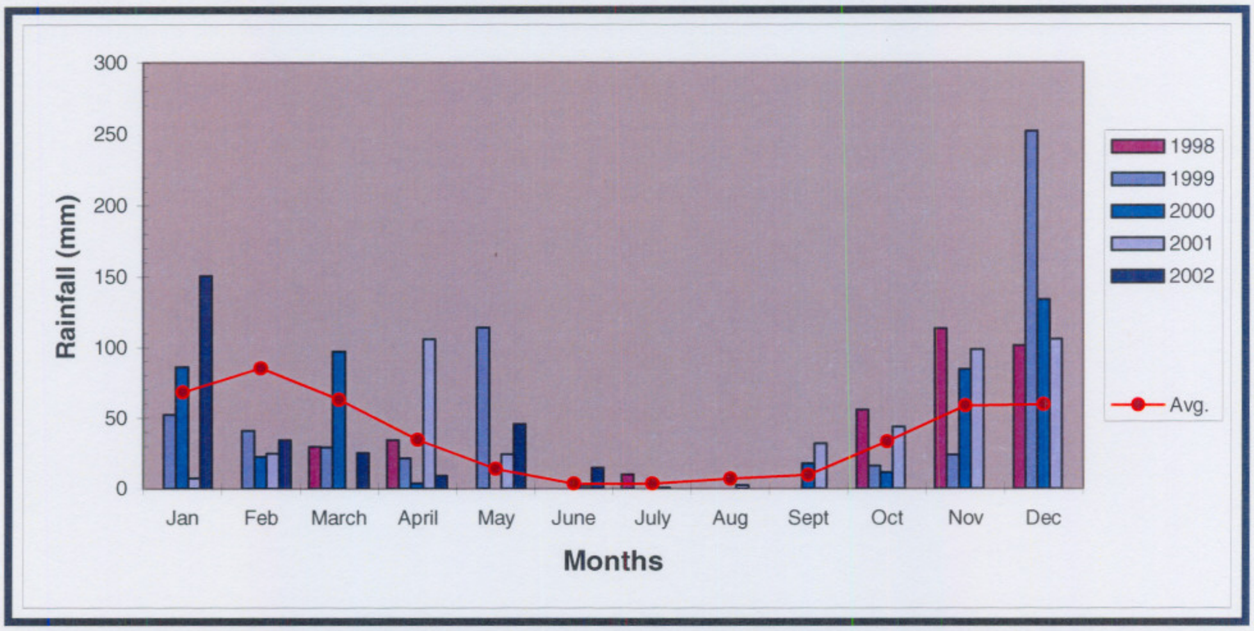

Figure 2.11: The average long term rainfall (mm) and the monthly rainfall (mm) from January 1998 to June 2002 as measured by the Taung weather station.

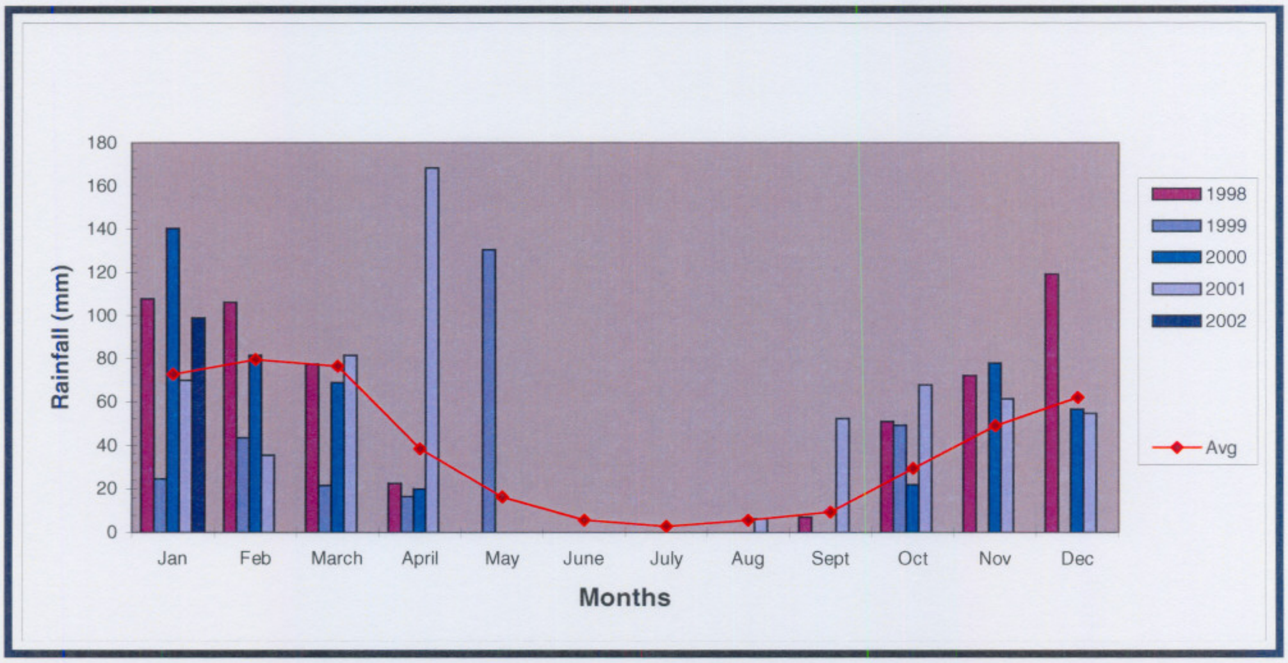

Figure 2.12: The average long term rainfall (mm) and the average monthly rainfall (mm) from January 1998 to June 2002 as measured by the Madrid weather station.

The rainfall data obtained from the Madrid weather station which is situated 7.43 km North East of Orange Grove is illustrated in Figure 2.12. A total average rainfall of 447.7 mm for this area was calculated from the data received of the past 29 years and is depicted in Figure 2.12 together with the monthly rainfall from January 1998 to June 2002.

The wettest months over the 29 year period were February (79.5 mm) and March (76.4 mm).

The first rain for the September 2000 to June 2001 growing season only fell in October 2000 (22.1 mm). November 2000 (78.1 mm) received above average rainfall while December 2000 (56.6 mm) received below average rainfall. April 2001 (168.4 mm) received a record rainfall for the past five years. The September 2001 to June 2002 growing season started with 52.5 mm for September but the rainfall ceased after the 99 mm received in January 2002.

iii) Soil and geology

Orange Grove is situated on red-yellow apedal well-drained soil with less than 15 % clay. The soil layer varies between 100mm – 200mm. The soil depth was observed when the soil samples were taken. The geology of this site is fine and course-grained dolomite, chert and dolomitic limestone with prominent inter-bedded chert, limestone and banded ironstone. Red to pink coloured wind-blown sand with surface limestone of the tertiary to recent age also occurs.

Ipelegeng is situated on an area with Glenrosa and/or Mispah soil. Lime is present throughout the area. The geology of Ipelegeng consists of a surface of limestone of the tertiary to recent age and fine and course grained dolomite, chert, limestone and banded ironstone.

iv) Topography

Orange Grove is slightly elevated and is situated as a plain on the ridges of the Ghaap plato. The site does not seem to have any slope of any nature and is situated 1400 meter above sea level (Smit, 2000).

Ipelegeng has a slight slope of no more than 3 degrees and is remarkably flat. This site is situated 1300 meter above sea level.

v) Vegetation

This part of the study site is broadly defined as the Kalahari thornveld veld type 16 (Acocks, 1988). Orange Grove is part of the *Acacia mellifera – Acacia tortillis – Tarchonanthus camphoratus* vegetation of the Ghaap plato (Smit, 2000).

Ipelegeng is situated in the *Acacia erioloba – Acacia tortillis – Eragrostis rigidior* rocky plains (Smit, 2000).

vi) Management

The objective of the residents of Orange Grove for applying for the LandCare project was the improvement of the rangeland for better grazing and to improve the condition of the livestock. The agriculturist, farmers and extension officers selected the benchmark sites. As already mentioned is Orange Grove a Morafe Ranch system. There are 22 farmers who is allowed 10 head of cattle each, and each farmer has his own area in the ranch that totals 3050ha.

The largest problem of the Ipelegeng study site is that it is located too close to Taung and other settlements. The gates and fences are stolen and people not belonging to the Ipelegeng community allow their cattle to over utilise the grazing and contribute to land degradation. The problem of theft is very common to the people of this communal grazing system. Figure 2.13 illustrates the problem of over utilisation at the Ipelegeng study site.

Figure 2.13: Bush thickening as a result of land degradation at the Ipelegeng study site. Take note of all the *Acacia hebeclada* and the lack of herbaceous vegetation cover.

Chapter 3

Materials and Methods

3.1 Introduction

LandCare projects were submitted by communities through the ADC managers of their region. The Provincial Department of Agriculture, Conservation and Environment then identified study sites in collaboration with the ADC managers for these particular projects (Chapter 2). It was agreed that the School of Environmental Sciences of Potchefstroom University for Christian Higher Education would assist in the monitoring of these areas where benchmark sites were established (see Aims of this study, Chapter 1). The study sites were chosen during December 2000 and January 2001.

3.2 Benchmark sites

Benchmark sites that represented a certain vegetation and soil type were chosen as demonstration sites. Exclosure plots of 50 x 50 meters in the grassland and 20 x 110 meters in savanna vegetation types were erected inside the benchmark sites. Vegetation composition and structure inside and outside the exclosure was similar and representative of the area.

The difference between exclosure and enclosure plots according to Weaver and Clements (1938) is merely in the purpose of the closure. If animals or insects are to be kept out of an appointed area to measure the reaction of vegetation without the element that was excluded, this area is called an exclosure. If the effect of, for example, grazing needs to be tested grazing animals would be put inside a designated area and this will be called an enclosure. All grazing paddocks can thus be referred to as enclosures but the term is mainly used for academic applications.

Goat proof fencing was used for the exclosure plots. Goat proof fencing consists of 16 strands of barbed wire and the wires are thus very close to each other (see Figure 3.1).

Exclosure plots were only grazed in winter so that the ideal capability of the rangeland is represented within the fences of the exclosure. The exclosure plot was used to demonstrate the changes in rangeland condition that could occur if the area is still grazed (outside) or rested (inside) the exclosure, according to a certain management strategy. Fifteen of these exclosure plots were used in this study. Four is located at Austrey, six at Water-Fouché, three at Heuningvlei, one at Orange Grove and one at Ipelegeng. The location of these sites is discussed in Chapter 2. The sites were chosen by the funding body of this project and do not show any pattern regarding rainfall or any other environmental factors except management.

Figure 3.1: Goat proof fencing and exclosure at the Orange Grove benchmark site, used to keep the herbivores out of the exclosure plot during the resting period.

3.3 Vegetation sampling methods

Vegetation sampling was carried out inside as well as outside the exclosure plots inside the benchmark site area. The size of the sampling plots on the inside and outside of the exclosure plot where the same. That is to say that if for example two 100 meter vegetation samples were taken inside the exclosure two 100 meter samples were taken outside the exclosure as well.

The belt transect sampling technique was used to monitor the woody structure and composition of the woody species in the benchmark sites. The belt transect sampling technique is determined from the line intercept sampling method. Most literature only describe the line intercept method (Kent & Coker, 1994). The sole purpose of the line intercept method in the past was to monitor dense, shrub dominated vegetation (Barbour *et al*, 1987). It is said that this method is just as effective as the quadrat methods but less time consuming (Barbour *et al*, 1987). The logic behind this method is that a quadrat in a single dimension is a line. The total decimal factor of the species canopy cover multiplied by 100, equals the percentage cover for each species on the line (Barbour *et al*, 1987). The disadvantages of the line intercept method are that the density and frequency measurements are lost because there is no area involved in a straight line. Frequency can be measured if the line is broken into segments (Barbour *et al*, 1987). To implement density to the line intercept method, quadrats surveys can be done along the line. The vegetation cover is then measured along the line and density or frequency is noted in the quadrats (Barbour *et al*, 1987). This method of quadrat measurement along a straight line is very effective when herbaceous vegetation is measured but does not quite represent the vegetation composition of an area with more woody vegetation. If the quadrats run continuously along the line, like the method used for this project, the method can be called a belt transect, strip transect or line strip method (Barbour *et al*, 1987). Sutherland (1996) define the belt transect method as a vegetation sample consisting of frame quadrats of a required size laid contiguously along the length of a transect. Though this method is mostly applied in forest type of vegetation, it is quite applicable to the savanna biome and woody species (bush) composition surveys (Barbour *et al*, 1987).

The method of setting up a belt transect vegetation sample is most thoroughly described by Weaver and Clements (1938) who states that a belt transect consists of a strip of vegetation of uniform width and of a substantial length. The width is largely determined by the type of vegetation (Weaver and Clements , 1938) and should be just large enough to depict the true vegetation structure of the sample area.

Most commonly, transect methods are used to determine changes in vegetation along an environmental gradient or contrary habitats (Sutherland, 1996). Not only can difference in vegetation be determined, but also the overall density and cover values of each species present in the survey area (Sutherland, 1996). The length of the transect depends on the purpose of the survey. If the change in vegetation over a gradient are to be measured, the transect can be up to several kilometres (called gradsects) but in the case of this study vegetation composition and cover were to be measured samples were kept to 100 meters (Sutherland, 1996).

The cover, as a function of height above the ground, can also be recorded by this method. Differences between vegetation types can be deducted from bar graphs drawn from the data obtained in this manner (Barbour *et al*, 1987).

The woody (bush) composition was measured by using a rope or measuring tape that was placed five meters from the fence from each side inside the exclosure plots. A two meter measuring stick was held horizontally to the rope to cover the area of the belt transect so that each woody component rooted in a strip of two meters on each side of the rope was noted. Figure 3.2 show surveyors using this technique. A belt of four meters wide and 100 meters long was sampled in the 20 x 110 meter benchmark sites and five belts of 10 meters were recorded in the 50 x 50 meter exclosure plots.

Floristic data was obtained by this survey technique. Floristic data, according to Kent and Coker (1994) can be described as where the species present in the study are identified and their presence/absence or abundance is recorded. In this study each species were identified and their presence and abundance was recorded.

The species composition and density were measured, as well as the canopy height in different height classes. The height classes are as follows:

- less than 0.5 m,
- 0.5 m - 1 m,
- 1m – 2 m,
- 2 m – 3 m,
- 3 m – 4 m and
- taller than 4 m.

The species composition, is the type of species that form the particular community at a specific location as a result of the external factors contributing to that specific environment. The density of a species as used in this study can be defined as the number of individuals per unit area in relation to other species occurring at the given site (Kent & Coker, 1994).

All the data could now be used to describe the structure of the woody vegetation, inside and outside the exclosure in the benchmark sites (Figure 3.2). Information on the influence of the trees on other vegetation could also be determined according to Weaver and Clements (1938). This study focuses only on the woody vegetation but herbaceous vegetation was also measured in a separate study that occurred parallel in time and place with this study. The latter study was conducted by Marina van Heerden (M Env. Sci, 2002).

Figure 3.2: The belt transect method being applied measuring the density, structure and composition at different height classes of the woody species in a four meter wide belt at the Heuningvlei study site.

A disadvantage that occurred during the surveys was that, not all the sampling was carried out by the same person at every sampling point or over the three periods. The research group had to depend on the assistance of land users and extension officers in the identified study areas. This may lead to problems in consistence of the identification of the seedlings of some woody species as well as the monitoring of the structure from one survey period to the next. Another mistake that was easily made is the number of individuals that were counted in a single bush clump. Some woody species, such as *Grewia flava,* form a multi-stemmed clump. Some samplers recorded the whole bush clump as one individual, while others counted every single stem of the clump. This resulted to many problems when the data was analysed, as a species such as *Grewia flava* could have been recorded in one year as a single (1) individual plant, and in the following year as e.g. eighteen separate individual plants. This resulted in an increase of 17 individuals from one year to the next, which is highly unlikely. Other species that were recorded the same way and which could have resulted in difficulties when quantifying the number of individuals when analysing the data, included species such as *Acacia hebeclada, Tarchonanthus camphoratus, Boscia albitrunca* and *Acacia haematoxylon.*

3.4 Soil sampling methods

Three soil samples were taken randomly inside and three samples outside the exclosure plot in the benchmark site. All three samples of, for example, the inside where placed in one soil sample bag and mixed so that a representative sample of the exclosure plot was obtained. Soil samples were taken objectively. One 25 cm top soil sample was taken under a tree or shrub, one 25 cm sample on a patch of bare soil and one sample amongst the grass. The three soil samples of 25 cm each were placed in the same bag and mixed. This soil sample was mainly in the topsoil due to the sandy A-horizon being up to two meters deep, except for the Orange Grove site, were the underlying layer was characterised by a hard limestone layer.

Each sample was marked with a permanent marker on the outside of the soil sample bag. The site number, location and whether the sample was taken inside or outside the exclosure, was also noted on a piece of paper placed inside the sample bags.

The following analysis was conducted on the soil samples. The pH was determined by the 1:2.5 water extraction test. The Phosphorus (P) content of the soil was determined by the Bray-I test. Calcium (Ca), Magnesium (Mg), Potassium (K), Sodium (Na) and the cation exchange coefficient (CEC) was determined with the Ammonium Acetate 1M test at a pH of seven. A water paste test was used to determine the conductivity of the soil (resistance measured in ohm). A hydrometer was used to determine three textures classes, namely the sand, clay and silt fractions of the soil. All of these factors influence the growth of plants. If the pH for example is too high or too low certain plants can not grow in that particular soil (Salisbury & Ross, 1992). Some elements such as Ca, P, Mg, K and Na are macro-elements and are vital for the survival of plants. It is also important for plants that these elements are available in sufficient concentrations. Microelements on the other hand such as copper (Cu) and iron (Fe) may be toxic to plants if present in high quantities. The CEC determine the speed of ion transfer from the soil to the plant. If the CEC of the soil is high ions will be transferred more readily to the plants than in the case of a low CEC (Salisbury & Ross, 1992).

3.5 Data analysis

It was already mentioned that each woody species in the sample area of the belt transect, was recorded at the different structure classes to determine the abundance (%), density and structure. In Table 3.1 an example of the total numbers of species (density and percentage of the total) as well as the number per height class per species can be seen. The surveys took place over a period of two years. The vegetation was sampled three times. The first samples took place in April 2001, the second sampling during December 2001 and the third sampling took place during May 2002.

Table 3.1: An example of the calculations of the woody vegetation at the Austrey 4 study site outside the exclosure plot for the April 2001 surveys.

Species	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**Total:**	**%**
Acacia erioloba	5	3	0	0	8	8.2
Acacia hebeclada	0	1	0	0	1	1
Acacia karroo	0	0	0	2	2	2.1
Dichrostachys cinerea	0	1	1	1	3	3.1
Diospyros lycioides	21	24	14	0	59	60.8
Grewia flava	2	1	7	4	14	14.4
Lantana rugosum	2	0	0	0	2	2.1
Lycium hirsutum	3	0	0	0	3	3.1
Tarchonanthus camphoratus	0	0	4	1	5	5.2
Total number of individuals per structure class	33	30	26	8	97	
Percentage of total	34	30.9	26.8	8.2		100

The percentage abundance of each species are in green in the data Tables and only species that represented more than 5 % of the average occurrence of the woody species over the entire sampling period are taken into account in the in graphs in the discussion of the results (Chapter 4).

The tree equivalent (TE) per hectare per structure class were also calculated to obtain the density of the woody species per hectare. A single stemmed tree or woody species at the height of 1.5 m is equal to one tree equivalent (Smit, 1988; Teague & Trollope, 1981; Richter *et al,* 2001). An area that has a tree equivalent of 2500 or more in the Molopo Thornveld, Mixed Vaalbos Thornveld and the Eastern Grass Bushveld have a problem of bush encroachment (Richter *et al,* 2001). To calculate the tree equivalents, per height class the following method was used. Each structure class was multiplied with a specific, predetermined height factor (see table 3.2) and then multiplied with 12.5

to determine the TE per hectare (Smit, 1988; Smit, 2002). The sampling plots may have differed in shape but the total surveying surface was equal (see Appendix II for the calculations of the predetermined factors).

Table 3.2: The height class factors used for the calculation of tree equivalents (TE).

Height class in meters	Factor
<0.5	0.33
0.5 – 1	0.67
1 – 2	1.0
2 – 3	1.67
3 – 4	2.33
>4	3.0

It was very important to calculate the TE for especially the lower classes (0.5m and 0.5-1m), as this would give an indication of the number of seedlings and individuals that could contribute to the problem of bush thickening and bush encroachment over time (Smit, 1988). The degree of tree density could also have an important influence on the grass cover with regard to the shading effect and competition for soil moisture which indicates the condition of the rangeland (Smit, 1988).

Chapter 4

Results and discussion

4.1 Introduction

The results of this study will be presented per magisterial district i.e. Ganyesa, Kudumane and Taung. The data of the two land use systems will not be compared to each other and between the districts, since the sites are located in different rainfall regions and the sites are of different ages. The exclosures were also not erected at the same time.

At each benchmark site, the woody vegetation will be discussed for both inside and outside the exclosure according to the vegetation structure (different height classes) and composition as sampled during April 2001, December 2001 and May 2002. The dominant species will be depicted in a bar chart. (A complete species list can be found in Appendix I). The tree equivalents per hectare (TE/ha) per height class as well as the total TE/ha for each benchmark for the total study period will be given. The results of soil sample analysis for each benchmark site will also be discussed.

As mentioned previously, the data of the study were monitored over a two year period and will therefore only serve as baseline data for on-going long term monitoring studies. Changes in composition and structure can only be determined over a longer time-span. However, it must be emphasised, that most of the benchmark sites will serve as demonstration plots. Due to the short period of this study, only certain tendencies with regard to changes in the structure and composition of the woody species occurring in the benchmark site, inside and outside the exclosure plots, and between sites in the same district, therefore be discussed at this stage.

4.2 Ganyesa magisterial district

4.2.1 Austrey study site

Four sites were selected representing different rangeland conditional states. The selection was carried out subjectively by agriculturists and land users, according to grass and tree species composition and other factors, the degree of degradation, the occurrence of bare ground and erosion, as well as the past grazing history of each benchmark. According to the subjective estimation by the agriculturists, extension officers and land users, the Austrey 1 benchmark site was characterised as the most degraded site, whilst the Austrey 4 benchmark the least degraded.

The benchmark exclosure plots were selected and erected during February 2001. The first surveys were carried out during April 2001. Due to a time constraint, only the Austrey 1, 2 and 4 benchmarks were surveyed during April 2001. During December 2001 and May 2002 all four the benchmarks were surveyed.

Woody vegetation

Austrey 1 benchmark site

Table 4.1 represent the total woody species composition in percentage frequency at the Austrey 1 benchmark site for April 2001, December 2001 and May 2002 accordingly. Only the woody species that had an abundance of, more than 5 % on average over the study period, both inside or outside the exclosure, were compared with each other and described (Figure 4.1). In Figure 4.2 the structure of the woody species at the different height classes at the Austrey 1 benchmark site for April 2001, December 2001 and May 2002 is presented. Tables 4.2 and 4.3 represent the number and percentage (%) of the total individual woody species per height class as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Austrey1 benchmark site for April 2001. The change in TE/ha per height class over the total three survey periods for inside and outside the exclosure plots are represented in Table 4.4 and Table 4.5.

Table 4.1: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Austrey 1 benchmark site over the three sampling periods (April 2001, December 2001 and May 2002), as well as the average percentage for each species.

	Apr-01		Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	**6.9**	**11.1**	**6.3**	**7.2**	**9.2**	**0.89**	**7.47**	**6.4**
Acacia hebeclada (Aca heb)	**4.5**	**2**	**7.3**	**5.9**	**7.28**	**1.19**	**6.36**	**3.03**
Acacia mellifera (Aca mel)	**4.5**	**10.4**	**6.3**	**10**	**7.28**	**8.61**	**6.03**	**9.67**
Acacia robusta (Aca rob)	**1.8**	**10.4**	**6.3**	**10.9**	**0**	**29.08**	**2.7**	**16.79**
Asparagus* spp. *(Asp. Spp)	**11**	**15**	**12.4**	**11.6**	**9.96**	**10.39**	**11.12**	**12.33**
Boscia albitrunca (Bos alb)	0.2	0.4	0	0	0	0	0.07	0.13
Dichrostachys cinerea (Dich cin)	1.6	0.7	1	0.6	1.15	0.89	1.25	0.73
Diospyros lycioides (Dios lyc)	1	0.7	0.5	0	0	0	0.5	0.16
Ehretia rigida (Ehr rig)	1.8	2	1.3	2.2	1.53	1.78	1.54	1.99
Grewia flava (Gre fla)	**11.2**	**12.4**	**10.1**	**23.4**	**11.88**	**7.42**	**11.06**	**14.41**
Grewia retinervis (Gre ret) (Identfied using Palgrave, 1977)	1.2	0	0	0	0	0	0.4	0
Lantana rugosum (Lant rug)	3.7	6.2	0	0	0	0	1.23	2.07
Lycium hirsutum (Lyc hir)	0.6	2.9	0	0	0	0	0.2	0.97
Maytenus heterophylla (May het)	**9.8**	**9.3**	**16.7**	**5.6**	**14.18**	**13.35**	**13.56**	**9.42**
Mundulea sericea (Mund ser)	**11.4**	**2.4**	**10.4**	**2.5**	**17.24**	**5.34**	**13.01**	**3.43**
Rhigozum brevispinosum (Rhig bre)	**7.5**	**7.1**	**7.8**	**10**	**7.66**	**10.98**	**7.65**	**9.36**
Rhus tenuinervis (Rhus ten)	2.8	4.6	5.3	4.4	2.68	2.37	3.59	3.79
Tarchonanthus camphoratus (Tarc camp)	0	1.8	0.5	2.2	1.53	1.78	0.68	1.93
Terminalia sericea (Term ser)	**18.7**	**0.4**	**7.3**	**3.4**	**8.43**	**5.64**	**11.48**	**3.15**
Ziziphus mucronata (Ziz muc)	0	0	0.3	0	0	0.3	0.1	0.1

Even in this table it becomes evident how the differences in interpretation of different plant growth forms influenced the consistency of the data. This feature will be discussed frequently throughout this chapter.

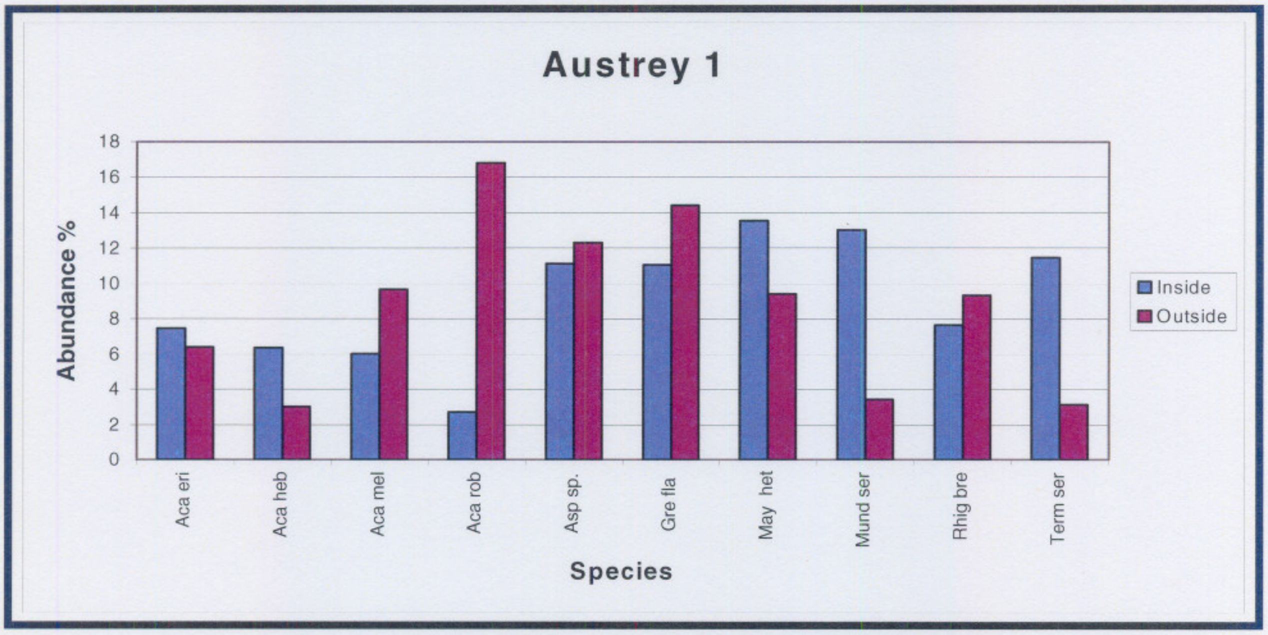

Figure 4.1: The average frequency of the woody vegetation whit an abundance of more than 5 % **inside** and **outside** the exclosure at the Austrey 1 benchmark site for all three the sample periods (April 2001, December 2001 and May 2002). (See Table 4.1 for species abbreviations)

Figure 4.2: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Austrey 1 benchmark site, for the sampling periods April 2001, December 2001 and May 2002.

The most dominant woody species inside and outside the exclosure at the Austrey 1 benchmark site was *Maytenus heterophylla* (13.56 % **inside**), whilst *Acacia robusta* (16.79 %), and *Grewia flava* (14.41 %) were the most abundant species **outside** the exclosure plot (Table 4.1 and Figure 4.1). The *Asparagus* species (11.12%), *Mundulea sericea* (13.61%) and *Acacia erioloba* (7.47%) all had an abundance of 10% abundance **inside** the exclosure. Other species that were present in more than 5 % abundance either inside or outside the exclosure included *A. erioloba* (7.47 % **inside** and 6.4 % **outside**), *Acacia hebeclada* (6.36 % inside), *Rhigozum brevispinosum* (7.65 % **inside** and 9.36 % **outside**), *Acacia mellifera* (6.03 % **inside** and 9.67 % **outside**) and *Terminalia sericea* (11.48 % **inside**) (Figure 4.1).

The dominant structure class for **inside** and **outside** the exclosure (Figure 4.2) was the less than 0.5 meter height class (60 %). The three woody species that contributed the most to this structure class during the April 2001 surveys were *M. heterophylla*, the *Asparagus* species and *T. sericea* **inside** the exclosure and *A. erioloba*, *A. robusta* and the *Asparagus* spp. **outside** the exclosure (Tables 4.3 and 4.4). During the December 2001 surveys *M. heterophylla*, the *Asparagus* species and *A. hebeclada* were the most abundant **inside** the exclosure plot while *A. robusta* and *G. flava* were the most abundant species **outside** the exclosure plot (Table 4.1).

Maytenus heterophylla, *A. erioloba* and *M. sericea* were the most abundant woody species in the less than 0.5 meter height class on the **inside** of the exclosure plot and *A. robusta*, *M. heterophylla* and *R. brevispinosum* on the **outside** of the exclosure plot during the May 2002 surveys (Table 4.1). The vegetation **inside** the exclosure plot at the less than 0.5 meter height class, has reduced with almost 15 % from April 2001 to May 2002. Available moisture and inter species competition may have been the most determining factor contributing to the reduction of the smaller woody species (Table 4.1).

The rapid decrease in the total abundance of *A. erioloba* **outside** the exclosure from April 2001 to the May 2002 surveys and the drastic increase in *A. robusta* in the May 2002 survey, could be ascribed to the possible incorrect identification of the seedlings of these two species as the surveys were done by different extension officers and land users (Table 4.1). The decrease in the number of *G. flava* on the **outside** of the exclosure from December 2001 to May 2002 may be due to the mistake of counting bush clumps as single stemmed individuals. The increase in leaves at the end of the growing season observed on the *G. flava* bushes, made the identification of individuals difficult, especially during the May 2002 surveys (Table 4.1).

The increase in the less than 0.5 meter height class of *M. heterophylla, M. sericea* and *T. sericea,* both **inside** and **outside** the exclosure (Table 4.1), could be ascribed to the increase of rainfall during the period of December 2001 to May 2002 (See Figure 2.7, Chapter 2 for rainfall).

The decrease in the total abundance of woody species in the **inside** of the exclosure, especially in the less than 0.5 meter height class could also be ascribed to the resting period of the rangeland, as well as the good rainfall received during the growing season. The resting and higher rainfall resulted in an increase in the density of the herbaceous layer, which could have outcompeted the small seedlings of the woody component.

Table 4.2: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Austrey 1 benchmark site **inside** the exclosure for April 2001.

Species	< 0.5 m	0.5–1 m	1 – 2 m	2 – 3 m	3 – 4 m	Total woody species	% abundance
Acacia erioloba	34	1				35	6.9
Acacia hebeclada	23					23	4.5
Acacia mellifera	11	6	4	2		23	4.5
Acacia robusta	9					9	1.8
Asparagus spp.	44	12				56	11
Boscia albitrunca	1					1	0.2
Dichrostachys cinerea	6			1	1	8	1.6
Diospyros lycioides	5					5	1
Ehretia rigida	7	1	1			9	1.8
Grewia retinervis	6					6	1.2
Grewia flava	4	7	38	8		57	11.2
Lantana rugozum	19					19	3.7
Maytenus heterophylla	48	2				50	9.8
Mundulea sericea	29	17	11	1		58	11.4
Rhigozum brevispinosum	33	5				38	7.5
Rhus tenuinervis	8	2	2	2		14	2.8
Lycium hirsutum	3					3	0.6
Terminalia sericea	36	3	56			95	18.7
Total woody species	326	56	112	14	1	509	
% abundance	64	11	22	2.8	0.2		
TE/ha	1344.75	469.00	1400.00	292.25	29.13		3535.13

Table 4.3: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Austrey 1 benchmark site **outside** the exclosure for April 2001.

Species	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia erioloba	47	2				1	50	11.1
Acacia hebeclada	6	3					9	2
Acacia mellifera	10	16	14	6	1		47	10.4
Acacia robusta	43	3				1	47	10.4
Asparagus spp.	41	27					68	15
Boscia albitrunca	1	1					2	0.4
Dichrostachys cinerea	1	1			1		3	0.7
Diospyros lycioides	2	1					3	0.7
Ehretia rigida	3		2	3	1		9	2
Grewia flava	13	18	21	4			56	12.4
Lantana rugosum	27	1					28	6.2
Maytenus heterophylla	40	2					42	9.3
Mundulea sericea	7	1	3				11	2.4
Rhigozum brevispinosum	25	4	2	2			33	7.1
Rhus tenuinervis	8	6	1	4	2		21	4.6
Lycium hirsutum	13						13	2.9
Tarchonanthus camphoratus			7	1			8	1.8
Terminalia sericea	1	1					2	0.4
Total woody species	288	87	50	20	5	2	452	
% abundance	63.7	19.2	11.1	4.4	1.1	0.4		
TE/ha	1188.00	728.63	625.00	417.50	145.63	75.00		3179.75

Table 4.4: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of April 2001, December 2001 and May 2002 at the Austrey 1 benchmark site **inside** the exclosure.

	Tree equivalents per height class					
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**3 - 4 m**	**Total**
April 2001	1344.75	469.00	1400.00	292.25	29.13	3535.13
December 2001	1320.00	167.50	500.00	313.13	0	2300.63
May 2002	540.38	594.63	525.00	313.13	58.25	2031.38

Table 4.5: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of April 2001, December 2001 and May 2002 at the Austrey 1 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
April 2001	1188.00	728.63	625.00	417.50	145.63	75.00	3179.75
December 2001	924.00	184.25	512.50	501.00	174.75	112.50	2409.00
May 2002	1027.13	242.88	337.50	501.00	174.75	75.00	2358.25

To determine the changes in the woody structure over the three sampling periods inside and outside of the exclosure at the benchmark site only the TE/ha per height class for the total species composition are discussed (Tables 4.4 and 4.5). Due to the problems of species identification and bush clump at individual plants monitoring, the contribution of each structure class per species to the total woody component at the benchmark site was only calculated for the first survey carried out in April 2001 (Table 4.2 and 4.3).

Maytenus heterophylla (48) and the *Asparagus* spp. (44) contributed the most to the less than 0.5 meter height class, inside exclosure at the Austrey 1 benchmark site of the total (64 %) in this structure class (Table 4.2). *Grewia flava* (38) and *Terminalia sericea* (56) contributed largely to the 1 – 2 meter height classes inside the exclosure (Table 4.2).

The *Asparagus* species (68) and *A. erioloba* (50) contributed the most to the total woody vegetation outside the exclosure (Table 4.3). *Acacia erioloba* (47), *Acacia robusta* (43) and the *Asparagus* spp. (41) were also the most dominant species in the dominant structure class of less than 0.5 meters, on the outside of the exclosure, for the April 2001 surveys (Table 4.3).

The total tree equivalents (TE) per hectare for the April 2001 survey were 3535.13 **inside** the exclosure (Table 4.4). A decline of 1234.5 TE/ha from April 2001 to December 2001 and a further decline of 269.25 TE/ha to May 2002 was observed (Table 4.4). This decline in total tree equivalents **inside** the exclosure of the benchmark at the Austrey 1 benchmark site could be due to the drastic decrease in woody vegetation in the less than 0.5 meter and 1 – 2 meter height classes, but only slight increase in the 0.5 – 1 meter and 2 - 3 meter height classes (Table 4.4). The total disappearance of woody vegetation in the 3 – 4 m during December 2001 and the reoccurrence of vegetation in that same height class during May 2001 can be attributed to the samplers concentrating too much on seedlings and not looking up (Table 4.4). It is also very possible to place the survey rope one pace (one meter) from the previous sampling position and that two large trees are excluded from the sample of December 2001 (Table 4.4).

Although not so drastic, similar decline in the TE/ha occurred **outside** the exclosure in the Austrey 1 benchmark site (Table 4.5). The TE/ha for the December 2001 surveys were all less than the TE/ha of the April 2001 surveys except for the values of the 2 – 3 meter as well as the 3 – 4 meter and the more than 4 meter structure classes (Table 4.5). Some of the shoots of the woody vegetation may have grown into the next structure class. The TE/ha for the 2 – 3 meter and the 3 – 4 meter height classes, on the **outside** of the exclosure remained unchanged for both the December 2001 and May 2002 surveys (Table 4.5). This could indicate that the surveys were done at precisely the same place for both of the surveys. The same surveyors might also have assisted in the surveys.

Maytenus heterophylla is considered as a less palatable species and the high abundance of this species, especially in the less than 0.5 meter height class could cause a serious problem in future. Thick stands of this species will not only cause bush thickening, but will also reduce the grazing capacity of the rangeland. *Grewia flava* on the other hand is a very palatable species and is greatly utilised by cattle if the grass is not available. The pods of *D. cinerea* are also utilised by goats and game but this species is known to invade degraded rangelands (Appendix I).

Austrey 2 benchmark site

Table 4.6 represents the total woody species composition in percentage frequency at the Austrey 2 benchmark site inside and outside the exclosure for April 2001, December 2001 and May 2002. The woody species that were represented, more than 5 % on average, either inside or outside the exclosure, were compared with each other and are shown in Figure 4.3. In Figure 4.4 the structure of the vegetation per height class at the Austrey 2 benchmark site for April 2001, December 2001 and May 2002 is presented. Table 4.7 and Table 4.8, represent the occurrence and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside and outside of the exclosure at the Austrey 2 benchmark site for April 2001. The TE/ha per height class and the total TE/ha for the whole survey period are represented (Tables 4.9 and 4.10).

Table 4.6: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Austrey 2 benchmark site over the three sampling periods (April 2001, December 2001 and May 2002), as well as the average percentage for each species.

	Apr-01		Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	**17.3**	**28.3**	**16.8**	**24.6**	**23.98**	**31.57**	**19.36**	**28.16**
Acacia hebeclada (Aca heb)	0	0.3	0	0.9	0.19	0.25	0.06	0.48
***Asparagus* spp (*Asp.* Spp.)**	**14.7**	**16.7**	**31.6**	**24.9**	**16.05**	**18.18**	**20.78**	**19.93**
Dichrostachys cinerea (Dich cin)	**3.8**	**6.7**	**4.9**	**7.5**	**5.22**	**4.55**	**4.64**	**6.25**
Diospyros lycioides (Dios lyc)	3	4.6	3.9	1.2	3.87	4.29	3.59	3.36
Ehretia rigida (Ehr rig)	1.1	0	1.6	0.3	0.97	0	1.22	0.1
Grewia flava (Gre fla)	**4.6**	**5.4**	**7.4**	**5**	**4.45**	**5.05**	**5.48**	**5.15**
Grewia retinervis (Gre ret)	0.8	0	0	0	0.19	0	0.33	0
Lantana rugosum (Lan rug)	1.1	0.5	0	0	0	0	0.37	0.17
Lycium hirsutum (Lyc hir)	0	3	5.9	0	0.19	0	1.93	1
Maytenus heterophylla (May het)	**37.8**	**12.4**	**10.7**	**2.8**	**32.5**	**20.96**	**27**	**12.05**
Mundulea sericea (Mund ser)	0	0.5	0	1.6	0	0	0	0.7
Rhigozum brevispinosum (Rhig bre)	**6.3**	**11.9**	**0**	**11.2**	**1.93**	**6.31**	**2.74**	**9.8**
Rhus tenuinervis (Rhus ten)	2.9	3.8	5.8	6.5	4.3	1.77	4.33	4.02
Tarchonanthus camphoratus (Tar cam)	0	0	0	0	0	0.25	0	0.08
Terminalia sericea (Ter ser)	**4.5**	**5.7**	**4.9**	**11.2**	**3.09**	**6.82**	**4.16**	**7.91**
Ziziphus mucronata (Ziz muc)	1.9	0.3	6.25	0.6	3.09	0	3.75	0.3
Ziziphus zeyherii (Ziz zey)	0	0	0.2	0	0	0	0.07	0

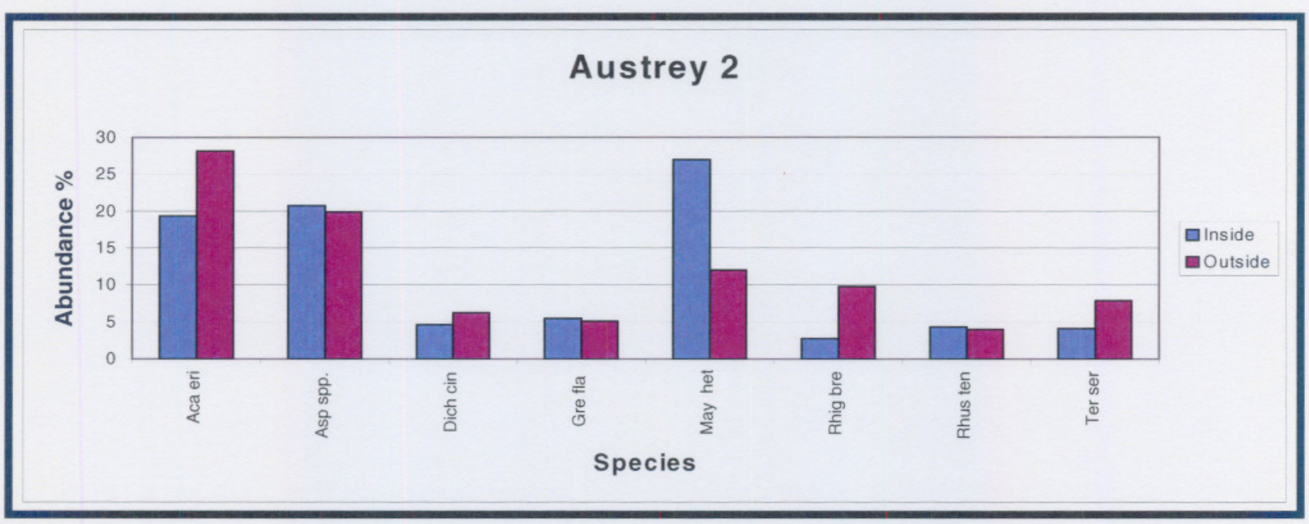

Figure 4.3: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the Austrey 2 benchmark site for the sample periods (April 2001, December 2001 and May 2002) (See Table 4.6 for abbreviations).

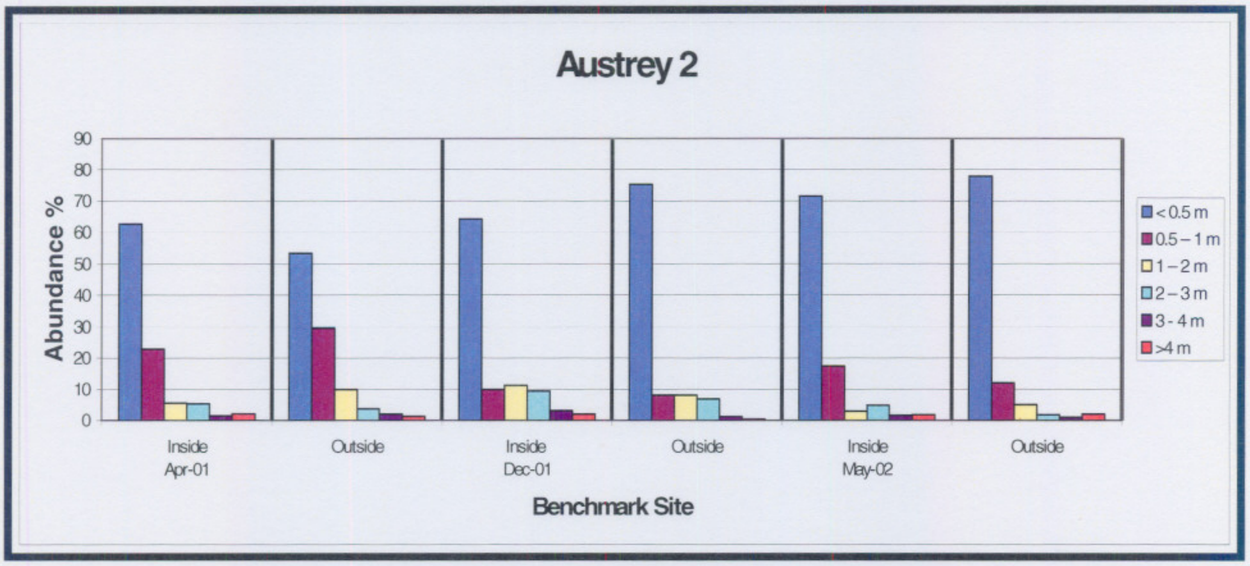

Figure 4.4: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Austrey 2 benchmark site, for the total sampling periods April 2001, December 2001 and May 2002.

Maytenus heterophylla (27 %) was the most abundant species **inside,** whereas *Acacia erioloba* (28.16 %) was the most abundant species **outside**, the exclosure plot (Table 4.6 and Figure 4.3). The *Asparagus* species was an abundant species both **inside** and **outside** the exclosure (20.78 % **inside** and 19.93 % **outside**) (Table 4.6 and Figure 4.3). Other species that occurred were *Dichrostachys cinerea* (4.64 % **inside** and 6.25 % **outside**), *Grewia flava* (5.48 % **inside** and 5.15 % **outside**), *Rhigozum brevispinosum* (9.8% **outside**), *Rhus tenuinervis* (4.33 % **inside**) and *Terminalia sericea* (7.91 % **outside**) (Table 4.6). The dominant structure class was the less than 0.5 meter height class. There was an increase in the abundance of the vegetation at this structure both **inside** and **outside** the exclosure plot during the study period (Figure 4.4).

During the April 2001 surveys, the most abundant species at this dominant structure class, were *M. heterophylla* (206), *A. erioloba* (75) and the *Asparagus* spp. (57) **inside** the exclosure and *A. erioloba* (48), the *Asparagus* spp. (46) and *M. heterophylla* (32) **outside** the exclosure (Tables 4.6, 4.7 and 4.8).

The varying differences in the occurrence of the *Asparagus* spp. could be ascribed to the difference in perception of bush clumps. During the monitoring of the benchmark different people noted the species unique to their own perception, especially if the difference in data of the December 2001 surveys to the April 2001 and May 2002 results are considered (Table 4.6). No trends in sampling perceptions can be detected for each survey was unique and consisted out of different personnel who were available for that day (Table 4.6). Without the average of the December surveys the total average of the *Asparagus* spp. would have been 15.38 % inside and 17.44 % outside the exclosure (Table 4.6). The same is true for *M. heterophylla* where the counts of this species are considerably lower for the December 2001 survey as for the April 2001 and May 2002 surveys (Table 4.6).

The rapid increases in the abundance of *A. erioloba* in especially the less than 0.5 meter height class could be ascribed to the high rainfall of the growing season in May 2002 (See Figure 2.7, Chapter 2 for rainfall). The reduction of *R. brevispinosum* could also be partly ascribed to the high rainfall in that period. According to Van Wyk & Van Wyk (1997) this woody species is frequently found in arid bushveld or semi-arid desert areas. Other factors such as competition for available sunlight may also have attributed to the reduction of *R. brevispinosum*.

The increase in the less than 0.5 meter height class from December 2001 to May 2002 could be ascribed to the increase in rainfall for the last growing season (Figure 4.4). The dryer growing season that preceded the wetter growing season may have resulted in the clearance of the herbaceous layer by herbivores. This may have lead to the reduction in competition exerted by the herbaceous plants for moisture on the woody seedlings and the proliferation of the seedlings for this growing season.

Table 4.7: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Austrey 2 benchmark site **inside** the exclosure for April 2001.

Species	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia erioloba	75	22	3	2		6	108	17.3
Asparagus spp.	57	35					92	14.7
Dichrostachys cinerea	7	7	6	3	1		24	3.8
Diospyros lycioides	8	6	5				19	3
Ehretia rigida	3			3	1		7	1.1
Grewia retinervis	2	2		1			5	0.8
Grewia flava	1	5	11	11	1		29	4.6
Lantana rugosum	6	1					7	1.1
Maytenus heterophylla	206	30					236	37.8
Rhigozum brevispinosum	14	18	5	2			39	6.3
Rhus tenuinervis	2	9	3	3	1		18	2.9
Terminalia sericea	8	3		6	4	7	28	4.5
Ziziphus mucronata	2	5	2	2	1		12	1.9
Total woody species	391	143	35	33	9	13	624	
% abundance	62.7	22.9	5.6	5.3	1.4	2.1		
TE/ha	1612.88	1197.63	437.5	688.88	262.13	487.5		4686.5

Table 4.8: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Austrey 2 benchmark site **outside** the exclosure for April 2001.

Species	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia erioloba	48	45	6	5		1	105	28.3
Acacia hebeclada	1						1	0.3
Asparags spp.	46	16					62	16.7
Dichrostachys cinerea	7	7	5	2	1	3	25	6.7
Diospyros lycioides	9	3	5				17	4.6
Grewia flava	2	5	10	3			20	5.4
Lantana rugosum	1	1					2	0.5
Lycium hirsutum	11						11	3
Maytenus heterophylla	32	12	2				46	12.4
Mundulea sericea	1		1				2	0.5
Rhigozum brevispinosum	26	11	4	3			44	11.9
Rhus tenuinervis	3	5	4	1	1		14	3.8
Terminalia sericea	11	4			5	1	21	5.7
Ziziphus mucronata		1					1	0.3
Total woody species	198	110	37	14	7	5	371	
% abundance	53.4	29.6	10	3.8	1.9	1.3		
TE/ha	816.75	921.25	462.5	292.25	203.875	187.5		2884.13

Table 4.9: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of April 2001, December 2001 and May 2002 at the Austrey 2 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
April 2001	1612.88	1197.63	437.50	688.88	262.13	487.50	4686.50
December 2001	1612.88	510.88	850.00	1189.88	553.38	450.00	5167.00
May 2002	1526.25	753.75	187.50	521.88	233.00	337.50	3559.88

Table 4.10: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of April 2001, December 2001 and May 2002 at the Austrey 2 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
April 2001	816.75	921.25	462.50	292.25	203.88	187.50	2884.13
December 2001	998.25	217.75	325.00	459.25	116.50	37.50	2154.25
May 2002	1274.63	402.00	250.00	146.13	116.50	300.00	2489.25

Maytenus heterophylla (206) and *A. erioloba* seedlings (75) contributed the most to the less than 0.5 meter height class **inside** the exclosure for the April 2001 survey. *Grewia flava* (11; 11) dominated both the 1 – 2 meter and 2 – 3 meter height classes **inside** the exclosure in April 2001. *Acacia erioloba* (6) and *Terminalia sericea* (7) were the only species found in the more than 3 – 4 meter height class **inside** the exclosure in April (Table 4.7).

Acacia erioloba (48) and the *Asparagus* species (46) contributed the most to the less than 0.5 meter height class on the **outside** of the exclosure during the April 2001 surveys (Table 4.8). *Grewia flava* dominated the 1 – 2 meter height class on the **outside** of the exclosure (Table 4.8).

There was a problem during the identification and counting of individual species per height class, just as with the surveys at the Austrey 1 benchmark site. The TE values for the December 2001 surveys different considerably, both inside and outside the exclosure, from the April 2001 and May 2002 surveys (Table 4.10). It is also clear that there was more *G. flava* inside than outside the exclosure if looked at the initial data of the December 2001 surveys. The largest difference in TE/ha data occurred in the 1 – 2 meter and 2 – 3 meter height classes (Tables 4.9 and 4.10). These structure classes are usually dominated by *G. flava*. This could have resulted in the drastic increase in the total TE/ha of 480.5 TE/ha from April 2001 to December 2001 and a decrease of 1607.12 TE/ha from December 2001 to May 2002 on the **inside** of the Austrey 2 exclosure plot (Table 4.9). On the **outside** of the exclosure a decrease of 729.88 TE/ha from April 2001 to December 2001 was observed (Table 4.10). This was followed by a 335 TE/ha increase from December 2001 tot May 2002 (Table 4.10). One surveyor most probably noted single stems during December 2001 while multi-stemmed individuals were noted during the other two surveys.

The total TE/ha also decreased more notably on the **inside** of the exclosure than on the **outside**, if the December 2001 results are ignored, such as in the case of the Austrey 1 benchmark (Table 4.9 and Table 4.10). The decrease was mostly observed in the less than 0.5 meter, 0.5 – 1 meter and 1 – 2 meter height classes if April 2001 and May 2002 are compared.

An increase in the TE/ha of the less than 0.5 meter and the more than 4 meter height classes on the **outside** of the exclosure (comparing only the April 2001 and May 2002 data) contributed the most to the lesser decrease in total TE/ha (Table 4.10). The increase of TE/ha in the less than 0.5 meter height class could be attributed to less rest received on the outside of the exclosure. The herbaceous layer could not compete so crucially with germinating seedlings and thus could not contain the numbers of woody species in this structure class. The increase in TE/ha in the more than 4 meter height class could be ascribed to the fact that the surveys could not be conducted on exactly the same spot, as the markers that indicated the situation of the previous belt has disappeared (Table 4.10). Some tall trees might have been rooted just out of the survey belt during the first survey, if only with a few centimetres.

The exclosure plots where chosen to represent the vegetation of the benchmark and some times the vegetation inside and outside the plots differed notably for the simple reason that large trees do not grow close to each other (due to competitive reasons). This can be seen when the TE for the inside of the exclosure plot is compared to the outside of the exclosure plot (Table 4.7 – 4.10). From the initial stage of this project there was more woody vegetation inside the exclosure (especially the < 0.5 meter and 2 – 3 meter height class) than outside the exclosure (Tables 4.7 and 4.8). The data obtained from this benchmark can be used more effectively as a reference in the future (in other words as a benchmark in time).

As far as the palatability of the woody species is considered, *Acacia erioloba* have a relatively palatable status and the pods of this species are mostly utilised by livestock and game. It is not known whether *T. sericea* is utilised (See Appendix I).

Austrey 3 benchmark site

Table 4.11 represent the total woody species composition in percentage frequency at the Austrey 3 benchmark site for December 2001 and May 2002. Due to a time constraint the Austrey 3 benchmark site could not be surveyed during April 2001. The woody species that were represented, more than 5 % on average, either inside or outside the exclosure, were compared with each other and are shown in Figure 4.5. In Figure 4.6 the structure of the vegetation per height class at the Austrey 3 benchmark site for December 2001 and May 2002 is presented. Table 4.12 and Table 4.13, represent the occurrence and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside and outside of the exclosure at the Austrey 3 benchmark site for December 2001. The TE/ha per height class and the total TE/ha for the whole survey period are represented in Tables 4.14 and 4.15.

Table 4.11: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Austrey 3 benchmark site over the two sampling periods (December 2001 and May 2002), as well as the average percentage for each species.

	Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	**2.86**	**10.24**	**1.57**	**7.3**	**2.21**	**8.77**
Acacia hebeclada (Aca heb)	**28.57**	**10.24**	**17.28**	**8.53**	**22.95**	**9.39**
Acacia mellifera (Aca mel)	0	3.61	0	1.9	0	2.76
Acacia robusta (Aca rob)	**0**	**7.83**	**36.13**	**31.6**	**18.06**	**19.72**
Asparagus* spp *(Asp spp.)	**5.71**	**7.83**	**6.8**	**12.6**	**6.26**	**10.22**
Boscia albitrunca (Bos alb)	1.43	1.2	0	0	0.72	0.6
Dichrostachys cinerea (Dich cin)	**8.57**	**0.6**	**2.6**	**1.9**	**5.59**	**1.25**
Diospyros lycioides (Dio lyc)	0	1.2	0	1.5	0	1.35
Ehretia rigida (Ehre rig)	**1.43**	**12.05**	**1**	**3.9**	**1.22**	**7.98**
Grewia flava (Gre fla)	**31.43**	**13.25**	**22**	**21.8**	**26.72**	**17.53**
Grewia retinervis (Gre ret)	0	2.41	0	0	0	1.21
Maytenus heterophylla (May het)	**0**	**11.45**	**0**	**1**	**0**	**6.23**
Rhus tenuinervis (Rhus ten)	1.43	3.61	0.5	3.9	0.97	3.76
Tarchonanthus camphoratus(Tarch camp)	0	0.6	0	0.5	0	0.55
Terminalia sericea (Ter ser)	5.71	0.6	2.6	3	4.16	1.8
Ziziphus mucronata (Zizi muc)	**12.86**	**13.25**	**9.4**	**3**	**11.13**	**8.13**

Figure 4.5: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the Austrey 3 benchmark site for the sampling periods (December 2001 and May 2002) (See table 4.11 for abbreviation description).

Figure 4.6: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Austrey 3 benchmark site, for the sampling periods of December 2001 and May 2002.

Grewia flava (26.72 % **inside** and 17.53 % **outside** the exclosure) was the most important species at the Austrey 3 benchmark site (Table 4.11 and Figure 4.5). *Acacia erioloba* (20.28 %) and *Acacia hebeclada* (21.34 %) were also dominant species **inside** the exclosure plot (Table 4.11). Other species that were abundant include *Acacia robusta* (18.06 % **inside**, 19.72 % **outside**), the *Asparagus* spp. (6.26 % **inside**, 10.22 % **outside**), *Dichrostachys cinerea* (5.59 % **inside**), *Ehretia rigida* (7.98 % **inside**), *Maytenus heterophylla* (6.23 % **outside**) and *Ziziphus mucronata* (11.13 % **inside**, 8.13 % **outside**) (Table 4.6).

The dominant structure was the less than 0.5 meter height class both **inside** and **outside** the exclosure for December 2001 (Table 4. 11 and Figure 4.5). During the December 2001 surveys the three dominant species in this structure class were *A. erioloba, A. hebeclada* and the *Asparagus* spp. **inside** the exclosure and *A. robusta,* the *Asparagus* spp. and *A. hebeclada* **outside** the exclosure (Tables 4.12 and 4.13).

The 1 - 2 meter height class was the most dominant structure **inside** the exclosure plot, during May 2002 and the dominant woody species **inside** the exclosure were *G. flava, Ziziphus mucronata* and *A. hebeclada* where as *Grewia flava, A. erioloba* and

Rhus tenuinervis were the dominant species on the **outside** of the exclosure. The less than 0.5 meter height class numbers have decreased almost with 30 % according to the May 2002 surveys (Figure 4.6). The herbaceous stand where visually more dense during May 2002. The presence of *Grewia flava* may have had an important effect on the data if the multi-stemmed shrubs were noted as single stemmed individuals. Some species might also have been very close to the next structure class (shorting 5 – 10 centimetres). This species might have increased in length to reach the next structure class.

The decline in the abundance of *A. erioloba* both **inside** and **outside** the exclosure could be ascribed to inter species competition of the seedlings as the seedlings grew from December 2001 to May 2002 (Table 4.11). The drastic high occurrence of *A. robusta* on the **inside** of the exclosure could have been that this species was wrongfully identified during the December 2001 surveys and only in May 2002 recognised after it had grown so that more of the diagnostic characteristics were visible. The increase in the abundance of *A. hebeclada* may be due to the seasonal changes. A possible explanation is the following: during May 2002 the leaves of this species have started to drop, as a result of seasonal changes. The real number of rooted bushes could be distinguished, as opposed to the prediction of the previous surveys. *Acacia mellifera* also showed a reduction in seedlings.

Dichrostachys cinerea could also have decreased due to the mortality of seedlings as a result of other inter species competition or decrease of soil water in the dry season. The decrease in the abundance of *Ehretia rigida* could be ascribed to the growth form of this species. *Ehretia rigida* tend to grow in clumps with other species such as *G. flava, Z. mucronata* and *Tarchonanthus camphoratus*. This may have caused the smaller trees to be over-shaded. A lack of sunlight and moisture competition may have resulted in the mortality of this species. The same tendencies could be observed for *M. heterophylla* that also tend to grow at the brim of bush clumps.

Grewia flava has decreased on the **inside** and has increased on the **outside** of the exclosure. This might be as a result of the competition for available soil water, with the seemingly denser grassy layer on the **inside** of the exclosure. The same may be true to explain the reduction in the abundance of *T. sericea* and *Z. mucronata* on the **inside** of the exclosure (Table 4.11).

Table 4.12: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Austrey 3 benchmark site **inside** the exclosure for December 2001.

Speies	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**Total woody species**	**% abundance**
Acacia erioloba	72				72	37.7
Acacia hebeclada	22	11			33	17.2
Asparagus spp.	13				13	6.8
Dichrostachys cinerea	2	1		2	5	2.6
Ehretia rigida				2	2	1
Grewia flava	6	6	30		42	22
Rhus tenuinervis		1			1	0.5
Terminalia sericea	4		1		5	2.6
Ziziphus mucronata	12	4		2	18	9.4
Total woody species	131	23	31	6	191	
% abundance	68.6	12	16.2	3.1		
TE/ha	540.375	192.625	387.5	125.25		1245.75

Table 4.13: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Austrey 3 benchmark site **outside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**> 4m**	**Total woody species**	**% abundance**
Acacia erioloba	13	1		1		15	7.3
Acacia hebeclada	13	3				16	7.8
Acacia robusta	57	2	1	1	4	65	31.6
Acacia tortilis		1	1			2	1
Asparagus spp.	24	2				26	12.6
Dichrostachys cinerea	3					3	1.5
Diospyros lycioides	3					3	1.5
Ehretia rigida	8					8	3.9
Grewia flava	3	8	30	4		45	21.8
Maytenus heterophylla	2					2	1
Rhus tenuinervis	8					8	3.9
Tarchonanthus camphoratus				1		1	0.5
Terminalia sericea	4				2	6	3
Ziziphus mucronata	6					6	3
Total woody species	144	17	32	7	6	206	
% abundance	70	8.3	15.5	4	3		
TE/ha	594	142.375	400	146.125	225		1507.50

Table 4.14: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of December 2001 and May 2002 at the Austrey 3 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	540.38	192.63	387.50	125.25	0	0	1245.75
May 2002	99.00	134.00	325.00	83.50	0	0	641.50

Table 4.15: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of December 2001 and May 2002 at the Austrey 3 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	594.00	142.38	400.00	146.13	0	225	1507.50
May 2002	503.25	117.25	237.50	62.63	0	300	1220.63

Nearly sixty nine per cent (68.6 %) of the total woody vegetation was in the less than 0.5 meter height class (on the **inside** of the Austrey 3 benchmark site, during December 2001). *Acacia erioloba* (72) was the most dominant species in this structure class. The most dominant species in the 1 – 2 meter height class was *G. flava* (30) (Table 4.12).

The less than 0.5 meter height class was also the most dominant structure class on the **outside** of the exclosure. The species that contributed the most to this structure class were *A. robusta* (57) and the *Asparagus* spp. (24) (Table 4.13). *Grewia flava* (30) also dominated the 1 – 2 meter height class on the **outside** of the exclosure. The occurrence of tall *A. robusta* trees may explain the abundance of this species in the dominant structure class, as tall trees disperse seed in a wide radius around the tree.

The total TE/ha decreased both **inside** and **outside** the exclosure from December 2001 to May 2002. The largest reduction in TE/ha **inside** the exclosure was in the less than 0.5 meter height class (Table 4.14). All the other structure classes on the **inside** of the exclosure showed some decrease in the TE/ha from December 2001 to May 2002.

The reduction of the total TE/ha on the **outside** of the exclosure was not so important as the reduction of total TE/ha on the inside of the exclosure (Table 4.15). The greatest reductions in TE/ha values occurred mostly in the 0.5 – 1 meter, 1 – 2 meter and 2 – 3 meter height classes. This might indicate that different surveyors conducted the surveys.

The great reduction in the TE/ha in the less than 0.5 meter height class on the **inside** of the exclosure and not so great decrease on the **outside** of the exclosure might indicate that the rest of the rangeland improved the herbaceous layer and in effect, an increase of competition for available soil moisture (Table 4.15). This in return attributed to the reduction of the seedlings.

Acacia robusta is a less palatable species and is only utilised in very low quantities. *Grewia flava* in considered to be a very palatable species. This can be viewed as good fodder bank in times of drought (Appendix I).

Austrey 4 benchmark site

Table 4.16 represent the total woody species composition in percentage frequency at the Austrey 4 benchmark site for April 2001, December 2001 and May 2002. The woody species that were represented, more than 5 % on average, either inside or outside the exclosure, were compared with each other and are shown in Figure 4.7. In Figure 4.8 the structure of the vegetation per height class at the Austrey 4 benchmark site for April 2001, December 2001 and May 2002 is presented. Tables 4.17 and 4.18, represent the abundance and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside and outside of the exclosure at the Austrey 4 benchmark site for April 2001. The TE/ha per height class and the total TE/ha for the whole survey period are represented (Tables 4.19 and 4.20).

Table 4.16: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Austrey 4 benchmark site over the three sampling periods (April 2001, December 2001 and May 2002), as well as the average percentage for each species.

	Apr-01		Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	**12.5**	**8.2**	**5.4**	**8.1**	**7.77**	**6.87**	**8.56**	**7.72**
Acacia hebeclada (Aca heb)	**6.25**	**1**	**6.5**	**0.4**	**17.48**	**6.11**	**10.08**	**2.5**
Acacia karroo (Aca kar)	0	2.1	0	2	0	3.82	0	2.64
Asparagus spp. *(Asp* spp.*)*	3.1	0	0	0.4	0	0	1.03	0.133
Dichrostachys cinerea (Dich cin)	1	3.1	1.2	1.6	1.94	5.34	1.38	3.35
Diospyros lycioides (Dio lyc)	**52.1**	**60.8**	**72.6**	**40.2**	**56.31**	**60.31**	**60.34**	**53.77**
Grewia flava (Gre fla)	**10.4**	**14.4**	**8.3**	**8.5**	**10.68**	**6.87**	**9.79**	**9.92**
Lantana rugosum (Lan rug)	4.2	2.1	0	0	0	0	1.4	0.7
Lycium hirsutum (Lyc hir)	5.2	3.1	0	0	0	0	1.73	1.03
Tarchonanthus camphoratus (Tarc camp)	**2.1**	**5.2**	**3**	**38.6**	**2.91**	**10.69**	**2.67**	**18.16**
Ziziphus mucronata (Ziz muc)	3.1	0	3	0	2.91	0	3	0

Figure 4.7: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the Austrey 4 benchmark site for the sample periods (April 2001, December 2001 and May 2002). (See table 4.16 for abbreviations).

Figure 4.8: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Austrey 4 benchmark site, for the sampling periods of April 2001, December 2001 and May 2002.

Diospyros lycioides (60.34 % **inside** and 53.77 % **outside** the exclosure) was the most dominant species at the Austrey 4 site (Table 4.16 and Figure 4.7). *Tarchonanthus camphoratus* (18.16 %) was more abundant on the **outside** of the exclosure plot. *Grewia flava* (9.79 % **inside** and 9.92 % **outside**) was the third most abundant species and equally present in both on the **inside** and **outside** of the exclosure plot (Table 4.16 and Figure 4.7). *Acacia erioloba* (8.56 % **inside**) and *Acacia hebeclada* (10. 08 % **outside**) were also present in higher abundance (Table 4.16 and Figure 4.7). The latter species was more abundant **inside** the exclosure plot than on the **outside** of the exclosure (Table 4.16 and Figure 4.7). The less than 0.5 meter height class was the dominant structure class during the April 2001 surveys with *Diospyros lycioides, A. erioloba* and *Lycium hirsutum* as the dominant species both **inside** and **outside** the exclosure plots (Figure 4.8).

During December 2001 the 0.5 – 1 meter height class was the dominant structure class **inside** the exclosure plot and the 1 – 2 meter height class was the dominant structure class **outside** the exclosure (Figure 4.8). The dominant species during December 2001 were *D. lycioides, A. hebeclada* and *G. flava* in the 0.5 – 1 meter height class and *D. lycioides, Tarchonanthus camphoratus* and *G. flava* in the 1 – 2 meter class.

These figures are represented in initial data although not represented in thesis (but available on request) for the data is more presentable in the processed format.

During the May 2002 surveys, the less than 0.5 meter height class was the dominant structure class **inside** the exclosure with *D. lycioides, A. hebeclada* and *A. erioloba* as dominant species. **Outside** the exclosure the dominant structure class was the 0.5 – 1 meter height class with *D. lycioides, A. hebeclada* and *A. erioloba* as the most dominant species. A probable cause for the difference in dominant height structures between the December and May survey periods both **inside** and **outside** the exclosure can be attributed to the high rainfall experienced during January 2002.

The increase in the less than 0.5 meter height class could only be ascribed to the increased rainfall during the past growing season that resulted in an increase in the germination of seedlings.

Table 4.17: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ ha per height class and total) and the total woody species and the percentage of each species of the Austrey 4 benchmark site **inside** the exclosure for April 2001.

Species	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia erioloba	8	1			1	2	12	12.5
Acacia hebeclada	1	2	3				6	6.25
Asparagus spp.	3						3	3.1
Dichrostachys cinerea				1			1	1
Diospyros lycioides	14	21	15				50	52.1
Grewia flava	2	2	4	2			10	10.4
Lantana rugosum	4						4	4.2
Lycium hirsutum	5						5	5.2
Tarchonanthus camphoratus			1	1			2	2.1
Ziziphus mucronata		1	1		1		3	3.1
Total woody species	37	27	24	4	2	2	96	
% abundance	38.5	28.1	25	4.2	2.1	2.1		
TE/ha	152.625	226.125	300	83.5	58.25	75		895.50

Table 4.18: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ ha per height class and total) and the total woody species and the percentage of each species of the Austrey 4 benchmark site **outside** the exclosure for April 2001.

Species	< 0.5 m	0.5 – 1 m	1 – 2 m	2 – 3 m	Total woody species	% abundance
Acacia erioloba	5	3			8	8.2
Acacia hebeclada		1			1	1
Acacia karroo				2	2	2.1
Dichrostachys cinerea		1	1	1	3	3.1
Diospyros lycioides	21	24	14		59	60.8
Grewia flava	2	1	7	4	14	14.4
Lantana rugosum	2				2	2.1
Lycium hirsutum	3				3	3.1
Lycium hirsutum			4	1	5	5.2
Total woody species	33	30	26	8	97	
% abundance	34	30.9	26.8	8.2		
TE/ha	136.125	251.25	325	167		879.38

Table 4.19: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of April 2001, December 2001 and May 2002 at the Austrey 4 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
April 2001	152.63	226.13	300.00	83.50	58.25	75.00	895.50
December 2001	231.00	519.25	400.00	250.50	87.38	112.50	1600.63
May 2002	202.13	251.25	175.00	125.25	87.38	37.50	878.50

Table 4.20: The change in tree equivalents (per hectare) per height for the total woody species composition over the survey periods of April 2001, December 2001 and May 2002 at the Austrey 4 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
April 2001	136.13	251.25	325.00	167.00	0	0	879.38
December 2001	235.13	527.63	1037.50	835.00	87.38	0	2722.63
May 2002	165.00	594.63	112.50	208.75	29.13	0	1110.00

Nearly thirty nine per cent (38.5 %) of the woody vegetation was represented in the less than 0.5 meter height class in the **inside** of the exclosure (Table 4.17). *Diospyros lycioides* (14) was the dominant species at this structure class while *A. erioloba* (2) dominated in the higher structure classes **inside** the exclosure (Table 4.17).

Diospyros lycioides (21) dominated the less than 0.5 meter height class on the **outside** of the exclosure as well (Table 4.18). The **outside** of the exclosure had no higher structure class than 2 – 3 meters during the initial surveys (Table 4.18). This might indicate that there were not enough sampling areas in a representative rangeland benchmark for scientific purposes, but for demonstration purposes one camp was sufficient. An increase in the total TE/ha of 705.13 TE/ha from April to December 2001 and a decrease of 722.13 TE/ha was observed from December 2001 to May 2002 on the **inside** of the exclosure (Table 4.19).

An increase in the total TE/ha of 1843.26 TE/ha from April to December 2001 and a decrease of 1612.63 TE/ha from December 2001 to May 2002 was observed for the **outside** of the exclosure (Table 4.20). The absence of any TE/ha value in the 3 – 4 meter height class during the April 2001 surveys could be ascribe to the sample not being taken on the exact same spot as that of the other surveys, as the dropper markers seems to be a well needed item in this area (Table 4.20).

The great increase in TE/ha for the December 2001 surveys could be ascribed to the wrong classification of multi-stemmed woody species. If 14 individuals were noted instead of two multi-stemmed individuals, the influence of 14 individuals will be calculated as TE/ha where, two multi-stemmed individuals would only influence the area to a lesser extent than that was calculated.

Soil analysis for the Austrey study site

The following data was obtained from soil samples that were taken during the May 2002 surveys. Figure 4.9 indicates the texture of the soil found at all the benchmark sites in the Austrey study area as very sandy (approximately 87 %) with almost no silt (approximately 5 %) and very little clay (approximately 9 %).

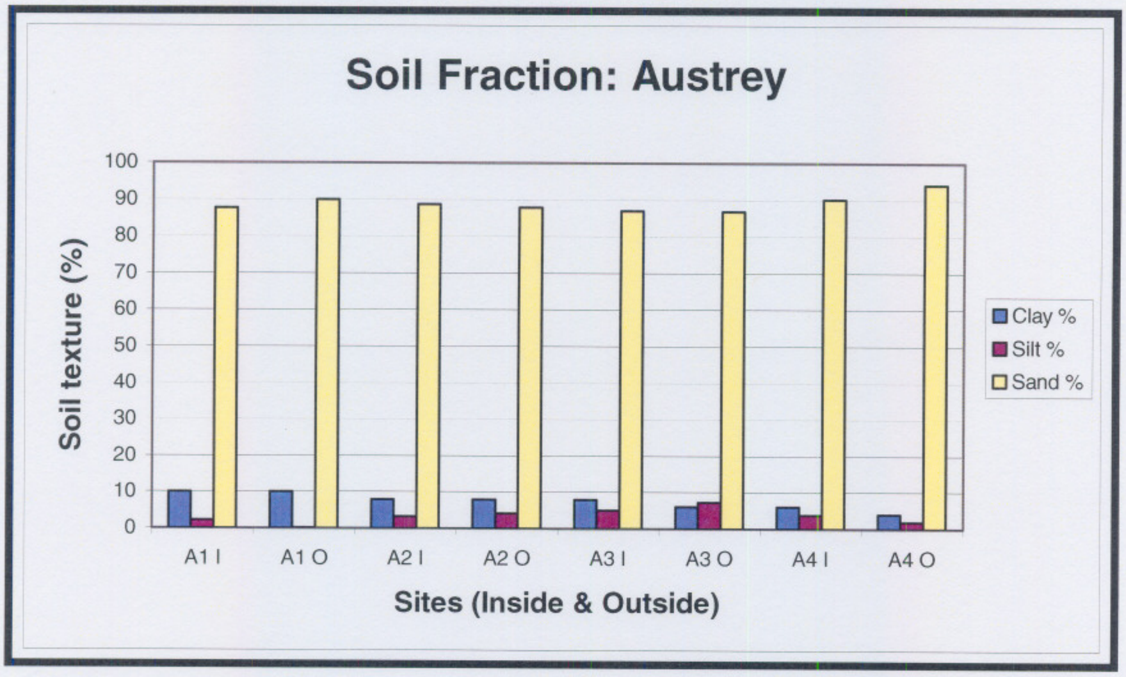

Figure 4.9: The soil texture (%) of the Austrey study site as obtained from the soil analysis done during the sampling of May 2002. (Note that: A - Austrey, I - inside the exclosure, O - outside the exclosure and the number relates to the survey location).

The data represented in Table 4.21 shows the soil pH for all the sites at an average of 5.54. Sweet-veld is usually characterised by alkaline soil due to the high nutrient status of the soil but the sandy quality of the soil of the Austrey site makes for poorer nutrient status. The carbon content is also low. The phosphate (P) averaged at 3.24. The calcium (Ca), magnesium (Mg) and potassium (K) varied from site to site. The sodium (Na) levels were very low, decreasing the possibility of sheet erosion due to crusting at the Austrey study site. As mentioned the organic carbon in the soil is also very low, namely in the vicinity of 0.24 %. This may be due to the climatic conditions, which are not suitable for micro-organisms responsible for the brake down of the plant and animal matter (Atlas, 1996).

The Austrey 3 benchmark site showed higher levels of potassium in comparison to the other Austrey benchmark sites. The Austrey 3 and Austrey 4 benchmark sites had higher levels of calcium than the other sites (Table 4.21). Higher abundance of *Acacia mellifera* could be expected at these two sites although this species only occurred in abundance at the Austrey 3 benchmark site (Smit, 1999). The previous management practise had exposed the rangeland at the Austrey 3 benchmark to more livestock activities than that of the Austrey 4 benchmark and this might have led to the higher abundance of *Acacia mellifera* at the Austrey 3 benchmark.

Table 4.21: The chemical soil analysis results from the samples taken during the May 2002 surveys (see Figure 4.9 for abbreviations).

	1:2.5 Water	**Bray-I**	**Amm. Acetate 1M (pH 7.00)**					**W.B.**	**Water paste**
Site	pH	P	Ca	Mg	K	Na	CEC	C	R
No.		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	Cmol(+)/kg	%	Ohm
A1 Inside	5.47	3.11	60.5	10.3	35	0	3.79	0.26	28000
A1 Outside	5.36	3.06	72.4	15.9	49.6	0	4.08	0.24	34000
A2 Inside	5.47	3.08	84.3	17.7	30.8	0	2.95	0.21	24000
A2 Outside	5.34	3.26	79	18.3	29.3	0	2.31	0.21	28000
A3 Inside	5.79	3.35	**138**	39.9	**68.8**	0	3.64	0.24	22000
A3 Outside	5.68	3.37	**142**	33.4	**70.1**	0.3	2.82	0.28	7800
A4 Inside	5.54	3.25	**125**	25.2	40.9	0.3	2.56	0.24	9000
A4 Outside	5.80	3.46	**143**	33.2	41.7	0	2.49	0.23	22000

Although this data does not yet show any tendencies, it could be used in the future as baseline data. The difference in soil fertility, inside and outside the exclosure plots could thus be measured over time to determine the extent of soil nutrient degradation.

Summery of the Austrey benchmark sites

Although the total TE/ha varied much, it is evident that the benchmarks at Austrey 3 and 4 were in a better condition than the benchmarks at Austrey 1 and 2. This proves that the subjective observations by the land users and agriculturists were indeed correct and that a gradient does exist from the Austrey 1 to the Austrey 4 benchmark sites if the density of the woody species is taken into consideration.

This statement can be based on the abundance of species such as *Maytenus heterophylla* in the Austrey 1 (13.56 % **inside**) and Austrey 2 (27 % **inside**) benchmarks. The high abundance of the *Asparagus* species could also contribute to proving this statement. The most important species at this study site were *Acacia erioloba*, the *Asparagus* species and *Maytenus heterophylla*. A species that occurred in relatively high abundance at the Austrey 4 benchmark was *Diospyros lycioides*. This could possibly be as a result of the nutrient status of the soil at that benchmark but no literature on the nutritional preferences of this specific species were found, so it can not be said for certain.

Most of these species, especially *Acacia erioloba* was dominant in the less than 0.5 meter and 0.5 – 1 meter height classes at all the benchmark sites. *Grewia flava* dominated the 1 – 2 meter height class of this study area.

The *Acacia erioloba* species is a relatively palatable species found mostly in deep sandy soils in arid and semi-arid areas. This tree is also considered as a typical Kalahari species. Despite the pods that are excellent fodder for livestock, the wood is also very good for firewood (Smit, 1999). The over utilisation of the wood of this tree has caused the tree to become more endangered and are protected by the law. This species poses no threat to the bush thickening problem.

Acacia hebeclada is a relatively less palatable species with the tendency to invade areas that is overgrazed. This species is a low growing shrub that can grow in a wide variety of sandy soils. It can also be associated with calcrete rich soil. *Acacia hebeclada* is found in dry savanna or grassland areas (Smit, 1999). This species was common in all the benchmark sites of the Austrey study site and poses a bush thickening threat to this area if overgrazing should be a common practise (Appendix I).

Diospyros lycioides is known as a less palatable species (Appendix I). This species occurred at low abundance at the Austrey study site except for the Austrey 4 benchmark where it had a very high abundance.

Grewia flava is known to be a relatively palatable species that is heavily utilised when there is a shortage in herbaceous vegetation (Appendix I). This species forms large bushes that can cover large areas in a rangeland. *Grewia flava* has a shallow root system and competes with the herbaceous layer for available soil moisture. This could be the reason that little or no grass grows underneath the *G. flava* thickets. *Grewia flava* is a good source of reserve fodder but may cause a threat to the grazing capacity of a rangeland if overgrazing is to take place. The Austrey 1 and 3 benchmarks had a moderate abundance of *G. flava* (11.06 % **inside** and 14.41 % **outside** -Austrey 1; 26.72 % **inside** and 17.53 % **outside** –Austrey 3), whilst the Austrey 2 and 4 benchmarks had low abundance of this species (5.48 % **inside** and 5.15 % **outside** -Austrey 2; 9.79 % **inside** and 9.92 % **outside** –Austrey 4). *Maytenus heterophylla* is a less palatable species, which could cause dense stands that rapidly reduce grazing areas.

Total TE/ha of the Austrey 1 and Austrey 2 benchmark was higher than the total TE/ha of the Austrey 3 and Austrey 4 benchmarks. The structure classes that contributed the most to the total TE/ha of the Austrey 1, 2 and 3 benchmark sites were the less than 0.5 meter height class. The 0.5 – 1 meter height class and the 1 – 2 meter height classes contributed the most to the total TE/ha for the Austrey 4 benchmark.

Rainfall had the most influence on the slight changes that occurred in the species composition and structure, as most of the variation in species composition occurred in the less than 0.5 meter height class. This is were the vegetation compete the most for available soil moisture as a result of the shallow root systems of seedlings, small woody species and herbaceous vegetation.

The soil fraction consisted of, mostly sand and with very low occurrence of clay or silt. The pH of the study site soil was more acidic indicating as a result of the high sand content of the soil.

4.2.2 Water-Fouché study site

Six sites (Water-Fouché 1-6) were selected to represent different range conditional states according to species composition and factors that indicate the degree of degradation, such as bare ground, occurrence of erosion and the past grazing history in this Morafe Ranch managed area. As in the previous area, agriculturists and land users did the selection of benchmark sites subjectively. The benchmarks were situated in two clearly distinguished vegetation types, namely the *Acacia erioloba* vegetation type, with *Acacia erioloba* present at all these benchmarks and an *Acacia haematoxylon – Grewia flava* dominated shrub rangeland (named the *A. haematoxylon* vegetation type from now on). The height classes of the woody component in the *A. erioloba* vegetation type were much higher than the structure of the vegetation in the *A. haematoxylon* type.

Only the Water-Fouché 1 benchmark site was surveyed during April 2001, seeing that it was the only site identified and fenced at that time. All the benchmark sites (Water-Fouché 1 – 6) were surveyed during December 2001 and May 2002.

Woody vegetation

Water-Fouché 1 benchmark site

Table 4.22 represent the total woody species composition in percentage frequency at the Water-Fouché 1 benchmark site for April 2001, December 2001 and May 2002. The woody species that were represented, more than 5 % on average, either inside or outside the exclosure, were compared with each other and are shown in Figure 4.10. In Figure 4.11 the structure of the vegetation per height class at the Water-Fouché 1 benchmark site for April 2001, December 2001 and May 2002 is presented. Table 4.23 and Table 4.24, represent the abundance and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside and outside of the exclosure at the Water-Fouché 1 benchmark site for April 2001. The TE/ha per height class and the total TE/ha for the whole survey period are represented in Table s4.25 and 4.26.

Table 4.22: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Water-Fouché 1 benchmark site over the three sampling periods (April 2001, December 2001 and May 2002), as well as the average percentage for each species.

	Apr-01		Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	3	1.2	3.7	0.8	2.16	1.35	3	1.12
Acacia hebeclada (Aca heb)	0.8	0	1.6	0	0.54	0	1	0
Acacia mellifera (Aca mel)	**8.4**	**9**	**12.7**	**9**	**14.05**	**9.46**	**11.7**	**9.15**
Asparagus* spp.*(Asp* spp.*)	**17.3**	**17.2**	**16.3**	**23.6**	**19.97**	**25.23**	**17.9**	**22.01**
Boscia albitrunca (Bos alb)	**22.4**	**15.6**	**29.4**	**14.1**	**30.81**	**11.26**	**27.5**	**13.7**
Dichrostachys cinerea (Dich cin)	0.8	0	0	0	0	0	0.3	0
Diospyros lycioides (Dio lyc)	0.4	0	0.4	0.3	0.54	0.45	0.4	0.3
Ehretia rigida (Her rig)	5.1	2.9	2.9	2.1	5.95	2.25	4.7	2.4
Euphorbia tirucalli (Euph tir)	0	0.4	0	0	0	0	0	0.1
Grewia flava (Gre fla)	**5.9**	**10.7**	**8.2**	**7.2**	**9.19**	**11.26**	**7.76**	**9.7**
Grewia retinervis (Gre ret)	0.8	2	0.8	4.2	1.08	0	0.7	2.1
Lycium hirsutum (Lyc hir)	**26.6**	**33.2**	**0**	**3.4**	**1.08**	**2.25**	**9.2**	**13**
Pollichia campestris (Pol camp)	**0**	**0**	**0**	**0**	**0**	**29.73**	**0**	**9.9**
Rhigozum brevispinosum (Rhig bre)	**3.8**	**4.9**	**16.7**	**32.4**	**0**	**14.05**	**6.8**	**17.1**
Rhus tenuinervis (Rhus ten)	0.8	0.8	1.2	0.5	4.32	2.7	2.1	1.3
Terminalia sericea (Ter ser)	0.4	0	0.4	0	0.54	0	0.4	0
Ziziphus mucronata (Ziz muc)	1.7	2	2.4	1.3	2.7	4.05	2.3	2.5

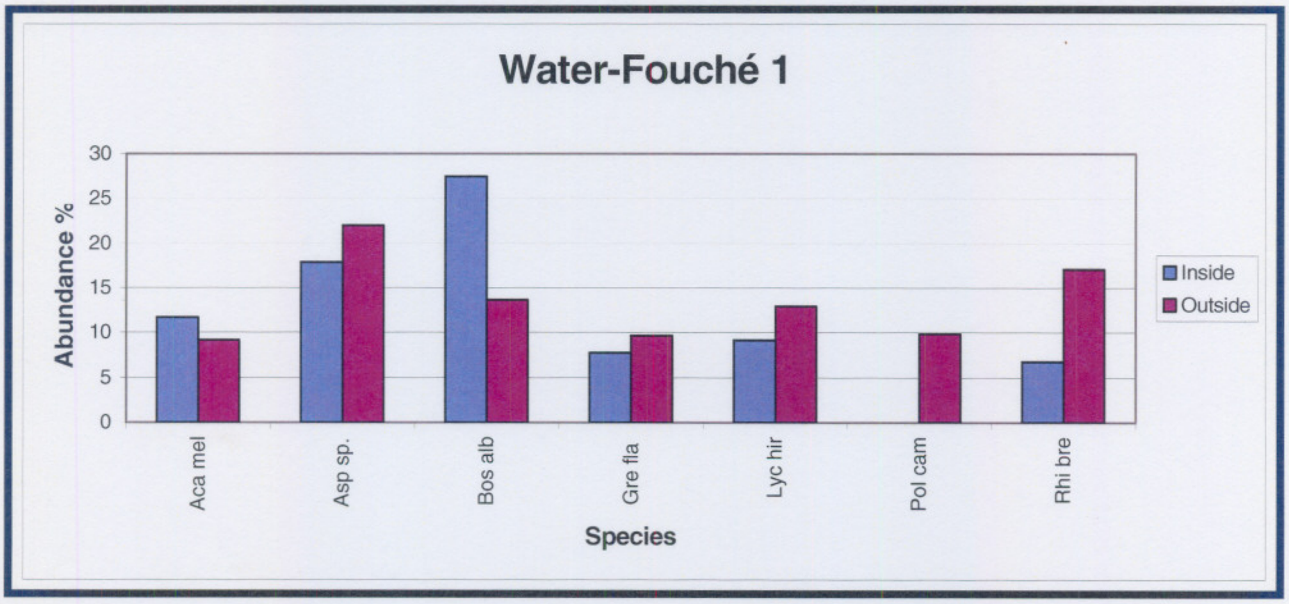

Figure 4.10: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the Water-Fouché 1 benchmark site for the sample periods (April 2001, December 2001 and May 2002). (See Table 4.22 for abbreviation description)

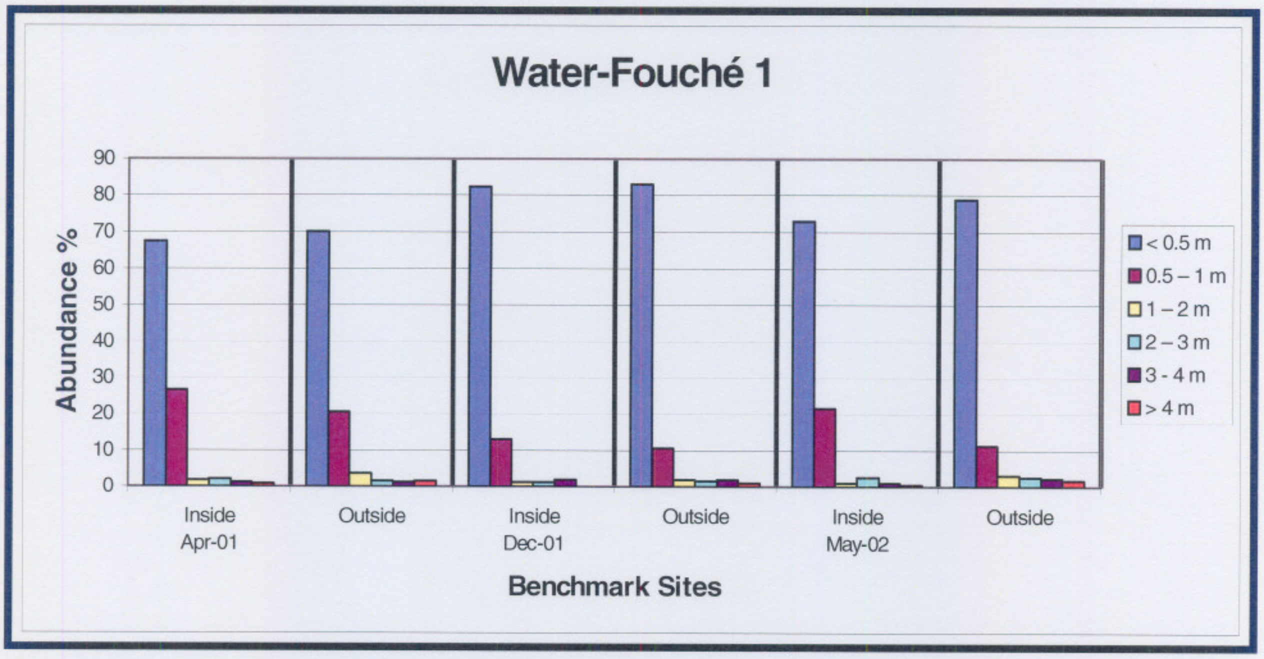

Figure 4.11: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Water-Fouché 1 benchmark site, for the total sampling periods April 2001, December 2001 and May 2002.

The most dominant species that was found during the April 2001 survey, was *Lycium hirsutum* (26.6 % **inside** and 33.2 % **outside** the exclosure plot), whereas *Boscia albitrunca* (27.5 % **inside** and 13.7 % **outside**) was the average dominant species at the Water-Fouché 1 benchmark site (Table 4.22 and Figure 4.10). The *Asparagus* species had a high abundance of 17.9 % **inside** the exclosure plot and 22.01 % **outside** the exclosure plot (Table 4.22 and Figure 4.10). Other species that had an average of more than 5 % included *A. mellifera* (11.7 % **inside** and 9.15 % **outside**), *G. flava* (7.76 % **inside** and 9.7 % **outside**), and *Rhigozum hirsutum* (6.8 % **inside** and 17.1 % **outside**) (Table 4.22 and Figure 4.10). *Pollichia campestris* (9.9 % **outside**), an annual shrub, was the most abundant species during the May 2002 surveys. This shrub has a good browsing potential and may have appeared as a result of the late rain during April and May 2002 (Table 4.22).

The dominant height class was the less than 0.5 meter height class for all the surveys (April 2001, December 2001 and May 2002) both **inside** and **outside** the exclosure (Figure 4.11). During the April 2001 surveys the following species were dominant, both **inside** as well as **outside** the exclosure namely, *Boscia albitrunca, L. hirsutum* and the *Asparagus* species (Tables 4.23 and 4.24).

During December 2001 *B. albitrunca,* the *Asparagus* species and *Rhigozum brevispinosum,* were the most abundant species **inside** and **outside** the exclosure plot respectively (initial data). This results is processed from the initial sampling data not shown here. Table 4.22 illustrates the initial data for April 2001.

Boscia albitrunca, the *Asparagus* species and *L. hirsutum* were the most abundant species **inside** the exclosure and *B. albitrunca,* the *Asparagus* spp. and *L. hirsutum* and were dominant species on the **outside** of the exclosure during the May 2002 surveys (initial data).

The reason for the decline in the abundance of *L. hirsutum* from April 2001 (26.6 % **inside** and 33.2 % **outside**), the exclosure, and the difference in the abundance values of *R. hirsutum* is primarily attributed to the mistakes made by the samplers during the surveys, as already discussed (Table 4. 22). The increase of *B. albitrunca* **inside** the exclosure was due to the exclusion of browsers, as this is a very palatable species, which is browsed by all livestock. The overall height of *B. albitrunca* in the Water-Fouché 1 benchmark site did not exceed 30 centimetres. They were all single stemmed twigs. *Boscia albitrunca* contributed the most to the high woody species density of the less than 0.5 meter height class secondly was the *Asparagus* species (Tables 4.23 and 4.24).

Table 4.23: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 1 benchmark site **inside** the exclosure for April 2001.

Species	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia erioloba	4	1		1	1		7	3
Acacia hebeclada	1	1					2	0.8
Acacia mellifera	7	4	1	4	2	2	20	8.4
Asparagus spp.	32	9					41	17.3
Boscia albitrunca	53						53	22.4
Dichrostachys cinerea	2						2	0.8
Diospyros lycioides		1					1	0.4
Ehretia rigida	10	2					12	5.1
Grewia flava	4	10					14	5.9
Grewia retinervis	2						2	0.8
Lycium hirsutum	32	28	3				63	26.6
Rhus tenuinervis	2						2	0.8
Rhigozum brevispinosum	5	4					9	3.8
Terminalia sericea	1						1	0.4
Ziziphus mucronata	4						4	1.7
Total woody species	160	63	4	5	3	2	237	
% abundance	67.5	26.6	1.7	2.1	1.3	0.8		
TE/ha	660.00	527.63	50.00	104.38	87.38	75.00		1504.38

Table 4.24: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 1 benchmark site **outside** the exclosure for April 2001.

Species	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia erioloba	1		1	1			3	1.2
Acacia mellifera	10		1	4	3	4	22	9
Asparagus spp.	33	9					42	17.2
Boscia albitrunca	37	1					38	15.6
Ehretia rigida	6	1					7	2.9
Grewia flava	15	6	5				26	10.7
Grewia tenuinervis	5						5	2
Lycium hirsutum	53	27	1				81	33.2
Rhus tenuinervis	2						2	0.8
Rhigozum brevispinosum	8	4					12	4.9
Ziziphus mucronata	1	2	2				5	2
Total	171	50	9	4	3	4	244	
% abundance	70.1	20.5	3.7	1.6	1.2	1.6		
TE/ha	705.38	418.75	112.50	83.50	87.38	150.00		1557.50

Table 4.25: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of April 2001, December 2001 and May 2002 at the Water-Fouché 1 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
April 2001	660.00	527.63	50.00	104.38	87.38	75.00	1504.38
December 2001	833.25	268.00	37.50	62.63	145.63	0	1347.00
May 2002	556.88	335.00	25.00	104.38	58.25	37.50	1117.00

Table 4.26: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of April 2001, December 2001 and May 2002 at the Water-Fouché 1 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
April 2001	705.38	418.75	112.50	83.50	87.38	150	1557.50
December 2001	1291.13	335.00	87.50	125.25	203.88	150	2192.75
May 2002	721.88	209.38	87.50	125.25	145.63	150	1439.63

The dominant structure during the April 2001 surveys of the Water-Fouché1 study site was the less than 0.5 meter structure class. Nearly sixty eight percent (67.5 %) of the woody species were abundant at this height class on the **inside** of the exclosure (Table 4.23). The most dominant species at the less than 0.5 meter class was van *Boscia albitrunca* (53), the *Asparagus* spp. (32) and *Lycium hirsutum* (32) (Table 4.23).

The dominant structure at the **outside** of the exclosure for the April 2001 surveys was also the less than 0.5 meter height class (70.1 %) (Table 4.24). The dominant species at this structure was *Boscia albitrunca* (37) (Table 4.24). The more than 4 meter height class was dominated by *A. mellifera* (Table 4.24). This benchmark is situated close to a watering point, which resulted in great disturbances due to trampling. If not managed correctly, it may lead to bush thickening (Teague & Smit, 1992).

The TE/ha values of the December 2001 surveys varied notably in comparison with the TE/ha values of the April 2001 and May 2002 surveys (Tables 4.25 and 4.26). This variation may be as a result of the surveys not carried out at the same spot from one year to the next, as well as the mistakes made by the surveyors discussed previously. The TE/ha of the 2 – 3 meter height class on the **inside** of the exclosure, were the same for April 2001 and May 2002 but was much lower in December 2001 (Table 4.25). A general decrease in TE/ha values for the **inside** of the exclosure was observed over the whole survey period. The TE/ha for the more than 4 meter height class decreased from April 2001 to December 2001, but increased again in May 2002 (Table 4.25). This figure in Table 4.25 proves that the survey was not conducted in the same spot from survey to survey.

There was an increase in smaller plants on the **outside** of the exclosure from April 2001 to December 2001, followed by a reduction from December 2001 to May 2002 (Table 4.26). The 2 - 3 meter height class and the 3 – 4 meter height class showed an increase in TE/ha values, which was not the case for the **inside** of the exclosure (Tables 2.25 and 2.26). The fact that the more than 4 meter height class had the same TE/ha values might indicate that the surveys were conducted on the same belt transect survey period. The increase in the less than 0.5 meter height class during the December 2001 surveys, could be explained by the good rains received during that particular growing season (See Chapter 2 for rainfall). The notable decrease in the TE/ha values on the **inside** of the exclosure could be ascribed to the resting period of the herbaceous cover due to no grazing. Although highly unlikely over such a short period of time, it could have increased the competitive value for available soil moisture by the herbaceous plants.(Table 4.25).

Water-Fouché 2 benchmark site

Table 4.27 represent the total woody species composition in percentage frequency at the Water-Fouché 2 benchmark site for December 2001 and May 2002. Only the woody species that had an abundance of, more than 5 % on average over the study period, both inside or outside the exclosure, were compared with each other and described in Figure 4.12. In Figure 4.13 the structure of the woody species at different height classes at the Water-Fouché 2 benchmark site for December 2001 and May 2002 is presented. Table 4.28 and Table 4.29, represent the number and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Water-Fouché 2 benchmark site for December 2001. The TE/ha per height class over the total two the survey periods for inside and outside the exclosure plots are represented in Tables 4.30 and 4.31.

Table 4.27: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Water-Fouché 2 benchmark site over the two sampling periods (December 2001 and May 2002), as well as the average percentage for each species.

	Dec-01		Apr-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	5.1	0.3	11.9	13.51	8.5	6.9
Acacia hebeclada (Aca heb)	15.4	0	7.14	0	11.27	0
Acacia mellifera (Aca mel)	17.9	20.6	16.67	13.51	17.29	17.06
Asparagus spp. *(Asp* spp.*)*	5.1	3.8	7.14	8.11	6.12	5.96
Boscia albitrunca (Bos alb)	0	0	2.38	0	1.19	0
Dichrostachys cinerea (Dich cin)	0	7.9	0	10.81	0	9.36
Diospyros lycioides (Dio lec)	0	15.9	0	0	0	7.95
Grewia flava (Gre fla)	56.4	22.2	54.76	54.05	55.58	38.13

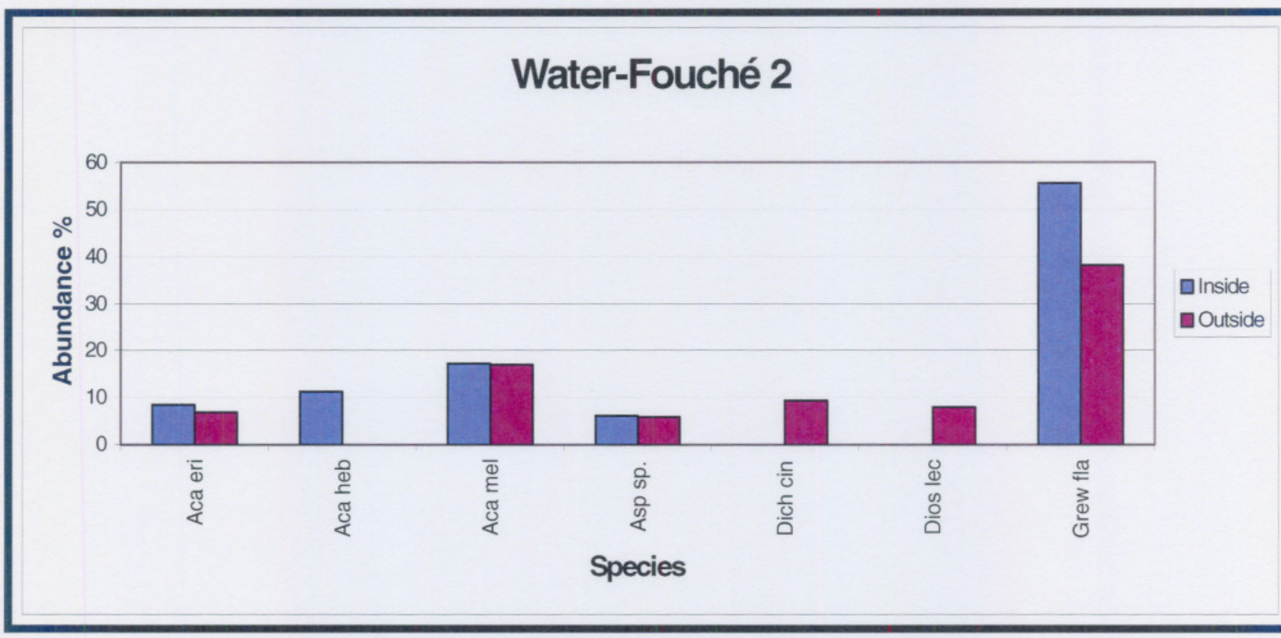

Figure 4.12: The average frequency of the woody vegetation more than 5% **inside** and **outside** the exclosure at the benchmark site of the Water-Fouché 2 benchmark site for the sample periods (December 2001 and May 2002). (See table 4.27 for abbreviations).

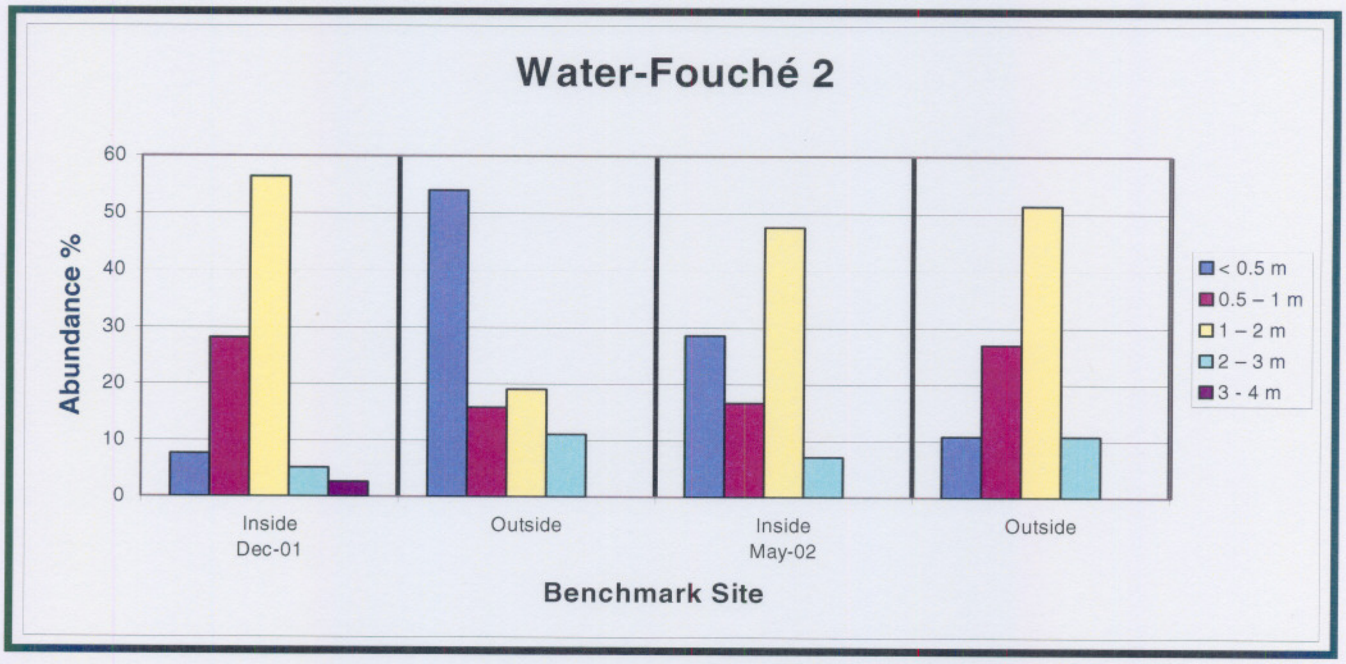

Figure 4.13: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Water-Fouché 2 benchmark site, for sampling period of December 2001 and May 2002.

Grewia flava was the most abundant species at the Water-Fouché 2 benchmark site, with an average of 55.58 % **inside** the exclosure plot and an average of 38.13 % **outside** the exclosure plot, for the study period December 2001 to May 2002 (Table 4.27). *Acacia mellifera* (17.29 % **inside** and 17.06 % **outside**), *A. hebeclada* (15.4 % **inside**) and *Diospyros lycioides* (7.95 % **outside**) were also relatively dominant species at this benchmark site (Table 4.27). The other species that were noted in the survey were the *Asparagus* species (6.12 % **inside** and 5.96 % **outside**), *A. erioloba* (8.5 % **inside** and 6.9 % **outside**) and *Dichrostachys cinerea* (9.36 % **outside**) (Table 4.27). *Acacia hebeclada* have decreased from 15.4 % to 7.14 % from December 2001 to May 2002. This may be ascribed to the change in season from summer to autumn. The foliage of this species reduced in such a manner that individuals could be distinguished.

The dominant structure during the December 2001 surveys was the 1 – 2 meter height class on the **inside** of the exclosure, and the less than 0.5 meter height class on the **outside** of the exclosure plot (Figure 4.13). *Grewia flava* and *Acacia mellifera* were the species most abundant on the **inside** and *A. mellifera, A. erioloba* and *D. lycioides* on the **outside** of the exclosure (Tables 4.28 and 4.29).

During the May 2002 surveys the dominant structure class was 1 – 2 meter for both **inside** and **outside** the exclosure (Figure 4.13). *Grewia flava* and *A. mellifera* were the dominant woody species **inside** and *G. flava* and *D. cinerea* on the **outside** of the exclosure (initial data). The sudden increase in the height of the dominant structure, on the **outside** of the exclosure, during May 2002 may be as a result of the survey not being conducted on the same place than the previous year, or due to inconsistency of sampling by divergent surveyors. (Figure 4.13).

The total decrease in the abundance of *D. lycioides* could be ascribed to the high mortality rate of seedlings as a result of the competition for moisture by the herbaceous layer (Table 4.27). The difference in values of *G. flava* **outside** the exclosure in the December 2001 and May 2002 surveys could be ascribed to an increase in rainfall during the previous growing season, as well as mistakes made by surveyors noting the single-stemmed plants as multi-stemmed individuals (Table 4.27).

The increase in the abundance of *A. erioloba* in the less than 0.5 meter height class, could most probably be ascribed to a dramatic increase in the seedling germination (Table 4.27). The decrease in the abundance of *A. hebeclada* could have occurred due to the leaves of the species that had fallen from the shrubs as winter approached. This resulted that all the rooted stems could be distinguished during the May 2002. Sampling period time had an influence on the accuracy and the relation of the true number of stems could be obtained. As mentioned previously unfortunately the increase and/or decrease in frequency of the woody component for the different sampling periods can mostly be ascribed to a sampling error. An estimation of the number of *A. hebeclada* was made during the previous survey.

Acacia mellifera showed a decrease in abundance from December 2001 to May 2002 (Table 4.27). This phenomenon could be ascribed to relative high mortality rates of seedlings that germinated during December 2001 as a result of the good rain of November that same year (See Chapter 2 for rainfall data). The reduction in the abundance of *A. mellifera* in the less than 0.5 m height class indicate a reduction of seedlings due to inter-species competition and competition with the herbaceous layer for available soil moisture (Table 4.27).

The reason for the increase in vegetation in the less than 0.5 meter height class **inside** the exclosure and the reduction of the abundance **outside** the exclosure could be linked to the good rainfall and the increase in seedlings (Figure 4.13). The seedlings, on the **outside** of the exclosure, were grazed and trampled by the cattle utilising the plants in the benchmark site till the December survey (Table 4.27). Most of the species increased in height could be due to the growth stimulated by the higher rainfall (see Chapter 2 for rainfall).

Table 4.28: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 2 benchmark site **inside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**3 - 4 m**	**Total woody species**	**% abundance**
Acacia erioloba	2					2	5.1
Acacia hebeclada		6				6	15.4
Acacia mellifera	1		3	2	1	7	17.9
Asparagus spp		2				2	5.1
Grewia flava		3	19			22	56.4
Total woody species	3	11	22	2	1	39	
% abundance	7.7	28.2	56.4	5.1	2.6		
TE/ha	12.38	92.13	275.00	41.75	29.13		450.38

Table 4.29: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 2 benchmark site **outside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**Total woody species**	**% abundance**
Acacia erioloba	9	8	1	1	19	0.3
Acacia mellifera	10	1		2	13	20.6
Asparagus spp.	2				2	3.8
Dichrostachys cinerea	4	1			5	7.9
Diospyros lycioides	9		1		10	15.9
Grewia flava			10	4	14	22.2
Total woody species	34	10	12	7	63	
% abundance	54	15.9	19	11.1		
TE/ha	140.25	83.75	150.00	146.13		520.13

Table 4.30: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of December 2001 and May 2002 at the Water-Fouché 2 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	12.38	92.13	275	41.75	29.13	0	450.38
May 2002	49.50	58.63	250	62.63	0	0	420.75

Table 4.31: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of December 2001 and May 2002 at the Water-Fouché 2 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	140.25	83.75	150.00	146.13	0	0	520.13
May 2002	16.50	83.75	237.50	83.50	0	0	421.25

Grewia flava was the most dominant woody species during December 2001, with a total average of 22 **inside** and 14 **outside** the exclosure (Tables 4.28 and 4.29). This species is, as already mentioned, considered as relatively palatable and could be heavily utilised by livestock when there is a shortage in the herbaceous layer (White, 1993).

Acacia mellifera (7) was the most dominant woody species on the **inside** of the exclosure in the less than 0.5 meter height class (December 2001) (Table 4.28). *Acacia mellifera* (10) was also the most abundant species on the **outside** of the exclosure in the less than 0.5 meter height class, during the December 2001 surveys (Table 4.29).

The total TE/ha **inside** the exclosure remained almost unchanged (December 2001 - 450.38 TE/ha and April 2002 - 420.75 TE/ha) (Table 4.30). The dominant structure class according to the TE/ha values was the 1 – 2 meter height class (Table 4.30). An increase in the less than 0.5 meter and 2 – 3 meter height classes were indicated by the TE/ha of the **inside** of the exclosure (Table 4.30) from Dec 2001 till May 2002. Again, this increase can be ascribed to a sampling error mentioned previously.

A more notable decrease in the total TE/ha was observed on the **outside** of the exclosure (Table 4.31). A reduction in vegetation in the dominant structure class (< 0.5 m) was observed. The 0.5 – 1 meter height class remained unchanged (Table 4.31) which may have been due to an increase in seedling mortality.

An absence of woody vegetation in the 3 – 4 meter and more than 4 meter height classes was observed on the **outside** of the exclosure, whilst there was no woody vegetation recorded in the more than 4 meter height class, on the **inside** of the exclosure (Tables 4.30 and 4.31).

Water-Fouché 3 benchmark site

Table 4.32 represent the total woody species composition in percentage frequency at the Water-Fouché 3 benchmark site for December 2001 and May 2002. Only the woody species that had an abundance of more than 5 % on average over the study period, both inside or outside the exclosure, were compared with each other and described in Figure 4.14. In Figure 4.15 the structure of the woody species at the Water-Fouché 3 benchmark site for December 2001 and May 2002 is presented. Tables 4.33 and 4.34, represent the number and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Water-Fouché 2 benchmark site for December 2001. The TE/ha per height class over the total two survey periods for inside and outside the exclosure plots are represented in Table 4.35 and Table 4.36.

Table 4.32: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Water-Fouché 3 benchmark site over the two sampling periods (December 2001 and May 2002), as well as the average percentage for each species.

	Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
Acacia hebeclada (Aca heb)	0	0	1.65	0	0.83	0
Acacia haematoxylon *(Aca hem)*	**69.2**	**67.1**	**63.64**	**68.15**	**66.42**	**67.63**
Asparagus spp.*(Asp* spp.*)*	0	1.4	0	0	0	0.7
Diospyros lycioides (Dios lec)	**15.4**	**2.7**	**14.88**	**1.91**	**15.14**	**2.3**
Grewia flava (Grew fla)	**9.2**	**20.5**	**12.4**	**14.01**	**10.8**	**17.26**
Rhus tenuinervis (Rhus ten)	**0**	**4.1**	**0**	**7.01**	**0**	**5.56**
Terminalia sericea (Term ser)	**6.2**	**4.1**	**7.44**	**8.28**	**6.82**	**6.19**

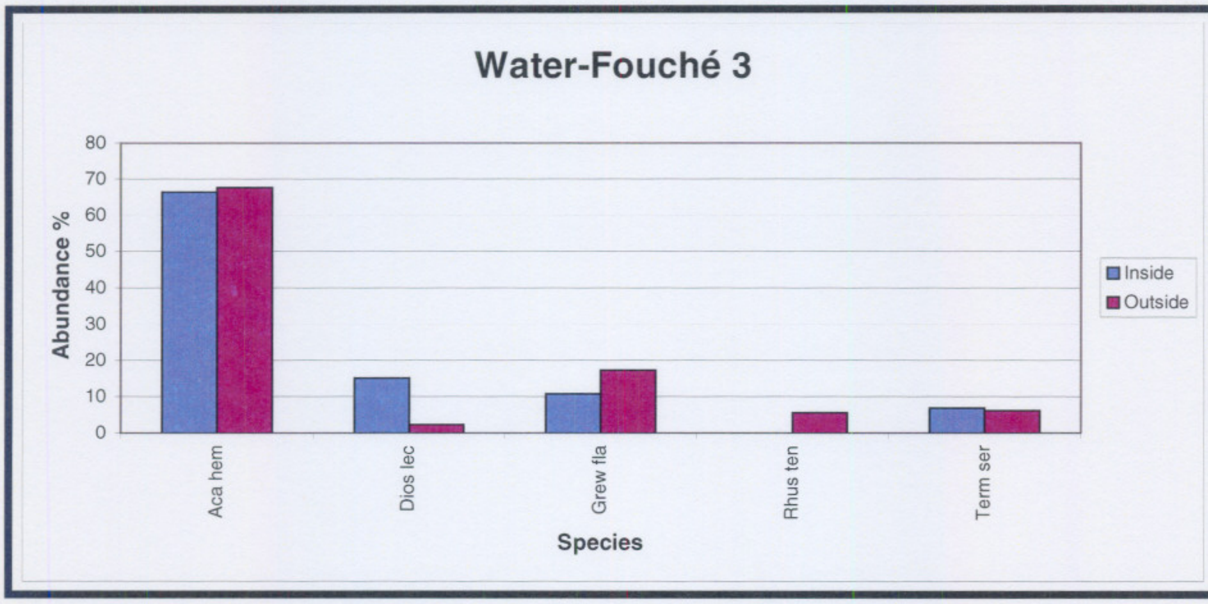

Figure 4.14: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the benchmark site of the Water-Fouché 3 benchmark site for the sample periods (December 2001 and May 2002). (See Table 4.32 for abbreviations).

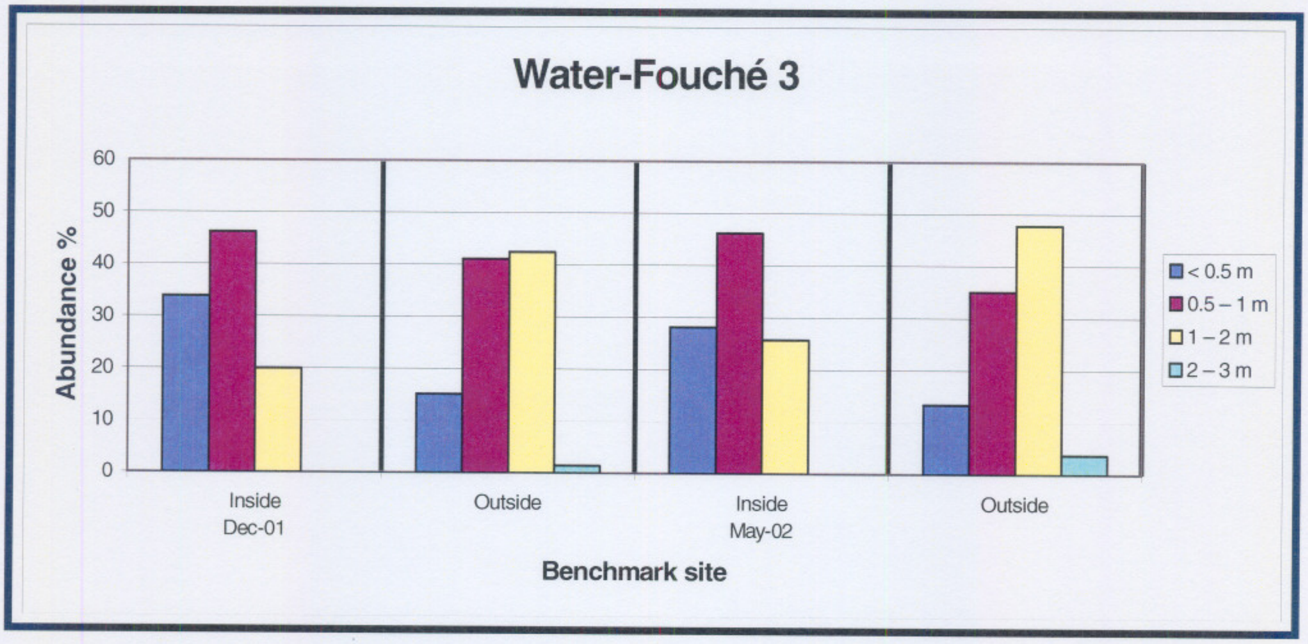

Figure 4.15: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Water-Fouché 3 benchmark site, for sampling periods of December 2001 and May 2002.

This benchmark site forms part of the *Acacia haematoxylon* vegetation type. The most abundant woody species in Water-Fouché 3 benchmark site were *Acacia haematoxylon* (66.42 % **inside** and 67.63 % **outside**) and *Grewia flava* (10.8 % **inside** and 17.26 % **outside**), as well as *Diospyros lycioides,* (15.14 % **inside**) *Rhus tenuinervis* (5.56 % **outside**) and *Terminalia sericea* (6.82 % **inside** and 6.19 % **outside**) (Table 4.32).

Acacia haematoxylon, dominated in all the height classes, from the less than 0.5 meter height class up to the 2 - 3 meter class (Figure 4.14). The abundance of all the other species in all the structure classes was less that 20 % (Figure 4.14).

The increase in *Terminalia sericea* and *Rhus tenuinervis* on the **outside** of the exclosure, may be due to an increase of seedlings, on mistakes made by the altered surveyors from on sampling period to the next. *Rhus tenuinervis* could also have increased due to the elimination of shading (Table 4.32). Large trees and shrubs were cleared when the fences of the exclosure were erected. The increase in this species from April 2001 to December 2001 could not be measured, as the exclosure were only erected during April after the sampled were completed at all the Water-Fouché study sites.

Grewia flava increased on the **inside** and decreased on the **outside** of the exclosure (Table 4.32). This species is a very palatable species and may have been utilised on the **outside** of the exclosure whereas the *G. flava* **inside** the exclosure have only benefited from the resting period and higher rainfall. (Table 4.32). The dominant structure on the **inside** of the exclosure was the 0.5 – 1 meter height class whilst the **outside** of the exclosure were dominated by the 1 – 2 meter height class for both surveys (Figure 4.15).

The 0.5 – 1 meter height class stayed the same for the two survey periods on the **inside** and **outside** of the exclosure although the 1 – 2 meter height class increased on the **outside** of the exclosure (Figure 4.15). This could have been that the surveys where not carried out on the same place between survey periods.

Table 4.33: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 3 benchmark site **inside** the exclosure for December 2001.

Species	< 0.5 m	0.5 - 1 m	1 - 2 m	Total woody species	% abundance
Acacia haematoxylon	13	24	8	45	69.2
Diospyros lycioides	9	1		10	15.4
Grewia flava		3	3	6	9.2
Terminalia sericea		2	2	4	6.2
Total	22	30	13	65	
% abundance	33.8	46.2	20		
TE/ha	90.75	251.25	162.50		504.50

Table 4.34: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 3 benchmark site **outside** the exclosure for December 2001.

Species	< 0.5 m	0.5 - 1 m	1 – 2 m	2 - 3 m	Total woody species	% abundance
Acacia haematoxylon	5	22	22		49	67.1
Asparagus spp.	1				1	1.4
Diospyros lycioides	1	1			2	2.7
Grewia flava	1	6	8		15	20.5
Rhus tenuinervis	3				3	4.1
Terminalia sericea		1	1	1	3	4.1
Total	11	30	31	1	73	
% abundance	15.1	41.1	42.5	1.4		
TE/ha	45.38	251.25	387.50	20.88		705.00

Table 4.35: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of December 2001 and May 2002 at the Water-Fouché 3 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	90.75	251.25	162.50	0	0	0	504.50
May 2002	140.25	469.00	387.50	0	0	0	996.75

Table 4.36: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of April 2001, December 2001 and May 2002 at the Water-Fouché 3 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	45.38	251.25	387.50	20.88	0	0	705
May 2002	86.63	460.63	937.50	125.25	0	0	1610

Acacia haematoxylon dominated every height class both **inside** and **outside** the exclosure (Table 4.33 and Table 4.34).

Approximately forty six percent (46.2 %) of the total woody vegetation was noted in the 0.5 – 1 meter height class on the **inside** of the exclosure (Table 4.33). and nearly forty three percent (42.5 %) of the total woody vegetation was noted in the 1 – 2 meter height class on the **outside** of the exclosure (Table 4.34). Unlike the Water-Fouché 1 benchmark, the Water-Fouché 3 vegetation in the benchmark had a lower dominant structure class which is characteristic of the *A. haematoxylon* vegetation type. The over all structure of the *A. haematoxylon* vegetation type does not normally reach higher than 3 meters (Tables 4.33, 4.34, 4.35 and 4.36).

Initial surveys showed that the total TE/ha **outside** the exclosure to be higher than on the **inside** (Tables 4.35 to 4.36). The height structure of the **inside** of the exclosure was however lower than the structure on the **outside** of the exclosure. This difference in TE/ha suggest that more exclosures should have been erected to obtain a better representative vegetation sample of each rangeland condition.

A general increase in the TE/ha per height class and the total TE/ha was observed for both **inside** and **outside** the exclosure from December 2001 to May 2002. A difference in sampling between surveyors might have been responsible for this change in TE/ha values as *A. haematoxylon* often has a multi-stemmed growth form.

Water-Fouché 4 benchmark site

Table 4.37 represent the total woody species composition in percentage frequency at the Water-Fouché 4 benchmark site for December 2001 and May 2002. Only the woody species that had an abundance of more than 5 % on average over the study period, both inside or outside the exclosure, were compared with each other and described in Figure 4.16. In Figure 4.17 the structure of the vegetation at the Water-Fouché 4 benchmark site for December 2001 and May 2002 is presented. Tables 4.38 and 4.39, represent the number and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Water-Fouché 4 benchmark site for December 2001. The change in TE/ha per height class over the total two survey periods for inside and outside3 the exclosure plots are represented in Tables 4.40 and 4.41.

Table 4.37: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Water-Fouché 4 benchmark site over the two sampling periods (December 2001 and May 2002), as well as the average percentage for each species.

	Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
***Acacia erioloba* (Aca eri)**	**14.8**	**7.7**	**14.29**	**1.2**	**14.55**	**4.45**
***Acacia haematoxylon* (Aca hem)**	**18.5**	**15.4**	**25.71**	**9.64**	**22.11**	**12.52**
***Diospyros lycioides* (Dio lec)**	**25.9**	**34.6**	**22.86**	**71.08**	**24.38**	**52.84**
***Grewia flava* (Gre fla)**	**37**	**26.9**	**28.57**	**10.84**	**32.79**	**18.87**
***Terminalia sericea* (Ter ser)**	**3.7**	**15.4**	**8.57**	**7.23**	**6.14**	**11.32**

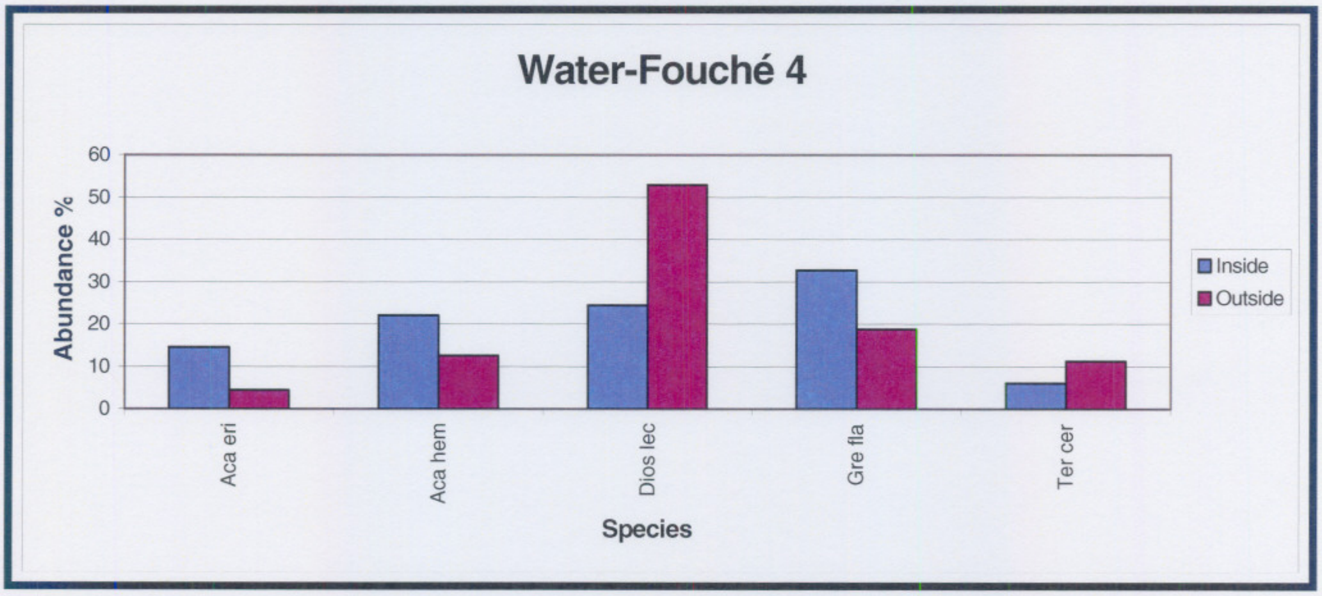

Figure 4.16: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the benchmark site of the Water-Fouché 4 benchmark site for the sample periods (December 2001 and May 2002). (See Table 4.37 for abbreviations.)

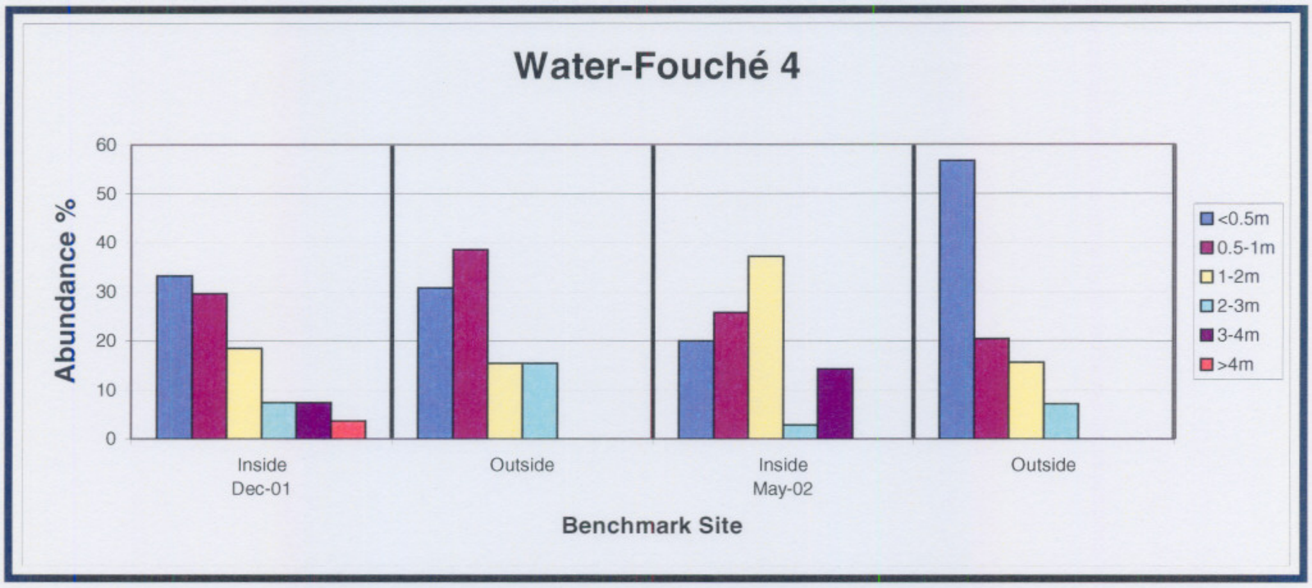

Figure 4.17: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Water-Fouché 4 benchmark site, for sampling periods of December 2001 and May 2002.

The most dominant species at the Water-Fouché 4 benchmark site was *Grewia flava* on the **inside** of the exclosure (32.79 %) and *Diospyros lycioides* on the **outside** of the exclosure (52.84 %) (Table 4.37 and Figure 4.16). The woody species of this benchmark site that occurred at abundances higher than 5 %, were *Acacia erioloba* (14.55 %) **inside**, *Acacia haematoxylon* (22.11 % **inside** and 12.52 % **outside**) and *Terminalia sericea* (6.14 % **inside** and 11.32 % **outside**) (Table 4.37 and Figure 4.16).

The dominant structure sampled during December 2001 **inside** the exclosure was less than 0.5 meter and 0.5 - 1 meter **outside** the exclosure (Figure 4.17). The dominant woody species contributing to the different height classes were *Diospyros lycioides* and *Grewia flava* respectively (Tables 4.38 and 4.39).

The dominant height class during the May 2002 surveys was the 1 – 2 meter **inside** the exclosure plot and the less than 0.5 meter height class **outside** the exclosure. The dominant woody species in each of these height classes were *A. haematoxylon* and *D. lycioides* respectively (initial data).

Table 4.38: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 4 benchmark site **inside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**3 - 4 m**	**> 4m**	**Total woody species**	**% abundance**
Acacia erioloba	2				2		4	14.8
Acacia haematoxylon		4	1				5	18.5
Diospyros lycioides	7						7	25.9
Grewia flava		4	4	2			10	37
Terminalia sericea						1	1	3.7
Total woody species	9	8	5	2	2	1	27	
% abundance	33.3	29.6	18.5	7.4	7.4	3.7		
TE/ha	37.13	67.00	62.50	41.75	58.25	37.50		304.13

Table 4.39: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 4 benchmark site **outside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**Total woody species**	**% abundance**
Acacia erioloba	1	1			2	7.7
Acacia haematoxylon		1	3		4	15.4
Diospyros lycioides	7	2			9	34.6
Grewia flava		6	1		7	26.9
Terminalia sericea				4	4	15.4
Total woody species	8	10	4	4	26	
% abundance	30.8	38.5	15.4	15.4		
TE/ha	33.00	83.75	50.00	83.50		250.25

Table 4.40: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of December 2001 and May 2002 at the Water-Fouché 4 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	37.13	67.00	62.50	41.75	58.25	37.50	304.13
May 2002	28.88	75.38	162.50	20.88	145.63	0	433.25

Table 4.41: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of December 2001 and May 2002 at the Water-Fouché 4 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 - 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	33.00	83.75	50.00	83.50	0	0	250.25
May 2002	193.88	142.38	162.50	125.25	0	0	624.00

If the total of woody species noted is considered the woody vegetation cover in the Water-Fouché 4 benchmark was, in general, very low. (Tables 4.48 and 4.49). The total increase in TE/ha for both **inside** and **outside** the exclosure site over the period form December 2001 to May 2002, could have been caused by the occurrence mistake of noting multi-stemmed species the May 2002 in stead of single-stemmed individuals, especially from December 2001 to May 2002. (Tables 4.40 and 4.41).

There had been a reduction of woody species in the less than 0.5 m height class on the **inside** of the exclosure (Table 4.40). The increase from 62.50 to 162.50 TE/ha from December 2001 to May 2002 in the 1 – 2 meter height class, may largely have been attributed to the increase of *A. haematoxylon.* The herbaceous layer was in an excellent condition and there was no need for the cattle to utilise the woody component.

In total the TE/ha increased by 129.12 TE/ha on the **inside** of the exclosure from December 2001 to May 2002, as well as 373.75 TE/ha on the **outside** of the exclosure for the same period. The largest increase was in the 1 – 2 meter height class for both **inside** and **outside** the exclosure which suggests that *A. haematoxylon, D. lycioides* and *Grewia flava* may have been noted differently during the two survey periods.

The overall height class on the **inside** of the exclosure was higher, as it included tree species up to higher than 4 m, than the structure on the **outside** of the exclosure. The structure on **inside** of the exclosure reached the more than 4 meter height class. While on the outside, only height classes up to 2 – 3 m were recorded (Tables 4.40 and 4.41).

Water-Fouché 5 benchmark site

Table 4.42 represents the total woody species composition in percentage frequency at the Water-Fouché 5 benchmark site for December 2001 and May 2002. Only the woody species had an abundance of more than 5 % on average, either inside or outside the exclosure, were compared with each other and described in Figure 4.18. In Figure 4.19 the structure of the woody species at the Water-Fouché 5 benchmark site for December 2001 and May 2002 is presented. Tables 4.43 and 4.44, represent the number and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Water-Fouché 5 benchmark site for December 2001. The TE/ha per height class over the total three survey periods for inside and outside the exclosure are represented in Tables 4.45 and 4.46.

Table 4.42: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Water-Fouché 5 benchmark site over the two sampling periods (December 2001 and May 2002), as well as the average percentage for each species.

	Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	**20.5**	**5.4**	**20.71**	**11.97**	**20.61**	**8.69**
Acacia hebeclada (Aca heb)	**1.8**	**17.3**	**0**	**23.94**	**0.9**	**20.62**
Acacia haematoxylon (Aca hem)	0	0.6	0	0	0	0.3
Acacia mellifera (Aca mel)	7.2	4.2	2.37	2.11	4.79	3.16
***Asparagus* spp. (*Asp* spp.)**	**6.6**	**12.5**	**1.18**	**16.2**	**3.89**	**14.35**
Boscia albitrunca (Bos alb)	**3.6**	**26.2**	**10.65**	**0**	**7.13**	**13.1**
Diospyros lycioides (Dios lec)	**19.3**	**11.9**	**15.98**	**11.27**	**17.64**	**11.59**
Ehretia rigida (Ehr rig)	1.2	0	0.59	0	0.9	0
Grewia flava (Grew fla)	**9.6**	**4.8**	**6.51**	**3.52**	**8.06**	**4.16**
Grewia retinervis (Gre ret)	2.4	0	1.18	0	1.79	0
Lycium hirsutum (Lyc hir)	**0**	**0**	**0**	**19.01**	**0**	**9.51**
Rhigozum brevispinosum (Rhig bre)	**0**	**2.4**	**16.57**	**4.93**	**8.29**	**3.67**
Rhus tenuinervis (Rhus ten)	**13.3**	**0**	**15.98**	**0**	**14.64**	**0**
Tarchonanthus camphoratus (Tarc camp)	**4.8**	**5.4**	**5.92**	**4.93**	**5.36**	**5.17**
Terminalia sericea	1.2	1.2	1.77	0	1.49	0.6
Ziziphus mucronata	0.6	0	0.59	0	1.19	0

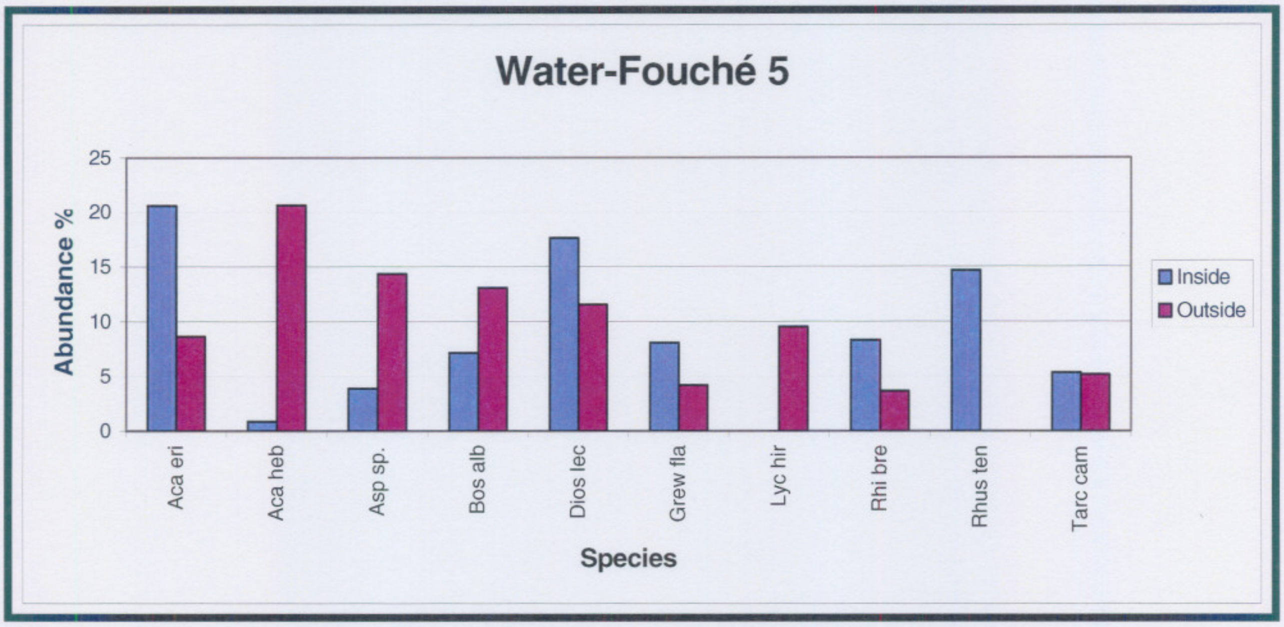

Figure 4.18: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure of the Water-Fouché 5 benchmark site for the sampling periods (December 2001 and May 2002). (See Table 4.42 for abbreviations)

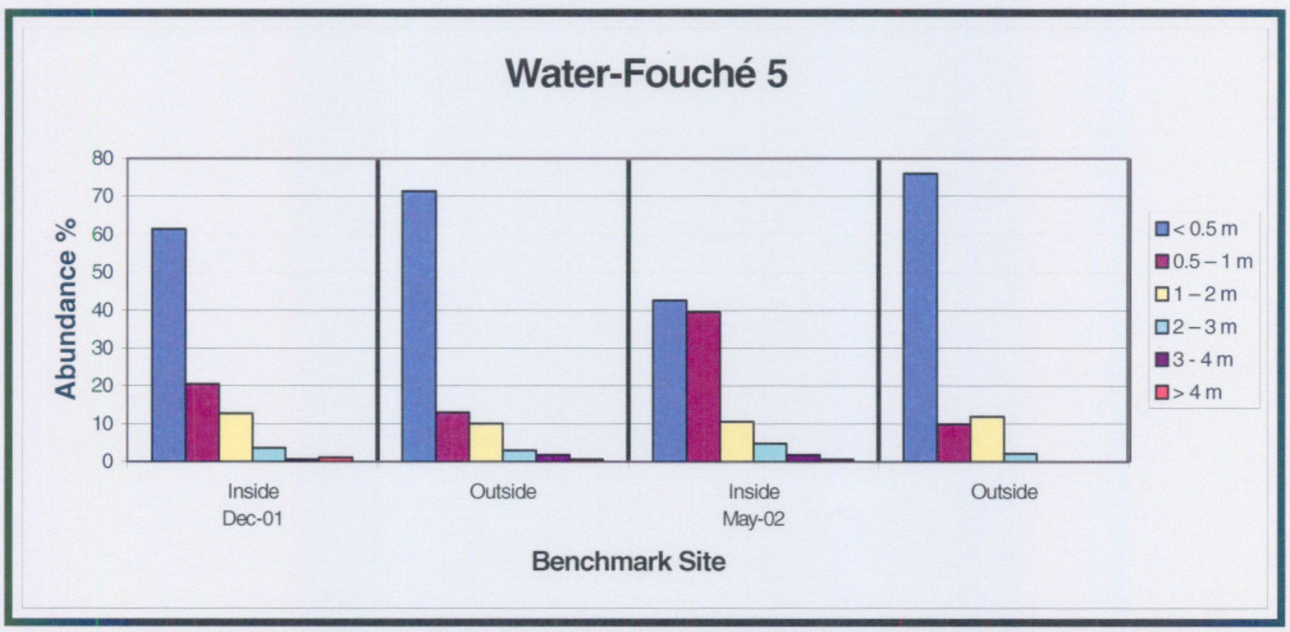

Figure 4.19: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Water-Fouché 5 benchmark site, for the period of December 2001 and May 2002.

The most dominant species at the Water-Fouché 5 benchmark were *Boscia albitrunca* (7.13 % **inside** and 13 % **outside**), *Acacia hebeclada* (20.62 % **outside**), *A. erioloba* (20.61% **inside** and 8.69 % **outside**), *Diospyros lycioides* (17.64 % **inside** and

11.59 % **outside**), *Lycium hirsutum* (9.51 % **outside**), *Rhigozum brevispinosum* (8.29 % **inside**), *Rhus tenuinervis* (14.64 % **inside**) and the *Asparagus* species (14.35 % **outside**) (Table 4.42). The other species that occurred more than 5 % were *Grewia flava* (8.06 **inside**) and *Tarchonanthus camphoratus* (5.36 **inside** and 5.17 **outside**) (Table 4.42).

Acacia erioloba showed an increase of 6.57 % from December 2001 to May 2002 on the **outside** of the exclosure (Table 4.42). There was only a slight increase in the abundance of smaller *A. erioloba* trees on the **inside** of the exclosure. A drastic decrease in the total woody species was noted, from December 2001 (168) to May 2002 (142) (Table 4.42).

The drastic decrease of the very palatable *Boscia albitrunca* species from 26.2 % in December 2001 to 0 % in May 2002, **outside** the exclosure, could mainly be ascribed to either a heavy utilisation of this tree or a sampling error. All the *B. albitrunca* noted at this site were within the grazing height (no more than *B. albitrunca* twigs with a few leafs) and confined to one small area, almost like a miniature *B. albitrunca* forest (Table 4.42).

The sudden occurrence of *Rhigozum brevispinosum*, especially on the **inside** of the exclosure, might be due to the gained knowledge of this species during the May 2002. This species was not noted during the December 2001 surveys. The only species that had a constant abundance of roundabout 5 % both **inside** and **outside** the exclosure, was *Tarchonanthus camphoratus* (Table 4.42).

The dominant height class of all the surveys (December 2001 and May 2002) of the Water-Fouché 5 benchmark site was the less than 0.5 meter height class both **inside** and **outside** the exclosure (Figure 4.19). The species that contributed the most to this structure class were *D. lycioides* (Dec 2001 **inside**), *B. albitrunca* (Dec 2001 **outside** and May 2002 **inside**) and *A. hebeclada* (May 2002 **outside**) (Tables 4.43 and 4.44 and initial data).

A drastic decrease occurred in the less than 0.5 meter height class on the **inside** of the exclosure, from December 2001 to May 2002. An increase in the 0.5 meter – 1 meter height class occurred at the same time which, could have indicated that a few individuals grew in size to the next height class on the **inside** of the exclosure (Figure 4.19). An increase in the less than 0.5 meter height class on the **outside** could be ascribed to the increase of *Acacia hebeclada* and *Diospyros lycioides* seedlings (Table 4.42).

A danger of bush thickening might be possible if the less palatable species, such as *Acacia hebeclada* increases more rapidly. With a sound rangeland management plan with adequate rest, this phenomenon should not however occur.

Table 4.43: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 5 benchmark site **inside** the exclosure for December 2001.

Species	**<0.5m**	**0.5-1m**	**1-2m**	**2-3m**	**3-4m**	**>4m**	**Total woody species**	**% abundance**
Acacia erioloba	17	9		7	1	1	35	20.71
Acacia mellifera	1		2		1		4	2.37
Asparagus spp.	2						2	1.18
Boscia albitrunca	18						18	10.65
Diospyros lycioides	16	11					27	15.98
Ehretia rigida			1				1	0.59
Grewia flava	2	1	8				11	6.51
Grewia retinervis	2						2	1.18
Rhus tenuinervis	11	16					27	15.98
Tarchonanthus camphoratus		2	7	1			10	5.92
Terminalia sericea	1	2					3	1.77
Rhigozum brevispinosum	2	26					28	16.57
Ziziphus mucronata					1		1	0.59
Total woody species	72	67	18	8	3	1	169	
% abundance	42.6	39.64	10.65	4.73	1.77	0.59		
TE/ha	297.00	561.13	225.00	167.00	87.38	37.50		1375.00

Table 4.44: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Water-Fouché 5 benchmark site **outside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**3 - 4 m**	**> 4m**	**Total woody species**	**% abundance**
Acacia erioloba	4	1	1		3		9	5.4
Acacia hebeclada	29						29	17.3
Acacia haematoxylon		1					1	0.6
Acacia mellifera	3		1	2		1	7	4.2
Asparagus spp.	15	6					21	12.5
Boscia albitrunca	44						44	26.2
Diospyros lycioides	17	2	1				20	11.9
Grewia flava			7	1			8	4.8
Rhigozum brevispinosum		4					4	2.4
Tarchonanthus camphoratus			7	2			9	5.4
Terminalia sericea	2						2	1.2
Total woody species	120	22	17	5	3	1	168	
% abundance	71.4	13.1	10.1	3	1.8	0.6		
TE/ha	495.00	184.25	212.50	104.38	87.38	37.50		1121.00

Table 4.45: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of December 2001 and May 2002 at the Water-Fouché 5 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	420.75	284.75	262.50	125.25	29.13	75.00	1197.38
May 2002	297.00	561.13	225.00	167.00	87.38	37.50	1375.00

Table 4.46: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of December 2001 and May 2002 at the Water-Fouché 5 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	495.00	184.25	212.50	104.38	87.38	37.50	1121.00
May 2002	445.50	117.25	212.50	62.63	0	0	837.88

Nearly forty three per cent (42.6 %) of the woody species noted on the **inside** of the exclosure occurred in the less than 0.5 meter height class during the December 2001 surveys (Table 4.43). An even higher abundance of this height class occurred on the outside of the exclosure (71.4%) of the benchmark site (Table 4.44).

An increase of 177.62 TE/ha of the total woody species were observed **inside** the exclosure, whereas a decrease of 283.12 TE/ha was observed for the total woody composition from December 2001 to May 2002 on the **outside** of the exclosure (Tables 4.45 and 4.46).

The sudden disappearance of the woody species in the 3 – 4 meter and taller than 4 meter height classes on the **outside** of the exclosure could be due to a shift in position of the belt transect from the December 2001 to May 2002 surveys (Table 4.46). Only three taller trees were not noted and it is possible that these trees were only one or two steps out of the sampling belt.

The notable decline in TE/ha in the less than 0.5 meter height class and the sudden increase in the 0.5 – 1 meter height class on the **inside** of the exclosure, could partly be ascribed to the better rainfall of the past growing season (See Chapter 2 Figure 2.10 for rainfall). Another reason for this increase might also have been a mistake in the sampling. The same mistakes apply to the drastic increase in the TE/ha in the 0.5 – 1 meter height class. Woody species do not grow that fast even with adequate rainfall conditions. The increase in the TE/ha of the 3 – 4 meter height class and the decrease in the TE/ha of the more than 4 meter height class suggest that the surveys might not have been conducted on the same place on the **inside** of the exclosure as well. It may also indicate the differences in perception of height by different surveyors.

The total decrease of TE/ha on the **outside** of the exclosure is mostly caused by the decrease in TE/ha in the 2 – 3 meter structure class (Table 4.46). *Grewia flava* is the most prominent multi-stemmed species found at that height class.

Water-Fouché 6 benchmark site

Table 4.47 represents the total woody species composition in percentage frequency at the Water-Fouché 6 benchmark site for December 2001 and May 2002. Only the woody species that had an abundance of more than 5 % on average over the study period, both inside or outside the exclosure, were compared with each other and described in Figure 4.20. In Figure 4.21 the structure of the woody vegetation at the Water-Fouché 6 benchmark site for December 2001 and May 2002 is presented. Tables 4.48 and 4.49, represent the number and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Water-Fouché 6 benchmark site for December 2001. The TE/ha per height class over the total three survey periods for inside and outside the exclosure plots are represented in Tables 4.50 and 4.51.

Table 4.47: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Water-Fouché 6 benchmark site over the three sampling periods (December 2001 and May 2002), as well as the average percentage for each species.

	Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	1.8	0	0	1.75	0.9	0.88
Acacia haematoxylon (Aca hem)	**80.4**	**65.1**	**95**	**71.93**	**87.7**	**68.52**
Grewia flava (Gre fla)	**17.9**	**32.6**	**5**	**26.32**	**11.45**	**29.46**

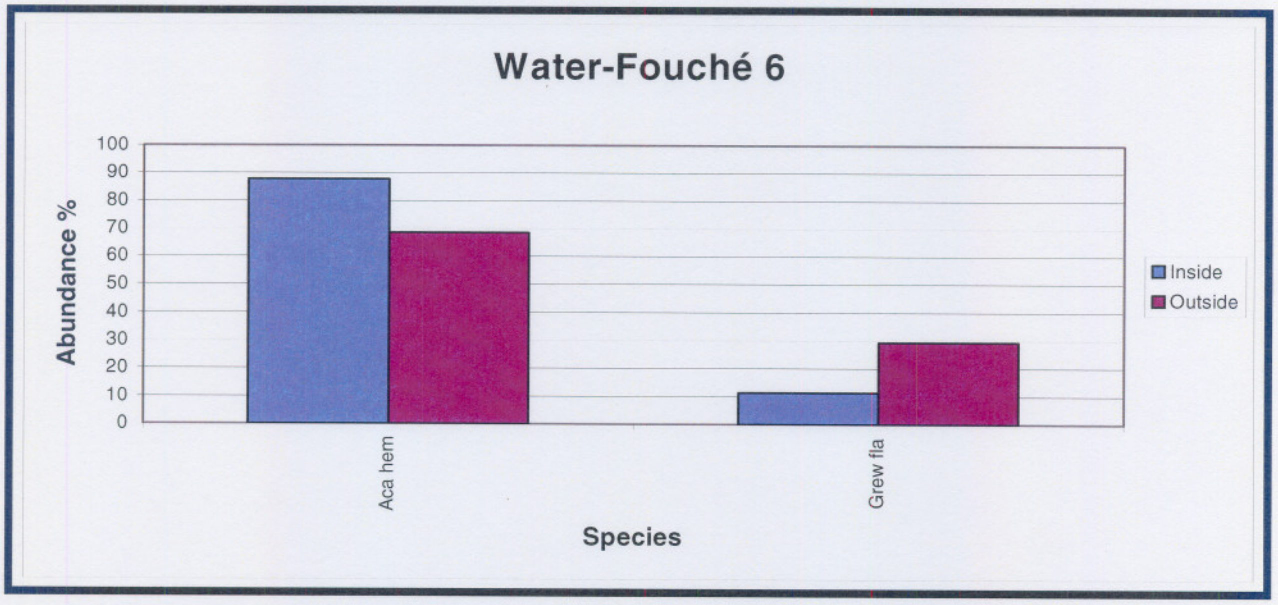

Figure 4.20: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the benchmark site of the Water-Fouché 6 benchmark site over the study period (December 2001 and May 2002). (See Table 4.47 for abbreviations)

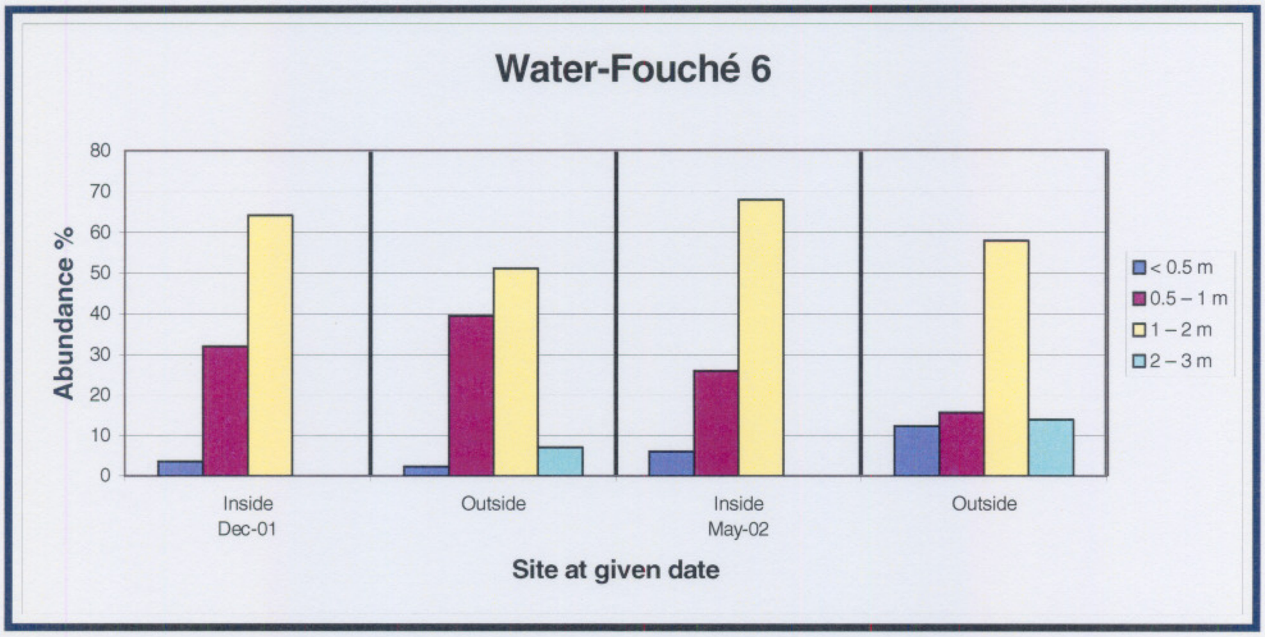

Figure 4.21: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Water-Fouché 6 benchmark site, for sampling periods of December 2001 and May 2002.

The most dominant species at this benchmark site was *A. haematoxylon* and appeared at an average of 87.7 % **inside** and 68.52 % **outside** the exclosure of the benchmark site for the period of December 2001 to May 2002 (Table 4.47 and Figure 4.20).

The decrease in the abundance of *Grewia flava* on the **inside** of the exclosure could be ascribed to the reduction of contribution this species have as the total woody vegetation noted increased (Table 4.47). The total abundance of woody species noted during December 2001 was 56 individuals on the **inside** (Table 4.47).

The dominant height class in all surveys was 1 – 2 meters (Figure 4.21). This is, as already mentioned, the height class at which the dominant species, *A. haematoxylon* is usually found (Figure 4.21). The species variance of this benchmark was very low with only three woody species present including a very low total cover (Tables 4.48 and 4.49).

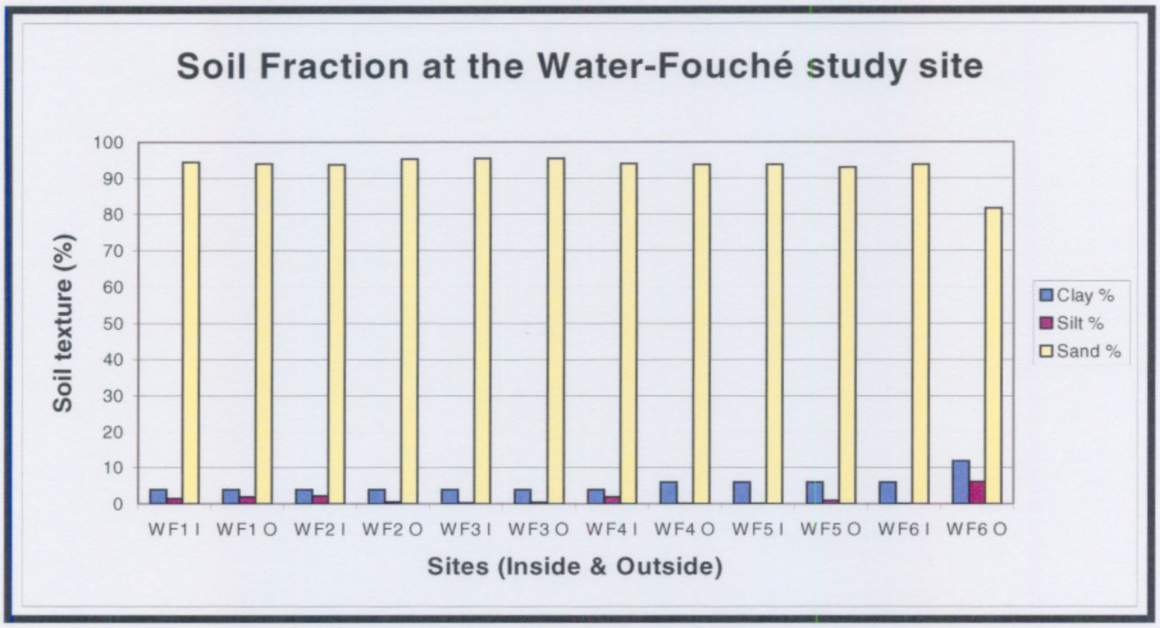

Figure 4.22: The soil texture (%) of the Water-Fouché study site as obtained from the soil analysis done during the sampling of May 2002. (Note that: WF-Water-Fouché, I – inside the exclosure, O – outside the exclosure and number relates to the survey location).

From the chemical soil analysis, which is presented in Table 4.52, it is clear that as for the Austrey study site, the organic carbon, phosphates and potassium levels are very low.

Table 4.52: The chemical soil analysis results from the samples taken during the May 2002 surveys (see Figure 4.22 for abbreviations).

	1:2.5 Water	**Bray-I**	**Amm. Acetate 1M (pH 7.00)**					**W.B.**	**water paste**
Site	pH	P	Ca	Mg	K	Na	CEC	C	R
No		Mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cmol(+)/kg	%	Ohm
WF1 I	6.04	3.28	**169**	32.6	31.2	0	2.44	0.14	24000
WF1 O	6.14	3.43	**189**	26.2	38.5	0	1.83	0.20	8400
WF2 I	6.12	3.29	124	33.3	38.3	0	2.22	0.18	22000
WF2 O	6.21	3.40	**156**	36.8	42.3	0	2.49	0.17	9200
WF3 I	6.16	3.50	121	35.1	33	0	3.09	0.15	9400
WF3 O	6.31	3.52	140	36.7	29.5	**2.1**	3.16	0.15	9800
WF4 I	6.12	3.48	101	28.4	42.3	0	2.52	0.17	30000
WF4 O	6.04	3.40	112	28.9	35.4	0	2.33	0.17	20000
WF5 I	5.98	3.20	**211**	**50.6**	37	0	3.21	0.17	18000
WF5 O	6.16	3.18	**197**	38.8	38.4	0	2.91	0.20	6800
WF6 I	6.06	3.29	147	**45**	**52**	0.1	2.70	0.18	9400
WF6 O	5.89	3.19	113	31.2	34.3	0	2.30	0.19	34000

The average pH of this site was 6.1 ,and is also similar to that of the Austrey study site (Table 4.52). The soil at Water-Fouché may be less leached than that of the Austrey study site, due to the lower rainfall in this region. Sites 1 and 5 had higher levels of calcium than the other sites. At these sites *Acacia mellifera* occurred in higher abundance. Organic carbon is also low, as in the case of the Austrey study site. The dry climate inhibited the functioning of micro-organisms associated with the carbon cycle (Atlas, 1996).

Summary of the Water-Fouché study sites.

This study site can be divided into two clearly distinguishable vegetation types. The *Acacia erioloba* vegetation type has a more heterogeneous vegetation composition with *Acacia erioloba* as dominant species in these benchmarks. These benchmarks include the Water-Fouché 1, 2 and 5 benchmark sites. The total TE/ha of the *A. erioloba* vegetation type seems to be considerably higher than the TE/ha of the other vegetation type. The vegetation structure of the *A. erioloba* vegetation type reaches the 4 meter height class, whilst the structure of the other vegetation type i.e. *A. haematoxylon* vegetation type only reaches the 2 –3 meter height class. The *A. haematoxylon* vegetation type is dominated by a more homogeneous composition, of *Acacia haematoxylon.* The Water-Fouché 3, 4 and 6 benchmark sites were located in the *A. haematoxylon* vegetation type.

The four most abundant species of the Water-Fouché 1 benchmark site were *Boscia albitrunca* (27.5 % **inside** and 13.7 % **outside** the exclosure), the *Asparagus* species (17.9 % **inside** and 22.01 % **outside**), *Lycium hirsutum* (9.2 % **inside**) and *Rhigozum brevispinosum* (17.1 % **outside**).

The Water-Fouché 2 benchmark was dominated by *Grewia flava* (55.58 % **inside** and 38.13 % **outside** the exclosure), *Acacia mellifera* (17.28 % **inside** and 17.06 % **outside**), *Acacia hebeclada* (11.27 % **inside**) and *Dichrostachys cinerea* (9.36 % **outside**).

The Water-Fouché 3 benchmark was situated in the *A. haematoxylon* vegetation type and was dominated by this species with 66.42 % occurring **inside** the exclosure and 67.63 % on the **outside** of the exclosure, respectively.

The Water-Fouché 4 benchmark was dominated by *Grewia flava* (32.79 %) on the **inside** of the exclosure, and *Diospyros lycioides* (52.84 %) on the **outside** of the exclosure. *Acacia haematoxylon* was the third most abundant species at this benchmark site, namely 22.11 % **inside** and 2.52 % **outside**, respectively.

The Water-Fouché 5 benchmark is part of the *Acacia erioloba* vegetation type as *A. erioloba* dominated the **inside** of the exclosure with 20.61 %. *Diospyros lycioides* had a 17.64 % abundance **inside** and 11.59 % on the **outside** of the exclosure. The abundance of *Rhus tenuinervis* (14.64 %) had increased **inside** the benchmark form December 2001 to May 2002. The reason for this might have been to the increase of sunlight, as some taller trees were eradicated to construct the fence of the exclosure plot. The succession occurring in these more open patches would be interesting to monitor over time in order to see if the woody component will still grow more rapidly than the herbaceous component in this rested area **inside** the exclosure.

Only two dominant woody species were present at the Water-Fouché 6 benchmark. This benchmark was characterised by a relatively homogeneous vegetation type. The dominant species were *Acacia haematoxylon* (87.70 % **inside** and 68.52 % **outside**) and *Grewia flava* (11.45 % **inside** and 29.46 % **outside**).

Acacia haematoxylon is a relatively palatable species. The straight spines found at the nodes make that this species is more often browsed especially by goats (Richter *et al*, 2001). This species is only found in the arid regions on deep sandy soil in the Kalahari (Smit, 1999). *Acacia haematoxylon* was only noted at the Water-Fouché 3, Water-Fouché 4 and Water-Fouché 6 study sites where it was the dominant woody vegetation.

The *Acacia hebeclada* species is a relatively less palatable species with the tendency to invade areas that are overgrazed. This species is a low growing shrub and grows in a wide variety of soils, especially in calcrete rich soils (Smit, 1999). *Acacia* *hebeclada* is found in dry savanna or grassland areas (Smit, 1999). Although *A. hebeclada* was present at the Water-Fouché 3 and Water-Fouché 4 benchmark sites it was only at very low abundances. At the Water-Fouché 5 benchmark *A. hebeclada* was relatively abundant on the outside of the exclosure for both surveys but it did not occur at the Water-Fouché 6 benchmark site.

Grewia flava is known to be a relatively palatable species that can be heavily utilised when there is a shortage in herbaceous production, such as in drought periods. This species forms large bush clumps that cover large areas in a rangeland. *Grewia flava* have a shallow root system and compete with the herbaceous layer for moisture. This could be the reason that no grass grows underneath *G. flava* thickets. *Grewia flava* is a good source of reserve fodder but may cause a threat to the grazing capacity of a rangeland as the woody species invade the habitat of the herbaceous vegetation. The Water-Fouché 1 and 5 benchmarks showed a low abundance of *G. flava*, while at the Water-Fouché 3 and 4 benchmark sites this species occurred moderately high. At the Water-Fouché 2 and 6 benchmark sites *G. flava* occurred in relatively high abundances.

Rhus tenuinervis could be regarded as an unpalatable species as all *Rhus* species seem to have a strong aromatic quality. This species was not in high abundance except at the Water-Fouché 3 and Water-Fouché 5 benchmark sites. *Rhus tenuinervis* also occurred in a very low abundance at the Water-Fouché 1 benchmark site. Visually this species seem to be an opportunistic pioneer species that only occupy bare patches. The possibility that *Rhus tenuinervis* can increase when overgrazing occur is possible but species such as *Acacia hebeclada* would more easily invade degraded rangelands. The dominant structure at the Water-Fouché 1 benchmark was less than 0.5 meters and this structure class contributed the most to the total TE/ha.

The structure of the Water-Fouché 2 benchmark **inside** differed extremely, from that on the **outside** of the exclosure. This difference might be as a result of the surveys on the **outside** of the exclosure that were not conducted in precisely the same spot. It could also have been a decrease in seedlings as a result of inter species competition for available resources. The dominant structure height **inside** the exclosure was the 1 – 2 meter height class, for both surveys, while the dominant structure recorded during

December 2002 on the **outside** was the less than 0.5 meter height class and the 1 - 2 meter height class during May 2002. The 1 – 2 meter height class contributed the most to the total TE/ha both **inside** and **outside** the exclosure.

The dominant structure **inside** the exclosure of the Water-Fouché 3 study site for both surveys was the 0.5 – 1 meter height class. The dominant structure on the **outside** of the exclosure for both survey, was the slightly higher 1 – 2 meter height class. The difference in dominant structure might indicate that more samples should have been taken to obtain a more representative sample of the woody vegetation. The TE/ha also indicate that the 0.5 - 1 meter height class contributed the most to the total tree density **inside** the exclosure, whilst the 1 – 2 meter height class contributed the most to the total TE/ha **outside** the exclosure. The increase in total TE/ha at this benchmark could largely be attributed to the increase the number of species noted in the dominant height classes. The May 2002 surveys, being autumn surveys, were characterised with woody vegetation with reduced foliage. This made it easier for the surveyors to detect the rooted bushes.

The Water-Fouché 4 study site was also characterised by differences in structure, if the two surveys are compared. The woody species structure according to the TE/ha data indicate the same phenomenon. The only clearly stated answer to this phenomenon is that different surveyors were conducting the surveys and that a multi stemmed species were noted as separate single stemmed individuals.

The dominant structure at the Water-Fouché 5 benchmark was the less that 0.5 meter height class for both **inside** and **outside** the exclosure. The reduction on the **inside** of the exclosure in the less than 0.5 meter height class and the increase in the 0.5 – 1 meter height class could have been that most of the species noted during December 2001 were just below the 0.5 meter mark and during the May 2002 surveys on the 0.5 meter mark or even past that. One person would probably have noted the species on the 0.5 meter mark as part of the less than 0.5 m height class, whilst another person could have placed it in the 0.5 – 1 meter height class. The TE/ha data show the less than 0.5 meter and 0.5 - 1 meter height classes to have contributed the most to the total TE/ha on the inside of the exclosure, whilst the less than 0.5 meter and 1 – 2 meter height classes contributed the most on the **outside** of the exclosure, for both the two surveys conducted. A total decrease in both the **inside** and **outside** of the benchmark was detected.

The dominant structure at the Water-Fouché 6 study site was the 1 – 2 meter height class. This correlated with the basic structure of the *A. haematoxylon* vegetation type. The same as what happened at the Water-Fouché 5 benchmark, might have happened at this benchmark concerning the great difference in the values of the 0.5 – 1 meter height class **outside** the exclosure. If a species is extremely close to 1 meter it could be placed in either height classes depending on that person.

The above average rainfall at this study site also contributed the most to the visual changes observed in vegetation composition. The rain could also have contributed to the occurrence of more small trees.

The pH of the soil was closer to neutral than that of the Austrey study site. This might be due to the lower rainfall resulting in less soil leaching.

4.3 Kudumane magisterial district

4.3.1 Heuningvlei study site

Agriculturists and land users selected the benchmark sites to represent different rangeland conditional states subjectively according to species composition and factors that indicate the degree of degradation, such as bare ground, occurrence of erosion and the past grazing history. The Heuningvlei study site represented the Morafe Ranch management system in the Kudumane district. Three of the sites at the Heuningvlei study site (A2, C2, F2) were surveyed by the Potchefstroom University for Christian Higher Education. For better identification of benchmark sites the extension officers marked blocks of the Morafe Ranch as A, B, C, D etc. after which each block was numbered 1, 2, and 3.

Woody vegetation

Heuningvlei A2 benchmark site

Table 4.53 represents the total woody species composition in percentage frequency at the Heuningvlei A2 benchmark site for December 2001 and May 2002. Only the woody species that had an abundance of more than 5 % on average over the study period, both inside or outside the exclosure, were compared with each other and described in Figure 4.23. In Figure 4.24 the structure of the vegetation at the Heuningvlei A2 benchmark site for December 2001 and May 2002 is presented. Table 4.54 and Table 4.55 represent the number and percentage (%) of the total individual woody species noted per height class, as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Heuningvlei A2 benchmark site for April 2001. The TE/ha per height class over the total three survey periods for inside and outside the exclosure plots are represented in Tables 4.56 and 4.57.

Table 4.53: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Heuningvlei A2 benchmark site over the two sampling periods (December 2001 and May 2002), as well as the average percentage for each species.

	Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	**3.6**	**30.6**	**1.42**	**32.35**	**2.51**	**31.48**
Acacia luederitzii (Aca lud)	3	0	2.84	0	2.92	0
Acacia mellifera (Aca mel)	1.2	3.2	1.42	2.94	1.31	3.07
Asparagus sp. (Asp spp.*)*	0.6	2.4	1.42	0	1.01	1.2
Boscia albitrunca (Bos alb)	**54.4**	**0**	**59.57**	**0**	**56.99**	**0**
Dichrostachys cinerea (Dich cin)	**17.8**	**33.1**	**14.18**	**16.67**	**15.99**	**24.89**
Grewia flava (Gre fla)	**13.6**	**30.6**	**13.48**	**45.1**	**13.54**	**37.85**
Grewia retinervis (Gre ret)	1.2	0	0.71	0	1	0
Lycium sp. (Lyc sp.)	0	0	0	1.96	0	0.98
Rhus tenuinervis (Rhus ten)	2.4	0.8	3.55	0.98	2.98	0.89
Terminalia sericea (Ter ser)	2.4	2.4	1.42	0	1.91	1.2

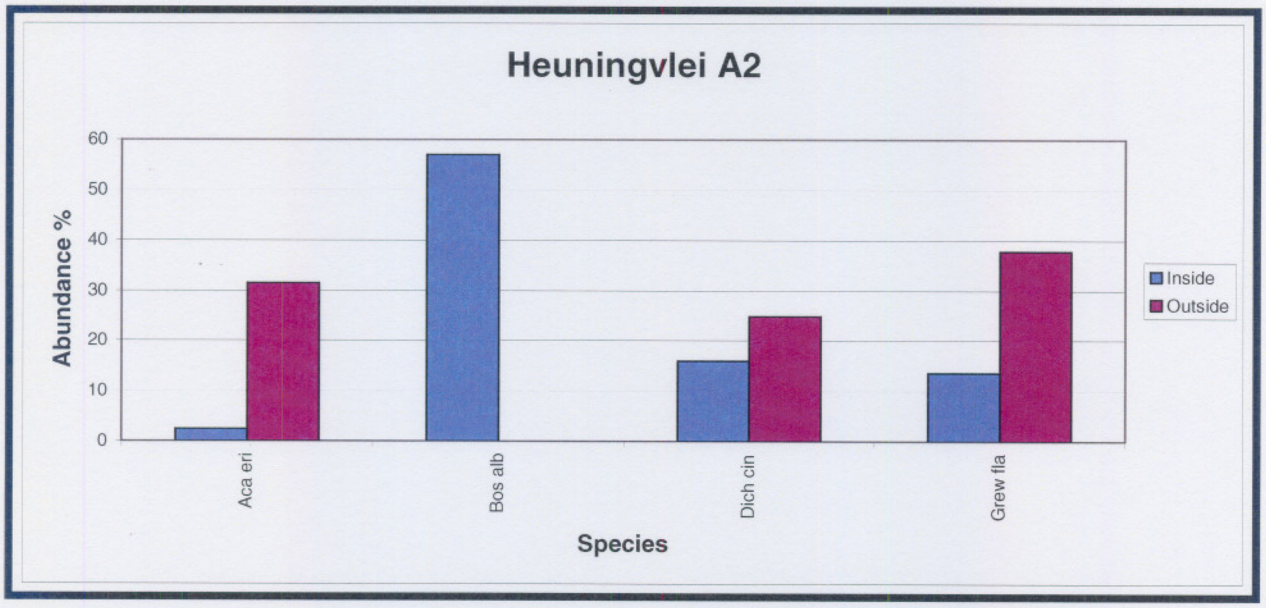

Figure 4.23: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure of the Heuningvlei A2 benchmark site for the sample periods (December 2001 and May 2002). (See Table 4.54 for abbreviations).

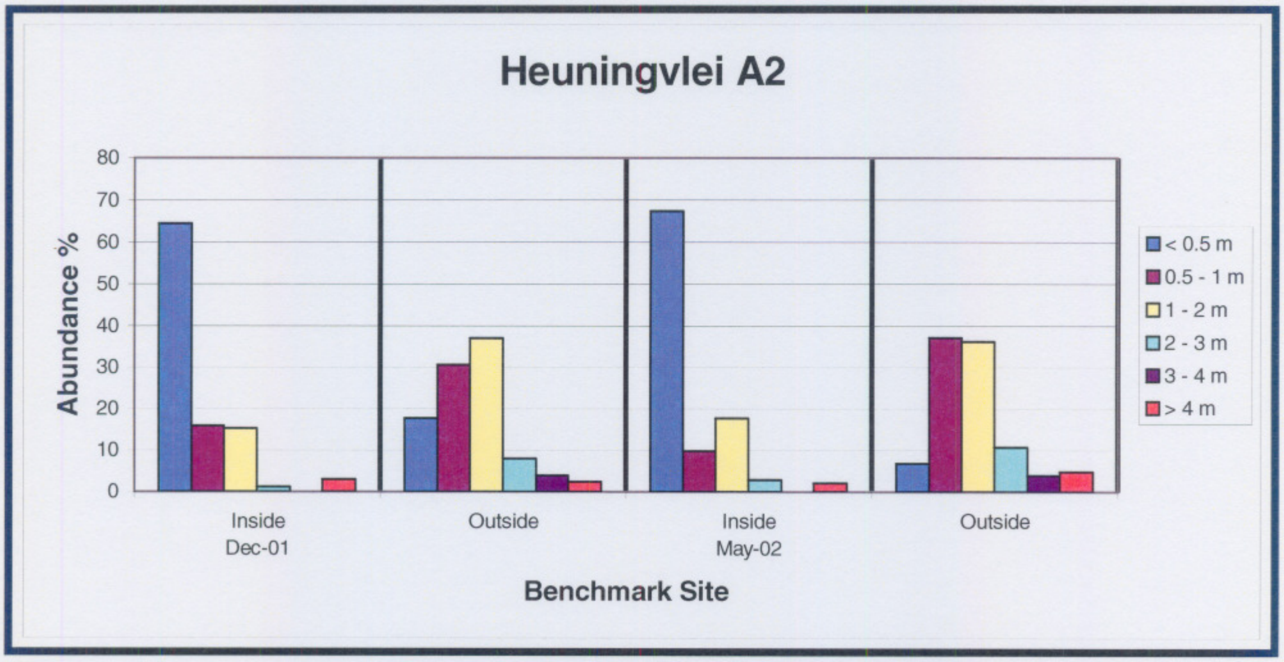

Figure 4.24: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Heuningvlei A2 benchmark site, for the sampling periods December 2001 and May 2002.

The average dominant woody species at the Heuningvlei A2 benchmark site over the study period were *Acacia erioloba* (31.48 % **outside**), *Boscia albitrunca* (56.99 % **inside**), *Dichrostachys cinerea* (15.99 % **inside** and 24.89 % **outside**) and *Grewia flava* (13.54 % **inside** and 37.85 % **outside**) (Table 5.52 and Figure 4.23).

In total there seemed to be a decline in the woody species from December 2001 to May 2002 both **inside** and **outside** the exclosure (Tables 4.55 and 4.56). The abundance of *D. cinerea* also decreased both **inside** and **outside** the exclosure (Table 4.52).

The relative high percentage of *D. cinerea* in the 0.5 – 1 meter height class, increased in size to the next height class, if the data from the 2 study periods are compared. Twenty one (21) *D. cinerea* individuals were noted on the **outside** in December 2001 and only 2 woody species in May 2002 in the 0.5 – 1 meter height class (Figure 4.24 and Table 4.54). Some of the *D. cinerea* of the 0.5 – 1 meter height class might have out-competed other *D. cinerea*, of the same height and caused some mortality and thus the decline in numbers of this species. The herbaceous layer that was in a healthy condition could also have contributed to the reduction of this species.

The increase of *G. flava* could be attributed to the good rainy season that started in September 2001. Light utilisation of this species could have stimulated growth in the study site **outside** of the exclosure (Table 4.52).

The dominant height class for the **inside** of the exclosure plot was the less than 0.5 meter class for both periods surveyed. The woody species that contributed the most to that particular height class were *Boscia albitrunca* and *Grewia flava* (Table 4.52).

The dominant height class **outside** the exclosure plot during December 2001was in the 1 – 2 meter class (Figure 4.24). The woody species contributing the most to this height class was *G. flava.* During May 2002 the number of species in the height classes of 0.5 – 1 meter and 1 –2 meter were almost equal. *Grewia flava* and *Dichrostachys cinerea* were the dominant woody species at the different height classes respectively.

Table 4.54: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Heuningvlei A2 benchmark site **inside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 – 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia erioloba		1	1			4	6	3.6
Acacia luederitzii	1	1	1	1		1	5	3
Acacia mellifera	1		1				2	1.2
Asparagus spp.		1					1	0.6
Boscia albitrunca	92						92	54.4
Dichrostachys cinerea	12	9	9				30	17.8
Grewia flava	1	11	11				23	13.6
Grewia retinervis			2				2	1.2
Rhus tenuinervis		4					4	2.4
Term sericea	2		1	1			4	2.4
Total woody species	109	27	26	2	0	5	169	
% abundance	64.5	16	15.4	1.2	0	3		
TE/ha	449.63	226.13	325.00	41.75	0	187.50		1230.00

Table 4.55: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE per height class and total) and the total woody species and the percentage of each species of the Heuningvlei A2 benchmark site **outside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 – 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia erioloba	3	2	13	8	5	3	38	30.6
Acacia mellifera	1		2	1			4	3.2
Asparagus spp.	2	1					3	2.4
Dichrostachys cinerea	9	21	11				41	33.1
Grewia flava	7	13	18				38	30.6
Rhus tenuinervis		1					1	0.8
Terminalia sericea			2	1			3	2.4
Total woody species	22	38	46	10	5	3	124	
% abundance	17.7	30.6	37.1	8.1	4	2.4		
TE/ha	90.75	318.25	575.00	208.75	145.63	112.50		1450.88

Table 4.56: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods December 2001 to May 2002 at the Heuningvlei A2 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	449.63	226.13	325.00	41.75	0	187.50	1230.00
May 2002	391.88	117.25	312.50	83.50	0	112.50	1017.63

Table 4.57: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods December 2001 to May 2002 at the Heuningvlei A2 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	90.75	318.25	575.00	208.75	145.63	112.50	1450.88
May 2002	28.88	318.25	462.50	229.63	116.50	187.50	1343.25

The TE/ha data indicates a total reduction in TE/ha both **inside** and **outside** the exclosure (Tables 4.56 and 4.57).

The advance in height of the woody species to the following structure class (e.g. >0.5 m to 0.5-1m the following year) as well as the decrease of individuals in a single height class but from one sampling period to the next, attributed to the change in total TE/ha during the study period. A example of this can be seen by the total decrease in TE/ha from December 2001 (1230 TE/ha **inside** and 1450.88 TE/ha **outside**) to May 2002 (1017.63 TE/ha **inside** and 1343.25 TE/ha **outside**), as some individuals could have suffered due to interspecies competition (Tables 4.55 and 4.56).

The TE/ha for the 0.5 – 1 meter height class on the **outside** of the exclosure stayed the same for both surveys while the lowest height structure on the **inside** of the exclosure showed a decrease in TE/ha from December 2001 (449.63 TE/ha) to May 2002 (391.88 TE/ha).

No woody species were found in the 3 – 4 meter height class on the **inside** of the exclosure whilst the more than 4 meter height class contributed relatively good to the total woody species of the Heuningvlei A2 benchmark both **inside** and **outside** the exclosure.

Heuningvlei C2 benchmark site

Table 4.58 represent the total woody species composition in percentage frequency at the Heuningvlei C2 benchmark site for December 2001 and May 2002. Only the woody species that were presented more than 5 % on average over the study period, both inside or outside the exclosure, were compared with each other and described in Figure 4.25. In Figure 4.26, the structure of the woody vegetation at the Heuningvlei C2 benchmark site for December 2001 and May 2002 is presented. Table 4.59 and Table 4.60 represent the number and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Heuningvlei C2 benchmark site for April 2001. The TE/ha per height class and the total TE/ha for the whole survey period are presented in Tables 4.61 and 4.62.

Table 4.58: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Heuningvlei C2 benchmark site over the two sampling periods (December 2001 and May 2002), as well as the average percentage for each species.

	Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
Acacia erioloba (Aca eri)	**1**	**6.1**	**1.67**	**6.35**	**1.34**	**6.23**
Acacia luederitzii (Aca lud)	5.4	1.2	2.5	1.59	3.95	1.4
Acacia mellifera (Aca mel)	**2.7**	**7.3**	**4.17**	**6.35**	**3.44**	**6.83**
Asparagus sp.(Asp spp.)	**11.7**	**12.2**	**11.67**	**0**	**11.69**	**6.1**
Boscia albitrunca (Bos alb)	2.7	2.4	0.83	3.17	1.77	2.79
Dichrostachys cinerea (Dich cin)	1	0	6.67	0	3.84	0
Ehretia rigida (Ehr rig)	3.6	1.2	1.67	1.59	2.64	1.4
Grewia flava (Gre fla)	**21.6**	**20.7**	**23.33**	**25.4**	**22.47**	**23.05**
Grewia retinervis (Gre ret)	1.8	2.4	1.67	1.59	1.74	2
Lycium sp. (Lyc sp.)	0	0	0	1.59	0	0.8
Maytenus heterophylla (May het)	**1**	**9.8**	**15**	**15.87**	**8**	**25.67**
Rhigozum brevispinosum (Rhig bre)	**36.9**	**26.8**	**30**	**30.16**	**33.45**	**28.48**
Rhus tenuinervis (Rhus ten)	**1.8**	**9.8**	**0.83**	**6.35**	**1.32**	**8.08**

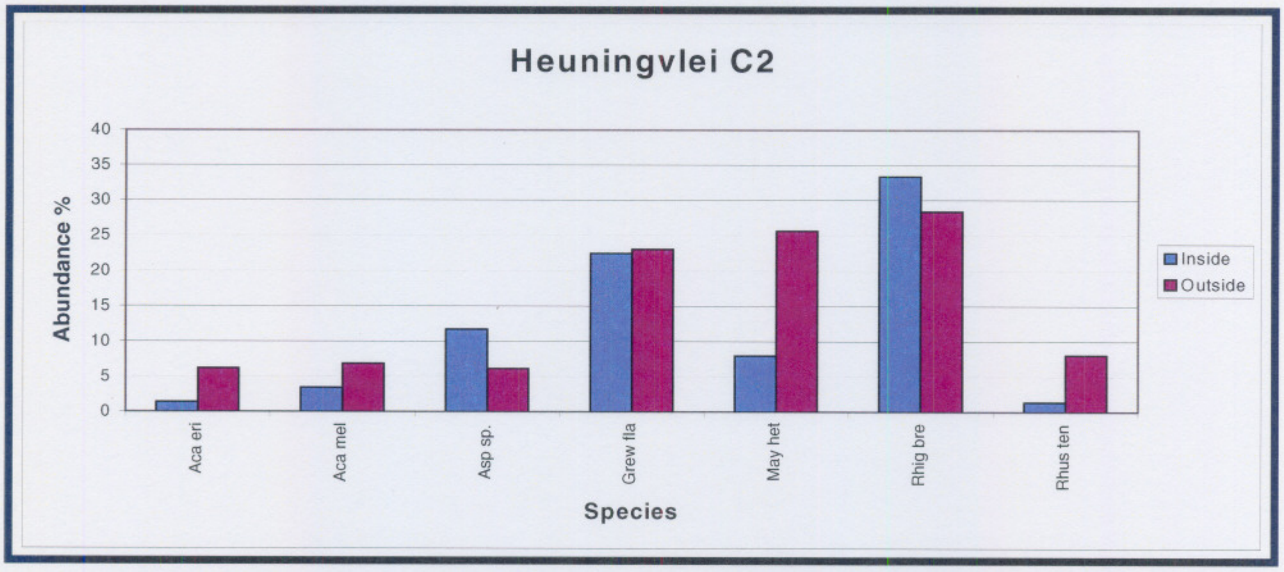

Figure 4.25: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the benchmark study site of the Heuningvlei C2 benchmark site for the sample periods (December 2001 and May 2002). (See Table 4.57 for abbreviations).

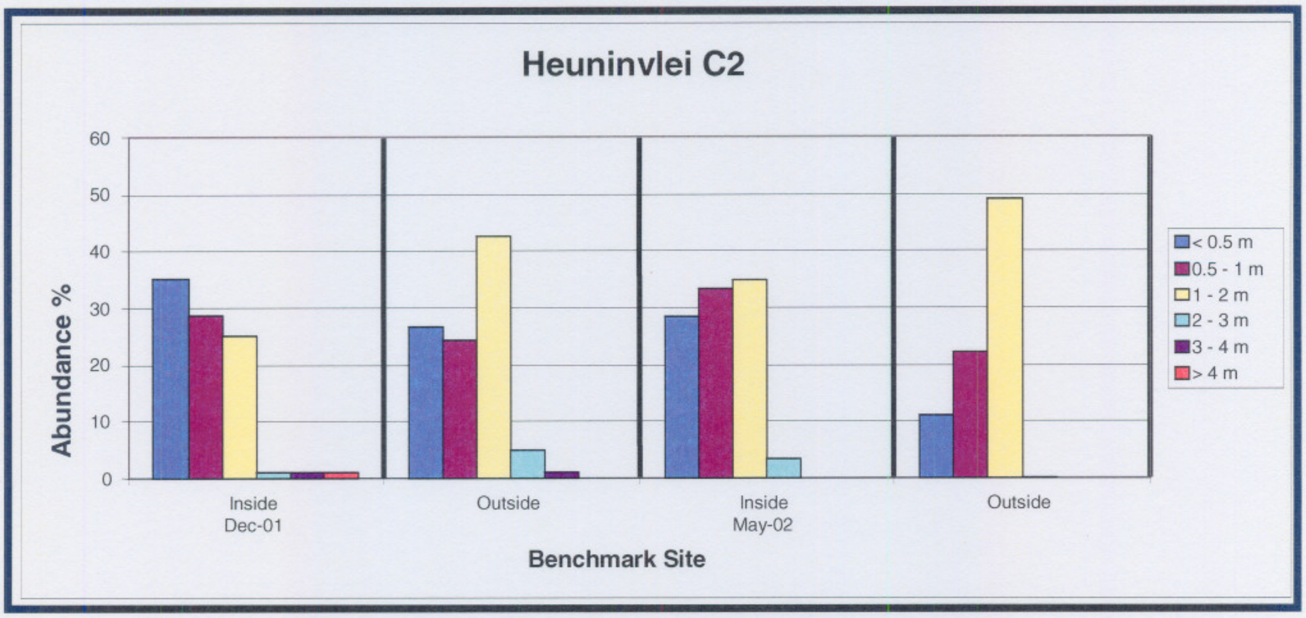

Figure 4.26: The structure of the woody vegetation structure at different height classes **inside** and **outside** the exclosure of the Heuningvlei C2 benchmark site, for the sampling periods of December 2001 and May 2002.

The dominant woody species at the Heuningvlei C2 benchmark site were *Rhigozum brevispinosum* (33.45 % **inside** and 28.48 % **outside**), *Grewia flava* (22.47 % **inside** and 23.05 % **outside**) and *Maytenus heterophylla* (8 % **inside** and 25.67 % **outside**). *Grewia flava* is the most dominant species in almost all the study sites and can be regarded as the species contributing to bush thickening in the Western Region of the North West Province, especially in the Vryburg district. Other woody species that had an abundance of more than 5 %, were *Acacia erioloba* (6.23 % **outside**), *A. mellifera* (6.83 % **outside**), the *Asparagus* species (11.69 % **inside** and 6.1 % **outside**) and *Rhus tenuinervis* (8.08 % **outside**) (Table 4.58 and Figure 4.25).

The dominant height class **inside** the exclosure, during the December 2001 surveys, was the less than 0.5 meter class and the woody species contributing the most to this height class was *Rhigozum brevispinosum* (Table 4.59 and Table 4.60). The 1 – 2 meter height class was dominated by *G. flava* both **inside** and **outside** the exclosure during the May 2002 survey (Tables 4.59 and 4.60).

The change in abundance of the species in the different height classes from one survey to the next can most probably be attributed to sampling errors or inconsistency between surveyors. The change in position of the so-called "permanent transect" could also have contributed to these mistakes. It is difficult to straighten the rope of the transect through thorny bushes as well as large *G. flava* and *Tarchonanthus camphoratus* bushes.

Table 4.59: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Heuningvlei C2 benchmark site **inside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia erioloba			1				1	1
Acacia luederitzii	1	2	3				6	5.4
Acacia mellifera		1	1	1			3	2.7
Asparagus spp.	11	2					13	11.7
Boscia albitrunca	1	2					3	2.7
Rhigozum brevispinosum	22	13	6				41	36.9
Dichrostachys cinerea	1		1				1	1
Ehretia rigida		2	1		1		4	3.6
Grewia flava		9	15				24	21.6
Grewia retinervis	1	1					2	1.8
Maytenus heterophylla	1						1	1
Rhus tenuinervis	1					1	2	1.8
Total woody species	39	32	28	1	1	1	111	
% abundance	35.1	28.8	25.2	1	1	1		
TE/ha	160.88	268.00	350.00	20.88	29.13	37.50		866.38

Table 4.60: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Heuningvlei C2 benchmark site **outside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**3 - 4 m**	**Total woody species**	**% abundance**
Acacia erioloba		3		1	1	5	6.1
Acacia luederitzii	1					1	1.2
Acacia mellifera		1	4	1		6	7.3
Asparagus spp.	10					10	12.2
Boscia albitrunca			2			2	2.4
Lycium hirsutum	2	3	15	2		22	26.8
Ehretia rigida			1			1	1.2
Grewia flava	1	4	12			17	20.7
Grewia retinervis		1	1			2	2.4
Maytenus heterophylla	6	2				8	9.8
Rhus tenuinervis	2	6				8	9.8
Total woody species	22	20	35	4	1	82	
% abundance	26.8	24.4	42.7	4.9	1.2		
TE/ha	90.75	167.5	437.5	83.5	29.125		808.375

Table 4.61: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods December 2001 to May 2002 at the Heuningvlei C2 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	160.88	268.00	350.00	20.88	29.13	37.50	866.38
May 2002	140.25	335.00	525.00	83.50	0	0	1083.75

Table 4.62: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods December 2001 to May 2002 at the Heuningvlei C2 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	90.75	167.50	437.50	83.50	29.13	0	808.38
May 2002	28.88	117.25	387.50	229.63	0	0	763.25

The increase of TE/ha in both the 0.5 – 1 meter and 1 – 2 meter height classes on the **inside** of the exclosure could be of concern, seeing that the height classes on the **outside** of the exclosure have decreased (Tables 4.60 and 4.61). The exclosure might not have been grazed during the winter months as this area is only recently been developed. The recent development lead to a very low stocking rate, mainly cattle. The total increase of TE/ha on the **inside** as well as the total decrease of TE/ha on the **outside** of the exclosure, indicate that the bush may have thickening on the **inside** of the exclosure. The increase of bush on the **inside** of the exclosure might also be as a result of the good rain and the absence of browsing (Table 4.61).

The fact that no tree equivalent values are presented in the 3 – 4 meter and more than 4 meter height classes during the May 2002 surveys on the **inside** of the exclosure, can again be contributed to sampling errors.

The same applies for the absence of TE/ha in the 3 – 4 meter height class on the **outside** of the exclosure. One tree was not noted and might have been just outside the belt sampling area.

The increase of *Maytenus heterophylla* in the lower height classes can be of concern, seeing that this is a less palatable species that can lead to woody thickening or encroachment.

Heuningvlei F2 benchmark site

Table 4.63 represents the total woody species composition in percentage frequency at the Heuningvlei F2 benchmark site for December 2001 and May 2002. Over the woody species that were present more than 5 % on average over the study period, both inside or outside the exclosure, were compared with each other and described in Figure 4.27. In Figure 4.28 the structure of the woody vegetation at the Heuningvlei F2 benchmark site for December 2001 and May 2002 is presented. Tables 4.64 and 4.65 represent the number and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Heuningvlei F2 benchmark site for April 2001. The TE/ha per height class and the total TE/ha for the whole survey period are presented in Tables 4.66 and 4.67.

Table 4.63: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Heuningvlei F2 benchmark site over the two sampling periods (December 2001 and May 2002), as well as the average percentage for each species.

	Dec-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
Acacia luederitzii (Aca lud)	1.3	0	0.93	1.05	1.12	0.53
Acacia mellifera (Aca mel)	**14.6**	**15.5**	**14.81**	**8.42**	**14.71**	**11.96**
Asparagus sp. (Asp spp.)	**42**	**31.1**	**46.3**	**34.73**	**44.15**	**32.92**
Boscia albitrunca (Bos alb)	1.3	1.9	2.78	3.16	2.04	2.53
Dichrostachys cinerea (Dich cin)	**8.3**	**5.8**	**4.63**	**8.42**	**6.47**	**7.11**
Diospyros lycioides (Dio lyc)	0	0	0.93	0	0.47	0
Ehretia rigida (Ehr rig)	0.6	3.9	0.93	4.21	0.77	4.06
Grewia flava (Gre fla)	**21**	**19.4**	**14.81**	**14.74**	**17.91**	**17.07**
Grewia retinervis (Gre ret)	**6.4**	**11.7**	**3.7**	**10.53**	**5.05**	**11.12**
Lycium sp. (Lyc sp.)	**0**	**0**	**3.7**	**11.58**	**1.85**	**5.79**
Rhigozum brevispinosum (Rhig bre)	0	7.8	0	0	0	3.9
Rhus tenuinervis (Rhus ten)	**4.5**	**2.9**	**6.48**	**3.16**	**5.49**	**3.03**

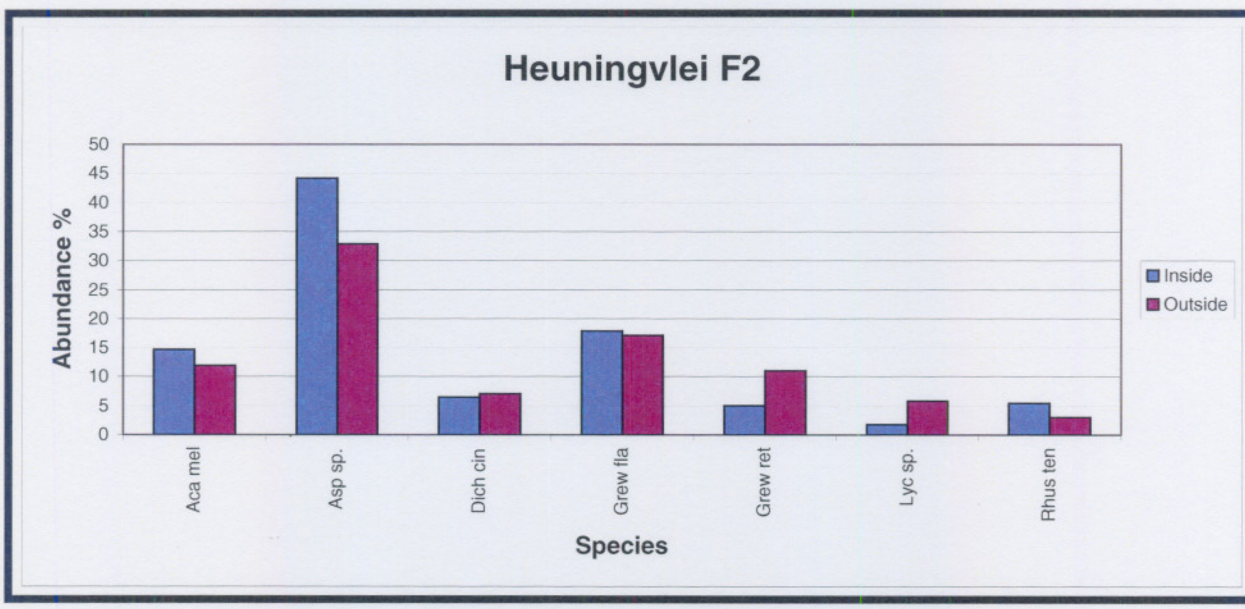

Figure 4.27: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the benchmark study site of the Heuningvlei F2 benchmark site for the sample periods (December 2001 and May 2002). (See Table 4.62 for abbreviations.)

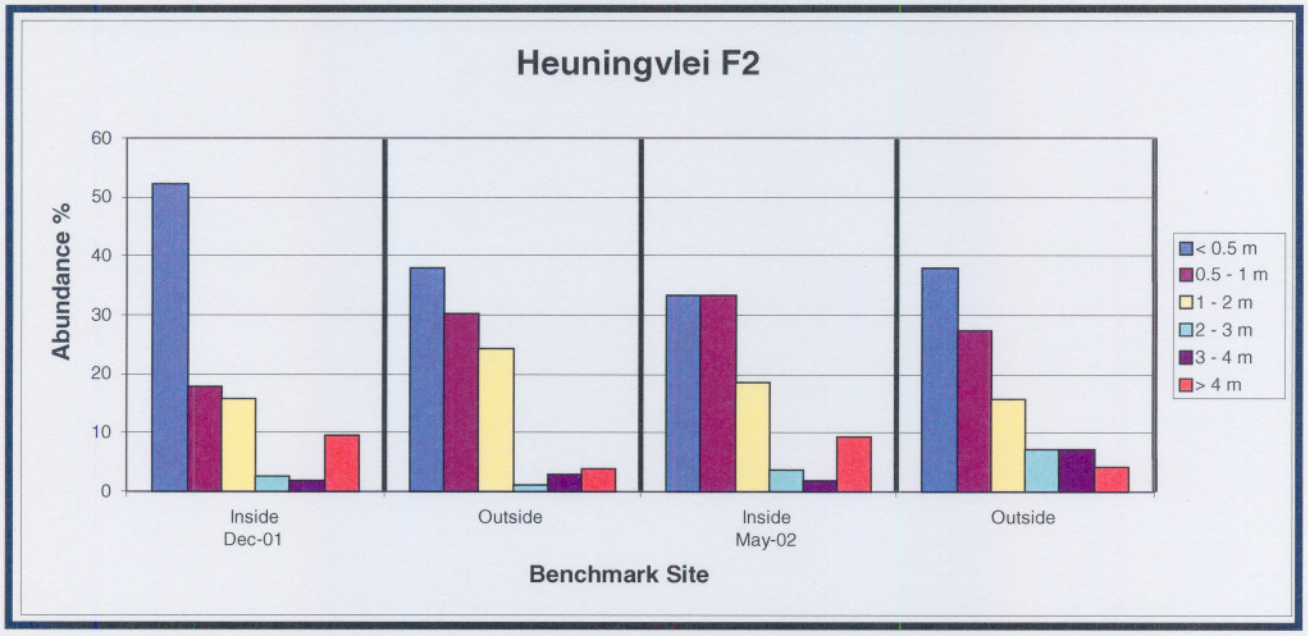

Figure 4.28: The structure of the woody vegetation at different height classes **inside** and **outside** the exclosure of the Heuningvlei F2 benchmark site, for the sampling periods December 2001 and May 2002.

The two most dominant woody species at the Heuningvlei F2 benchmark site were the *Asparagus* species (44.15 % **inside** and 32.92 % **outside**) and *Grewia flava* (17.91 % **inside** and 17.07 % **outside**). Other dominant species included *Acacia mellifera* (14.71 % **inside** and 11.96 % **outside**), *Dichrostachys cinerea* (6.47 % **inside** and 7.11 % **outside**), *Grewia retinervis* (5.05 % **inside** and 11.12 % **outside**), *Lycium* sp. (5.79 % **outside**) and *Rhus tenuinervis* (5.49 % **inside**) (Table 4.63 and Figure 4.27).

The decrease of *A. mellifera* on the **outside** of the exclosure could most probably be due to inter species competition as most of the *A. mellifera* species noted was in the 1 – 2 meter height class (Table 4.63). The decrease of *D. cinerea* on the **inside** (December 2001 to May 2002) and the increase on the **outside** of the exclosure could be as a result of more disturbance (cattle grazing and trampling of the soil) occurring on the **outside** than on the **inside** of the exclosure. *Dichrostachys cinerea* is a species that tend to invade grazing areas, as the livestock utilise the pods and distribute the seeds (Appendix I).

The decrease in *G. flava* both **inside** and **outside** the exclosure from December 2001 to May 2002 could be largely attributed to the decrease in abundance in both the less than 0.5 meter and 0.5 – 1 meter height classes. This reduction could be as a result of inter species competition, combined with a sampling error by the different surveyors.

The total reduction of *Rhigozum brevispinosum* could be due to the relatively high rainfall that was experienced from September 2001 to May 2002. *Rhigozum brevispinosum* only occur in arid savannas and semi-deserts. If the rainfall should increase in an area, this species would decrease in abundance (Van Wyk & Van Wyk, 1997). *R. brevispinosum* did not appear to be in a good condition during the May 2002 surveys. The above average rainfall experienced during January 2002 may have caused this species to reduce in abundance.

The dominant height class was in the less than 0.5 meter for all the surveys both **inside** and **outside** the exclosure plot. During the May 2002 survey the number of species were the same in both the less than 0.5 meter and the 0.5 – 1 meter height classes **inside** the exclosure (Figure 4.27). The *Asparagus* species contributed the most to these structure classes both **inside** and **outside** the exclosure (Tables 4.64 and 4.65).

The decrease of the woody species in the less than 0.5 meter height class, from December 2001 to May 2002, could be as a result of the good rainfall that stimulated growth. Inter-species competition may have caused seedling abundance to remain constant and not proliferate. The increase in the 2 – 3 meter height class during May 2002 could have been due to some woody species have increased in height from the 1 – 2 meter class (Figure 4.28).

Table 4.64: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Heuningvlei F2 benchmark site **inside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia luederitzii	1					1	2	1.3
Acacia mellifera	2		2	3	2	14	23	14.6
Asparagus spp.	59	5	2				66	42
Boscia albitrunca			1	1			2	1.3
Dichrostachys cinerea	6	4	3				13	8.3
Ehretia rigida			1				1	0.6
Grewia flava	13	15	5				33	21
Grewia retinervis		2	7		1		10	6.4
Rhus tenuinervis	1	2	4				7	4.5
Total	82	28	25	4	3	15	157	
% abundance	52.2	17.8	15.9	2.5	1.9	9.6		
TE/ha	338.25	234.5	312.5	83.5	87.375	562.5		1618.625

Table 4.65: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Heuningvlei F2 benchmark site **outside** the exclosure for December 2001.

Species	**< 0.5 m**	**0.5 - 1 m**	**1 - 2 m**	**2 - 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia mellifera	2		7	1	3	3	16	15.5
Asparagus spp.	26	6					32	31.1
Boscia albitrunca			1			1	2	1.9
Dichrostachys cinerea		2	4				6	5.8
Ehretia rigida	2	1	1				4	3.9
Grewia flava	5	13	2				20	19.4
Grewia retinervis		3	9				12	11.7
Lycium hirsutum	4	4					8	7.8
Rhus tenuinervis		2	1				3	2.9
Total woody species	39	31	25	1	3	4	103	
% abundance	37.9	30.1	24.3	1	2.9	3.9		
TE/ha	160.875	259.625	312.5	20.875	87.375	150		991.25

Table 4.66: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods December 2001 to May 2002 at the Heuningvlei F2 benchmark site **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	338.25	234.50	312.50	83.50	87.38	562.50	1618.63
May 2002	148.50	301.50	250.00	83.50	58.25	375.00	1216.75

Table 4.67: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods December 2001 to May 2002 at the Heuningvlei F2 benchmark site **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
December 2001	160.88	259.63	312.50	20.88	87.38	150.00	991.25
May 2002	148.50	217.75	187.50	146.13	203.88	150.00	1053.75

Nearly fifty two per cent (52.2 %) of the woody species noted during the December 2001 surveys, **inside** the exclosure, were found to be in the less than 0.5 meter height class (Table 6.64). *Acacia mellifera* dominated the more than 4 meter height class on the **inside** of the exclosure.

The structure on the **outside** of the exclosure differed notably as only 37.9 % of the woody species were noted in the less than 0.5 meter height class compared to the 52.2 % on the **inside** of the exclosure (Tables 4.64 and 4.65). The percentage difference between the less than 0.5 meter height class and the 0.5 – 1 meter height class do not differ that notably on the **outside** of the exclosure if compared to the percentage difference on the **inside** of the exclosure. The percentage difference on the **inside**, between these two structure classes was 34.4 % while the difference on the **outside** of the exclosure, was only 7.8 %. The 1 – 2 meter height class on the **outside** of the exclosure only differed six percent (6 %) from the 0.5 – 1 meter height class. From this data it is evident that the species had high abundance in the lower height classes less than 0.5 meter – 2 meter and dominated the woody vegetation of this exclosure.

The *Asparagus* species contributed the most to the less than 0.5 meter height class whilst *Grewia flava* contributed the most to the 0.5 – 1 meter height class on the **outside** of the exclosure (Table 4.65).

Though there was an increase in the TE/ha in the 0.5 – 1 meter height class for May 2002, the total TE/ha decreased on the **inside** of the exclosure. An increase in the total TE/ha on the **outside** of the exclosure from December 2001 to May 2002 could mostly be attributed to the increase on the 2 – 3 meter and 3 – 4 meter height classes (Tables 4.66 and 4.67). When woody species reach a certain height structure class the contribution to the total TE/ha increases, from what it had been previously (lower).

The decrease in the TE/ha in the less than 0.5 meter height class both **inside** and **outside** the exclosure could be partly attributed to growth of the woody species and partly to a sampling error by a misclassification of species in the 0.5 meter height class(Tables 4.66 and 4.67). If a woody species is on the 0.5 meter mark it can be classified either in the less than 0.5 meter height class or in the 0.5 – 1 meter height class, depending on the opinion and interpretation of the surveyor.

The presence of large *Acacia mellifera* trees creates a threat of bush thickening, as it is a less palatable species that can cause dense stands in overgrazed areas. The presence of this species at this site is greatly ascribed to the higher calcium content of the soil (Smit, 1999).

Soil analysis for the Heuningvlei study site

Figure 4.29 represent the soil fraction of the topsoil of the Heuningvlei benchmark site. The soil is very sandy with virtually no silt at all. Only the Heuningvlei F2 benchmark had 3 % silt on the **inside** of the exclosure. This benchmark was also the only site that had 10 % clay in the soil. All the other sites had 8 % or less clay and 1 % silt in the soil composition. Nutrients could easily leach out of the soil. Moisture would certainly be limited in this soil type.

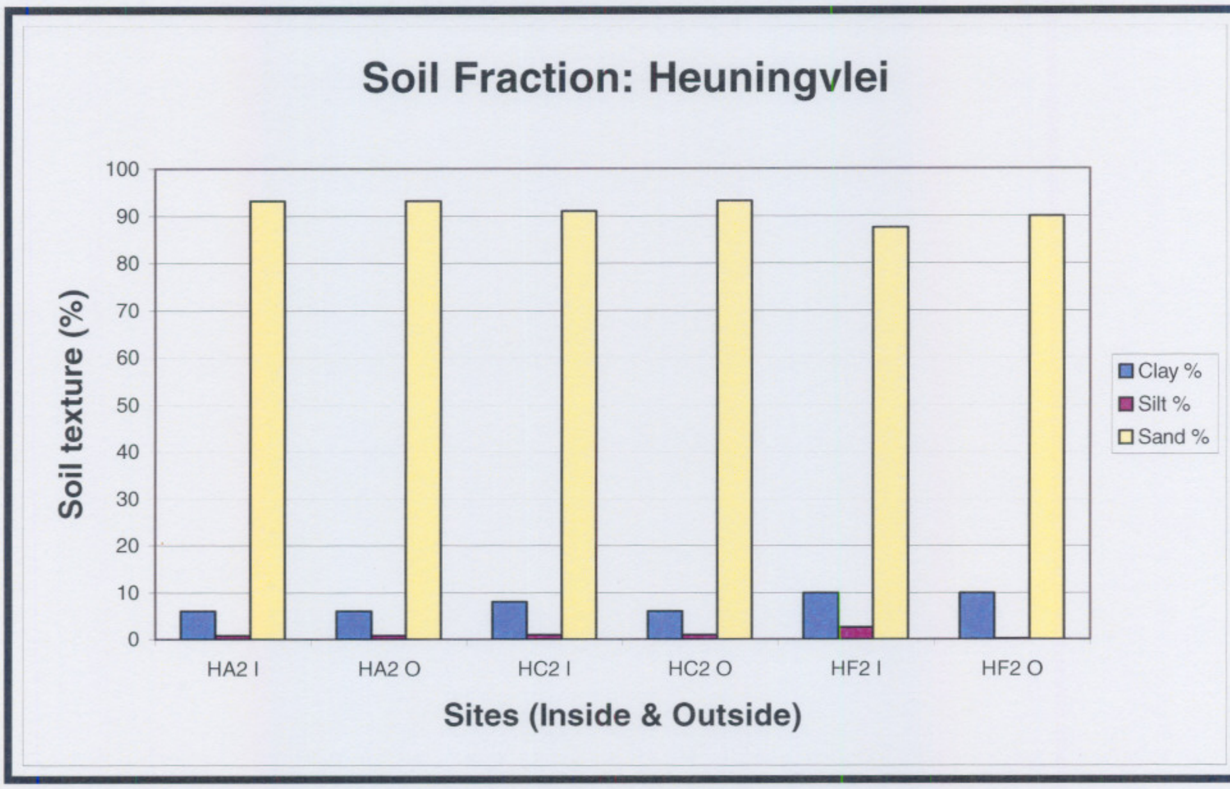

Figure 4.29: The soil texture (%) of the Heuningvlei study site as obtained from the soil analysis done during the sampling of May 2002. (Note that: H – Heuningvlei, I – inside the exclosure, O- outside the exclosure and A2, C2 and F2 relates to the survey location).

Table 4.67 indicate the chemical composition of the benchmarks of the Heuningvlei study site.

Table 4.68: The chemical soil analysis results from the samples taken during the May 2002 surveys (see Figure 4.29 for abbreviations).

	1:2.5 Water	**Bray-I**	**Amm. Acetate 1M (pH 7.00)**					**W.B.**	**water paste**
Site	pH	P	Ca	Mg	K	Na	CEC	C	R
no		Mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	Cmol(+)/kg	%	ohm
HA2 I	6.44	3.51	134	25.1	20.5	0	5.82	0.16	28000
HA2 O	6.37	3.38	**193**	31.7	28.7	0	3.17	0.19	7900
HC2 I	6.35	3.35	**243**	**37.5**	**38.0**	0	4.22	0.21	8100
HC2 O	6.44	3.25	**208**	**37**	**34.6**	0	4.12	0.16	8000
HF2 I	6.60	3.33	**268**	27.8	25.9	0	3.31	0.27	3600
HF2 O	6.24	3.04	**225**	34.1	25.3	0	2.22	0.26	4900

The average pH was 6.41. The average phosphate level was 3.31 and no sodium was present. The organic carbon was also low as in the case of all the other study sites already described. The increase in calcium content in the soil attributed to the species composition and difference in the dominant species of each benchmark. As the calcium content in the soil increased, the conductance (CEC) declined as well. The Heuningvlei C2 benchmark had the highest levels of manganese and potassium if compared to the rest of the benchmarks of this study site.

Summary of the Heuningvlei study sites

The dominant woody species at the Heuningvlei A2 benchmark was *Boscia albitrunca* (56.99 %), *Dichrostachys cinerea* (15.99 %) and *Grewia flava* (13.54 %) **inside** the exclosure and *G. flava* (37.85 %), *Acacia erioloba* (31.48 %) and *D. cinerea* (24.89 %) **outside** the exclosure.

The Heuningvlei C2 benchmark was dominated by *Rhigozum brevispinosum* both **inside** (33.45 %) and **outside** (28.48 %) the exclosure, followed by *Grewia flava* on the **inside** (22.47 %), and **outside** the exclosure (23.05 %). *Maytenus heterophylla* (25.67 %) and the *Asparagus* species (11.69 %), where both prominent species at this site, although not in extreme abundance.

The Heuningvlei F2 benchmark were dominated by the *Asparagus* species with abundances of 44.15 % **inside** and 32.92 % **outside** the exclosure. *Grewia flava* was the second most abundant species at this benchmark site with 17.91 % occurring **inside** and 17.07 % occurring **outside** the exclosure plot. The high abundance of the *Asparagus* species could be linked to the high abundance of *G. flava*, as the *Asparagus* species tend to invade the bare ground underneath these shrub species. The fact that *Acacia mellifera* also occurred at this benchmark in high abundance with 14.71 % **inside** and 11.96 % **outside** the exclosure, may as well contributed to the high abundance of the *Asparagus* species as more bare ground occurred under the *A. mellifera* trees.

Although *Acacia mellifera* is mostly regarded as an unpalatable species it is utilised by game and livestock. Dense thickets may form in areas that are severely overgrazed (Appendix I). It is known as a small tree that can grow in a variety of soil types ranging from heavy clay soils to deep sandy soils (Smit, 1999). *Acacia mellifera* compete with the herbaceous layer for moisture, as it has a wide spreading shallow root system. At each benchmark in the Heuningvlei study site, *A. mellifera* occurred on a gradient that ranged from more to less from the Heuningvlei F2 to Heuningvlei A2 benchmark site. The calcium content of the soil also increases from the Heuningvlei A2 benchmark to the Heuningvlei F2 benchmark (Table 4.68, p159). The increase in *A. mellifera* may possibly not only be associated with management malpractice but also the calcium content of the soil. Most of the *A. mellifera* trees found at the Heuningvlei F2 were in the more than 4 meter height class.

Boscia albitrunca is a relatively palatable species (Van Wyk & Van Wyk, 1997). Where this species was noted in abundance, none of the plants were more than 0.5 meters high (usually only up to 20 cm). This could be attributed to the utilisation by cattle (White, 1993). This species, fortunately causes no threat to bush thickening.

The Heuningvlei A2 benchmark had the highest abundance of *D. cinerea,* followed by Heuningvlei F2 whilst Heuningvlei C2 had the least *D. cinerea* at the benchmark. Of all the benchmark sites, Heuningvlei A2 is the most at risk of bush thickening due to *D. cinerea.*

Rhigozum brevispinosum only occurs in arid savannas and semi-deserts. If the rainfall in an area should increase, this species would decrease in abundance (Van Wyk & Van Wyk, 1997). The surveys situated more to the western site towards the arid areas had higher abundances in *R. brevispinosum.* A drier climate is therefore more suitable for *R. brevispinosum*

The dominant height class **inside** the exclosure at the Heuningvlei A2 benchmark, was the less than 0.5 meter height class, whereas the dominant structure **outside** the exclosure was the 0.5 – 1 meter and 1 – 2 meter height classes. The structure class that contributed most to the total TE/ha on the **inside** of the exclosure of the Heuningvlei A2 benchmark, was the less than 0.5 meter and the 1 – 2 meter height classes. The 1 – 2 meter height class contributed the most to the total TE/ha on the **outside** of the exclosure of this benchmark site.

The reduction of the less than 0.5 meter height class and the increase in the 0.5 – 1 meter height class **inside** the exclosure of the Heuningvlei C2 benchmark might have been, that a great number of species noted during the December 2001 surveys, were very near or on the 0.5 meter mark. At the follow-up survey in May 2002, the surveyors may have noted all the species in the following higher height class as some species where, closely, of the same length. The same could be said for the 1 – 2 meter height class on the **outside** of the exclosure as an increase in this height class was observed. The 1 – 2 meter height class contributed the most to the total TE/ha in both the **inside** and **outside** of the exclosure. The relatively high increase in the total TE/ha could be ascribed to the increase in the number of species contributing to the 0.5 – 1 meter height class. The impact that a taller plant has on an area, is greater than the effect of smaller plants. The TE/ha calculations are designed to incorporate this effect and the total TE/ha would differ notably.

The absence of values in the 3 – 4 meter and more than 4 meter height classes **inside** the exclosure during the May 2002 surveys, may be due to one tall tree that was rooted just outside the area of the belt transect. In other words one tree in the 3 – 4 meter height class represents 29.13 TE/ha or 29.13 trees at the height of 1.5 meters. A tree in the more than 4 meter height class equals 37.5 TE/ha. It is thus very important to monitor the rangeland at precisely the same locality when using permanent plots.

The same could be said for the Heuningvlei F2 study site. When the difference in structure both **inside** and **outside** the exclosure is considered, the structure stayed almost the same, except for the large reduction in the less than 0.5 meter height class and the increase in the 0.5 – 1 meter height class. The more than 4 meter height class contributed the most to the total TE/ha. This height class was dominated by *A. mellifera.*

Lower rainfall and the soil nutrient status contributed to the vegetation composition of this site. *Acacia mellifera* was moreover the most dominant at the Heuningvlei F2 benchmark as the soil was higher in calcium content than the soil at the other two benchmark sites.

4.4 Taung magisterial district

4.4.1 Orange Grove study site

Although initial planning for the Orange Grove study site was that two benchmarks are to be erected only one benchmark was erected and surveyed during April 2001 and May 2002. The same person did the surveys both in April 2001 and May 2002 which makes these surveys more comparable and scientifically sound. Agriculturists and land users did this selection subjectively to represent the effect of resting of the Morafe Ranch management system. Soil type, topography, vegetation and signs of degradation were taken into account when the selection of the benchmark was done. Due to the homogeneity of the vegetation a 50 x 50 meter exclosure was erected. The site was characterised by shrubby woody vegetation. *Grewia flava, Tarchonanthus camphoratus* and *Rhus cilliata* dominated the woody vegetation.

Woody vegetation

Orange Grove benchmark site

Table 4.69 represent the total woody species composition in percentage frequency at the Orange Grove benchmark site for April 2001 and May 2002. Only the woody species that had an abundance of, more than 5 % on average over the study period, both inside or outside the exclosure, were compared with each other and described in Figure 4.30. In Figure 4.31 the structure of the woody species at the Orange Grove benchmark site for April 2001 and May 2002 is presented. Table 4.70 and Table 4.71, represent the number and percentage (%) of the total individual woody species per height class, as well as the TE/ha per height class and the total TE/ha for the inside or outside of the exclosure at the Orange Grove benchmark site for April 2001. The TE/ha per height class over the total two survey periods for inside and outside the exclosure plots are represented in Tables 4.72 and 4.73.

Table 4.69: The frequency (%) of the total woody vegetation **inside** and **outside** the exclosure plot at the Orange Grove benchmark site over the two sampling periods (April 2001and May 2002), as well as the average percentage for each species.

	Apr-01		May-02		Average	
Species	Inside	Outside	Inside	Outside	Inside	Outside
Acacia karroo (Aca kar)	0.1	0	0.12	0	0.11	0
Acacia mellifera (Aca mel)	0.4	0.1	0.24	0.09	0.32	0.1
Asparagus spp. (*Asp* spp.)	2.5	0.7	2.72	0.57	2.61	0.64
Diospyros lycioides (Dio lyc)	**7.1**	**0.2**	**5.32**	**0.09**	**6.21**	**0.15**
Grewia flava (Gre fla)	2.8	2.6	0.77	2.47	1.79	2.54
Grewia retinervis (Gre ret)	0	0	0.3	0	0.15	0
Maytenus heterophylla (May het)	**27.4**	**8.4**	**30.5**	**13.47**	**28.95**	**10.94**
Rhus cilliata (Rhus cil)	**45.1**	**77.6**	**41.78**	**73.53**	**43.44**	**75.57**
Rhus lancea (Rhus lan)	0	0.3	0.06	0	0.03	0.15
Tarchonanthus camphoratus (Tarc camp)	**10.9**	**5.6**	**12**	**7.12**	**11.45**	**6.36**
Ziziphus mucronata (Ziz muc)	0.2	0	0	0	0.1	0
Ziziphus zeyherii (Ziz zey)	3.5	4	6.15	2.56	4.83	3.28

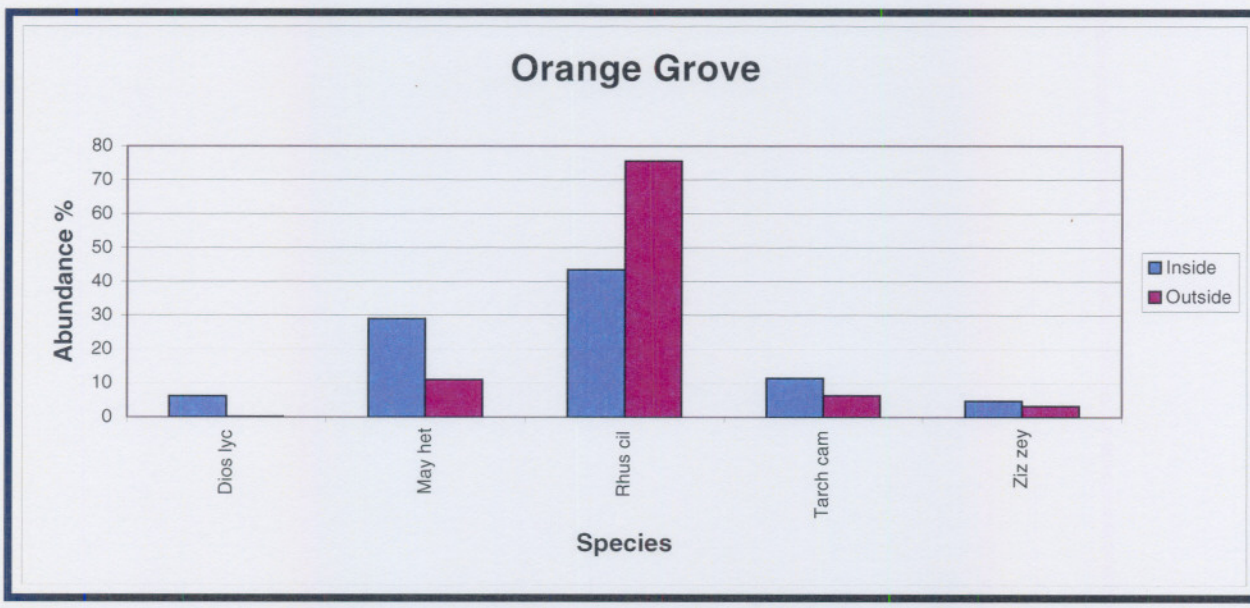

Figure 4.30: The average frequency of the woody vegetation more than 5 % **inside** and **outside** the exclosure at the benchmark site of the Orange Grove benchmark site for the sample periods (April 2001 and May 2002). (See Table 4.69 for abbreviations.)

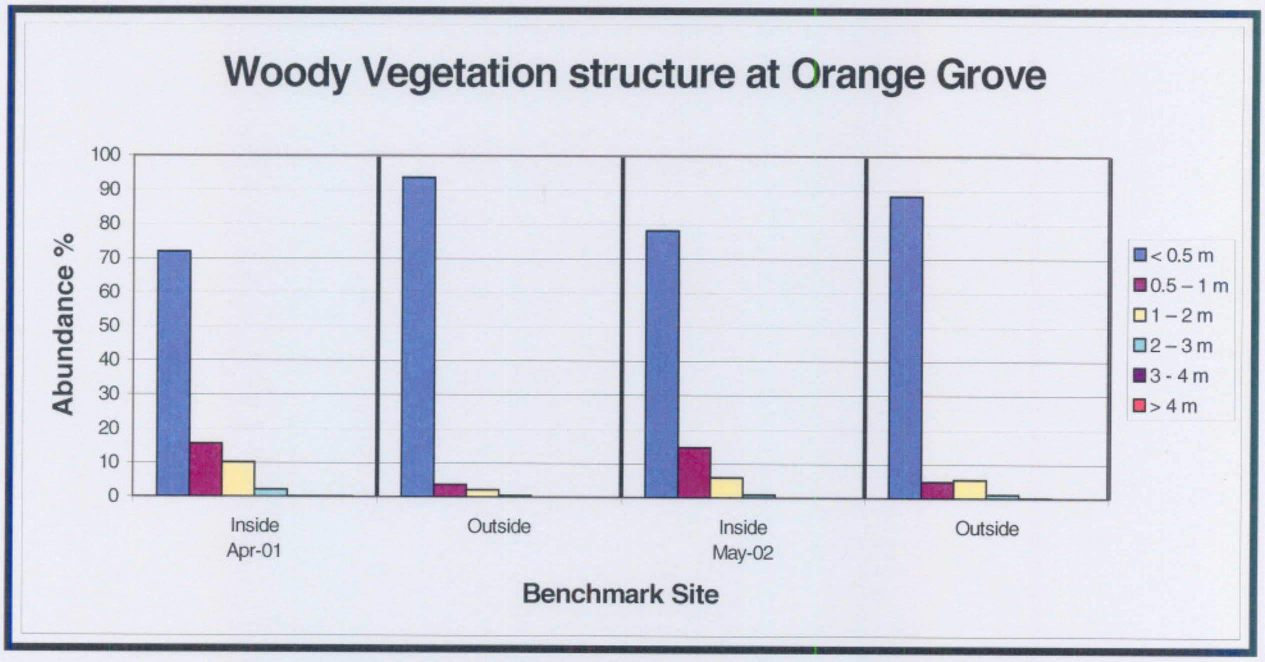

Figure 4.31: The structure of the woody vegetation structure at different height classes **inside** and **outside** the exclosure of the Orange Grove benchmark site, for the sampling periods of April 2001 and May 2002.

The dominant woody species was *Rhus cilliata* consisting an average over the 2 study periods of 43.44 % **inside** the exclosure and 75.57 % of the woody vegetation **outside** the exclosure (Table 4.69). The second most abundant species occurring at this benchmark, was *Maytenus heterophylla* (28.95 % **inside** and 10.94 % **outside** the exclosure) and the third most abundant species was *Tarchonanthus camphoratus* that represented 11.45 % on average on the **inside** of the exclosure and 6.36 % on the **outside** of the exclosure (Table 4.69 and Figure 4.30). Another dominant species was *Diospyros lycioides* (6.21 %) that occurred mainly on the inside of the exclosure (Table 4.69).

From the April 2001 to the May 2002 surveys *Grewia flava* and *Diospyros lycioides* showed a slight decrease both inside and outside the exclosure (Table 4.69). *Tarchonanthus camphoratus* on the other hand increased both inside and outside, whist *Ziziphus zeyherii* increased only on the **inside** of the exclosure (Table 4.69). *Tarchonanthus camphoratus* could have increased due to less competition with *G. flava* that reduced in numbers both **inside** and **outside** the exclosure.

Only slight changes in the height structure of the vegetation from April 2001 to May 2002 occurred (Figure 4.31).

The dominant structure was without a doubt the less than 0.5 meter height class. The dominant *Rhus cilliata* species contributed the most to this structure class. According to the TE/ha data the less than 0.5 meter height has contributed the most to the total TE/ha of this benchmark site, both **inside** and **outside** the exclosure (Tables 4.70, 4.71, 4.72 and 4.73).

Rhus cilliata is an unpalatable species that is not normally utilised by any livestock. The high abundance of *Rhus cilliata* at the Orange Grove study site, will also have an impact on the herbaceous layer and may limit the primary production potential of the grass component.

Table 4.70: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Orange Grove benchmark site **inside** the exclosure for April 2001.

Species	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**3 - 4 m**	**> 4 m**	**Total woody species**	**% abundance**
Acacia karroo		1					1	0.1
Acacia mellifera							5	0.4
Diospyros lycioides	49	33	10	6			98	7.1
Grewia flava	8	22	9				39	2.8
Maytenus heterophylla	185	115	81				381	27.4
Asparagus spp.	25	10					35	2.5
Rhus cilliata	627						627	45.1
Tarchonanthus camphoratus	57	34	37	23	3	1	151	10.9
Ziziphus mucronata		2	1				3	0.2
Ziziphus zeyherii	49						49	3.5
Total woody species	1000	217	142	30	3	1	1389	
% abundance	72	15.6	10.2	2.2	0.2	0.1		
TE/ha	4125.00	1817.38	1775.00	626.25	87.38	37.50		8468.5

Table 4.71: The number of individuals and percentage (%) of the total per height class for each woody species, as well as the tree equivalents (TE/ha per height class and total) and the total woody species and the percentage of each species of the Orange Grove benchmark site **outside** the exclosure for April 2001.

Species	**< 0.5 m**	**0.5 – 1 m**	**1 – 2 m**	**2 – 3 m**	**Total woody species**	**% abundance**
Acacia mellifera	2				2	0.1
Diospyros lycioides	3				3	0.2
Grewia flava		31	8		39	2.6
Maytenus heterophylla	115	10			125	8.4
Asparagus spp.	11				11	0.7
Rhus cilliata	1156				1156	77.6
Rhus lancea	4				4	0.3
Tarchonanthus camphoratus	38	13	24	8	83	5.6
Ziziphus zeyherii	60				60	4
Total woody species	1396	54	32	8	1490	
% abundance	93.7	3.6	2.1	0.5		
TE/ha	5758.50	452.25	400.00	167.00		6777.75

Table 4.72: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey periods of April 2001 and May 2002 at the Orange Grove benchmark **inside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
April 2001	4125.00	1817.38	1775.00	626.25	87.38	37.50	8468.50
May 2002	5461.50	2093.75	1262.50	334.00	29.13	0	9180.88

Table 4.73: The change in tree equivalents (per hectare) per height class for the total woody species composition over the survey period of April 2001 and May 2002 at the Orange Grove benchmark **outside** the exclosure.

	Tree equivalents per height class						
Date	**< 0.5 m**	**0.5 – 1 m**	**1 – 2m**	**2 – 3m**	**3 – 4 m**	**> 4m**	**Total**
April 2001	5758.50	452.25	400.00	167.00	0	0	6777.75
May 2002	3848.63	418.75	725.00	250.50	29.13	0	5272.00

According to the TE/ha data the structure **inside** and **outside** the exclosure differed slightly. The 0.5 – 1 meter height class seemed to be more dense on the **inside** of the exclosure for both surveys (April 2001 and May 2002) (Tables 4.73 and 4.74).

The total TE/ha at the Orange Grove benchmark site for both **inside** and **outside** was extremely high if compared to any other study site. The woody species abundance on the **inside** has increased with 712.38 TE/ha whilst the woody species on the **outside** of the exclosure have decreased with 1505.75 TE/ha (Tables 4.27 and 4.73). This can mainly be attributed to the increase and decrease of the lower height classes i.e. less than 0.5 meter and the 0.5 – 1 meter and the 3 – 4 meter height classes. The 2 – 3 meter and 3 – 4 meter height classes decreased on the **inside** and increased on the **outside** of the exclosure for both surveys. This can indicate that the transect of May 2002 was not precisely on the same location as the previous transect of April 2001.

The total TE/ha have increased **inside** the exclosure, whilst the total TE/ha have decreased on the **outside** of the exclosure. This might have been as a result of the exclosure not being grazed during the winter. Evidence of above mentioned statement was that the gate was closed on a more permanent basis.

Another point of concern is that of all the dominant species, more than 5 % are unpalatable or less palatable species (*Rhus cilliata, Maytenus heterophylla* and *Tarchonanthus camphoratus*), which have a tendency to invade rangelands and reduce the grazing capacity thereof in the long term (Figure 4.30) (Appendix I).

The overall structure on the **inside** of the exclosure was higher than the structure on the **outside** of the exclosure, as the woody component on the **inside** included species were taller than the 4 meter height class (Figure 4.31). This was mainly *Tarchonanthus camphoratus*, which also had a high crown cover. Such large shrubs occupy a large area and could reduce the available space for herbaceous vegetation.

Soil analysis for the Orange Grove study site

The geology at this site differs to that of the previously described study sites. This site is slightly elevated and forms part of the Ghaap plato. The geology consists of fine and course-grained dolomitic limestone with a prominent interbedded chert, limestone and banded ironstone (Smit, 2000). Wind-blown sand occurs as A-horizon on this rocky surface (Smit, 2000). Though the soil was very shallow it was still very sandy (79%) (Figure 4.32). The silt and clay content was higher than in previous study sites and the soil also had a darker colour. The only other benchmark that had 10 % clay was the Water-Fouché 6 benchmark site.

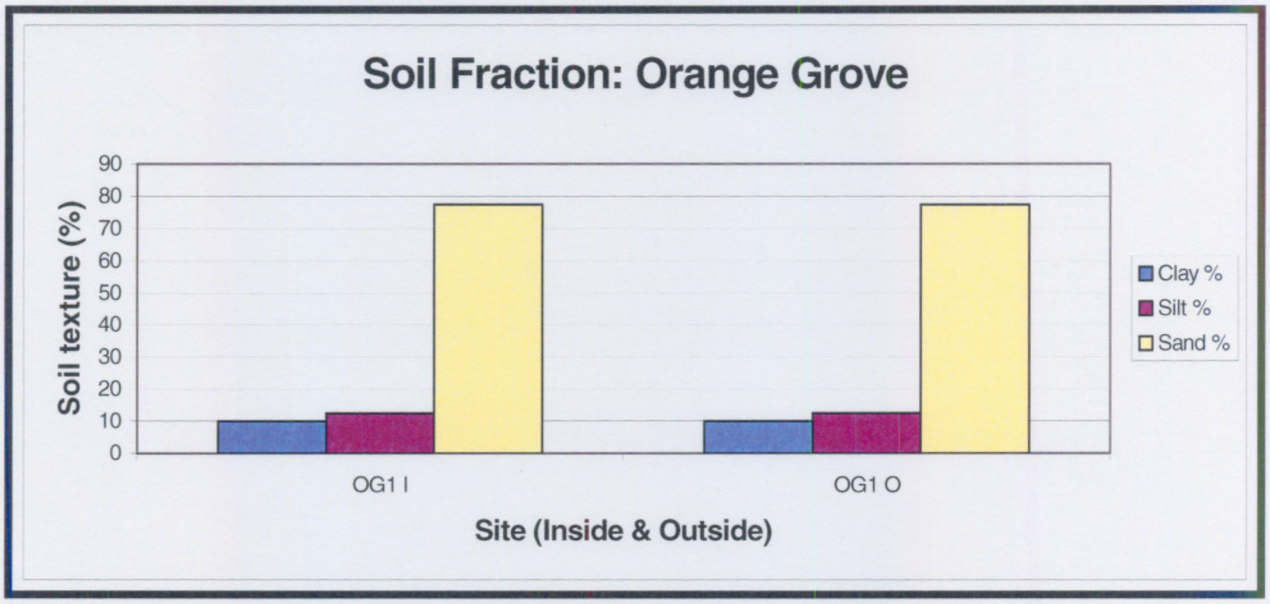

Figure 4.32: The soil texture % of the Orange Grove study site as obtained from the soil analysis done during the sampling of May 2002. (Note that: OG – Orange Grove, I – inside the exclosure, O – outside the exclosure and the number relates to the survey location).

Table 4.74 presents the results of the chemical analysis of the soil at the Orange Grove benchmark site. The soil at this site had more alkaline soil than the other sites due to the higher calcium content. There is also more organic carbon present. The higher clay and silt content of the soil contributed to the higher moisture capacity and the higher nutrient content of the soil.

Table 4.74: The chemical soil analysis results from the samples taken during the May 2002 surveys (see Figure 4.32 for abbriviations).

	1:2.5 Water	**Bray-I**	**Amm. Acetate 1M (pH 7.00)**					**W.B.**	**Water paste**
Site	PH	P	Ca	Mg	K	Na	CEC	C	R
No		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cmol(+)/kg	%	Ohm
OG1 I	7.84	3.46	**1747**	174.6	169.6	1.5	9.93	0.85	2000
OG1 O	7.21	3.62	**1245**	141.5	123.9	0	8.88	0.60	3400

The CEC of this site is much higher than that of the other sites while the resistance of the soil is much lower. This indicates the higher nutrient status of this shallow soil in this wetter climate. The rainfall at this benchmark is also higher than the previous study site (see Chapter 2 for rainfall data)

4.4.2 Ipelegeng study site

Only one site was surveyed on April 2001. Only the **inside** of the exclosure was surveyed at that time due to the delay in construction of the exclosures at the Ipelegeng study site. The exclosure was only erected in time for the December 2001 surveys. The surveys were conducted both **inside** and **outside** the exclosure from this time forward. This site was selected to represent the rangeland conditional state according to species composition and factors that indicate the degree of degradation, such as bare ground, occurrence of erosion and the past grazing history. Agriculturists and land users did the site selection subjectively.

This site was an experimental site and therefore the size of the benchmark site was 30 x 100 meter in size. This was done to test the representative vegetation sample obtained from three belts of 4 x 90 meter each in stead of the two 4 x 100 meter belts.

Not much co-operation regarding the surveys or promptness of erection of benchmarks was received by the community or agricultural officers. The reason for this might have been that the sites situated in the Taung magisterial district (including the Orange Grove study site) were too close to the town of Taung, which could have lead to the more negative attitude.

Gates of the exclosures were frequently stolen by other locals not residing at the Ipelegeng study site. This kind of incidents lead to a lack of control over the study site in, especially the resting of the vegetation in the exclosure.

Without any consultation, a bush eradication programme was initiated in the early months of 2002 at the study site. These actions were not communicated to the researcher. The aim of the extension officer was to increase the grazing capacity of the other areas of the study site that were terribly encroached with, mostly *Acacia hebeclada*. This action lead to a drastic decrease in woody vegetation and composition.

Communication between different parties involved in the LandCare project was not clear. Despite all the problems sampling went ahead at this study site.

It was however felt that, regarding the above mentioned problems such as no control of grazing in the exclosures and the application of herbicides in the study site, it was decided that the data of the Ipelegeng study site will not be discussed in this thesis. The results are available on request. The situation was discussed with officials and the data was presented to the land users and agricultural officers. After these sessions the problem of communication was breached and more positive future collaboration ensured.

Chapter 5

Conclusion and recommendations

5.1 Introduction

Grazing management systems such as the communal and commercial farming systems such as the Morafe Ranch may all contribute to the bush thickening problem that threatens the rangelands of South Africa. In this study the influence of the communal rangeland system and the Morafe Ranch rangeland system on bush thickening was investigated.

Bush thickening is a major problem in some areas of the Western region of the North West Province. This problem lowers the productive potential of rangelands and inadvertently also livestock production. To evaluate the extent of bush thickening in some of these areas and change over time, the aims of this study included the following:

- To identify the type of species and the structure of the most important woody vegetation contributing to bush thickening in two rangeland management systems.
- To evaluate the extent of bush thickening in the selected areas, which can serve as baseline data for long-term monitoring projects.
- To contribute to the awareness, education and training of land users and agriculturists as part of the LandCare initiative.

5.2 Study site selection and vegetation sampling procedures

The study was conducted in three magisterial districts in the North West Province namely: Ganyesa, Kudumane and Taung. Using magisterial districts as reference points, has its advantages, as most of the census data is gathered per district and a vast amount of information regarding a district could thus be obtained for research purposes such as this one (Hoffman & Ashwell, 2001).

All three districts of the study are situated in the Kalahari Thornveld, (Acocks, 1988) veld type 16 and both Morafe Ranch and Communal rangeland management systems occurred in each district as well. The aim was to evaluate the change in bush densities and structure in both these systems due to grazing and resting the rangeland inside the exclosure. The two management systems however could not be compared with each other at this stage of the project, since the Morafe Ranches were only developed during 2000 and the exclosure plots and fences of the paddocks were already erected at the beginning of 2001. The communal managed rangelands have been active for many years, but in most cases the rotational grazing system was only properly introduced with the erection of new paddock fences at the beginning of the LandCare project.

Another reason contributing to the fact that the sites could not be compared was that some of the study sites in the same magisterial district differed in geology (for example the Orange Grove and Ipelegeng study sites), rainfall isopleths and soil types.

The study sites were identified during 2000 in collaboration with the land users and the extension officers of the districts. The sites were chosen on account of the progress that had been made with the project, by the extension officers. During January 2001, the research team of the Potchefstroom University for Christian Higher Education, were introduced to the stakeholders involved in the project.

Surveys were conducted on three occasions for this study. The first survey was conducted during April 2001, the second during December 2001 and the final survey was conducted during May 2002. A final report back session was held during December 2002. The latter exercise was done to give some feedback of the results obtained during the study and improve environmental awareness of the communities thus encouraging them to keep up the good work in managing the rangelands in a responsible way. The data obtained during the April 2001 survey should be taken as baseline data for future long term monitoring projects as the sampling was done by the same team of reseachers of the University and mostly the same techincians from the previous sampling periods.

A number of benchmarks were identified in each study site. The benchmarks were, where possible, chosen on a gradient from a good rangeland condition to a more degraded condition.

Exclosure plots, which were erected inside the benchmarks, were either 50 x 50 meters or 20 x 110 meters depending on the homogeneity and structure of the vegetation. The vegetative surveys included 4 m x 100 m belt transects both inside and outside the exclosure.

The density and structure of the woody component for six height classes were determined inside the belt transect and converted to TE/ha. This quantitative vegetation sampling method, that was time efficient and simple, was used to determine the extent of bush thickening in the selected study areas. The sampling method was kept simple, but also scientifically sound, so that communities can participate in the surveys conducted in their area.

The weather data was obtained from the National Weather Bureau and the National Department of Agriculture. The average long term, along with the short term rainfall, for at least the past 10 years, was used to find possible explanations for the changes in vegetative composition and structure from one survey to the next in the different study sites.

Three random soil samples were taken in each sampling area (three samples on the inside of the exclosure and three on the outside, respectively). The three samples were placed in a soil sample bag and mixed to obtain a representative sample for the inside as well as the outside of the exclosure in the benchmark site.

The extension officers informed the communities of the planned surveys in their areas. The people were briefed on the survey technique. The researcher specialists helped to encourage the participation of as many land users as possible. A brief conclusion for each of the study sites in the three magisterial districts will be discussed according to the aims set by this study.

5.2.1 Ganyesa magisterial district

Austrey study sites

This communal managed rangeland system have four benchmarks in rangeland of good to more degraded condition. The Austrey 3 and 4 benchmarks were in a better condition than the Austrey 1 and 2 benchmarks. This statement can be based on the abundance of species such as *Maytenus heterophylla* and the *Asparagus* species in the Austrey 1 and Austrey 2 benchmarks. However *Grewia flava* was present at all four benchmarks in relatively high abundance.

Species, but especially *Acacia erioloba, A. robusta, Maytenus heterophylla* and the *Asparagus* species were dominant in the less than 0.5 meter height class at all the benchmark sites. The less than 0.5 meter height class was the dominant height class at the Austrey study site. *Acacia erioloba* is not considered to contribute to bush encroachment according to the Conservation of Agricultural Resources Act of 1983.

Acacia hebeclada is listed as a species that needs to be managed according to the Conservation of Agricultural Resources Act of 1983. The management consists of rangeland management practises such as rotational grazing practises and resting.

Grewia flava is governed under Regulation 16 of the Conservation of Agricultural Resources Act (1983) which indicates that this species should be managed by applying good agricultural practises such as resting the rangeland and keeping to livestock stocking rates.

Total TE/ha of the Austrey 1 and Austrey 2 benchmark was higher than the total TE/ha of the Austrey 3 and Austrey 4 benchmarks (see Chapter 4). The height classes that contributed the most to the total TE/ha of the Austrey 1, 2 and 3 benchmark sites were the less than 0.5 meter height class. The 0.5 – 1 meter height class and the 1 – 2 meter height classes contributed the most to the total TE/ha for the Austrey 4 benchmark. The last surveys during May 2002 showed a decrease in the high numbers of seedlings and an increase in the other height classes especially in the 0.5 – 1 meter height class. This could mean that the herbaceous vegetation cover is starting to recover and that seedlings have less opportunity to germinate.

The rainfall data for the past five years could be considered as above average, and it had a notable impact on the germination of seedlings of the woody species, which could have contributed to the higher abundance in the less than 0.5 meter height class in the study sites.

Only extension officers and technicians of the Ganyesa magisterial district participated in the surveys of the Austrey study site. This was an approach implemented by the extension officers to ensure that they were familiar with the survey methods and that the surveys conducted in other FSU's (Field Service Units) were done in a scientific manner. This however never guaranteed the consistency of the data collected. There was never a problem in the attitude towards the LandCare project by the extension officers and technicians participating in the surveys.

Water-Fouché study sites

This Morafe Ranch can be divided into two clearly distinguishable vegetation types. The one vegetation type has a more heterogeneous vegetation composition with *Acacia erioloba* represented in these benchmarks, and therefore also named the i.e. *A. erioloba* vegetation type. The other vegetation type has a more homogeneous vegetation composition and is dominated by *Acacia haematoxylon*, i.e. *A. haematoxylon* vegetation type. *Acacia haematoxylon* was only noted at the Water-Fouché 3, Water-Fouché 4 and Water-Fouché 6 study sites where it was the dominant woody vegetation with a domination of 50% or more.

Three woody species that were found in most benchmark sites at Water-Fouché included *A. haematoxylon*, *G. flava* and *Diospyros lycioides*. Only the latter two can cause bush thickening if not managed and is regulated by law.

The tree equivalent per hectare (TE/ha) of the *A. erioloba* vegetation type seems to be considerably higher than the TE/ha of the *Acacia haematoxylon* vegetation type. The vegetation structure of the *A. erioloba* vegetation type reached the more than 4 meters height class while the structure of the *Acacia haematoxylon* vegetation type only reached the 2 –3 meter height class. The overall dominant height class seemed to be the 1 – 2 meter height class. The above average rainfall at this study site also contributed the most to the notable changes observed in vegetation composition especially in the lower height classes.

Just as in the case of the Austrey study site, the surveys were only conducted by extension officers and technicians of the Ganyesa magisterial district of the Provincial Department of Agriculture. The surveys were conducted more swiftly as everybody was familiar with the surveying techniques. The assurance that the community on this Morafe ranch was fully aware of the LandCare project is very debatable. No clear directions were received when directions to the exclosure plots were asked but it could have been only an isolated incident and only one farmer not aware of the project. Some awareness and education is still needed in this area.

5.2.2 Kudumane magisterial district.

Heuningvlei study sites

A benchmark at the Heuningvlei study site, had an notably higher lever of calcium (Ca) content in the soil compared to the other benchmark sites of this study area. The higher level of calcium in the soil resulted that more *Acacia mellifera* were found at that benchmark. *Acacia mellifera* is associated with soil with a high calcium content (Smit, 1999). The high abundance of this species had nothing to do with management malpractice as this specific ranch only started operating during 2001, after all the water points were established. Before the functioning of the water points, the pressure of livestock was not high, as the sites were too far from sustainable water and livestock farming was most difficult. The knowledge of the soil composition could aid in the future management programs in this benchmark site. The farmers are aware that this land with the higher Ca soil content is more prone to *Acacia mellifera* bush thickening and if not managed correctly *A. mellifera* could cause severe problems regarding bush thickening.

Dense thickets of *Acacia mellifera* can form in areas that were severely overgrazed in the past. *Acacia mellifera* is also a less palatable species although it can be utilised by game and livestock it is usually the last result taken for nutrition. It is known as a small tree that can grow in a variety of soil types ranging from heavy clay soils to deep sandy soils (Smit, 1999). It competes with the herbaceous layer for moisture as it has a wide spreading shallow rooting system. Although the calcium content of the soil is responsible for the species composition at this study site it is still mandatory that this site is managed correctly according to Regulation 16 of the Conservation of Agricultural Resources Act (1983) for this site has the potential to become encroached by *Acacia mellifera.*

The most dominant species throughout the study of the Heuningvlei study site was *Grewia flava* followed by the *Asparagus* species. These two species seems to be associated with each other due to the bare ground created by *G. flava* bushes. Such statements need to be evaluated further.

The dominant structure inside the exclosure at the Heuningvlei A2 benchmark, was the less than 0.5 meter height class, where as the dominant structure outside the exclosure was the 0.5 – 1 meter and 1 – 2 meter height classes. The height structure that contributed the most to the total TE/ha on the inside of the exclosure of the Heuningvlei A2 benchmark, was the less than 0.5 meter and the 1 – 2 meter height classes. The 1 – 2 meter height class contributed the most to the total TE/ha on the outside of the exclosure of this benchmark. The dominant height class seems to be the 0.5 – 1 meter height class.

Lower rainfall and the soil nutrients, contributed to the vegetation composition of this site. *Acacia mellifera,* as already mentioned, was the most dominant at the Heuningvlei F2 benchmark, as the soil was more calcium rich than the soil at the other two benchmarks. The high abundance of *Rhigozum brevispinosum* is a result of the lower rainfall of this region as, this species is found in arid savannas or semi-arid deserts.

The attitude towards the LandCare project of the Heuningvlei community is very positive. It is evident that all the land users on this Morafe Ranch, are aware of sustainable management practises. The enthusiasm, with which they had done the surveys, was a clear sign that rangeland condition was very important to them. The only point of criticism this community had, was that they never receive any feedback on the surveys that had been conducted on their rangeland in the past.

5.2.3 Taung magisterial district

Orange Grove study site

Both surveys in this study site were conducted by the same persons each time. This means that more value can be obtained from the data from this study site, as there is more consistency in the data. The dominant woody species was *Rhus cilliata* consisting of 43.44 % of the woody vegetation inside the exclosure and 75.57 % of the woody vegetation outside the exclosure. The second most abundant species occurring at this benchmark, was *Maytenus heterophylla* (28.95 % inside and 10.94 % outside the exclosure). The third most abundant species was *Tarchonanthus camphoratus* that represented 11.45 % on average on the inside of the exclosure and 6.36 % on the outside of the exclosure.

The dominant structure was without a doubt the less than 0.5 meter height class. The dominance of *Rhus cilliata* contributed the most to that height class. According to the TE/ha data the less than 0.5 meter height class contributed the most to the total TE/ha of this benchmark site, both inside and outside the exclosure.

Rhus cilliata is an unpalatable species and will not be utilised by any livestock. The way *Rhus cilliata* occurs at the Orange Grove study site it must surely be in competition with the herbaceous layer. Where dense stands are present, almost no grass occurred. This may not be an impermeable thicket, but still limits to the rangeland production potential.

Although *Tarchonanthus camphoratus* is utilised by game and livestock during the initial months of growth it becomes too aromatic during the flowering season which makes it a less palatable species. *Tarchonanthus camphoratus* was in low abundance at the Orange Grove study site.

Ziziphus zeyherii is a small shrub only known to encroach grazing areas with no nutritional contribution to livestock production. The abundance of this species at the Orange Grove study site serves as an indicator that great care must be taken to manage this fragile rangeland condition for degradation can easily occur. The shallow soil is another indication of a fragile landscape prone to degradation if not managed well.

The total TE/ha have increased inside the exclosure, while the total TE/ha have decreased on the outside of the exclosure. This might have been as a result of the exclosure not being grazed during the winter.

The attitude towards the LandCare project was not so acceptable. No community members were ever present with the surveys and the attitude of the extension officers and technicians of the Taung magisterial district was poor. They were very reluctant to assist in any surveys. After the feedback session in December 2002 the attitude changed as results were given and some progress was made.

Ipelegeng study site

This Communal grazing site was an experimental site with benchmarks of 30 x 100 meter but due to problems as discussed in Chapter 4 no data of this study site is represented in this thesis.

5.3 Problems & challenges experienced during this study.

In many ways the LandCare project could be compared to a large sail ship. Just like a ship it needs a whole crew to keep it afloat. Even the smallest contribution to this project helped it to succeed as much as it has. But just like in the case of a ship it was not always smooth sailing.

- The most problematic factor in this whole project was time. It was two different worlds meeting in the middle. The one world had an academic time scale and the other an agricultural time scale. If a date was set it was important to keep to this date, as it was almost impossible to rearrange the whole organisation especially with the rural communities.

- Another problem of this study is the comparison of the two different management systems. Each study site could have been evaluated but the management systems could not be compared. Most of the Morafe ranches that were sampled during this study were in its initial phase and the rangeland was still under-stocked while the Communal managed rangeland systems were in place for a long time.

- The time frame of this project also did not provide for the speed that woody species would react to rangeland management. Woody vegetation has a longer life span than most herbaceous plants and in effect, grows more slowly than herbaceous plants. The growth rate makes the response time to certain management practices for woody species much longer.

- Though some structure differences between surveys was observed, these only occurred in the lower height classes where inter-species competition and herbaceous-tree competition still had a detrimental effect on the seedlings. A monitoring period of up to ten years is needed to see the meaningful trends in rangeland management to prevent bush thickening.

- The initial surveys went extremely slow. This could have been as a result of inexperience in the survey methods and also the names of the plant species vegetation. The initial time consuming surveys resulted in an excess of time budgeted for the surveys that followed. This meant that the researchers arrived too early for most of the surveys at the next site during December 2001 and April 2002. The study sites were in the most cases very remote, making communication very difficult. This made changing a date on the last minute almost impossible. Most of the extension officers had produced excellent alternative measures to conduct the surveys even if the researchers were almost a week too early.

- The initial stages of the project where stricken with doubt. Some communities were reluctant to assist in surveys because they were under the impression that their land was going to be taken away from them. All these misperceptions and misinterpretations had to be proven wrong by hard work and perseverance. The researchers had to pay for the so-called "sins of their fathers" in a way. The communities previously saw this project, as so many in history, as just another great scheme not suited for South Africa. Another scheme of a few researchers to waste time and not give relevant information aiding in the actual problems of the area. The attitude changed over time as promises were kept and the communities received feedback.

- Like all tasks in life some are more preferred than others, because it is less effort or just more interesting. The bush is a secondary factor that influences the production of any rangeland. If the grazing potential of a rangeland is to be determined people tend to look at the grass, which is quite logical. The interest is more in getting to know the grass species than getting to know the tree species. The realisation that bush thickening may result in the reduction of grazing capacity of a rangeland still needs to be proven in a visual way in most cases and that is why the benchmark approach is such a good demonstration method for this area.

- A lack in consistency in surveys is prominent throughout Chapter 4, where the results are discussed. The probable reasons for the inconsistency in data lies in the whole approach of the study. One of the aims of the study was to make people more aware of their surroundings and the positive effects of rangeland management. To achieve this, several people participated in the surveys and as all people, had different perceptions of height and size.

There is a saying that knowledge is power. Awareness that rangeland management can prevent famine under the animals during drought is a tool, but some training is needed to use a tool such as knowledge. This became apparent in the type of questions asked by the people when the surveys were done. The reason for all the changes in years of agricultural practice needs to be elaborated on. The education of the people about the relevance of the different species in the rangeland and what role the different species play in this ecosystem, is still in its baby shoes. The difference in for example pioneer species vs. climax species and each species function is of great importance to promote an understanding of the system and how it should be managed.

5.4 Positive achievements of this study

- Sufficient baseline data was collected for long term monitoring and managing projects as one of the aims of the study stipulated. The extent of bush thickening was determined per height class and a total calculated by using tree equivalents per hectare (TE/ha). The most important woody species contributing to a threat of bush thickening, were *Acacia hebeclada, A. mellifera, Asparagus, Diospyros lycioides, Grewia flava* and *Maytenus heterophylla* . These species are all shrub-like woody species and most of them have shallow root systems that compete directly with the herbaceous component for available soil moisture. All the species that were present in the study site were identified and is noted in Appendix I.

- The data collected in this survey is a very good indication of the woody vegetative resources on the sites. Strategies can now be adopted to manage for the preferred vegetation and the optimum livestock production of choice.

- The awareness of the communities is the most important factor contributing to the success of this project. The awareness of the communities is directly linked to the attitude of the extension officer assigned to that area. Awareness was expanded seeing that interest was shown especially at the end of this project. Interest in some subject is a sign of awareness. The land user's positive attitude towards surveying and eagerness to learn the species and survey techniques made it very easy to reach this aim. Feedback seemed to inspire the communities to stick to the rotational management system.

- Certain ecological principles were also explained to the communities whilst indigenous knowledge was obtained by the researchers. It was a learning process for both parties involved in this study.

Hoffman and Ashwell (2001) stated in their book Nature divided: "Nowhere is it suggested that communal land tenure causes degradation. In some cases the two may be associate, especially where institutional control has broken down. But communal tenure has also been shown to be an effective means of managing region's natural resources for a large number of users."

Although the management systems, Communal grazing and Morafe Ranch could not be compared at this stage due to temporal and spatial differences, it could be said that both systems in the three magisterial districts are on the right track to prevent bush thickening and rangeland degradation. Stocking densities are measured, rangeland condition is assessed at regular intervals and rotational grazing implemented. This could only be a step in the right direction.

5.5 Recommendations for future studies

Consistency in survey times and dates need to be established in future. The survey dates needs to be an institution like a public holiday once a date and time was agreed upon. These survey dates needs to be determined early in the year or even the previous year to assure that it is common knowledge. Surveyors especially, need to respect and realise that it is not easy to change a date at the last minute.

In future training in the surveying techniques is essential before each survey, as people tend to forget something that is not practised. The knowledge of the difference in species, especially seedlings, is essential to ensure the accuracy of the data collected during a survey. A lot of discrepancies were found in the woody species data, especially in some species that were surveyed. According to the data great differences in values of *Grewia flava, Acacia hebeclada, Tarchonanthus camphoratus* and the *Asparagus* species were found. The differences between the seedlings of the *Acacia* species also caused some confusion. Multi-stemmed woody species should be monitored accordingly. Each species should be monitored as single stemmed or multi-stemmed. The multi-stemmed species is then multiplied by 2.25 meters in stead of the 1.5 meters to account for a TE/ha value that is closer to the actual rangeland situation. The surveys should be done in summer, preferably once a year during March.

Although some feedback was given to the communities, more awareness is still needed. The researchers need to plan for a feedback session. The personnel of the Department of Agriculture also need to improve awareness by explaining each step in the construction and development of a rangeland management system. It should be a case of sharing knowledge all the time. More time should be spend in educating the land users in the significance of each species. The awareness will also ensure the maintenance of the benchmarks.

A repetition of surveys by the technicians and the communities is needed to enhance the knowledge and to learn the names of the species. Scientific names are difficult to learn especially if it they aretotally unknown. Education in assistance in the field survey technique was achieved. The scientific names of certain species were obtained and positively identified for the first time by the communities and technicians. Some of the Setwana names for some species and the particular functioning of the rangelands were obtained from the extension officers and community members.

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Appendix I

Bush species found in the benchmark sites

Scientific name	English name	Afrikaans name	Setswana name	Grazing value
Acacia erioloba	Camel thorn	Kameel doring	Mokala/ Mogotlho	Relatively palatable (Pods utilised)
Acacia haematoxylon	Grey Camel thorn	Vaalkameel-doring		Relatively palatable
Acacia hebeclada subsp. hebeclada	Candle thorn	Trassiedoring	Sekhi	Less palatable-can invade grazing areas where overgrazing took place
Acacia karroo	Sweet thorn	Soetdoring	Mooka	Relatively palatable-increases in overgrazed areas
Acacia luederitzii var. luederitzii	False Umbrella thorn	Baster haak-en-steek		
Acacia mellifera subsp. detinens	Black thorn	Swarthaak	Mongana	Less palatable-utilised by game and livestock-creates dense stands in overgrazed areas
Acacia robusta subsp. robusta	Ankle thorn	Enkeldoring	Moku/ Moga	Less palatable-only browsed in low quantities
Acacia tortilis subsp. heteracantha	Umbrella thorn	Haak-en-steek	Mosu	Relatively palatable-leaves and pods are utilised; elephants utilise bark
Boscia albitrunca	Shepherd's tree	Witgat boom	Motlopi	Very palatable
Cadaba aphylla		Swartstorm		Palatable despite its hard and leafless appearance
Dichrostachys cinerea	Sickle bush	Sekelbos	Moselesele	Pods are utilised by game and livestock-invades grazing areas
Diospyros lycioides	Blue bush	Bloubos	Motlhaja/ Letlhaja	Less palatable
Ehretia rigida	Puzzle bush	Deurmekaar-bos	Morobe	Relatively palatable
Grewia flava	Velvet raisin	Rosyntjiebos/ Vaalrosyntjie	Moretlwa	Relatively palatable-heavily utilised when there is a shortage in grass production
Grewia flavesens	Sand paper raisin	Skurwe rosyntjie	Mokgompatha	Relatively palatable
Lycium hirsutum	River honey thorn	Kriebos/ Kriedoring		Less palatable
Maytenus heterophylla/ Gymnosporia buxifolia	Common spike thorn	Pendoring/ Lemoendoring		Less palatable-dense stands reduce grazing areas
Mundulea sericea	Cork bush	Kurk bos		Leaves, browsed by game.
Olea europea subsp.europea	Wild olive	Olienhout	Motlhaware/ Mokware	Less palatable-leaves utilised by game and livestock
Phaeoptilum spinosum		Brosdoring		Produces palatable fruit, but has few leaves

Protasparagus sp.- Protasparagus africanus		Katbos		
Rhigozum brevispinosum	Short-thorn pomegranate	Kortdoring-granaat		
Rhus cilliata		Suurkaree		Unpalatable
Rhus lancea	Karree	Karee	Moshabele	Unpalatable, although used as fodder-poor quality-in droughts. It has been observed that boergoats utilise bark
Rhus pyroides	Common wild currant	Gewone taaibos	Mogodiri	Unpalatable
Rhus tenuinervis	Kalahari currant	Kalahari taaibos		
Tarchonanthus camphoratus	Wild camphor bush	Vaalbos/ Wildekanfer-bos	Mohatlha/ Mfatlha	Relatively to less palatable-utilised by game and livestock
Terminalia sericea	Silver cluster-leaf	Sandgeelhout/ Vaalboom	Mogonono/ Mokubu	
Ziziphus mucronata	Buffalo-thorn	Blinkblaar wag-'n-bietjie	Mokgalo	Described as a pioneer plant that establishes in degraded areas-leaves and fruit utilised by game and livestock to a lesser extent. Provides fodder for livestock during droughts
Ziziphus zeyherii	Dwarf buffalo-thorn	Klein blinkbaar wag-'n-bietjie	Sekgalo fatshe	Encroaches in grazing areas