

**Changes in Grass Species
Composition and Production
in Two Rangeland Management
Systems: A LandCare Initiative
in the North West Province,
South Africa.**

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**LANDCARE
SOUTH AFRICA**



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AND PRODUCTION IN TWO RANGELAND
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Opsomming

Veranderinge in die Grasspesiesamestelling en Produksie in Twee Veldbestuursisteme: ‘n “LandCare” Inisiatief in die Noordwes Provinsie, Suid-Afrika.

Velddegradasie is wêreldwyd in geografiese omvang, globaal in omgewings en sosio-ekonomiese impakte, en laat geen kontinent onaangeraak nie. Dit is dus ‘n dringende prioriteit dat weë gevind word om die degradasie van natuurlike hulpbronne te voorkom. Hierdie stelling geld ook vir die Noordwes Provinsie van Suid-Afrika. Die Provinsie staan voor ‘n enorme uitdaging, naamlik die beskerming en volhoubare bestuur van natuurlike hulpbronne, veral teen die huidige tempo van bevolkingsaanwas en die groeiende werkloosheidsyfer. Dit is die strewe van die Provinsie om te verseker dat die natuurlike hulpbronne oordeelkundig en versigtig bestuur, verbruik en verbeter word. Verskeie “LandCare”-programme, inisiatiewe van die Suid-Afrikaanse Nasionale Regering, is geïmplimenteer om sodoende volhoubare grondgebruiks-praktyke aan te moedig en te ondersteun, omgewingsbewustheid te verbeter en ‘n hulpbronbewaringstelsel te bevorder. “LandCare” is ‘n volhoubare hulpbronverbruikprogram, wat gegrond in die gemeenskap en deur beide die publieke en privaat sektore bestuur word deur middel van vennootskappe en samewerking.

Die doel van hierdie projek was om ‘n basislynstudie te ontwikkel om sodoende moniterings- en evalueringsisteme te vestig om die vordering van die spesifieke LandCare projek te monitor, asook om nuwe en veranderende behoeftes oor die langtermyn te bepaal. Bepaling van veranderinge in die grasspesiesamestelling en produksie by agtien verskillende verwysingspersele, in drie landdrosdistrikte, naamlik Ganyesa, Kudumane en Taung, van die westelike streek in die Noordwes Provinsie, is gebruik om hierdie doel te bereik. Die veranderinge in die grasspesiesamestelling en produksie is gemonitor in die kommunale beweiding (Austrey, Maketlele, en Ipelegeng studiegebiede) en die “Morafe ranch”-bestuursisteme (Waterfouchè, Heuningvlei en Orange Grove studiegebiede). Die “Morafe ranch”-bestuursstelsel en sommige strategieë om die effek van rus in kommunale bestuursisteme te evalueer, is geïmplimenteer by bogenoemde studiegebiede vanaf Januarie 2001. Die studiegebiede is geleë in verskillende Landboukundige Ontwikkelingsentrums (LOS), wat op hul beurt weer verdeel kan word in verskillende Velddienseenhede (VDE).

Verwysingspersele wat verskillende veldtoestande verteenwoordig, is in samewerking met die voorligtingsbeamptes van die Departement Landbou van die Noordwes Provinsie geïdentifiseer in geselekteerde areas in beide die “Morafe ranch” en kommunale bestuursisteme. Uitsluitingspersele, wat gebruik is om beweiding deur beeste en bokke uit te sluit, is binne die verwysingspersele opgerig. Die hoofdoel van die oprigting van uitsluitingspersele was om die voordele wat rus vir die veld inhou te demonstreer.

Om die doelwitte van hierdie projekte te bereik is die grasspesiesamestelling en produksie van die veld bepaal in samewerking met die landboukundige voorligtingsbeamptes en die plaaslike grondgebruikers van elke studiegebied. Die

grasspesiesamestelling is binne en buite die uitsluitingspersele bepaal deur middel van die lyntransek-metode, waarvolgens die naaste meerjarige en eenjarige grasspesie in 'n radius van 30cm op een meter intervale, langs twee 100m-transekte aangeteken is.

Die grasproduksie is slegs binne die uitsluitingsperseel bepaal deur middel van die kwadraat metode. Twee herhalings van vyf-en-twintig 1m²-kwadrate is ewekansig op vier meter intervale langs die twee 100m-transekte uitgeplaas. Die gras is per spesie op 'n hoogte van 3cm bo die grond gesny en daarna gedroog (24 uur by 60°C) en geweeg. Die klassifikasie van die grasspesies in hoogs gewenste, gewenste, minder gewenste en nie-gewenste klasse vir weiding, volgens Van Oudtshoorn (1999) en die deskundige kennis van tegnisi en navorsers van die Departement Landbou van die Noordwes Provinsie, is gebruik vir die doel van hierdie studie.

Grondmonsters is binne en buite elke uitsluitingsperseel geneem. Alhoewel die resultate van die grondontledings gebruik kan word om veranderinge in die grasspesiesamestelling en produksie te verklaar, vind drastiese veranderinge in grondeienskappe normaalweg slegs oor die langtermyn plaas. Hierdie resultate dien dus hoofsaaklik as grondslag vir die monitering van hierdie verwysingspersele in die toekoms.

Die frekwensie waarteen die verskillende grasspesies, kruide en kaalkolle binne en buite die uitsluitingspersele van die verskillende verwysingspersele voorgekom het, is bereken deur die persentasie te bepaal wat elke spesie in verhouding tot die totale hoeveelheid spesies, wat aangeteken is tydens 'n spesifieke spesiesamestellingopname, uitmaak. Die Z-indeks (%) van ooreenkoms of gelyksoortigheid (Du Toit, 1998) is toegepas om sodoende te bepaal of veranderinge in die grasspesiesamestelling tussen die binne- en buitekant van die uitsluitingspersele wél plaasgevind het gedurende die studie tydperk van twee jaar (gedurende 2001 en 2002).

Die konsep van 'n grootvee-eenheid (GVE) (Tainton, 1999) is gebruik om die huidige seisoenale weidingkapasiteit van die veld te bepaal deur middel van die formule voorgestel deur Moore *et al.* (1985). Deur verskillende benuttingsfaktore (Smit, 2002) aan die proporsionele produksiesyfers (kg/ha) van die grasspesies, verdeel in verskillende gewentheidsklasse toe te ken, is die seisoenale weidingkapasiteit van die verskillende verwysingspersele bepaal. Drie verskillende benaderings is gevolg tydens die berekening van die seisoenale weidingkapasiteit en met mekaar vergelyk.

Die hoë Z-indekswaardes by al die verwysingspersele dien as 'n aanduiding dat die ooreenkoms tussen die grasspesiesamestelling binne en buite die uitsluitingspersele steeds baie hoog is. Dit dui daarop dat die studietydperk te kort was om enige definitiewe veranderinge in die grasspesiesamestelling as gevolg van die toepassing van rus (toegepas binne die uitsluitingsperseel) en verskillende bestuursisteme, waar te neem. Die geringe verandering wat wel plaasgevind het, kan hoofsaaklik toegeskryf word aan die variërende reënvalpatroon van elke spesifieke studiegebied. O'Connor (1994) stel ook voor dat die bevolkingsdinamika van belangrike savannegrasspesies meer afhanklik is van die variërende reënvalpatroon as van die beweiding wat toegepas word. Die beskikbaarheid van saad in die grondbank is egter 'n belangrike beperkende faktor vir die vestiging van saailinge tydens jare van

voldoende reënval. Gevolglik is dit baie belangrik dat veld versigtig bestuur moet word, veral tydens tydperke van lae reënval.

Die veld by elke verwysingsarea is geklassifiseer as veld in 'n goeie, gemiddeld-goeie, gemiddelde, of swak veldtoestand. Dit is hoofsaaklik gedoen volgens die grasspesiesamestelling, wat op sy beurt weer 'n beslissende invloed het op die verwagte produktiwiteit en uiteindelijke seisoenale weidingkapasiteit van die grasveld (Snyman, 2000). Die grasspesies, *Schmidtia pappophoroides*, *Eragrostis lehmanniana* en *Aristida stipitata*, is geïdentifiseer as goeie indikatore van die veldtoestand in die Ganyesa en Kudumane landdrosdistrikte. Die drie grasspesies dui onderskeidelik op 'n goeie, gemiddeld-goeie en gemiddelde veldtoestand. Die grasspesiesamestelling van die verwysingspersele geleë in die Taung landdrosdistrik verskil egter van dié van die Ganyesa en Kudumane distrikte as gevolg van verskille in die topografie, grondfaktore en geologie tussen die drie landdrosdistrikte.

Ten spyte daarvan dat sommige verwysingspersele in dieselfde studiegebied gekenmerk word deur dieselfde grondtipe en aan dieselfde reënvalpatroon en bestuursstelsel blootgestel word, het reaksies in terme van grasspesiesamestelling en produksie veranderinge tot 'n groot mate verskil. Dit kan hoofsaaklik toegeskryf word aan die feit dat hierdie areas blootgestel was aan verskillende veebeladings in die verlede. Die historiese beweidingsintensiteit wat vir baie jare in die verlede gevolg was, sal steeds 'n groot impak op die resultate van opnames wat reeds gedoen is en nog gedoen gaan word, hê. Die sukses van 'n plant in 'n gebied wat beskik oor 'n spesifieke omgewingsgradiënt word dus bepaal deur die plant se spesifieke strategie of lewensgeskiedenis-eienskappe (McCook, 1994).

Al was dit nie een van die doelwitte van hierdie studie om die “Morafe ranch” en die kommunale bestuursstelsels met mekaar te vergelyk nie, is verskille wél waargeneem. Dit is duidelik dat die verwysingsareas onder die “Morafe ranch”-bestuursstelsel (die Waterfouchè, Heuningvlei en Orange Grove verwysingspersele), oor die algemeen in 'n beter toestand was as die verwysingspersele onder kommunale bestuur (die Austrey, Maketlele en Ipelegeng verwysingspersele). Dit kan afgelei word uit die feit dat hulle oor 'n meer gewenste grasspesiesamestelling, hoër totale produksiesyfers en beter seisoenale weidingkapasiteite beskik in vergelyking met meeste van die verwysingspersele onder kommunale bestuur. Aangesien die “Morafe ranch”-bestuursstelsel onlangs geïmplimenter is en dus nie kon lei tot so 'n groot verbetering in die veldtoestand nie (soos waargeneem tydens hierdie studie), kan die beter veldtoestand hoofsaaklik toegeskryf word aan die beperkte beskikbaarheid van waterpunte in hierdie gebiede in die verlede. Daar kan dus afgelei word dat hierdie verwysingspersele, as gevolg van waterhulpbron beperkinge nie aan oorbeweidings blootgestel was in die verlede nie.

Gevolglik kan die afleiding gemaak word dat alhoewel die twee jaar tydperk te kort was vir plantegroeidinamika studies om spesiesamestelling veranderinge waar te neem, hierdie voorlopige resultate reeds gebruik kan word as onderbou om 'n langtermyn moniteringsstelsel te vestig en implimenter. Die resultate sal ook verder dien om die omgewingsbewustheid van die grondgebruikers en landboukundige voorligtingsbeamptes, wat reeds deur hierdie projek geïnisieer is, te verbeter in terme van die toepassing van volhoubare bestuurspraktyke. Gevolglik het positiewe

samewerking tussen die akademiese instelling (Potchefstroom Universiteit vir CHO) en die landboukundige voorligtingsbeamptes en grondgebruikers ontstaan.

Sleutelwoorde: Kommunale bestuur, “Morafe ranch”, “LandCare”, Z-indeks, seisoenale weidingskapasiteit, grasspesiesamestelling, verwysingsarea, uitsluitingsperseel, hoogs gewenste grasspesies, gewenste grasspesies, minder gewenste grasspesies, nie-gewenste grasspesies.

Tshobokanyo

Go Fetoga ga Boleng jwa Mefuta e e Farologaneng ya Bojang le Selekanyo se bo Golang ka sone mo Dipolasing tse pedi tse di nang le Dithulaganyo tsa go di tlhokomela: Moleko wa Tlhokomelo ya Mmu kwa Porofenseng ya Bokone Bophirima, ya Afrika Borwa.

Go senyega ga mmu, ga tikologo le ga ikonomi mo setšhabeng ke selo se se diregang mo lefatsheng lotlhe se se nang le diphelelo tse di sa siamang, mme se ama dikontinente tsotlhe. Ka jalo, go bona ditsela tsa go thibela go senngwa ga dikungwa tsa rona tsa tlhago, le go busetsa tshenyo eno morago, ke selo se se potlakileng fela thata. Go ntse jalo le kwa Porofenseng e e kafa Bokone Bophirima ya Afrika Borwa. Porofense eno e lebane le bothata jo bo seng kana ka sepe: jwa go sireletsa le go tlhokomela motswedi wa dikungwa tsa rona tsa tlhago ka tsela e e atlegileng, go sa kgathalesege maemo a a leng teng gone jaanong a go gola ga palo ya baagi le go tlhoka mebereko. Boikaelelo jwa Porofense eno ke go tlhomamisa gore dikungwa tsa tlhago di dirisiwa ka botlhale le gone ka kelotlhoko, le ka tsela e e botoka. Go dirilwe dithulaganyo tse di farologaneng tsa Tlhokomelo ya Mmu ga ba ga tlhomiwa melao ya Puso ya Bosetšhaba ya Afrika Borwa ya go rotloetsa batho gore ba tshegetse thulaganyo ya go dirisa mmu ka tsela e e molemo, go ba ruta go dira jalo le go ba rotloetsa gore ba somarele dikungwa tsa rona tsa tlhago. Tlhokomelo ya Mmu ke thulaganyo e e berekanang le go dirisiwa ga dikungwa tsa rona tsa tlhago mo setšhabeng ka go di somarela, e e dirisiwang ke batho mo setšhabeng le ke mekgatlho e e seng ya puso, e e golaganeng le batho mo setšhabeng le go dirisana mmogo le bone.

Boikaelelo jwa porojeke eno ke go dira patlisiso e e tla re thusang go tlhoma thulaganyo e re tla e dirisang ka metlha ya go lepa kgatelopele e e dirwang mo go seno le go sekaseka maemo a masha a a tlhagang le diphetogo tse di nnang teng. Gore go fitlhelelwe mokgele ono, go ne ga dirisiwa mokgwa wa go tlhotlhomisa go fetoga ga boleng jwa mefuta e e farologaneng ya bojang le selekanyo se bo golang ka sone kwa mafelong a le lesome le borobedi a a tshwailweng, a a mo dikgaolong tse dikgolo tse tharo tsa Ganyesa, Kudumane le Taung, tsa kgaolo e e kafa bophirima ya Bokone Bophirima jwa Porofense eno. Go ne ga dirwa tshekatsheko ya go bona gore boleng jwa mefuta e e farologaneng ya bojang bo fetoga jang le gore bo gola ka selekanyo se se kana kang mo mafulong a go fulang diruiwa tsotlhe mo go one (mafelo a go dirilweng patlisiso mo go one, e leng Austrey, Maketlele le Ipelegeng) ga ba ga dirwa tshekatsheko ya go bona gore go ne go dirisiwa mekgwa efe ya go tlhokomela polasi ya ga Morafe (mafelo a go dirilweng patlisiso mo go one, e leng Waterfouchè, Heuningvlei le Orange Grove). Mekgwa ya go tlhokomela mafulo a polasi ya ga Morafe le ditsela tse dingwe tsa go sekaseka diphelelo tse di nnang gone fa go dirwa gore mafulo a a tlhokomelwang ke batho ba le bantsi a ikhutse go sekae gore diruiwa di se ka tsa fula mo go one, di ne tsa tlhomiwa mo mafelong a go neng go dirwa dipatlisiso mo go one fa e sa le ka January 2001. Mafelo ano a go neng go direlwa dipatlisiso mo go one a mo dikarolong tse di farologaneng tsa Agricultural Development Centers (ADC's), tse di kgaogantsweng ka di Field Service Unit (FSU) tse di farologaneng.

Mafelo a a tshwailweng a a nang le mebu e e sa tshwaneng, a ne a tlhaolwa mo mafelong a a tlhophilweng mo polasing ya ga Morafe le mo dipolasing tse di tlhokomelwang ke batho ba le bantsi ka go dirisana mmogo le badiredi ba bangwe ba Lephata la Temothuo, Tshomarelo le Tikologo. Mo teng ga mafelo ano a a tshwailweng, go ne ga agiwa magora go thibela dikgomo le dipodi gore di se ka tsa fula mo go one. Boikaelelo-bogolo jwa go aga magora ano e ne e le go supa diphelelo tse di molemo tse di nnang gone fa go dirwa gore mafulo a ikhutse go se kae.

Gore go fitlhelelwe mokgele wa porojeke eno, go ne ga dirwa tshekatsheko ya go bona gore boleng jwa mefuta e e farologaneng ya bojang jwa mafulo ano bo ne bo tllile go fetoga jang le gore bojang joo bo ne bo tllile go gola ka selekanyo se se kana kang, ka thuso ya badiredi ba bangwe ba temothuo le ya batho ba ba nnang mo lefelong lengwe le lengwe le go neng go direlwa dipatlisiso mo go lone, ba ba dirisang mmu wa teng. Go ne ga dirwa patlisiso ka boleng jwa mefuta e e farologaneng ya bojang jo bo leng mo teng ga magora le jo bo ka kwa ntle ga one, go dirisiwa mokgwa wa go kgaoganya naga ka bogare go bo go kwalwa pego ka mofuta wa bojang jo bo fetsang ngwaga otlhe bo ntse bo tshela jo bo leng disentimetara di le 30 ka fa ntle ga halofo nngwe le nngwe ya naga eno e e kgaogantsweng ka bogare, tse nngwe le nngwe ya tsone e leng bogolo jwa dimitara di le 100.

Go ne ga dirwa tshekatsheko ya go bona gore bojang jo bo mo teng ga magora ano bo ne jwa gola ka selekanyo se se kana kang ka go dira ditema tse di khutlonnè-tsepa. Ditema tse di khutlonnè-tsepa di le masome a mabedi le botlhano tse nngwe le nngwe ya tsone e leng bogolo jwa 1m^2 di ne tsa bapisiwa ka go refosanngwa, nngwe le nngwe e katogane le e nngwe ka sekgala sa dimmetara di le nnè, mo teng ga ditsha tse pedi tse sengwe le sengwe sa tsone se neng se le bogolo jwa dimmetara di le 100. Go ne ga segiwa bojang go ya ka mefuta ya jone, jo bo leng bogodimo jwa disentimetara di le 3, jwa omelediwa (diura di le 24 ka mogote o o kana ka 60°C) bo bo bo bewa mo godimo ga selekanyo go bona boima jwa jone. Go ya ka Van Oudtshoorn (1999), e leng mankge wa tsa kitso ya botejeniki le go dira dipatlisiso wa Lephata la Temothuo, Tshomarelo le Tikologo, mo patlisisong eno, mefuta ya bojang e ne ya kgaoganngwa ka ditlhopho tse di farologaneng, tsa bojang jo bo eletsegang thata, jo bo eletsegang, jo bo mo magareng le jo bo sa eletsegeng gotlhelele.

Go ne ga tabolwa disampole tsa mmu mo teng ga legora lengwe le lengwe le kafa ntle ga lone. Le mororo dipholō tse di bonweng morago ga go tlhatlhoba mmu di ka dirisiwa go tlhalosa gore boleng jwa mefuta e e farologaneng ya bojang le selekanyo se bo golang ka sone di fetolwa ke eng, gantsi go tsaya lobaka lo loleele pele diphetogo tse dikgolo tse di nnang teng tsa mebu e e farologaneng di simolola go iponatsa. Ka jalo, dipholō tseno di dirisediwa fela go lepa gore mafelo a a tshwailweng a tla bo a ntse jang mo isagweng.

Lobaka lo mefuta e e farologaneng ya bojang, dimela tse dingwe le lebala le le se nang sepe di neng tsa iponatsa morago ga lone mo teng ga magora le kafa ntle ga one mo mafelong a a farologaneng a a tshwailweng, lo ne lwa lekanngwa ka go sekaseka go bona gore mofuta mongwe le mongwe wa bojang o ne o na le diperesente tse kae ka go di bapisa le diperesente tsa mefuta e mengwe yotlhe ya jone tse di neng tsa begiwa fa go ne go dirwa patlisiso e e kgethegileng ya go bona gore mofuta mongwe le mongwe wa bojang o ne o na le tse kae. Go ne ga dumalanwa gore go dirisiwe mokgwa wa go lekanya wa Z-index (%), kgotsa mongwe o o tshwanang le one (Du

Toit, 1998), go bona gore a tota boleng jwa mefuta ya bojang jo bo leng mo teng ga magora le jo bo leng kafa ntle ga one bo ne jwa fetoga fa go ne go dirwa patlisiso e e tsereng lobaka lwa dingwaga di le pedi (mo ngwageng wa 2001 le 2002).

Go bona gore ke mafulo afe a a siametseng gore diruiwa di ka fula mo go one, go ne ga dirisiwa mokgwa wa large stock unit (LSU), (Tainton, 1999), go dirisiwa molawana o o tlamilweng ke Moore *et al.* (1985). Go ne ga tlhomiwa ditsela di le tharo (Smit, 2002) tsa go bona gore ke leng lefelo lengwe le lengwe le le tshwailweng le siametseng gore diruiwa di ka fula mo go lone, go lebilwe gore mefuta e e farologaneng ya bojang jo bo kgaogantsweng ka ditlhopho tse tharo tse di sa tshwaneng bo godile ka selekanyo se se kana kang (kg/ha). Go ne ga dirisiwa mekgwa e le meraro ya go bona seno, mme mekgwa eo e bo e bapisiwa ka boraro jwa yone go bona gore ke ofe o o botoka.

Dipholo tse di kwa godimo tse di neng tsa bonwa fa go sena go dirisiwa mokgwa wa go lekanya wa Z-index mo mafelong otlhe a a neng a tshwailwe, di bontsha gore boleng jwa mefuta e e farologaneng ya bojang jo bo leng mo teng ga legora le jo bo leng ka fa ntle ga lone bo sa ntse bo tshwana fela thata. Seno se bontsha gore lobaka lwa go dira patlisiso lo ne lo le lokhutshwane thata gore go ka bonwa dipholo tse di tlhomameng tsa go fetoga ga boleng jwa mefuta e e farologaneng ya bojang jo bo mo teng ga legora le jo bo leng ka kwa ntle ga lone, ka ntlha ya go dira gore (mafulo a a leng mo teng ga mafelo a a tshwailweng a ikhutse) gore diruiwa di se ka tsa fula mo go one, le ka ntlha ya mekgwa e e farologaneng ya go tlhokomela dipolasi tseno. Diphetogo di se kae fela tse di nnileng gone di ka tswa di bakilwe ke ditsela tse di sa tshwaneng tse pula e nang ka tsone mo lefelong lengwe le lengwe le go dirilweng patlisiso mo go lone. O'Connor (1994) le ene o ne a tlhalosa gore go bonala bontsi jwa bojang jo bo botlhokwa jwa naga bo ikaegile thata ka go na ga pula ka ditsela tse di sa tshwaneng mo mafelong ano, go na le go ikaega ka go fula ga diruiwa mo go one. Le fa go ntse jalo, peo e e robetseng kafa tlase ga mmu e botlhokwa thata ka gonne e tla mela mo dingwageng tsa fa pula e na sentle. Ka ntlha ya seno, go botlhokwa thata gore mafulo a tlhokomelwe ka kelotlhoko, segolobogolo mo dinakong tse pula e sa neng sentle ka tsone.

Mafulo a a mo lefelong lengwe le lengwe le le tshwailweng a ka kgaoganngwa ka dikarolo tse di farologaneng, tsa mafulo a a siameng, a a siameng ka tsela e lekanetseng, a a mo magareng kgotsa a a sa siamang gotlhelele go ikaegile ka boleng jwa mefuta e e farologaneng ya bojang jwa one le selekanyo se bo golang ka sone le gore a siametse gore diruiwa di ka fula leng mo go one. Mefuta e e farologaneng ya bojang, e leng jwa *Schmidtia pappophoroides*, *Eragrostis lehmanniana* le *Aristida stipitata*, e ne e bontsha gore mafulo a a mo dikgaolong tse dikgolo tsa Ganyesa le Kudumane a ne a siame, e bile gape a ne a bontsha gore mafulo ano e ne e le a a siameng, a a siameng ka tsela e e lekanetseng, le a a leng mo magareng fela, ka go farologana ga one. Le fa go ntse jalo, boleng jwa mefuta e e farologaneng ya bojang jwa mafelo a a tshwailweng a a kwa kgaolong ya Taung jone bo ne bo farologane le jwa mafulo a dikgaolo tsa Ganyesa le Kudumane, ka ntlha ya ditebego tse di sa tshwaneng tsa naga, mmu le jeoloji mo dikgaolong tse tharo.

Le mororo mafelo a a tshwailweng a a leng mo lefelong le le lengwe fela le go dirilweng patlisiso mo go lone a ne a na le mmu o o tshwanang, e bile a ne a nelwa ke pula ka tsela e e tshwanang le go tlhokomelwa ka tsela e e tshwanang, tsela e ka yone

a neng a amiwa ke go na ga pula e ntsi, e leng go fetoga ga boleng jwa mefuta e e farologaneng ya bojang le selekanyo se bo golang ka sone, e ne e sa tshwane gotlhelele. Seno se ka tswa se bakilwe ke gore diruiwa di ne di sa fule mo mafelong ano ka tsela e e tshwanang le e di neng di fula mo go one ka yone mo nakong e e fetileng. Mokgwa o o sa bolong go latelwa dingwaga di le dintsi tse di fetileng wa go fula ga diruiwa mo mafelong ano o sa ntse o tla nna le diphelelo tse di sa siamang tse di seng kana ka sepe, mme o tla nna o lephilwe gone jaanong le mo isagweng. Ka jalo, mokgwa ope fela o semela se golang ka one, kgotsa hisitori ya botshelo jwa sone, ke yone e e tla supang gore a semela seno se tla tswelela se tshela fa se le mo lefelong lengwe le le rileng (McCook, 1994).

Le mororo boikaelelo jwa go dira patlisiso eno e ne e se go bapisa polasi ya ga Morafe le dipolasi tse di tlhokomelwang ke batho ba le bantsi, gone go ne ga lemogiwa dipharologanyo dingwe fa gare ga dipolasi tseno. Go ne ga bonala sentle gore mafelo a a tshwailweng a polasi ya ga Morafe (mafelo a a tshwailweng a Waterfouchè, Heuningvlei le Orange Grove), a ne a le botoka thata go gaisa mafelo a a tshwailweng a a tlhokomelwang ke batho ba le bantsi (mafelo a a tshwailweng a Austrey, Maketlele le Ipelegeng). Seno se ne sa lemogiwa ka go bo a ne a na le boleng jwa mefuta e e farologaneng ya bojang jo bo eletsegang thata, palo e e kwa godimo ya selekanyo se bo godileng ka sone le dipaka tse di botoka tse diruiwa di neng di letlwa go fula mo go one ka tsone, fa a bapisiwa le mafulo a mangwe a a tlhokomelwang ke batho ba le bantsi. E re ka thulaganyo ya go tlhokomela polasi ya ga Morafe e sa tswa go tlhomiwa bosheng jaana e bile e se yone e ka tswang e dirile gore mafulo a gagwe a tokafale jalo, boemo jo bo botoka jwa one bo ka tswa bo ikaegile ka gore a go ne go na le metswedi e e lekaneng ya metsi mo mafelong ano mo nakong e e fetileng. Ka jalo, tshwetso e re e dirang ke gore diruiwa di ne di sa fule go feta selekanyo mo mafelong a a tshwailweng ano, e re ka go ne go se na diruiwa di le dintsi e bile go ne go na le mathata a go bona metsi.

Fa re konela, re ka bolela gore le mororo lobaka lwa dingwaga di le pedi lo le lo khutshwane thata go ka dira patlisiso e e tseneletseng ya go bona gore boleng jwa mefuta e e farologaneng ya bojang bo fetoga jang, dipholō tseno tsa ntlha di ka dirisiwa go tlhotlhomisa le go tlhoma thulaganyo e e nnetseng ruri ya go lepa gore maemo a tswelela jang mo mafulong ano. Dipholō tseno gape di tla re thusa go tokafatsa tsela ya go ruta batho ba ba berekang mo dipolasing le badiredi ba bangwe ba temothuo, mme seno se ne se setse se simolotswe ka porojeke eno, e e malebana le mekgwa ya go tlhokomela dipolasi ka tsela e e atlegileng. Ka ntlha ya seno, go nnile le tirisanommogo e e molemo tota fa gare ga setheo sa thuto (Potchefstroom University for CHE) le badiredi ba bangwe ba temothuo le batho ba ba berekang mo dipolasing.

Mafoko a konokono: Dipolasi tse di tlhokomelwang ke batho ba le bantsi, Polasi ya ga Morafe, Tlhokomelo ya Mmu, Z-index, paka e diruiwa di letlelelwang go fula mo mafulong ka yone, boleng jwa mefuta e e farologaneng ya bojang, selekanyo se mefuta e e farologaneng ya bojang bo golang ka sone, lefelo le le tshwailweng, legora, mofuta wa bojang jo bo eletsegang thata, mofuta wa bojang jo bo eletsegang, mefuta e e farologaneng ya bojang jo bo mo magareng, mefuta e e farologaneng ya bojang jo bo sa eletsegang gotlhelele.

Abstract

Changes in Grass Species Composition and Production in Two Rangeland Management Systems: A LandCare Initiative in the North West Province, South Africa.

Land degradation is worldwide in geographic extent, global in its environmental and socio-economic impacts and it leaves no continent unaffected. It is thus a matter of urgent priority that ways be found to prevent and even reverse, the degradation of the natural resources. This is also true for the North West Province of South Africa. An enormous challenge faces this Province: that of protecting and sustainably managing the natural resource base, even under the present condition of population growth and rising unemployment. It is the intention of the Province to ensure that the natural resources are wisely and carefully managed, utilized and improved. Various LandCare programs, initiatives of the South African National Government, has been implemented in order to encourage and support sustainable land use practices, raising awareness and promoting a resource conservation ethic. LandCare is a sustainable resource utilization program, based in the community and driven by both the public and private sectors through partnerships and co-operation.

The purpose of this project was to develop a baseline study in order to establish and implement monitoring and evaluation systems to monitor progress and assess emerging and changing needs on an ongoing basis. Determining the changes in the grass species composition and production at eighteen different benchmark sites, in three magisterial districts, namely Ganyesa, Kudumane and Taung, of the western region in the North West Province, was used to achieve this goal. The changes in the grass species composition and production were monitored in the communal grazing (Austrey, Maketlele and Ipelegeng study sites) and Morafe ranch management systems (Waterfouchè, Heuningvlei and Orange Grove study sites). The Morafe ranch management system and some strategies to evaluate the effect of resting in communally managed systems were implemented at these study sites since January 2001. The study sites are situated in different Agricultural Development Centers (ADC's), which in turn are divided into different Field Service Units (FSU's).

Benchmark sites representing different conditional states, were identified in selected areas in both the Morafe ranch and communal managed systems in collaboration with extension officers of the Department of Agriculture, Conservation and Environment. Exclosures, used to exclude any grazing by cattle and goats, were erected inside the benchmark sites. The main purpose of erecting the exclosures was to demonstrate the advantages of resting the rangeland.

In order to achieve the aims of the project, the grass species composition and production of the rangeland were determined with the help of the agricultural extension officers and the local land users at each of the study sites. The grass species composition was determined inside and outside the exclosures, by means of the line transect method, where the nearest perennial and annual grass species was recorded in a radius of 30 cm at 1 meter intervals along two transects of 100m each.

The grass production was only determined inside the exclosures by means of the quadrat method. Two replications of twenty-five 1m² quadrats were alternately placed at four meter intervals, along the two 100m transects. The grass was cut per species at a height of 3cm above the ground, dried (24 hours at 60°C) and weighed. The classification of the grass species into highly desirable, desirable, less desirable and non desirable classes for grazing, according to Van Oudtshoorn (1999) and the expert knowledge of technicians and researchers of the Department of Agriculture, Conservation and Environment, were used for the purpose of this study.

Soil samples were taken on the inside and outside of each exclosure. Although results from the soil analyses can be used to explain changes in the grass species composition and production, drastic changes in the soil characteristics usually only take place over the long-term. These results thus mainly serve as baseline data for the monitoring of these benchmark sites in future.

The frequency at which the different grass species, forbs and bare ground occurred inside and outside the exclosures at the different benchmark sites, were calculated by determining the percentage that each species composed of the total amount of species, recorded during a specific species compositional survey. The Z-index (%) of agreement, or similarity (Du Toit, 1998), was applied in order to determine if changes in the grass species composition between the inside and outside of the exclosures did occur during the study period of two years (during the years 2001 and 2002).

The concept of a large stock unit (LSU), (Tainton, 1999), was used to establish the current seasonal grazing capacity of the rangeland by means of the formula proposed by Moore *et al.* (1985). By appointing different utilization factors (Smit, 2002) to the proportional production (kg/ha) of the grass species, divided into the different desirability classes, the seasonal grazing capacities of the different benchmark sites were determined. Three different approaches in calculating the seasonal grazing capacities were used and compared with each other.

The high Z-index values at all the benchmark sites, indicates that the similarity between the grass species composition inside and outside the exclosure is still very high. This signifies that the study period was too short for definite changes to occur between the grass species composition inside and outside the benchmark sites, due to the rest (applied inside the benchmark sites) and different management systems applied. The slight changes that occurred could mainly be attributed to the rainfall variability at each specific study site. O'Connor (1994) also stated that population dynamics of important savanna grass species appears to be more dependent upon rainfall variability than upon grazing. However, the availability of seed in the soil seed bank is an important constraint on seedling recruitment in years of suitable rainfall. Consequently, it is very important that rangelands should be very carefully managed, especially during periods of low rainfall.

The rangeland at each benchmark site could be classified into a good, moderately good, moderate, or poor rangeland condition mainly according to its grass species composition, which in turn has a decisive influence on the productivity and eventually on the seasonal grazing capacity expected from grasslands (Snyman, 2000). The grass species, *Schmidtia pappophoroides*, *Eragrostis lehmanniana* and *Aristida stipitata*, were identified as good indicators of the rangeland condition in the Ganyesa and

Kudumane magisterial districts, indicating a good, moderately good and moderate rangeland condition, respectively. The grass species composition at the benchmark sites situated in the Taung magisterial district however differed from those in the Ganyesa and Kudumane districts, due to differences in the topography, soil and geology at the three magisterial districts.

Even though some benchmark sites in the same study area were characterized by the same soil type, and were subjected to the same rainfall pattern and management system, their responses to a higher rainfall, in terms of grass species composition and production changes, differed to a greater extent. This could mainly be attributed to the fact that these sites were subjected to different grazing pressures during the past. The historical grazing regime that was followed over many years in the past, will still have a great impact on the results which are and will be monitored in future. A plant's particular strategy, or life history traits, thus determines its success at a particular region of any environmental gradient (McCook, 1994).

Even though it was not the objective of this study to compare the Morafe ranch and communal management systems, some differences were observed. It was evident that the benchmark sites managed by the Morafe ranch system (the Waterfouchè, Heuningvlei and Orange Grove benchmark sites), were generally in a better condition than the communally managed benchmark sites (the Austrey, Maketlele and Ipelegeng benchmark sites). This was deduced from the fact that they consisted of a more desirable grass species composition, higher total production figures and better seasonal grazing capacities than most of the communally managed benchmark sites. Seeing that the Morafe ranch management system was only recently implemented and could therefore not have led to such an improvement in the rangeland condition, the better condition could mainly be attributed to the limited availability of watering points at these sites in the past. It can therefore be concluded, that these benchmark sites were not subjected to overgrazing in the past, due to the low livestock densities and water resource constraints.

In conclusion it can be said that although the timespan of two years is too short for vegetation dynamic studies to detect species compositional changes, these preliminary results can already be used as baseline data to establish and implement a long-term monitoring system. The results will also assist to further improve the environmental awareness of land users and agricultural extension officers, which was already initiated by means of this project, with regard to sustainable management practices. As a consequence a very positive collaboration between the academic institution (Potchefstroom University for CHE) and the agricultural extension officers and land users were created.

Keywords: Communal management, Morafe ranch, LandCare, Z-index, seasonal grazing capacity, grass species composition, grass species production, benchmark, exclosure, highly desirable grass species, desirable grass species, less desirable grass species, non desirable grass species.

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Chapter 1: Introduction

1.1. Land degradation

Land degradation implies the global reduction or loss (in arid, semi-arid and dry sub-humid areas) of productive land resources (UNEP, 2000). It contributes to the loss of global biodiversity, loss of the earth's biomass and bioproductivity and to global climate changes. Land degradation can thus lead to economic instability and political unrest in affected areas and also puts pressure on the economy and the stability of societies outside the affected areas. Accordingly it prevents the achievement of sustainable development in affected areas and countries. The need to address the global problem of degradation is becoming increasingly urgent. Consequently sustainable land use, that can be continually applied without degrading the land, is urgently needed to address global land degradation. Sustainable land use, however, depends both on the properties of the resource and the way in which it is managed (UNEP, 2000).

Root causes of land degradation are highly complex as well as site specific. Degradation is caused by human intervention or by processes arising from human activities and habitation patterns and include (Hoffman & Ashwell, 2001):

- abuse of the environment through ignorance;
- unjudgemental land management;
- agricultural activities;
- political, industrial and historical issues;
- soil erosion by wind and/or water;
- deterioration of the physical, chemical, and biological or economic properties of soil; and
- long-term loss of natural vegetation.

It is thus not the condition of the resource, but rather man's influence that is a causative factor for land degradation (Kellner, 2000).

According to Hoffman *et al.* (1999) the biggest causes of land degradation is the large influxes of people to peri-urban areas, lack of infrastructure, betterment planning, poor runoff control and shifts to different breeds of grazing animals. A wildcard for the future is the threat of global warming (Scholes & Van der Merwe, 1999). Increasing temperatures and changing weather patterns may tip the balance even further towards desertification in both marginal and productive agricultural areas (Hoffman & Ashwell, 2001).

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

In Africa alone, an estimated further 5-6 million hectares of productive land are affected by land degradation each year. This means that several million hectares of new land has to be opened up for agriculture every year just to offset the effects of degradation (UNEP, 2000). Africa's rangelands are currently overstocked and the residents of dry Africa should thus quickly learn, or be forced to adopt, some new habits (Behnke & Abel, 1996).

In Africa, where large populations are dependent on natural resources for their livelihood and subsistence agriculture and pastoralism forms the backbone of the economy, the direct and most severe impact of land degradation and desertification is food insecurity that may ultimately result in famine (Macdonald & Richardson, 1989). The only alternative for survival of local communities is often to expand agriculture and grazing areas into marginal land and wilderness areas - a process that often degrades forests, woodlands and grasslands, fragments natural ecosystems and reduces biodiversity. The unsustainable use of these resources can lead to accelerated erosion, physical and chemical deterioration of soils beyond the limit of possible restoration of their productive capacity. Serious impacts of land degradation include siltation and pollution of reservoirs, lakes and corral reefs with consequent impacts on aquatic biodiversity.

South Africa has the third highest level of biological diversity in the world. This high level of diversity is due to the broad range of climatic, geological, soil and landscape forms found in South Africa. Most of the land area (86%) is used for crop cultivation or grazing of livestock. Less than 10% of the area is conserved (Barnard & Newby, 1999). South Africa is a semi-arid country, and drought and desertification are real threats to food security. Twenty five per cent of South Africa's land area has been transformed, of which 13% is for cultivation of crops, 1.5% for forestry, and 2.5% to settlements. Five per cent of soils are affected by water erosion, over 8% of South Africa have been invaded by alien vegetation, and millions of hectares are affected by bush encroachment. Five per cent has been degraded and only 6% are under formal protection (Barnard & Newby, 1999).

Production pressures on terrestrial ecosystems that result in degradation of the vegetation and soil leave the land less productive. In 1970 there was 0.86 hectares of agricultural land available for each person in South Africa. This decreased to 0.5 hectares per capita in 1980 and it is estimated that this will decrease further to 0.2 hectares per capita by 2020 (Barnard & Newby, 1999). This has serious implications for income generating exports, and domestic food security.

The population in South Africa was 40.6 million in 1996, and is growing at about 2% per year. If this trend persists, by the year 2035, there will be nearly 82 million people living in South Africa, dependent on the same level of natural resources which are already under pressure (Barnard & Newby, 1999). More people mean a greater demand for resources.

According to Barnard (2002) fourteen million of the total South African population of 40.58 million people live in the former homelands on soil that is to a large extent unsuitable for farming. Both the high population densities in the former homelands and the unbalanced distribution of land, rather than farming methods, have

contributed to massive soil erosion. An estimated 1.2 million hectares of pasture in marginal areas are viewed to be lost to production because of overgrazing.

Accordingly South Africa's dependence on productive agricultural land for food security is self-evident. Approximately 80% of the land is used for agriculture, but only about 13.5% is considered arable (Hoffman & Ashwell, 2001). Droughts, such as the catastrophic episodes of 1982-83 and 1991-92, are inevitable in South Africa. However, while well-managed land recovers rapidly after drought, degraded land is less resilient (Hoffman & Ashwell, 2001). As land becomes degraded and more susceptible to drought, South Africa's ability to feed itself is undermined. This makes the country more reliant on expensive imports and foreign aid. In the face of a growing population, another drought as severe as that of 1991-92 poses a serious threat to food security.

According to Hoffman *et al.*, (1999) six main types of rangeland degradation can be recognised:

- **Loss of cover** largely as a result of the grazing and trampling patterns of domestic livestock;
- **Change in species composition** of the vegetation, again largely as a result of the selective grazing patterns of domestic animals;
- **Bush encroachment** as a result of the increase in cover of indigenous trees and shrubs;
- **Alien plant** invasions;
- **Deforestation** as a result of the removal of trees and shrubs by people usually for domestic energy or construction purposes;
- **Other** forms of rangeland degradation, which usually encompassed the clearing of rangeland for the planting of agricultural crops, or mining pollution.

In general, the North West Province, where this project was carried out, is showing signs of increased land and soil degradation (Figure 1.1). All magisterial districts show signs of degradation and desertification (Department of Environmental Affairs and Tourism, 1997). The most severely affected are those that are communally managed. The Province is ranked as the fourth worst affected province in South Africa. This has numerous negative consequences for agriculture in the Province such as decreased productivity of the croplands.

The types of rangeland degradation perceived as first priority in the North West Province's western region are a loss of cover, change in species composition and bush encroachment. The Province is the third highest province in South Africa in terms of the severity of rangeland degradation. Bush encroachment remains a serious problem in the North West Province. In nine of the twenty-eight magisterial districts in the North West Province, there are areas where bush encroachment is so severe that the land is not reclaimable by farmers (Department of Agriculture, Conservation and Environment, 2002).

Natural or semi-natural ecosystems mostly covered by indigenous, natural vegetation and often referred to as rangelands, can potentially be used for different production systems. Rangelands are defined as: "those areas of the world, which by reason of physical limitations, low and erratic precipitation, rough topography, poor drainage, or cold temperatures, are unsuited for cultivation, and which are a source of forage for

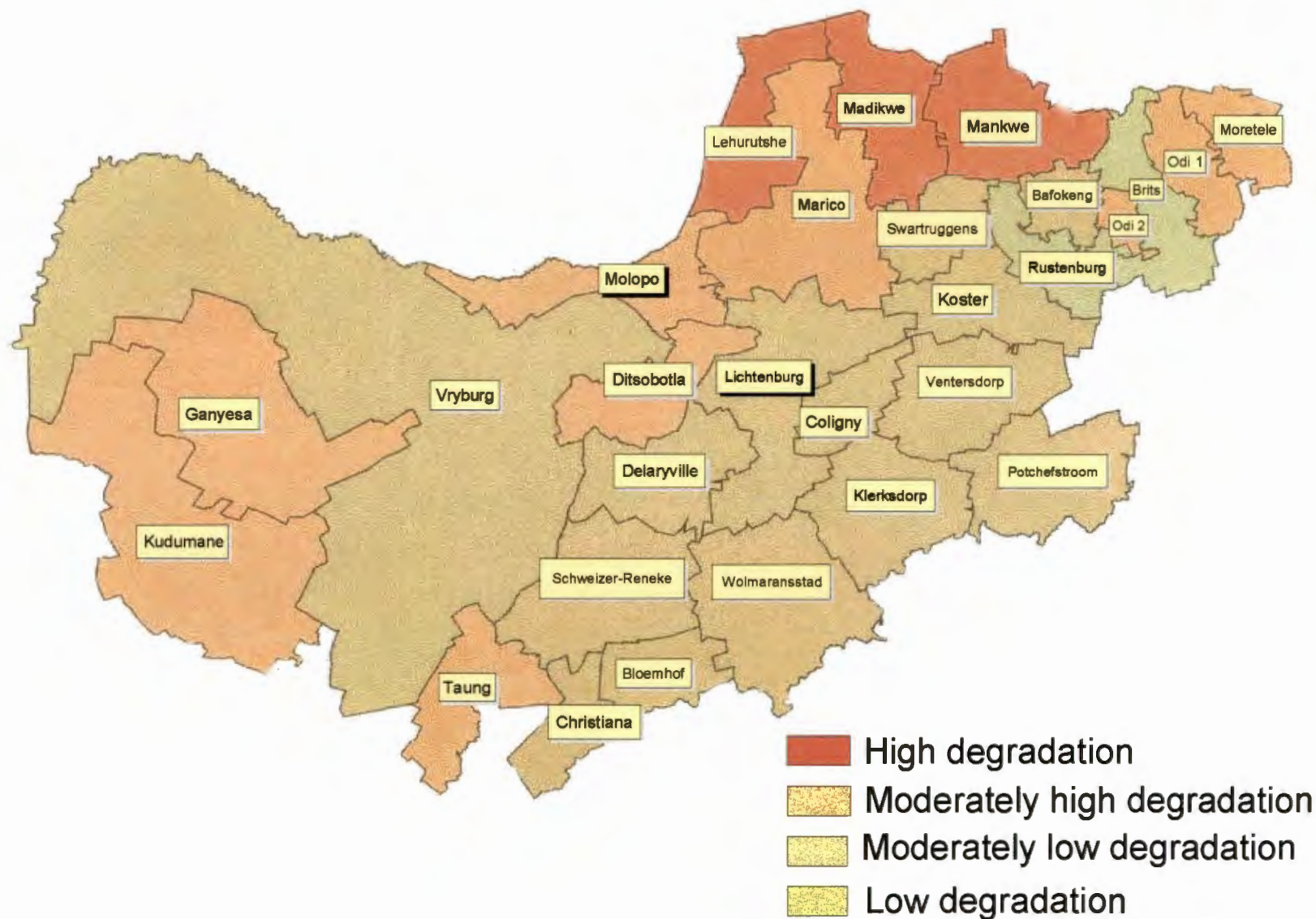


Figure 1.1: A map of the magisterial districts in the North West Province indicating the extent of land degradation (supplied by Dept. of Agriculture, Conservation and Environment).

free ranging native and domestic animals, as well as a source of wood products, water and wildlife” (Miller, 1997). Land degradation can thus also be defined as the change in rangeland status to a poorer condition (Kellner, 2000).

Indigenous vegetation on rangelands - trees, shrubs and grass - is the primary resource of the pastoral economy in arid and semi-arid regions of Africa. How indigenous vegetations are managed is vital for the survival of people in the arid and semi-arid zone. A key factor for the sustainable development of arid and semi-arid regions is thus the ability to maintain their biodiversity.

Two of the most important types of rangeland degradation in the North West Province are bush encroachment and the loss of vegetation cover together with changes in species composition.

1.1.1. Bush encroachment

Bush encroachment of indigenous or exotic woody species is a serious type of land degradation in many savanna areas of the world. In South Africa, bush encroachment includes the concept of bush thickening. It has come to mean both the large scale conversion of former grassland vegetation to a savanna physiognomy by encroaching indigenous trees, as well as the increase in size and density of woody plants within historical savanna areas (Hoffman & Ashwell, 2001).

Bush encroachment is usually described as a successional sequence in which small-leaved, leguminous woody species, often *Acacias*, initiate the process (Hoffman & Ashwell, 2001). These species are then followed by broadleaf woody species and, in some instances by succulent elements as well. The overall trend in affected areas is towards closed-canopy woodland.

Although it assumes a somewhat simplistic view of the problem, the determinants of bush encroachment can be divided into primary and secondary factors (Hoffman *et al.*, 1999). Primary factors include:

- High rainfall periods;
- Drought; and
- An increase in atmospheric CO₂.

Secondary factors influencing bush encroachment include:

- Elimination of diverse indigenous browser element;
- Replacement of browsers with cattle;
- Changes in the fire regime;
- Reductions in fuel wood harvesting by people.

Although bush encroachment is a widespread phenomenon, only a few species are perceived as problem elements. The most important of these are small-leaved *Acacia* and other legume species including *Acacia karroo*, *A. tortillis*, *A. mellifera*, *A. nilotica*, *A. hebeclada* and *Dichrostachys cineria*. *Tarchonanthus camphoratus* is also regularly cited in the North West Province as an encroaching plant. Shrubby elements, which were highlighted and can also become a problem in certain areas,

include *Protasparagus spp.*, *Lycium spp.*, *Euryops spp.*, *Elytropsapus rhinocerotis*, *Leucosidea sericea* and *Rhigozum trichotomum* (Hoffman *et al.*, 1999).

Guidelines for the control of bush encroachment have existed for a long time and incorporate a wide range of methods including mechanical, chemical, biological and the use of fire. Irrespective of the method one uses it has to, however, be accompanied by good rangeland management.

1.1.2. Loss of cover and change in species composition

Change in the species composition of rangeland reflects the rangeland condition or the “state of health” of a particular sample of rangeland and generally refers to the ecological status of the rangeland in terms of its botanical composition and cover, as well as its fodder value, in terms of its productivity and palatability (Hoffman *et al.*, 1999).

Rangeland condition is affected by climatic and management factors, such as woodcutting, fire, drought, and grazing. Grazing by domestic livestock, in association with rainfall, is the most important factors influencing rangeland condition (Hoffman & Ashwell, 2001). Animals do not only remove mature plants, but they also eat flowers, thus reducing seed set. They also trample and kill young seedlings. Palatable fodder plants are particularly susceptible to overgrazing because it is repeatedly grazed by animals and not given the chance to flower and disperse seed. Continuous grazing can have long-term effects on the composition of plant communities.

It is important to point out that the long-term impacts of high stocking rates under communal land tenure systems are poorly understood and researched in South Africa. The entire concept of rangeland condition and grazing capacity, as applies to the commercial areas, has generally been rejected by the land users in communal areas. It is, however, a well known fact that misconceptions in terms of how rangelands function exist. In the past and even today, these misconceptions still give rise to various disputes, especially when it comes to the impact the livestock industry has on the environment (Jordaan, 1999).

When causes for rangeland degradation are discussed, the biggest scapegoat is usually over-utilization or simply too many animals (Figure 1.2). Solutions for this cause are usually easy – simply reduce the number of animals and allow the rangeland to rest. However, experience has shown that it is not that simple. Big mistakes are often made because the techniques used to quantify over-grazing are not always the correct ones for a specific situation, nor are they always interpreted correctly (Jordaan, 1999). The extension message given is usually one-sided and does not take the recipient’s needs and/or circumstances into consideration. There is not just one set of solutions for the problem of rangeland degradation right across all regions.



Figure 1.2: Over-utilization or simply too many animals usually cause rangeland degradation. This figure indicates the over-utilization of rangeland by goats and cattle.

Each environment's problems are unique, and must therefore also receive unique treatment as an entity on its own. The first requirement in any plan is thus the careful study of the local situation and the careful sampling of the opinions of those that live and work in the local environment.

It is crucial for any policy, arising from the South African National Action Plan to Combat Desertification, that agriculture in the communal areas is not viewed simply as "white commercial agriculture in the making" (Hoffman *et al.*, 1999). The imposition of general theory, developed primarily for commercial agricultural systems, onto communal areas, should be avoided.

1.1.3. Different schools of thought to understand changes in rangeland condition

1.1.3.1. The Conventional Succession Theory

Assessing rangeland condition relies on assumptions about the ideal state of rangeland and it is also, to a great extent, a matter of perception. It could thus have a different meaning to different people. Probably the greatest source of confusion over range degradation is the Clementsian succession theory, which has been the mainstay of range management for most of this century (Behnke & Abel, 1996). According to it, a vegetation community at a site is believed to be able to exist in a number of stages, each characterised by a particular composition of species. Thus, after vegetation in an area has been disturbed by fire, heavy grazing or bush clearing, plants will recolonise the area in a series of overlapping stages (Hoffman & Ashwell, 2001).

This implies that there is an orderly and predictable process of succession where one plant association is replaced by another in an orderly manner (Jordaan, 1999). This replacement or transition continues until such time as a stable "climax", which is in equilibrium with the prevailing climate, is reached. The objective of range management, using this model, is therefore to maintain a balance between the grazing pressure and the successional tendency so that a flow of livestock products are readily available to meet market demands. Retrogression will take place as soon as deterioration in rangeland condition occurs. Overgrazing by too many animals can

lead to such a state. The same stable climax stage can be reached again by simply reducing the animal numbers. This model is depicted graphically in Figure 1.3.

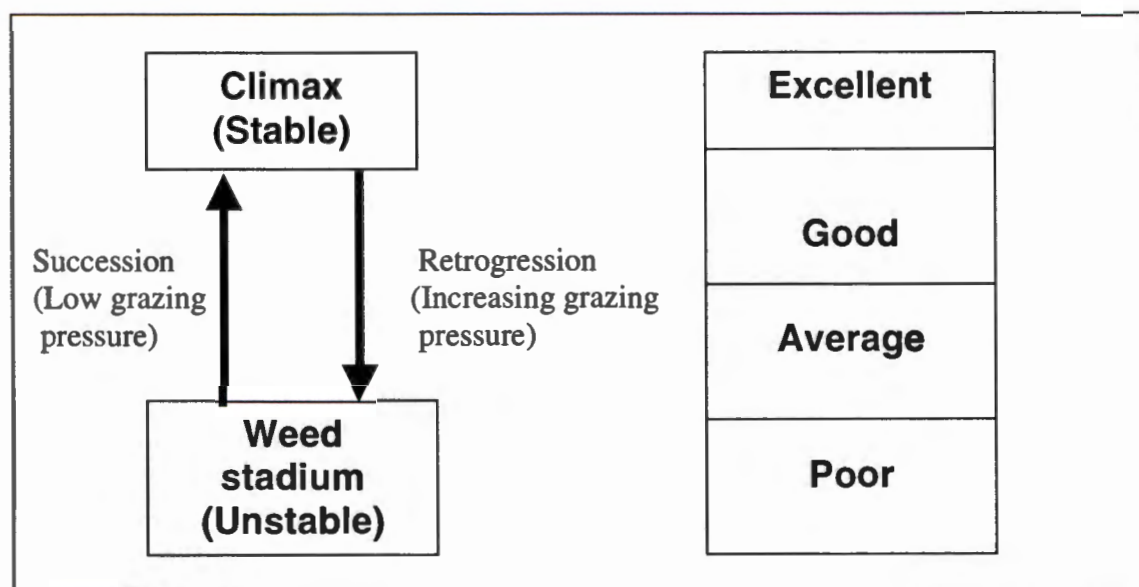


Figure 1.3: The relationship between rangeland condition and degree of succession toward or retrogression from climax conditions (Jordaan, 1999).

The Clementsian model, however, suggests a direct change from one condition (climax) to another (sub-climax) and vice versa. It also takes for granted that the climax vegetation is always the best vegetation in a certain environment and for a specific use, such as animal production. The inability of certain vegetation states to recover to former levels of productivity, especially in the arid and semi-arid areas, can also not be explained by this model (Van Rooyen, 2000).

The transition of vegetation from one state to another is dependent on external factors such as the timing of rainfall events, dry spells, and the interaction of management practise (Bosch & Kellner, 1991). Predicting the composition that could develop during the recovery process of a degraded community on the basis of the classical succession mode, without knowing how various climatic factors and their interaction with management will influence the direction of succession, will therefore be extremely difficult.

1.1.3.2. Modern Succession Theories

These limitations of the Clementsian model led to the recent development of non-equilibrium models. One of these, which are regarded as more realistic, is that of Westoby *et al.* (1989). The author suggest using the so called State and Transition model by means of which vegetation dynamics or change in the rangeland condition can be described. According to this model, a type of vegetation or area of rangeland is in a certain state or condition. Changes in this condition (improvement or deterioration) do not happen instantaneously, but discreet transitions take place (Jordaan & Kellner, 1999). The transition from one condition (state) to another can either be caused by natural events (climatic circumstances, fire, etc.) or by management activities (change in grazing pressure, planned burning, fertilising,

sowing of other plant species, etc.). A simplified representation of this model is provided in Figure 1.4.

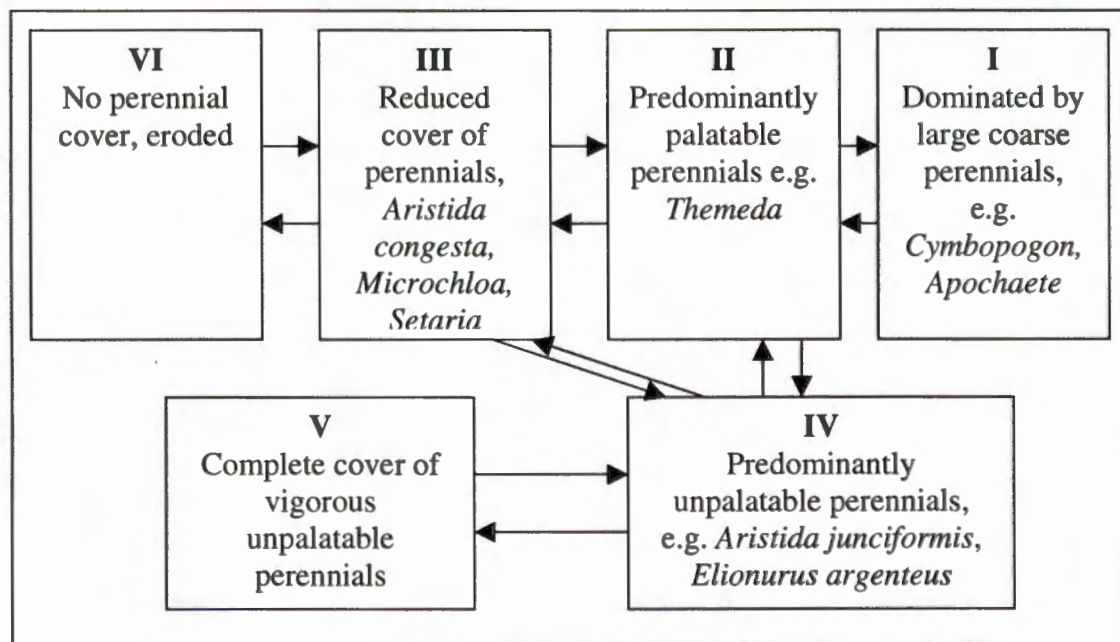


Figure 1.4: State-and-transition model for tall grassrangeland in South Africa (Humphreys, 1997).

This model does not only imply movement or transition from one condition (state) to the other, but that definite threshold values or limits of resiliency occur in the development of the plant community. The characteristics of a limit of resiliency are the following (Jordaan, 1999):

- It is the boundary in time and space between two conditions, for instance rangeland proceeding to grass/shrubs or savanna as a result of overgrazing; and
- If a limit of resiliency is exceeded, recovery to the previous condition will not take place within a practical time limit, unless there is a certain intervention, for instance the application of pesticides, or management procedures, such as the use of heavy machinery or even fire. Thus where a limit of resiliency has been exceeded, it is not enough to adapt the grazing capacity only.

Stable conditions (domains of attraction) occur when vegetation can change and recover (Jordaan, 1999). As soon as a limit of resiliency is exceeded (for instance where prolonged overgrazing results in changes in the soil condition) the vegetation proceeds to another domain of attraction. Recovery to the previous domain is virtually impossible without intervention by the manager.

Although states and transitions, and thresholds are valuable concepts, they are scale dependent, and their place in a spatial hierarchy needs redefining. The scale of operation is important, as it will not only influence the knowledge of how the system functions, but will also influence conclusions with regard to the results of monitoring actions (Van Rooyen, 2000).

Recognising the role of climatic factors (rainfall) and management practice (stocking rates, grazing system, burning practice, and animal types) in community development holds important practical implications (Scholes & Van der Merwe, 1999). In intensive rangeland systems it could often be important to be able to manage an area to achieve a specific composition goal. For this, transition from one domain to another and the soil condition factors that limit recovery will have to be known, while the soil condition factors that limit recovery will have to be understood. In addition to this, an understanding of the factors controlling transitions from one state to another will also be required. This could be achieved in long-term vegetation monitoring programmes. Analysis of this data to explain transitions from one state to another, and an understanding of the factors that will limit transitions from one domain to another, could be of great assistance in defining management strategies to achieve particular composition goals (Bosch & Kellner, 1991).

In the commercial sector, where farmers strive to maximise meat and wool production, the equilibrium model continues to be favoured (Hoffman & Ashwell, 2001). However, this approach applies less to rangeland management in communal areas, where farmers keep animals for many more purposes besides meat or wool production. The differences between conditions and farming practices in the commercial and communal areas make the development of a general theory of rangeland management difficult. The unique condition in communal areas necessitate the development of rangeland management systems that take account of their particular historical, climatic and socio-economic contexts.

This discussion of the equilibrium and non-equilibrium view of rangeland science suggests that a paradigm shift is necessary in rangeland science policy and practise. It is however too soon to evaluate just how much of a paradigm shift there has really been in South African agriculture (Hoffman *et al.*, 1999).

1.2. Rangeland management in the communal areas of southern Africa

People are dependent on the natural environment for meeting all their needs and therefore the interactions between people and the environment cannot be separated. What is important, is to study the impacts of using resources and how best to manage these, so that human and environmental needs can be met, now and in the future (Barnard & Newby, 1999)

Communal rangelands are defined as those areas where agriculture is largely subsistence-based and where rangelands are generally communally-owned and managed, as opposed to private or individual ownership (Tainton, 1999). In South Africa these areas comprise the previous homelands and constitute approximately 12% of the country (Tainton, 1999). In spite of perceptions that these areas are badly degraded, they are reported to "support" a quarter of South Africa's human population and half of the livestock population (De Bruyn *et al.*, 1998). It is, however, important to appreciate that people living in these areas are in effect sustained financially largely by income earned outside the communal areas. Although the areas may carry approximately a quarter of the livestock population of the country, their proportional production is likely to be much lower than this.

To follow is an overview of current issues that need to be addressed to achieve sustainable land management in communal areas. These are issues such as land tenure, historical, social and ecological factors, as well as policy and legislation issues.

1.2.1. Land tenure

Property rights are the foundation of resource use, management and conservation. According to Tainton (1999), free access to common resources is a recipe for environmental disaster, because communal land tenure leads to overstocking and resource over-exploitation resulting in the “tragedy of the commons”.

It is very important not to confuse free access, where resources are available on a free for all basis, with the true commons. The true commons is an area of mutual benefit and responsibility, managed by those using it in a manner that acknowledges that environmental resources are limited. Communities dependent on common property resources have adopted various institutional arrangements to manage these resources with varying degrees of success in achieving sustainable use (Tainton, 1999). This success is largely dependent on the effectiveness of the tribal authorities and emerging rangeland management institutions in managing the communities under their control. Such institutions are likely to be the key to future sustainable range management and they will need to overcome, among other problems, the very skewed ownership of livestock, and the tendency for a large proportion of the livestock to be in the hands of absent members employed in industry outside the communal area. The livestock that such individuals accumulate in the communal area, primarily for the purpose of their wealth, denies the local inhabitants of a large proportion of the resources of the rangeland. In any event, unequal livestock ownership must be recognised when planning range management strategies.

Commonly it has been shown that users in non-freehold systems do feel secure enough to invest in production and conservation; but that the detailed design of such systems, and a range of locally variable factors affecting their performance, will determine whether this is so in any particular instance. Conversely, it has been recognised that private ownership is not a guarantee of environmentally responsible behaviour. Ignorance or external economic incentives may also lead freehold farmers into land degradation.

Much international analysis and programme design has assumed that security of tenure is necessary for adequate land conservation. Without such security, it has been argued, farmers will “mine” their land resources and will not consider investment in soil conservation economically attractive. One solution would be privatisation of common resources. Where this cannot be attained, it has been argued that indigenous African tenure systems should at least be converted into registered, more readily transferable land rights (Hoffman *et al.*, 1999).

Closer inspection shows such arguments to be based on a number of assumptions (Hoffman *et al.*, 1999):

- That indigenous tenure systems are static and cannot adjust to the changing economic and demographic circumstances of modern times;
- That land users in unregistered, non-freehold tenure systems do not feel secure enough to invest in measures that will lead to higher productivity or assure the conservation of land resources;
- That group ownership and/or management of land is inimical to land conservation;
- Those measures to combat or prevent land degradation require substantial, long-term investment of the sort for which these unregistered, non-freehold tenure systems supposedly cannot provide adequate security

According to Hoffman *et al.* (1999) and Tainton (1999), land reformation is currently underway in South Africa to address the history of unequal land distribution. Many planners have called for privatisation of land to stop over-grazing. However, in many cases resource productivity per unit area is not high enough to guarantee the individual or groups the returns needed to sustain private property regimes. In addition, resource poor people that have been allocated private property regimes may not be able to bear the cost that these systems impose (Turner & Ntshona, 1999).

Private ownership is not necessarily the answer to land tenure problems. It can lead to land grabbing and does not always ensure easy access to credit, nor is it a guarantee of good land stewardship. It is suggested that the solution to natural resource management problems in southern Africa is to be found in a combination of institutional arrangements that combine the best attributes of private, common and state property (Tainton, 1999). Any new land policy therefore needs to take into account the diversity of conditions under which rangelands are used in South Africa, the range of stakeholders involved and the variety of socio-economic conditions under which rangelands are managed.

Involvement of communities in decision making and sharing of benefits from conservation areas, together with education, extension and research, and a balance between addressing social and environmental issues, will enhance feelings of ownership, and contribute to the success of schemes to promote sustainable development (Barnard & Newby, 1999).

1.2.2. Historical issues

Traditionally the response of African pastoral societies to variable forage availability was to retain a high degree of mobility (nomadic pastoralism). The poorer the resource base, the greater the dependence on rangelands and the greater the mobility. Increased population pressure and political changes have contributed to the breakdown of this type of pastoral production (Tainton, 1999).

Since 1913 (when the 1913 Land Act was implemented), non-white South Africans were increasingly deprived of the right to own land in the so-called white areas, although this trend actually started in the nineteenth century (Barnard & Newby, 1999). This process was intensified by the unfolding of the policy of separate development since 1948, and the concurrent removal of several thousand people from

their land to the so-called homelands or areas that were designated to them ("Bantu Reserves").

The South African agricultural sector was progressively characterised by extensive farms in the possession of a limited number of private and company ownership. In contrast, about eight million people were concentrated on 13 percent of South Africa's surface, mainly in the former homelands (Van Zyl *et al.*, 1996). This had detrimental effects on small-scale farming and put severe pressure on the environment. In 1932 a Commission of Enquiry into the Agricultural Economy of "Bantu Reserves" warned that accelerated soil erosion due to over-grazing was turning developing areas into deserts. This led to the proclamation of "Betterment" Areas in 1939 (Tainton, 1999).

Many communal areas in South Africa were subjected to "Betterment", which was implemented in the 1950's. Planners who sought to impose a "scientific" resource management regime divided communal areas into the following three main resource areas (Tainton, 1999):

i. The homestead area

Villages replaced the traditional settlement pattern of scattered homesteads where a family was allocated land on which to build their homestead. Tenure for this land was generally secure. It was common for this area to be fenced and used for kraaling livestock, keeping poultry and growing fruit and vegetables.

ii. The fields

Households had usage rights to specific fields. Tenure of this land was relatively secure and was allocated by the "tribal authority". Rights to exclusive use of the fields were reserved for the summer months. In winter the fields were used for communal grazing. All maize stalks (stover) were considered to be part of the communal winter grazing resource. Fields could be re-allocated under specific conditions such as continued non-use. In some cases land was rented out.

iii. Rangeland

This area was designated largely for summer grazing, but was also used for other resources such as water, thatch grass, fuel wood, timber and medicinal plants. All members had access to this area, and use patterns were controlled by local regulations. There was no limit to the number of livestock that an individual could keep. In some areas permits were required to keep livestock, but these were not used to control livestock numbers.

From the early 1990s, this distribution of ownership of agricultural land was recognised as politically, economically and socially unacceptable. With the passing of the Restitution of Land Rights Act in November 1994, the restoration of the land rights of disadvantaged South Africans was started in earnest. The ideal was, amongst others, to create 1.5 million net livelihoods by redistributing land from the commercial agricultural sector (Barnard & Newby, 1999).

The results of the reforms for the environment are still largely unknown. A major part of the reforms will occur on marginal agricultural land (particularly in the former homelands), which has already been negatively affected by intensive agriculture and human residence, as evidenced by overgrazing, soil deterioration, overutilization of water sources and erosion.

1.2.3. Current Rangeland and livestock management

When "Betterment" was first initiated, the government implemented a destocking campaign, but after strong opposition this was discontinued (Barnard & Newby, 1999). Traditionally, livestock management was the responsibility of the men, and young boys carried out herding. Today women play a major role in livestock management. As men migrate to industrial and mining sites in search of jobs, women are left in rural areas as heads of households. Although women's interactions with cattle have increased over the years, decisions on issues such as slaughtering and selling are still vested with the men.

During the 1950's when "Betterment" was implemented, the grazing area was fenced off from the cropping area and individual grazing paddocks were also fenced (Tainton, 1999). However, the fencing system has collapsed largely because of theft and a lack of maintenance. It is clear that any cattle and rangeland management strategy will require some mechanism to control cattle movement. Physical fencing or "social" fencing, such as herding can control cattle movement.

Managing individual livestock herds on communal rangelands is largely exercised by herders and the level of herding varies. Over much of South Africa the absence of young boys, who now attend school, imposes a major limitation to livestock management (de Bruyn *et al.*, 1998). Increased social development, including increased schooling, effects a breakdown in the traditional herding system. This results in losses through theft of stock and conflict between crop and cattle owners when untended cattle destroy crops.

In spite of large livestock losses in communal areas during droughts, livestock numbers have shown no obvious directional change. Although this may be interpreted as evidence that degradation is not occurring in communal areas, the practice of buying in cattle after droughts and supplementing feed must be taken into account.

Traditional livestock herding practices are not static but alter in response to changing socio-economic and economic pressures. The grazing system in communal rangelands closely follows the cropping cycle (Tainton, 1999). During the cropping season in summer, the cattle are moved away from the crop fields to graze on the surrounding natural grasslands. Milk cows and calves are usually kept in the vicinity of the homesteads. In winter, following the harvest of crops, the cattle graze on stover in addition to rangeland. Fodder shortage, especially during the dry winter season, is one of the main constraints to livestock production. In variable environments key resource areas are important to sustain livestock through the dry season.

1.2.4. Social issues

The social changes which are currently exerting pressure on the environment can be summarised in the following three categories (Barnard & Newby, 1999):

i. Population and demographic change

The first national census in South Africa was held in 1904, when the total population amounted to 5.17 million people. As already mentioned in section 1.1 the population has since increased to the official figure of 40.58 million, and is growing by approximately 2% each year. A larger population means greater demand for natural resources and environmental services, as well as increased waste generation and pollution.

ii. Social and economic development

The alleviation of poverty is one of the national and international priorities for achieving sustainable development. However, equally if not more important in reducing environmental degradation is changing the lifestyles of the affluent to become less consumer orientated and less wasteful. This will ensure that resources are used sustainably so that future generations may have adequate resources. There is a lack of data regarding the extent of socio-economic development in South Africa, however, and the nature of the impact on the environment is therefore difficult to determine.

Differences in wealth among the people of South Africa have also pressurised natural resources (Van Horen *et al.*, 1998). The more affluent people tend to consume more resources and generate more waste, on a commercial and domestic level. Wealthier people, for example, tend to use more resources such as energy and water, and commercial agricultural and industrial development transforms natural habitats, and generates wastes and pollution. Poor people exert different environmental pressures, cultivating unsuitable areas of land, overgrazing the rangeland, and removing large quantities of wood for fuel.

iii. Changing Values and Beliefs

Whereas the majority of people were historically based in the rural areas where they were in close contact with the natural environment, many came to lose continuous and even intermittent contact with nature. The “new” life, working environment and ethic which has developed, have resulted in most people not having contact with the natural environment and therefore not realising that environmental integrity is necessary for their own survival.

Past failures of development initiatives to solve the problems of environmental degradation have been attributed to the lack of consultation and involvement of the rural population (Barnard & Newby, 1999). Community development is a process, which emphasises learning, participation and action and is directed towards improved socio-economic livelihoods. In the past, the top-down approach of implementing management strategies excluded the local people from decision making.

New conservation policies are based on the principle that the land belongs to the people who are part of the environment. The recognised need to adopt more socially responsible methods of conservation management in Africa is reflected in new labels of resource management in rural areas: community-based natural resource management (CBNRM), village-land management, grassroots management and common property resource management (Tainton, 1999). The aim was to use these types of approaches in this study.

1.2.5. Principles of managing rangeland and sustainable utilisation

The management of communal rangelands is a dynamic and challenging process. The diversity of stakeholders and socio-economic conditions makes it difficult to apply formal management to communal rangelands. Many of the conventional views on African rangeland dynamics have been criticised in recent years. A multidisciplinary understanding of these farming systems is necessary if new policies are to make any appreciable difference to rural livelihoods (Tainton, 1999). Intervention in communal rangelands must therefore focus on the people and make production an integral part of sustainable land management.

Sustainable agricultural land-use is nonetheless vital for economic and social development in these areas. In the past, development initiatives aimed to achieve sustainability through the control of excessive livestock numbers. These efforts failed because they clashed with the basic reasons for which people were keeping cattle, i.e. milk, draft, security, etc (Hoffman *et al.*, 1999). In an effort to address problems of resource degradation sectors of the scientific world are now not only attempting to understand all aspects of communal land use, but are also introducing different grazing programmes, the concepts such as resting, or the implementation of active restoration practises to these communities (de Bruyn *et al.*, 1998).

1.2.6. Ecological issues

System dynamics in African rangelands are strongly influenced by rainfall (O'Connor, 1995). A basic distinction between equilibrium and non-equilibrium systems is their degree of fluctuation. Arid and semi-arid grazing systems are prone to the effects of highly variable rainfall and are regarded as non-equilibrium systems. Recent thinking in range management suggests that in arid, non-equilibrium systems the danger to the environment from overstocking is relatively small since external factors such as droughts cause frequent periodic mortality of livestock but this may be too late to prevent excessive stress being applied to the range. In South Africa there is general agreement that serious degradation has occurred in arid communal rangelands and in some cases irreversible soil changes have occurred. There is also evidence of degradation in semi-arid communal areas (Barnard & Newby, 1999).

One of the issues that are currently widely debated is that of applying commercial grazing capacity norms to communal rangelands (Hoffman *et al.*, 1999). There are in fact many different economic carrying capacities depending on the land user's objectives. Commercial beef farmers aim to make a profit from meat production. They manage the rangeland by controlling animal numbers and applying grazing management systems (e.g. rotational resting) to avoid degradation of the grass resource (Mentis, 1989).

By contrast, producers on communal lands have much broader livelihood strategies, of which livestock production may only be a small part. In addition, livestock are kept for multiple reasons including draft power, security, milk and meat (Hoffman *et al.*, 1999). They therefore aim to maximise animal numbers per area and focus on the maintenance and survival of those animals. Management of the communal systems tends to be low cost. Available grazing which fluctuates with variable rainfall controls animal numbers.

A universal "norm" of grazing capacity is thus meaningless in systems that are not related to production objectives (Tainton, 1999). However, if maximising the animal numbers forms one of the main objectives of management, care needs to be taken to ensure that the rangeland is not so badly stressed that the system degrades.

It is apparent that land degradation means different things to different people. For example, commercial beef ranchers see a change in grass species composition over time as an indicator of degradation (Hoffman & Ashwell, 2001). By contrast, communal farmers see degradation as a long-term decline in livestock survival rates that are perceived to be independent of rainfall or drought. Conservation managers on the other hand may even regard declines in biodiversity as degradation.

Many communal areas have been classified as degraded on the basis of the structural differences in the vegetation when compared to commercial rangelands (e.g. lower biomass, lower grazing height and more bushes). However, despite these differences many of these areas are as productive as their commercial counterparts, and are thus also able to support large herds of livestock (de Bruyn *et al.*, 1998). While the visual impact of communal areas leads to the conclusion that it is badly degraded, closer observation shows that many of the climax species may still be present, even if not particularly productive. This highlights the need for appropriate indices of degradation (Tainton, 1999).

According to Tainton (1999) one of the problems in addressing degradation is the lack of basic information on whether degradation is occurring. A major research gap exists on the long-term quantitative biological and economic effects of high stocking rates under communal systems. Unfortunately, the economic effects of such degradation are often very slow in expressing itself and, by the time it do become apparent, the financial implications of reversing the downward trend in rangeland condition may be prohibitive.

Restoration ecology is one of the solutions that exist to the problem of degradation. It is the discipline which includes those activities which seek to upgrade damaged and degraded land, or the activities to recreate land that has been destroyed, bringing it back to beneficial use in a form in which the biological potential is restored (De Wet, 2001).

In the simplest circumstances, restoration consists of removing or modifying a specific disturbance, thereby allowing ecological processes to bring about an independent recovery as in the case with this study, where passive restoration of the rangeland is applied by resting the rangeland. The restored ecosystem often requires continuing management to counteract the invasion of opportunist species, the impacts

of various human activities, climate change, and other unforeseeable events (SER, 2002).

Ecosystem management is thus of utmost importance seeing that ecological restoration aims at assisting or initiating recovery, whereas ecosystem management is intended to guarantee the continued well-being of the restored ecosystem thereafter. In the case of this study ecological restoration however depends upon the long-term participation of local people.

1.2.7. Policy and Legislation

At a national level, policies are government instruments used to drive change, enforce or encourage certain actions, and prevent or discourage other actions. Policy guides decision-makers in setting priorities and allocating resources. Lack of policy can cause confusion over rights and responsibilities, and result in undesirable behaviours and disputes. In an environmental context, lack of policy can lead to abuse of resources, inequity and degradation of systems (Department of Agriculture, Conservation and Environment, 2001).

The advent of democracy in South Africa in 1994 has increased the participation of stakeholders and the public in policy formation (Fakir *et al.*, 1999). In particular, it has raised the level of public debate to promote policy aimed at achieving sustainable development rather than serving narrow group and sectoral interests.

South Africa is ahead of many other developing countries in sustainability policy development because, in addition to several new, far-sighted environmental management policies, the Constitution makes provision for each citizen to have the right to a healthy environment, and the right to have the environment protected (Barnard & Newby, 1999).

During the 1990s, a number of new environmental policy processes were initiated in South Africa. The most recent, referred to as the Consultative Environmental Policy Process (CONEPP) culminated in the release of a draft White Paper on a National Environmental Management System. This represented a paradigm shift from the concept of environment being narrowly regarded as relating only to conservation (green issues), to the broader concept of sustainable development including the integration of social, economic and environmental factors (Barnard & Newby, 1999). Further it included a more democratic and participatory system of policy formulation, and a wider recognition that environmental degradation is a function of market and institutional failures.

The focus in South Africa at present is on meeting basic needs (i.e. ensuring that all citizens have proper housing, water supply and sanitation, electricity, health care and other services) (Barnard & Newby, 1999). There have also been radical changes to the Constitution, so that it now reflects the interests of all sectors of the population, creates empowerment of individuals and communities, and upholds the rights of humans and the environment.

South Africa also recognises and has participated in international efforts to promote sustainable development, including the adoption of Agenda 21, and a commitment to

implementing it at the national, provincial and local levels (Fakir *et al.*, 1999). South Africa has developed policies and passed a number of laws that aim to alleviate the pressures of social imbalances on natural resources, and to promote sustainable development (Barnard & Newby, 1999). These include the Reconstruction and Development Programme, a White Paper on Population Policy, and the National Crime Prevention Strategy.

With current changes in land reform in South Africa, the time is ripe to challenge the management of communal rangelands. Like the rest of South Africa, historical policies and legislation of the colonial and apartheid eras have affected the environment of the North West Province. Post-1994 national policies and legislation introduced during the last five years are currently being implemented (Department of Agriculture, Conservation and Environment, 2002). Environmental management in the North West Province is mainly driven by national and international priorities and requirements (e.g. CITES, Agenda 21, Convention of Desertification).

Management of the environment is considered to be a provincial competency under the Constitution of South Africa. The North West Provincial Government has not fully exercised its Constitutional powers, as it has not yet promulgated its own province-specific environmental legislation (Department of Agriculture, Conservation and Environment, 2002).

Some key national legislation, which impacts on environmental policy and management in the Province, includes the:

- Constitution of the Republic of South Africa (Act No. 108 of 1996);
- National Environmental Management Act (Act No. 107 of 1998);
- Environment Conservation Act (Act No. 73 of 1989);
- National Water Act (Act No. 36 of 1998);
- Atmospheric Pollution Prevention Act (Act No. 45 of 1965);
- Minerals Act (Act No. 50 of 1991); and
- Conservation of Agricultural Resources Act (Act No. 43 of 1983).

The successful implementation of policy is largely a function of political will, adequate funding, good integration and co-ordination between the lead agency and other agencies where functions and responsibilities have been delegated, and a well-trained group of staff to manage programs and projects. The National Environmental Management Act took three years to develop, and needs strong capacity building programmes and commitment of resources at all levels of government to be effectively implemented (Barnard & Newby, 1999).

Policy, legislation and planning are all responses that set the scene for specific actions necessary for effective implementation. Without implementation of policies, plans and programmes there can be no effective environmental management or reversal of negative environmental trends. Programmes of action are projects or programmes that address specific environmental issues or problems. A number of new resource conservation and land management programmes are currently being initiated in South Africa to deal with the problem of resource degradation. The establishment of these programmes implies a radical new direction for resource conservation. One of these programmes is the South African LandCare Initiative, which is based on the ideal that

sustainable agricultural resource utilisation forms the foundation for establishing a conservation ethic.

1.3. LandCare in South Africa

According to Schutte (1999), LandCare is about managing land, water, plants and animals sustainably. LandCare is nothing new and has been done in Africa and in South Africa. Some people call it community based resource management; others use the term integrated catchment management, or stewardship of the land. No matter which terms are used, the main objective is that governments must move from top-down departmentally led programs to landholder-initiated actions.

LandCare originated in Australia with the objective of promoting sustainable land management by putting landholders in charge of their own problems. After a decade of LandCare in Australia, tangible social, economic and ecological benefits have been derived from restoring the quality of the land and promoting sustainable use of the resources (Barnard, 2002). A typical LandCare group is made up of concerned farmers and other community members and meets regularly to decide how best to address local issues. The empowerment of the farmer and the community in decision making led to the development of highly skilled groups and individuals involved in LandCare.

The South African LandCare Program is a community based and government-supported land management program. The LandCare program offers financial support to LandCare community groups, who will identify, implement and monitor the conservation activities needed to deal with the land degradation problems they experience (Schutte, 1999).

It is a matter of urgent priority that ways be found to prevent and even reverse, degradation of natural resources in the North West Province. Indeed, an enormous challenge of protecting and sustainably managing the natural resource base, even under the present condition of population growth and rising unemployment, faces the Province. It is the intention of the Province to ensure that the natural resources are wisely and carefully conserved, utilised and improved (Department of Agriculture Conservation and Environment, 2001).

LandCare aims to bring improvement, optimal utilization and conservation of natural resources through the actions of people, resulting in sustainable agriculture and a better quality of life (Figure 1.5). LandCare will thus build the skills and grow the capacity of people through education, knowledge sharing, participatory interaction and better access to resources (Department of Agriculture Conservation and Environment, 2001). Institution building at all levels will enable communication, networking, financial, and other support services. LandCare will also foster a resource conservation ethic, resulting in a nation motivated and empowered to care for the environment, so that the environment remains productive and can contribute optimally to the socio-economic growth of the country.



Figure 1.5: No Care versus LandCare (Department of Agriculture Conservation and Environment, 2001).

1.3.1. What is LandCare?

LandCare is about encouraging and supporting sustainable land use practices, raising awareness and promoting a resource conservation ethic (Department of Agriculture, Conservation, and Environment, 2001). It is a sustainable resource utilisation programme based in the community and driven by both the public and private sectors through partnerships and co-operation. LandCare also seeks to address poverty and create jobs through the launching of various natural resource rehabilitation, improvement and conservation projects.

1.3.2. The National LandCare Programme

LandCare is developing and implementing integrated approaches to natural resource management in the country, which are efficient, sustainable, equitable and consistent with the principles of ecologically sustainable development. LandCare partners have consequently designed key strategies for sustainable natural resource management (Department of Agriculture, Conservation, and Environment, 2001).

i. Major works

Serious concerns about land and water degradation, which impact on sustainable resource use, are identified in each province and specific projects developed to address these issues head on.

ii. Capacity building

The purpose of this strategy is to empower resource-poor communities to develop LandCare groups and activities through awareness, training and education.

iii. *Awareness programme*

This includes communication strategies directed towards rural community groups and young people.

iv. *Policy and legislation*

This strategy stimulates the formulation of policy and legislation to develop incentives for natural resource management.

v. *Research and evaluation*

The purpose of research and evaluations is to establish and implement a monitoring system to evaluate progress, assess contemporary issues and to provide a basis for planning and research. This very important key strategy forms the basis of the study for this thesis. Ongoing monitoring of change in terrestrial ecosystems, and in particular quantitative data on the extent of degradation and land transformation, are priorities for further research (Barnard & Newby, 1999).

1.3.3. The North West LandCare Programme

Land and water degradation are examples of serious environmental issues facing all of South Africa, and the North West Province is no exception. These problems affect all South Africans because they impact on the economy, the environment, our communities and our quality of life. The North West Province with its erratic rainfall and dry climate has seen much of its cropland and grazing land deteriorate through soil erosion, overgrazing, bush encroachment, invasion of alien plants and inappropriate land use practices (Department of Agriculture Conservation and Environment, 2001).

It is thus a matter of urgent priority that ways be found to prevent and even reverse, degradation of natural resources in the North West Province. An enormous challenge faces the province, that of protecting and sustainably managing the natural resource base, even under the present condition of population growth and rising unemployment. Consequently the intention of the Province to ensure that the natural resources are wisely and carefully conserved, utilised and improved (Department of Agriculture Conservation and Environment, 2001).

The overall goal of the North West Province, drawn from that of LandCare South Africa, is to optimise productivity and sustainability of resources and thus bring about greater productivity, food security, job creation and better the livelihood of all people (Department of Agriculture Conservation and Environment, 2001).

The specific objectives of the North West Province LandCare programme, of which most are also the purpose for this study, are:

- To improve rangeland management through implementation of different rangeland management systems;
- To improve production and vegetation composition of rangeland through improved bush control practices;
- To improve rangeland production and composition through limiting stocking densities;
- To establish an effective LandCare Programme through which the resource owners and users will take responsibility for the maintenance, correct management, improvement, and sustainable utilisation of the natural resources; and
- To monitor and evaluate the impact of the programme on resources, on society, and on the economy (Department of Agriculture Conservation and Environment, 2001).

Planning and implementation of the North West LandCare programme is based on the following principles (Department of Agriculture Conservation and Environment, 2001):

- Maximum scope for decision-making to be left with communities; and
- Decisions to support LandCare interventions are based on improved information about the community and its resource base.

LandCare is implemented in the following ways in the North West Province (Department of Agriculture Conservation and Environment, 2001):

- Involvement and mobilisation of local communities and landowners to take responsibility for natural resource management (Figure 1.6);
- Building of partnerships between all stakeholders;
- The provision of effective and efficient management structures;
- Effective implementation of initiatives and projects to ensure 'best ecological practices; and
- Financing of ecological management programmes through matching funding involving all spheres of government and resource users.



Figure 1.6: Involving communities in LandCare projects.

The North West Province LandCare programme aims to ensure that LandCare is community based: "By the people, for the people". Community initiated resource conservation and improvement projects will assist with achieving this goal (Department of Agriculture Conservation and Environment, 2001). LandCare community projects will be sustainable if the community is directly involved in identifying, assessing, planning, implementing and monitoring projects (Figure 1.6). LandCare community projects will have tangible socio-economic and resource conservation benefits. Children will reap the benefits of LandCare efforts. Their involvement in LandCare is an investment for the future.

The Department of Agriculture, Conservation and Environment of the North West Province (DACE-NW) plays a vital role in supporting the establishment of LandCare forums and raising awareness of the importance of a "duty of care" (Department of Agriculture Conservation and Environment, 2001). In addition, a LandCare manual (for the use of the extension officers) is developed and skill development and capacity building programmes are to be established by DACE-NW. Empowered communities can thus ensure that LandCare is practised, and thereby ensuring a sustainable future for all.

Elements of the LandCare Programme are as follows (Department of Agriculture Conservation and Environment, 2001):

i. Control of bush encroachment

The three most important types of rangeland degradation that occur in the North West Province are bush encroachment/thickening, loss of basal cover and change in species composition (Hoffman *et al.*, 1999). These three causes are so interwoven and consequently this makes it extremely difficult to point out a single causing factor. Loss of cover and changes in the species composition can lead to bush encroachment. Bush thickening for whatever reason, however, also leads to changes in the species composition and is accompanied by a decrease in the basal cover. This aspect is covered by another M.Sc. study (by Miss Anja Janse van Vuuren) in the School of Environmental Sciences and Development, Potchefstroom University for Christian Higher Education.

ii. Rangeland restoration

Rangeland restoration can be defined as the process of assisting the recovery and management of ecological integrity. It is also defined as the process by which an area (a damaged or degraded portion of land) is returned to its original state prior to degradation of any sort, i.e. back to a fully functioning self-sustaining ecosystem (De Wet, 2001).

In almost all communal areas of the North West Province, land degradation has occurred to such an extent that normal managing practices as well as total withdrawal would not help in the recovery process by which an area is returned to its original state prior to degradation of any sort, i.e. back to a fully functioning, self-sustaining ecosystem (Department of Agriculture Conservation and Environment, 2001). It is not about science alone but also

about the restoration of land and peoples' lives. People cannot be excluded from the problems and solutions found in nature. The whole of creation is subject to mankind and they are responsible for ruling over it. People are so involved in this matter, that scientists agree that degradation and ecological restoration is as much a socio-economic issue as it is an environmental issue (De Wet, 2001). In fact, the social component is at the root of many restoration projects.

iii. *Integrated resource management*

It will be of no use to do bush control or rangeland restoration if a proper resource management plan does not form part of it. The success of any control or restoration efforts depends on the management strategy for the area thereafter (Department of Agriculture Conservation and Environment, 2001).

iv. *Soil conservation*

Soil degradation implies degradation that will occur in both the rangeland as well as the croplands. The most important types of soil degradation in the rangeland of the North West Province are rill, gully and donga erosion. These types of erosion occur in 71% of the magisterial districts of the province (Department of Agriculture Conservation and Environment, 2001). The most important forms of soil degradation in croplands are sheet erosion (water), a loss of topsoil (wind), as well as rill, gully and donga erosion (water).

v. *Eradication of alien vegetation*

Invading alien shrubs and trees cover an area of about ten million hectares in South Africa. If all these plants were condensed into a single area, they would cover the equivalent of 1,7 million hectares, which is more than the total area under commercial forestry, and about the size of Gauteng province. Because most trees and shrubs require at least 500 mm of rain per annum, woody aliens usually become established in places where there is adequate water (Hoffman & Ashwell, 2001). It is essential to systematically eradicate the alien invasive species, which have invaded amongst others the river catchment areas and a sizeable portion of productive agricultural land.

vi. *Conservancies*

Conservancies are a practical way of implementing LandCare principles in an area. A conservancy is defined as "co-operative, ecological management of a demarcated area by all its residents and/or users" (Department of Agriculture Conservation and Environment, 2001).

Conservancies are based on community participatory principles where the residents and resource users take ownership of and responsibility for their area to ensure effective agro-ecological management and sustainable resource utilisation. In the process, the needs of the community and the environment are catered for. This requires the wholehearted active participation of all interested and affected parties.

1.3.4. Approach to LandCare

The LandCare initiative in South Africa is approached by addressing the following aspects (Department of Agriculture Conservation and Environment, 2001):

i. Community-based natural resource management

The basic LandCare trend is for groups of people, some from different backgrounds to get together to talk about mutual problems and coming up with solutions. It is this grassroots approach that is the motivating force for the LandCare programme and has been a major reason for its success.

Community participation is being implemented via regional and local LandCare information and/or participation days. Local councillors, community members, agricultural sector representatives, business sector representatives, environmental interest group representatives, relevant government department representatives and the local media will be invited to these days.

ii. Forums

With suitable motivation and assistance, LandCare institutional structures can be established (operating at local and regional level). The aims and objectives of LandCare forums are:

- To ensure that LandCare is community based and that it is managed in an ordered and structured way; and
- To establish effective, operational and empowered forums to serve as vehicles for information flow, gathering support at local level, propagating LandCare, planning and managing LandCare activities/projects in an ecological area, fundraising, community liaison and mobilisation and to act as "change agents".

iii. Partnerships

LandCare is successful in building partnerships between the public, community and private sectors. Partnerships are effective because they foster community spirit and people are realising the need for LandCare.

iv. Local action

LandCare encourages people to take local action. It also promotes local economic development through employment creation. Local LandCare groups have access to technical information and advice.

v. Food security

Socio-economic benefits add value to LandCare. These include greater productivity, food security and poverty relief.

vi. *Integrated and innovative approaches*

LandCare promotes integrated and innovative approaches to natural resource management. In this way, the causes of environmental and resource degradation are addressed rather than the symptoms.

vii. *Redress*

LandCare assists resource-poor communities from rural areas and addresses the needs of formerly disadvantaged groups.

1.3.5. LandCare themes

LandCare themes are grouped into two main areas, namely Focused Investment (Watercare, Veldcare, Soilcare, Juniorcare) and Small Community Grants (Department of Agriculture, Conservation, and Environment, 2001).

1.3.5.1. Focused Investment

- i. *Watercare* - The Watercare theme specially targets the Limpopo Province, because of water shortages and the importance of water for irrigation. This theme is establishing a framework for managing land and preventing the silting up of dams for irrigation.
- ii. *Veldcare* – This theme, which is the theme of the LandCare project of this study, entails the promotion of the best grazing systems and erosion prevention practices to improve production. It aims to develop and maintain agricultural activities in accordance with the principles of ecologically sustainable development within the North West Province. It also ensures that economic and social development opportunities are realised by improving grazing areas and maintaining viable grazing areas throughout rural communities.
- iii. *Soilcare* - This theme encourages rural farmers in KwaZulu-Natal, the Eastern Cape and Mpumalanga to build innovative structures to combat soil erosion.
- iv. *Juniorcare* – The future generation will reap the benefits of LandCare efforts. Children's involvement is thus an investment that will deliver future benefits. The objectives of Juniorcare are to empower previously disadvantaged young people with regard to training in facilitation and leadership skills.

1.3.5.2. Small Community Grants

This theme improves the ability of resource-poor communities to manage land, water, and vegetation in a sustainable and self-reliant manner. It includes elements from all the themes already mentioned.

1.4 Aims of the project

The appearance of rangeland deterioration has regularly been reported in South Africa, especially in the last thirty years, and accordingly several extension and research programs have been launched to address this problem. It seems that in earlier approaches, systematic resting of rangeland was emphasised. Since 1966 the emphasis changed to the control of the degree of utilisation of rangeland, largely by manipulation of the grazing procedure (number of paddocks, periods of absence, and periods of stay) in a rotational grazing system. To remedy this situation various techniques have been developed of which the most widely used are based on comparisons with vegetation benchmarks or reference points (Hoffman *et al.*, 1999).

Benchmarks are mostly selected to represent the normal potential of the vegetation and accordingly serve as reference sites that can be used in the assessment of rangeland condition (Hurt & Bosch, 1991). A concept of the normal potential is often theoretically synthesized from information on remnants of undisturbed vegetation or relict soil, protected in some way, from grazing. Usually benchmarks are selected to represent the “ideal” for the main vegetation types in specific regions (Bosch *et al.*, 1987). In the past the ungrazed “climax” vegetation has been emphasized in selecting benchmarks. This approach has a number of deficiencies of which the most important is probably the fact that vegetation communities are now viewed as dynamic entities with both temporal and spatial heterogeneity. For the purpose of this study however, the benchmarks were selected, in collaboration with the agricultural extension officers, to represent rangelands in different states of degradation due to grazing. Their choice in benchmark sites accordingly serves as a reflection of what is perceived by them as representations of good, moderate and poor rangeland conditions.

The selection and description of benchmarks have a marked influence on the evaluation of change in a specific area of vegetation (Bosch *et al.*, 1987). Much attention was therefore given to the nature of benchmarks selected in the different ecological situations. The habitat differences within one ecotope also have an important effect on the nature and number of benchmarks to be selected.

Research has shown that with the removal of heavy grazing pressure, species composition in protected sweetveld grassland sites changes to a more palatable sward and basal cover, also increases over relatively short time periods – i.e. less than ten years (Hoffman *et al.*, 1999). Earlier generalizations from several fence-line contrast studies in South Africa, suggest that heavy grazing has a greater impact on plant species diversity and composition in relatively more arid environments, although rainfall can often mask the effects of grazing under arid and semi-arid conditions (Hoffman *et al.*, 1999). Stocking rate (both light and heavy) significantly affects the composition of some rangelands but it is not known how permanent such changes are. The problem with these studies, as well as the study conducted to compile this thesis, is that the composition and diversity of the vegetation was not known prior to the commencement of heavy continuous grazing pressure.

As already discussed, most degraded land in the North West Province, especially in the more arid, western region of the Province, where this study was conducted, occur in the communal managed areas. Many factors, including land tenure, legislation, social, historical and ecological issues, have contributed to the degradation of these areas. National and Provincial Government are aware of all the problems and have therefore implemented initiatives, such as the LandCare program. To study and understand the processes of degradation and ensure better sustainable resource management practices, all these programs, with its objectives, elements and approaches, especially in the communal managed areas have to be considered. It is therefore very important to include as many elements as possible of initiatives, such as LandCare, in any research study that is carried out.

Thus, the aims with this project were to:

1. Establish and implement monitoring and evaluation systems in order to monitor changes in grass species composition and production in two rangeland management systems;
2. Evaluate changes in the rangeland condition by using the benchmark site approach;
3. Create an environmental awareness and train the agricultural extension workers, technicians, and land users; and
4. Use the data and results to serve as baseline data for future LandCare projects to be conducted in the same or other, similar study areas;

Accordingly the aims of this project will contribute to the objectives of the North West Province's LandCare program.

This study is complicated to a great extent seeing that it consists of many facets, for instance creating an awareness, training and developing basic vegetation survey skills, such as monitoring and sampling techniques. It can thus not just be viewed as a basic research project.

A clear understanding of the environmental factors and population processes primarily responsible for population and community change will only be achieved within the context of long-term field experiments. According to O'Connor (1994) the minimum length of study should cover the periodicity of climatic influences and ideally, the lifespan of the plants. Consequently the 2-year window of this study doesn't measure up to this requirement. It is thus hypothesized that no significant changes in the grass species composition and production of the rangelands will be observed, and the results of this study will primarily serve as baseline data.

Chapter 2: Study Area

2.1. Rangeland Management Systems

The LandCare projects or initiatives of the North West Province, which were used for the purpose of this study, consist of the following two rangeland improvement systems:

- Morafe ranch system; and
- Communal grazing systems, where exclosures were erected at benchmark sites in order to illustrate the benefits of resting the rangeland.

These improvement systems are being implemented by means of several projects financed through the LandCare programme of the National Department of Agriculture in South Africa.

2.1.1. Resting in Communal grazing systems

Communal grazing involves the utilisation of the available land, that belongs to the community as a whole, for any farming or agricultural purpose (Jordaan, 1999). The concept of resting rangeland is being introduced in communal grazing systems by erecting fences in these areas in order to apply some kind of rotational grazing system.

Periodic resting of rangeland for all or part of the growing season is considered essential to maintain rangeland condition. Resting to allow seeding, seedling establishment and/or the restoration of stored carbohydrate reserves in desirable grass species is consequently recommended for all rangeland types. Following a drought in semi-arid savanna, rangeland condition recovers far more rapidly under resting than under grazing owing to large-scale seedling establishment and a reduction in tuft mortality (O' Reagain & Turner, 1992). Resting is also recommended to accumulate fodder reserves for use during the dormant season or in droughts. For example, it is recommended that, in the semi-arid sweetveld, a third of the rangeland be given a full season's rest on an annual basis. Given the extreme intra- and inter-seasonal variability in rainfall experienced in southern Africa, and the associated fluctuations in fodder production, the advantages of such rests are obvious (O' Reagain & Turner, 1992).

As suggested by Tainton (1999) and already mentioned in Section 1.4 (Chapter 1), benchmark sites were identified in the different study sites. These benchmarks were selected (in co-operation with extension officers of the Department of Agriculture) to represent different rangeland conditional states with respect to degradation. Exclosures (fenced with goat-proof fencing) were erected in order to exclude grazing animals, such as cattle and goats. These exclosures, where rest was applied, thus serves as reference sites to measure divergence in rangeland status.

2.1.2. Morafe ranch

Morafe ranches are common property systems that consist of a management group or “owner” group that has the right to exclude non-members. All the co-owners have their own duty in the maintenance of their piece of land (Anim & van Schalkwyk, 1996).

In the Morafe ranch approach the land, mostly previously communally managed, is divided into sub-units of for example 1200 hectares (ha), depending on how much land was appointed to the specific community. Each of these sub-units is then again divided into paddocks (e.g. four paddocks) by fences. A rotational grazing system (e.g. a four camp rotational grazing system), where one of the paddocks should be rested for a whole year, is then applied in each sub-unit. The farmers must apply for their non-freehold ownership on a Morafe ranch at their Provincial Department of Agriculture, Conservation and Environment. A specified number of Large Stock Units (LSU) is allowed to graze on a sub-unit, for example no more than 120 LSU (Large Stock Units) are allowed on a 1200ha sub-unit. This implies a grazing capacity of 10ha/LSU. Two or more farmers can be appointed to a sub-unit as long as they stay within the grazing capacity of the area. The farmers must renew their application as owners of their piece of land after a period of five years.

The DACE advises the farmers against the detainment of goats and sheep on the Morafe ranches. This can be ascribed to the fact that sheep and goats are regarded as being particularly detrimental to rangeland, while cattle are considered to be relatively less destructive (O’ Reagain & Turner, 1992). Evidence suggests that sheep are even more detrimental than goats in having a greater potential to cause rangeland degradation. Sheep grazing in savanna areas causes perennial grasses to decline significantly after just three years while, with goats, rangeland condition improves substantially. In comparison to cattle, goats have a relatively smaller impact upon the grass layer, but have a larger impact upon the available browse, at least in savanna areas (O’ Reagain & Turner, 1992). The farmers are also compelled to sell calves at nine months of age, and also pay a minimal wage of R22/cow/year to their tribal authority. These funds are then used for maintenance purposes.

2.2. Description of the Study Area

2.2.1. Introduction

The North West Province of South Africa is the sixth largest of the nine provinces covering a total area of 123 370 km² (Hoffman & Ashwell, 2001). It is divided into three principal agricultural regions (the Eastern, Central and Western) and 28 magisterial districts (Department of Agriculture, Conservation and Environment, 2002). This study was conducted in the Ganyesa, Kudumane, and Taung magisterial districts in the western region of the North West Province, South Africa (Figure 2.1).

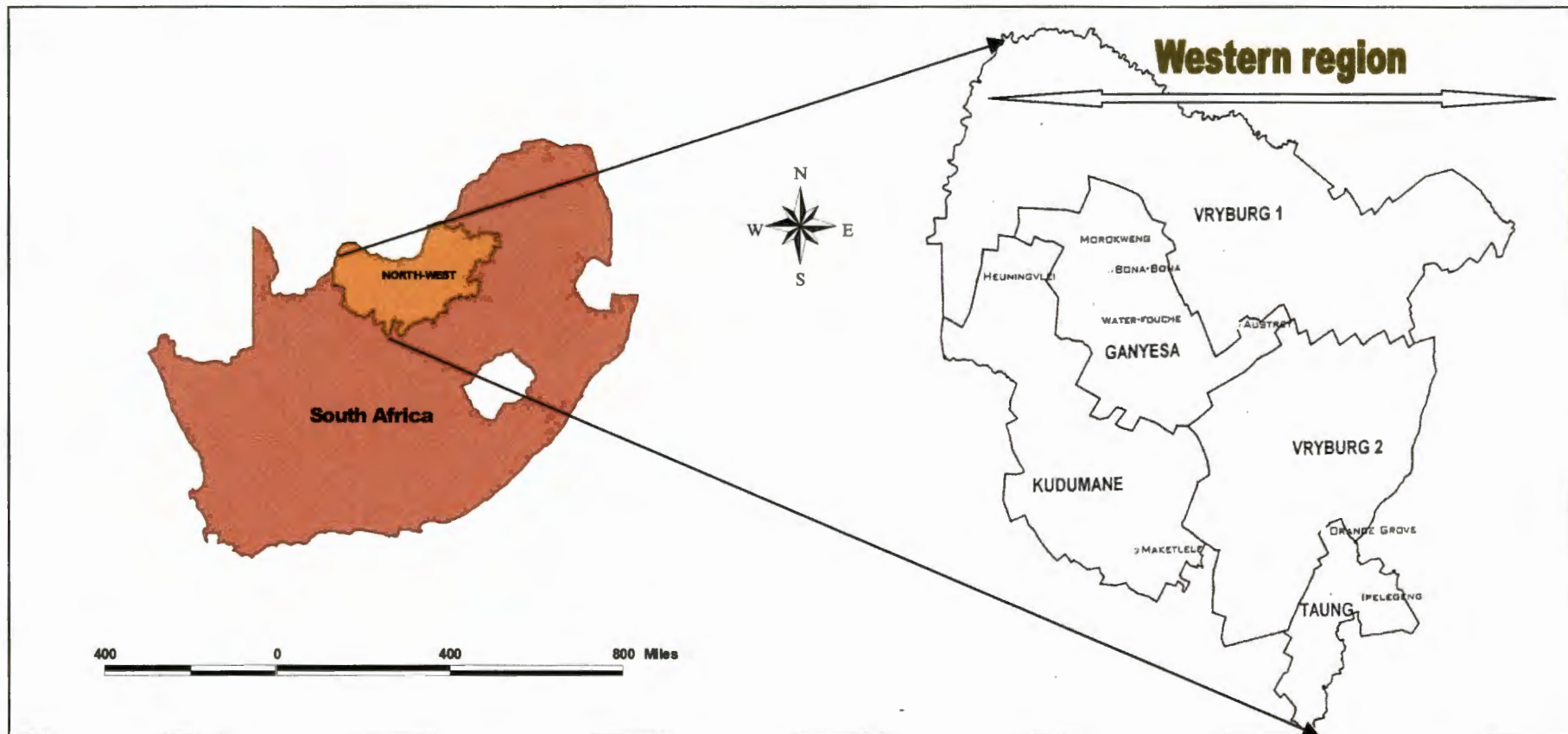


Figure 2.1: A map of South Africa indicating the location of the North West Province, as well as the western region in which the three magisterial districts, namely Kudumane, Ganyesa and Taung, are situated. The location of the six different benchmark sites, Maketlele, Heuningvlei, Austrey, Waterfouchè, Ipelegeng and Orange Grove, are also indicated. (supplied by Dept. of Agriculture, Conservation and Environment).

The North West Province has a total population of approximately 3,7 million people with some 65% of the population living in rural areas. The Province is one of the poorest in South Africa with a provincial gross geographic product (GGP) of R 3 964 per person, which is well below the national average of R 6 498. Agriculture is the second-most important sector (mining forms the backbone of the provincial economy) with 13% of the GGP and 18% of employment. The present status of land tenure is complex with the majority of land being privately owned (Department of Agriculture, Conservation and Environment, 2002). Approximately 10% are state-owned, and large areas are under tribal administration, particularly in the former Bophuthatswana homeland areas of the western region, where this study was conducted. The study sites are all situated in a communal land tenure system, of which some areas have been converted to the Morafe ranch management system. This conversion has only been effectively implemented since January 2001.

According to the distribution of the five UNCCD (United Nations Convention to Combat Desertification) aridity classes in South Africa the study area can be classified as arid (Hoffman & Ashwell, 2001). The aridity class reflects the ratio of mean annual precipitation (MAP) to potential evapotranspiration (PET). This implies that the North West Province is 57% arid and 43% semi-arid (Table 2.1).

Table 2.1: The percentage (%) distribution of the five aridity zones in the North West Province (Hoffman *et al.*, 1999).

Province	% Aridity class according to ratio of MAP:PET				
	Hyper arid	Arid	Semi-arid	Dry sub-humid	Humid
North West Province	0	57	43	0	0

According to Hoffman *et al.* (1999) the study areas, situated in the Ganyesa, Kudumane, and Taung magisterial districts of the North West Province's western region, are between 1001 – 1500m above sea level and have a slope of 0 – 1%. The climate of the total area is characterised by well defined seasons with hot summers and cool sunny winters. The mean annual temperature correlates with the altitude of the area, and thus varies between 16 – 20°C. The rainfall in this region falls mainly in the summer months (from October to March) and varies between 300 – 500mm per annum (Figure 2.2). Rainfall at the study areas will be discussed in more detail in Chapter 4, during the discussion of changes that occurred in the grass species composition and production. The DACE provided this average, long-term and short-term rainfall data.

Because the study area is situated in an area with a low rainfall, high temperatures (Figure 2.2), moderate frost-free winters, it can be concluded that the area mainly consist of sweet rangeland. According to Van Oudtshoorn (1999) most of the grass species in sweet rangeland produces palatable grazing throughout the year, provided that the rangeland is managed well and subsequently is in a good condition. Sweet rangeland is very sensitive to overgrazing, especially when the rangeland is already under stress if rainfall is scarce. However, the rangeland can recover quickly from heavy grazing (not overgrazing - defined by Van Oudtshoorn (1999) as the repeated utilisation of the grass plant until the reserve nutrients in the roots are exhausted) if the rangeland is managed correctly (Van Oudtshoorn, 1999).

In the extensive grazing areas of South Africa, with a mean annual rainfall of 500mm or less, water availability is the environmental factor most limiting to herbage production (Snyman, 1997). Water is thus considered to be the key limiting factor for development and productivity in the North West Province. The surface waters in the Province are in the form of rivers, dams, pans, wetlands and dolomitic eyes fed by aquifers. Perennial surface water resources are generally scarce, particularly in the arid to semi-arid western region of the Province (Figure 2.3). Runoff as a percentage of the precipitation is less than 1% in the western region. The North West Province thus relies heavily on groundwater resources to meet its needs.

The study area, in the western region of the North West Province, falls within the Savanna Biome (grassland with scattered trees) in the Kalahari thorn- and bushveld vegetation type (Acocks, 1988). According to Acocks (1988) the study area is situated within the western form of the Kalahari thornveld rangeland type No. 16a. This implies a typical form of open savanna with *Acacia erioloba* and *A. haematoxylon*. Along rivers and near ranges of hills and mountains greater quantities of *A. erioloba*, *A. haematoxylon*, *Boscia albitrunca*, *Grewia flava*, *Lycium hirsutum* and *Rhigozum trichototum* are found. The grasses are tufted and mostly *Aristida*, *Eragrostis*, *Schmidtia* and *Stipagrostis* spp. can be identified (Acocks, 1988). The sparse tuftedness of the grass and the looseness of the virtually bottomless sand, make this rangeland extremely vulnerable to grazing pressure. It is thus fortunate that the absence of surface water has kept it so largely uninhabited.

2.2.2. Process for study site selection

At first the need for researchers to become involved in LandCare projects was identified by the National Department of Agriculture. The main reason for the involvement of scientists is to establish and implement long-term monitoring and evaluation systems. Funds are also provided in order to conduct the specific research projects. To become involved with the identified LandCare projects, the researchers were compelled to attend the provincial LandCare meetings.

For the purpose of this study, the western region of the North West Province's LandCare meetings were attended at the Department of ACE's offices at Armoedsvlakte in Vryburg. At these meetings the specific survey areas in the different districts were identified in co-operation with the Agricultural District Centre managers (ADC managers) and agricultural extension officers. Within the survey areas, benchmarks representing different conditional states, were identified (already mentioned in Sections 1.4 and 2.1.1). Exclosures, representative of the bigger area, were then erected inside the benchmark sites in order to exclude grazing by cattle and goats. The objective hereof is to monitor the effect of the continued grazing, outside the exclosure, on the grass species composition and production, in comparison with the inside vegetation of the exclosure, that is only being grazed during the winter period. In order to achieve the aims of the project the site surveys were arranged and planned in collaboration with the ADC managers, extension officers and the local communities. Hereafter site visits were conducted, together with the extension officers, farmers and other community members at the different study sites in January 2001. This was done in order to meet and inform the communities about the proposed research process at the different study sites, thus contributing to community participation.

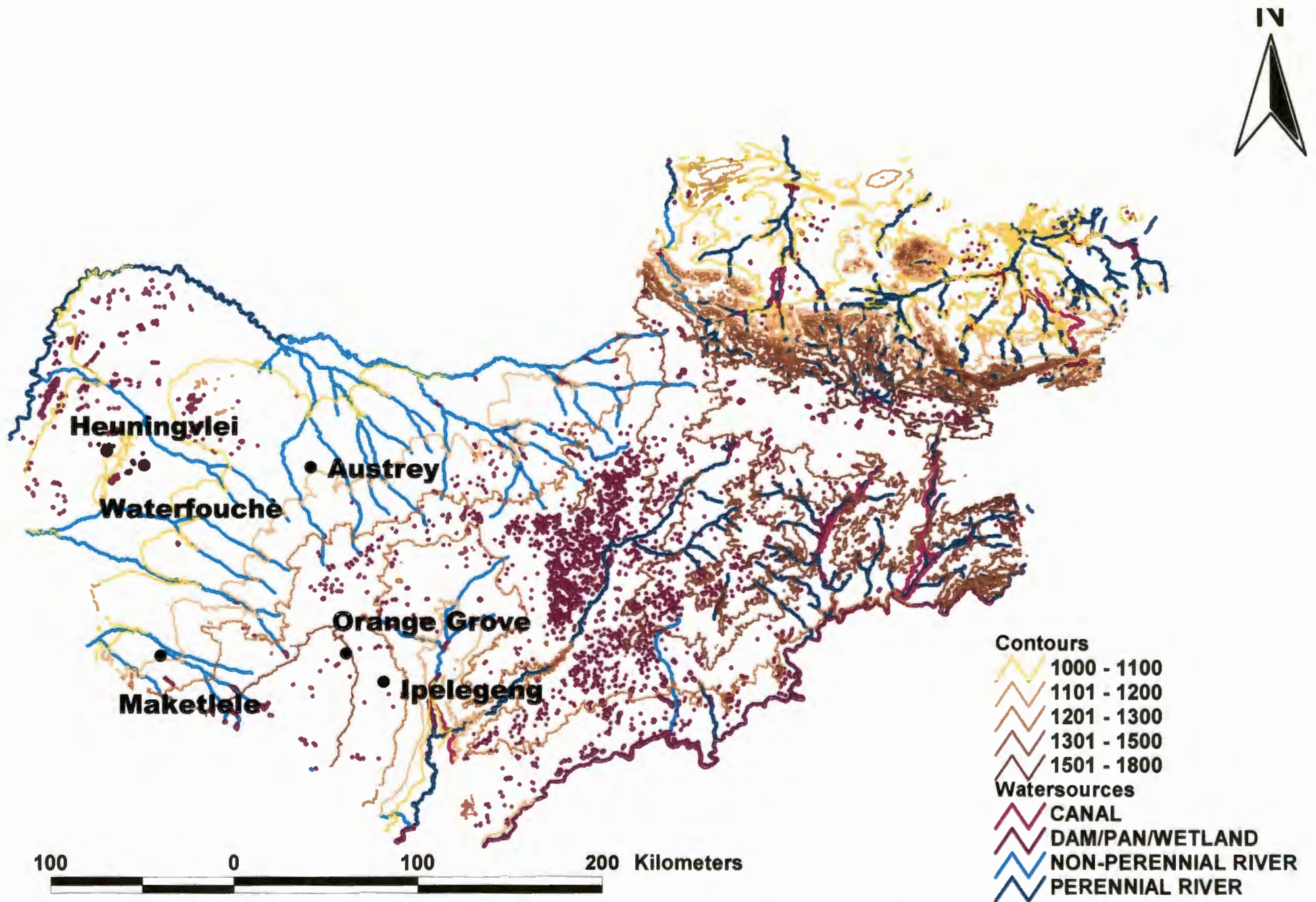


Figure 2.3: A map indicating the topography and water sources of the study area in the western region of the North West Province (supplied by Dept. of Geography and Environmental Study: Cartographic and GIS Services).

The first rangeland surveys were then scheduled and later conducted in April 2001. The communities were empowered to develop LandCare groups and activities through awareness, training and education.

Another crucial part of the study is however for the researchers to analyse the data obtained through the surveys in order to give feedback of the results on the regional and local LandCare information and participation days. This ongoing feedback process is of utmost importance to show the communities the results of their efforts and also to further contribute to the improvement of a positive attitude towards the LandCare projects. The results of the study should also serve as baseline data for future studies and long-term monitoring and evaluation systems.

At first a hint of resentment towards the LandCare projects was detected in some communities (especially in the Taung magisterial district). However, during the course of the project, as the communities (in collaboration with the ADC managers and extension officers) was more informed and became more involved with the LandCare projects, they became more enthusiastic and at last reflected a very positive attitude towards the LandCare projects. This can be attributed to the fact that one of the processes that are being used to develop approaches and methods to make research more relevant to the needs of the people is Participatory Rural Appraisal (PRA).

Participation empowers people and gives them a sense of ownership of the project (Tainton, 1999). Participatory Rural Appraisal is being used internationally in rural areas for investigative work, planning, implementing, monitoring and evaluating the work done with communities. While there is still a place for formal scientific methods, participatory methods play a central role in research and development work in rural communities. The new approach is for extension workers to work with farmers in participatory partnership.

During a series of 34 consultative workshops held during 1997 and 1998 the assessments of Agricultural Extension officers and Resource Conservation Technicians identified six main land use types (LUT) within South Africa. According to this the LUT of the study areas is grazing land or rangeland. This implies that the land is mainly used for animal production on natural rangeland. These assessments also recommended a grazing capacity of 8.1–8.2 LSU per hectare for the study areas identified for this project.

As mentioned in Section 2.1 (Chapter 2) the rangeland improvement systems that were chosen for this study were monitored in three magisterial districts of the western region, namely Kudumane, Ganyesa and Taung (Figure 2.1). All three districts are currently being ranked as moderately high degraded (Figure 1.1). The Department of ACE further divided each of these districts into three Agricultural Development Centers (ADC's). Accordingly the Kudumane magisterial district is divided into the Heuningvlei, Glenred and Seoding ADC's, Ganyesa into the Ganyesa, Pomfret, and Vryburg ADC's and Taung into the Taung North, South and Central ADC's.

These ADC's are then further divided into a number of Field Service Units (FSU's) in which the different benchmark sites of this study are situated. The benchmark sites in the Kudumane magisterial district, namely Maketlele and Heuningvlei, are both situated in the Heuningvlei ADC, but are then divided into the Allendale and Heuningvlei FSU's respectively. The Austrey benchmark sites in the Ganyesa magisterial district is situated in the Tlagameng FSU of the Ganyesa ADC, while the Waterfouchè benchmark site is situated in the Driefontein FSU of the Pomfret ADC. In the Taung magisterial district the Ipelegeng benchmark site is located in the Ipelegeng FSU of the Taung Central ADC, and the Orange Grove benchmark site is located in the Moretle FSU in the Taung North ADC (Figure 2.4).

Table 2.2 also shows the magisterial districts in which the benchmark sites are situated. It serves as a summary to indicate the type of management that is applied at each study area, the number of benchmarks used in the different magisterial districts for the purpose of this study, the size of the exclosures erected inside the benchmark sites, and when these exclosures were erected. The motivation why the exclosures were different sizes will be discussed in Section 3.2 (Chapter 3).

Table 2.2: An indication of the different benchmark site's attributes in the associated districts.

Magisterial District	Benchmark sites	Applying rest in Communal grazing areas	Morafe ranch	Number of benchmark sites	Exclosure size	Date when exclosures were erected
Taung	Orange Grove		✓	1	50m x 50 m	Jan 2001
	Ipelegeng	✓		2	100m x 30m	June 2001
Kudumane	Heuningvlei		✓	3	110m x 20m	June 2001
	Maketlele	✓		2	50m x 50m	June 1999
Ganyesa	Waterfouchè		✓	6	110m x 20m	April 2001
	Austrey	✓		4	110m x 20m	April 2001

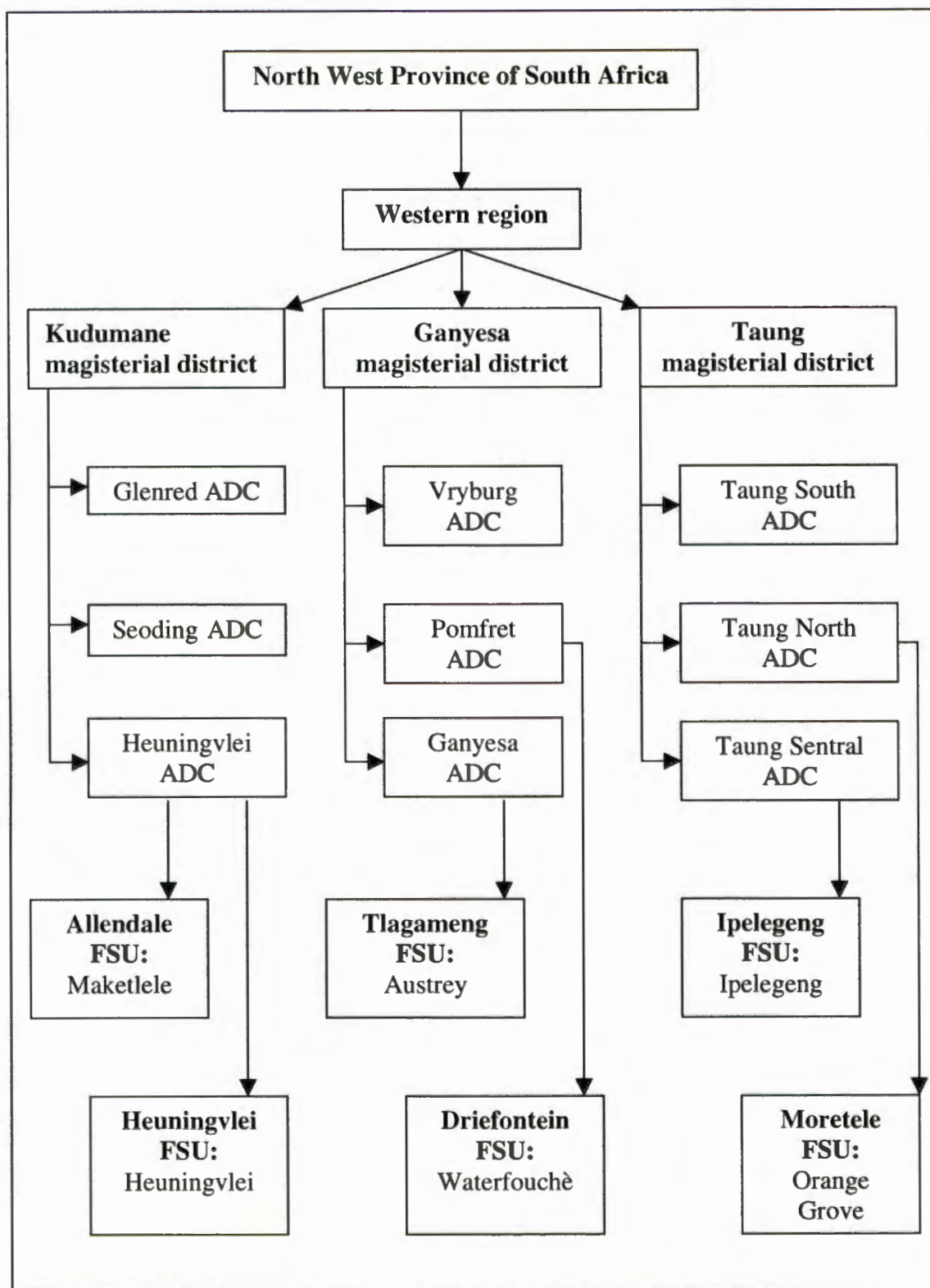


Figure 2.4: A diagrammatic representation of the division of the benchmark sites into the different Agricultural Development Centres (ADC's) and Field Service Units (FSU's).

The location, as well as some environmental and management factors for each of the study areas will accordingly be discussed.

2.2.3. Specific study site description

2.2.3.1. Ganyesa magisterial district

i. *Location*

The grid reference of the study sites Austrey and Waterfouchè are portrayed in Table 2.3.

Table 2.3: The location of the study sites in the Ganyesa magisterial district.

Study site	Grid reference
Austrey	26°27'52"Lat., 24°10'35"Long
Waterfouchè	26°25'59"Lat., 23°28'59"Long

As already mentioned in Section 2.2.2 the Austrey study site falls into the Ganyesa ADC and is further divided into the Austrey FSU. The study site at Waterfouchè on the other hand falls into the Pomfret ADC and is divided into the Driefontein FSU (Figure 2.4).

ii. *Climate*

The Austrey study site is situated in the 400 – 500mm rainfall zone, while the Waterfouchè study site falls within the 300 – 400mm rainfall zone (Figure 2.2). The was provided by De Villiers (2002). The long-term climatic data (long-term average monthly rainfall and air temperatures for each magisterial district), was however only available up to 1990. According to De Villiers (2002) the average long-term yearly rainfall for the Ganyesa magisterial district is 490.0mm (Table 2.4). Both study sites consists of an average maximum air temperature of 26.7°C and an average minimum air temperature of 9.5°C. The highest and lowest air temperatures recorded for the Ganyesa magisterial district is 40.0 °C and –9.3°C, respectively (De Villiers, 2002).

Table 2.4: The long-term (1961-1990) average monthly rainfall (mm) and air temperatures (°C) of the Ganyesa magisterial district (De Villiers, 2002).

Month	Average monthly rainfall (mm)	Average monthly air temperatures (°C)	
		Average maximum air temperatures (°C)	Average minimum air temperatures (°C)
January	92.0	32.1	17.0
February	81.0	30.4	16.3
March	80.0	28.9	14.4
April	42.0	25.7	9.8
May	14.0	22.6	4.6
June	6.0	19.4	0.7
July	3.0	20.0	0.2
August	7.0	22.8	2.6
September	17.0	26.8	7.6
October	33.0	29.0	11.4
November	56.0	30.6	13.9
December	59.0	31.9	15.7
Yearly Averages	490.0	26.7	9.5

iii. *Soil and Geology*

Both study sites, Austrey and Waterfouchè, are located in the Ah3 land type (Figure 2.5) (Department of Environmental Affairs and Tourism, 1997). Accordingly they both consists of red-yellow apedal, freely drained soils with a high base status, clay content of less than 15% and an effective depth of more than 750mm (Figure 2.6). These soils are thus of poor suitability for arable agriculture where climate permits. The geology of these study sites can be described as aeolian sand of recent age with a few outcrops of tertiary Kalahari beds (surface limestone, silcrete and sandstone) in the riverbeds (Figure 2.7).

iv. *Topography*

The Waterfouchè study site is situated at 1100m above sea level, while the Austrey study site is situated at 1200m above sea level (Figure 2.3). The terrain morphology of both study sites can be described as plains (Department of Environmental Affairs and Tourism, 1997).

v. *Vegetation*

The Austrey and Waterfouchè study sites are both situated in the Kalahari thornveld and shrub bushveld vegetation type (Figure 2.8), and consists of a land cover of degraded thicket and bushland. The vegetation at both study sites can be described as *Acacia mellifera* – *Rhigozum trichotomum* – *Stipagrostis uniplumis* sandy plains (Smit, 2000).

vi. *Management History*

Communal management has been applied at the Austrey and Waterfouchè study sites since the 1960's according to the agricultural extension officers*. Morafe ranches has however been allocated to farmers at the Waterfouchè study site since January 2001.

2.2.3.2. Kudumane magisterial district

i. *Location*

The location of the two study sites in the Kudumane magisterial district, Maketlele and Heuningvlei, is reflected in Table 2.5 (Figure 2.7).

Table 2.5: The location of the study sites in the Kudumane magisterial district.

Study site	Grid reference
Maketlele	27°20'35"Lat., 23°39'42"Long
Heuningvlei	26°17'20"Lat., 23°10'53"Long

*Kenneth Makwati (Austrey) and Gert Namelang (Waterfouchè)

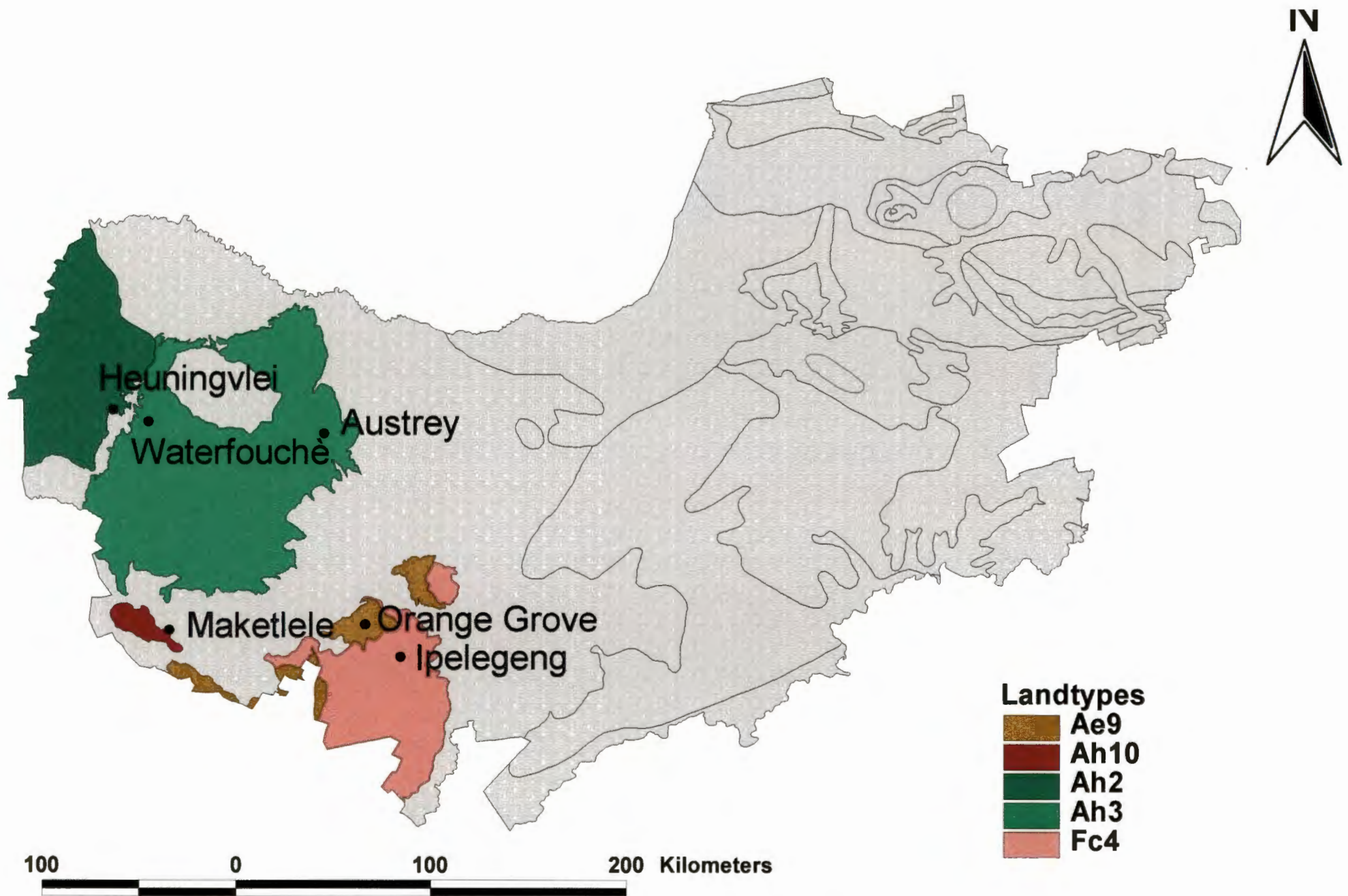


Figure 2.5: Landtypes of the study area in the western region of the North West Province (supplied by Dept. of Agriculture, Conservation and Environment).

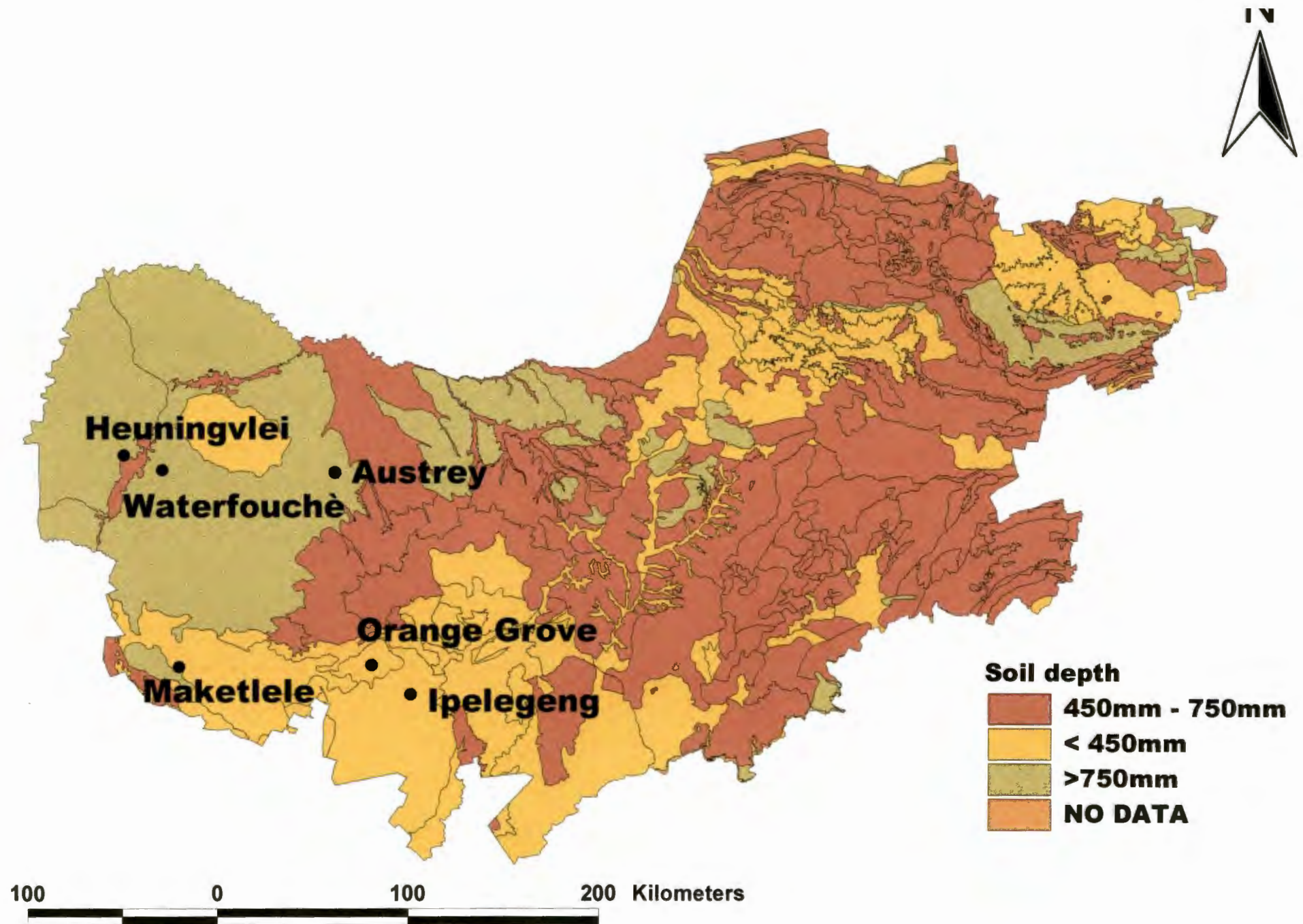


Figure 2.6: The effective soil depths of the study area in the western region of the North West Province
(supplied by Dept. of Geography and Environmental Study: Cartographic and GIS Services).

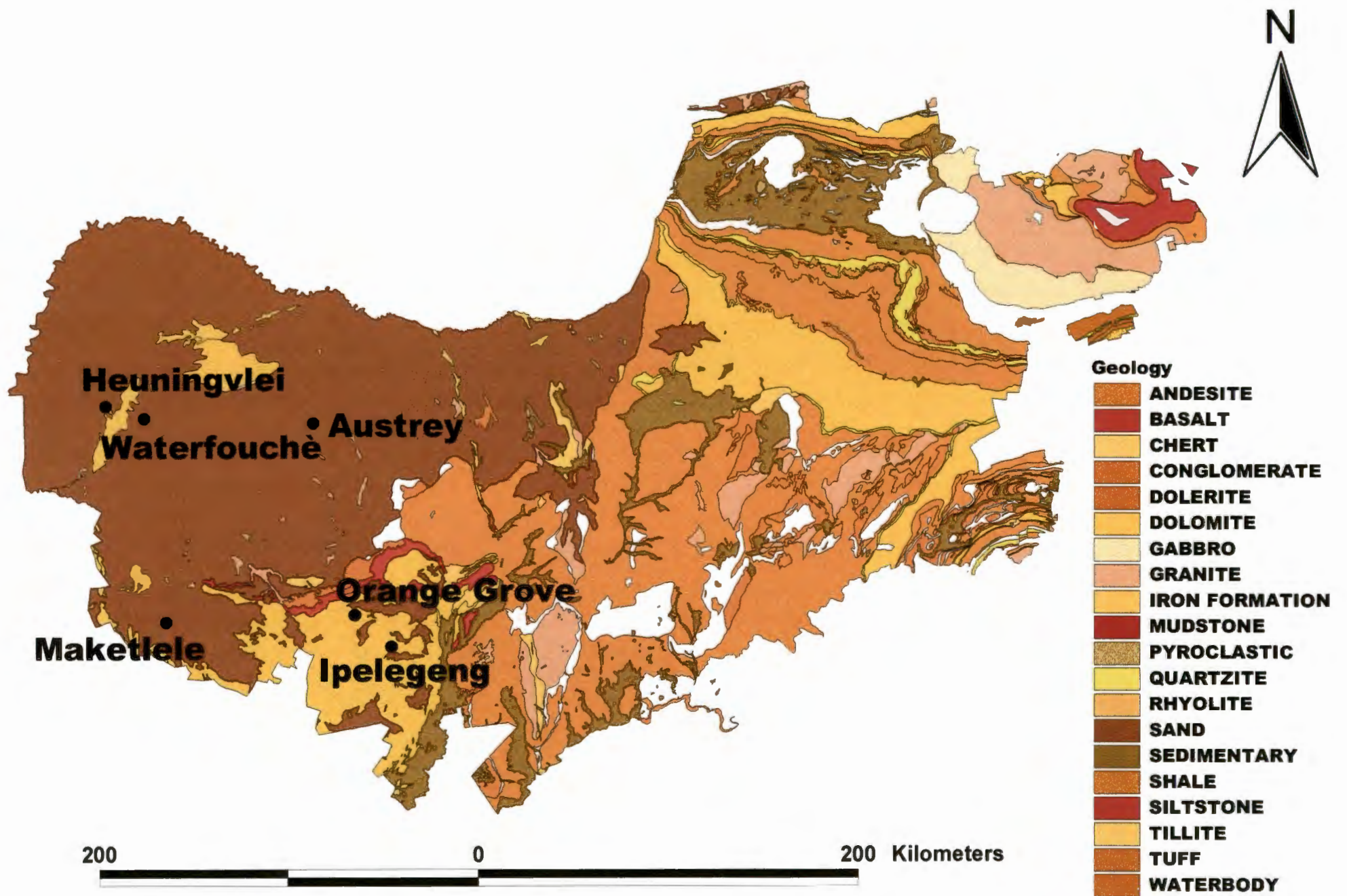


Figure 2.7: A geology map of the study area in the western region of the North West Province (supplied by Dept. of Geography and Environmental Study: Cartographic and GIS Services).

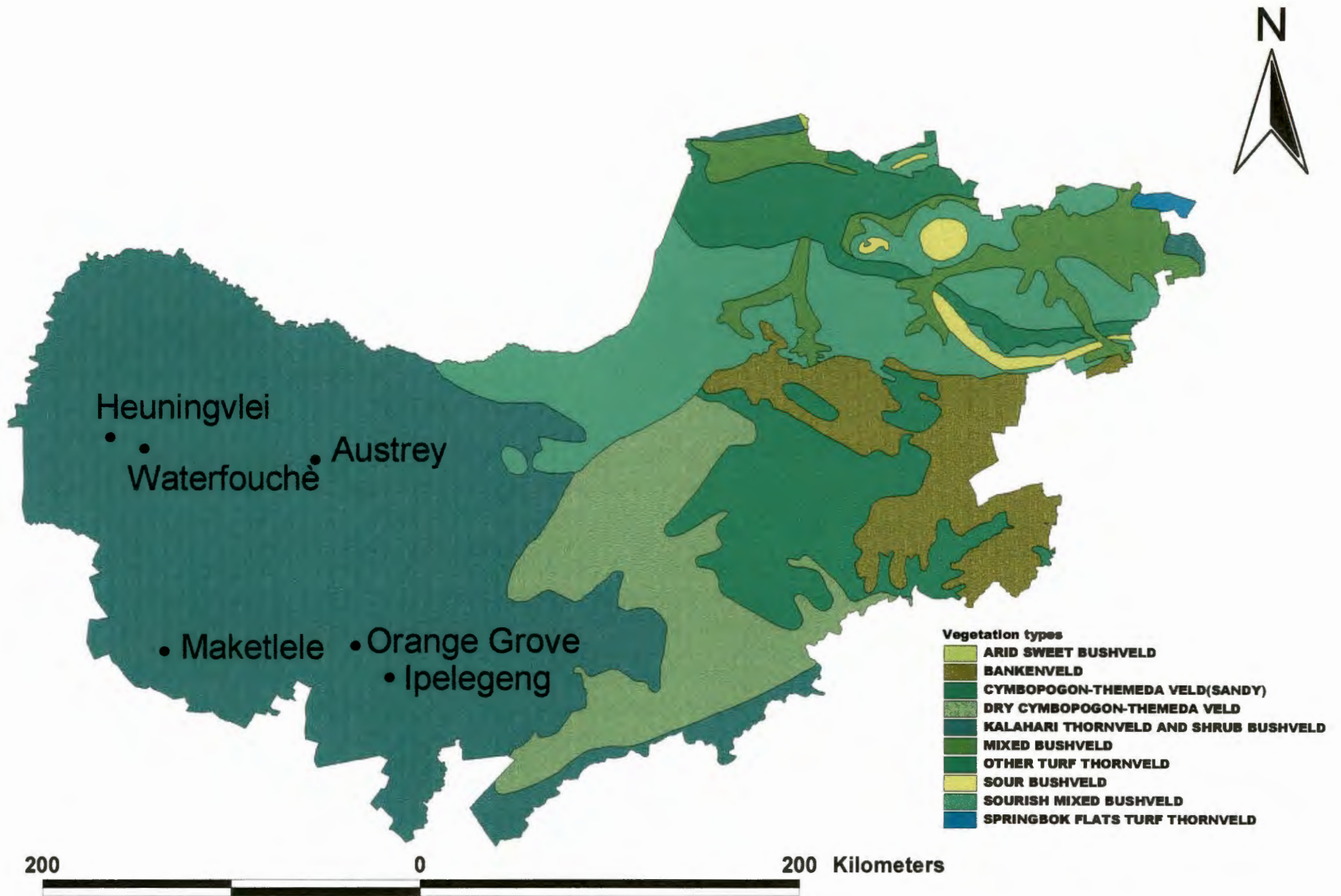


Figure 2.8: Vegetation types of the study area in the western region of the North West Province
(supplied by Dept. of Geography and Environmental Study: Cartographic and GIS Services).

The Maketlele and Heuningvlei study sites are both situated in the Heuningvlei ADC. It is however divided into different FSU's. Maketlele is situated in the Allendale FSU and Heuningvlei is situated in the Heuningvlei FSU (Figure 2.4).

ii. *Climate*

Due to its location on the brim of the Kalahari, the Kudumane district is renowned for extreme temperatures during the summer and winter (Scholes & Van der Merwe, 1999). Frost generally occurs during the winter months. Humid north and north-east bearing winds result in thunderstorms during December to April.

The Maketlele study site is situated in the 400 – 500 mm rainfall zone and is characterised by an average monthly maximum temperature of 25.9°C, and an average monthly minimum air temperature of 9.6°C (Table 2.6 and Figure 2.2). The Heuningvlei study site on the other hand is situated in the 300 – 400 mm rainfall zone, but is also characterised by the same minimum and maximum average monthly air temperatures as the Maketlele study site (Department of Environmental Affairs and Tourism, 1997). The highest maximum and lowest minimum air temperatures recorded for the Kudumane magisterial district are 39.9°C and –7.6°C, respectively (De Villiers, 2002).

Table 2.6: The long-term (1961-1990) average monthly rainfall (mm) and air temperatures (°C) of the Kudumane magisterial district (De Villiers, 2002).

Month	Average monthly rainfall (mm)	Average monthly air temperatures (°C)	
		Average maximum air temperatures (°C)	Average minimum air temperatures (°C)
January	83.0	31.5	16.6
February	83.0	30.2	16.2
March	81.0	28.4	14.1
April	50.0	24.8	10.0
May	20.0	21.7	5.0
June	7.0	18.6	1.6
July	3.0	19.3	1.2
August	8.0	21.7	3.1
September	6.0	25.8	7.7
October	27.0	27.8	10.9
November	43.0	29.8	13.5
December	46.0	31.2	15.5
Yearly Averages	457.0	25.9	9.6

iii. *Soil and Geology*

According to the Department of Agriculture, Conservation and Environment (2000) the Maketlele study site is situated in the Ah10 land type (Figure 2.5). Accordingly it consists of red-yellow apedal, freely drained soils with a high base status and clay content less than 15% (Department of Environmental Affairs and Tourism, 1997). The effective depth of the soil is less than 450mm (Figure 2.6). Accordingly the soils

are not suitable for arable agriculture. The geology of the Maketlele study site comprises of aeolian sand of recent age with few outcrops of tertiary Kalahari beds (surface limestone, silcrete and sandstone) in the riverbeds (Figure 2.7).

The Heuningvlei study site is located in the Ah2 land type (Figure 2.5), and the soil can be described as red-yellow apedal freely drained soils with a high base status, a clay percentage of less than 15% and an effective soil depth of more than 750mm (Figure 2.6) (Department of Environmental Affairs and Tourism, 1997). These soils are thus not suitable for arable agriculture. The geology of this area can be described as red aeolian sand of recent age with few outcrops of tertiary Kalahari beds (surface limestone and silcrete) with jaspillite and banded ironstone of the Asbestos Hills formation of the Griquatown Group (Figure 2.7).

iv. *Topography*

The Maketlele study site is situated at approximately 1200m above sea level, while the Heuningvlei study site is situated at 1100m above sea level (Figure 2.3). The terrain morphology of both study sites can be described as plains (Department of Environmental Affairs and Tourism, 1997).

v. *Vegetation*

Both study sites, Maketlele and Heuningvlei, is situated in the Kalahari Thornveld and shrub bushveld (Figure 2.8). The vegetation at the Maketlele study site can be described as *Acacia erioloba* – *Tarchonanthus camphoratus* – *Rhynchosia holosericea* plains (Smit, 2000), while Heuningvlei is characterised by *Acacia mellifera* – *Rhigozum trichotomum* – *Stipagrostis uinplumis* sandy plains. The land cover at these two study sites is degraded thicket and bushland (Department of Environmental Affairs and Tourism, 1997).

vi. *Management History*

The Maketlele study site has been under communal management since the 1960's (According to the agricultural extension officers*). The Heuningvlei study site has also been under communal management until Morafe ranches were allocated to the farmers when the LandCare program was initiated in the North West province during the year 2000.

2.2.3.3. Taung magisterial district

i. *Location*

Taung lies between the two towns of Kimberley and Mafikeng in the northern Cape Province in an area where the North West Province, the North Cape, Botswana and the former homeland, Bophuthatswana, meet. The district has been further demarcated into five sub-districts namely Taung Central, Pudumong, Pampierstadt, Molelema and Reveilo. The exact location of the study sites is depicted in Table 2.7.

*Andrew Mathe (Maketlele) and Marcus Nhlapo (Heuningvlei)

The Ipelegeng study site is situated in the Ipelegeng FSU of the Taung North ADC, while the Orange Grove study site is situated in the Moretele FSU of the Taung Central ADC (Figure 2.4).

Table 2.7: The location of the study sites in the Taung magisterial district.

Study site	Grid reference
Ipelegeng	27°32'31"Lat., 24°46'48"Long
Orange Grove	27°16'59"Lat., 24°27'00"Long

ii. *Climate*

The Ipelegeng and Orange Grove study sites are both situated in the 400 – 500 mm rainfall zone (Figure 2.2), and receives an average yearly rainfall of 447mm (Table 2.8). They are also both subjected to average long-term maximum and minimum monthly air temperatures of 27.8°C and 11.0°C, respectively (Table 2.8). The extreme temperatures recorded for the Taung magisterial district are a highest maximum air temperature of 41.0°C, and a lowest minimum air temperature of – 7.1°C (De Villiers, 2002).

Table 2.8: The long-term (1985-1990) average monthly rainfall (mm) and air temperatures (°C) of the Taung magisterial district (De Villiers, 2002).

Month	Average monthly rainfall (mm)	Average monthly air temperatures (°C)	
		Average maximum air temperatures (°C)	Average minimum air temperatures (°C)
January	57.0	33.9	18.2
February	102.0	30.5	17.6
March	50.0	30.5	14.9
April	45.0	27.2	11.0
May	6.0	24.8	6.4
June	3.0	20.5	2.0
July	2.0	20.9	1.2
August	3.0	24.3	5.0
September	29.0	26.6	9.2
October	46.0	29.5	13.1
November	47.0	31.7	15.9
December	57.0	33.1	17.6
Yearly Averages	447.0	27.8	11.0

iii. *Soil and Geology*

The Ipelegeng study site is located in the Fc4 land type (Department of Agriculture, Conservation and Environment, 2000) and accordingly consists of Glenrosa and/or Mispah soil forms (Figure 2.5). Lime is generally present in the entire landscape. These soils has and effective depth of less than 450mm (Figure 2.3) and also consists of a clay percentage of less than 15% (Department of Environmental Affairs and Tourism, 1997). Because of these characteristics the soil are not suitable for arable

agriculture but can be suited for grazing if the climate is favourable. The geology of the area consists of surface limestone of tertiary to recent age and fine and coarse-grained dolomite, chert and dolomitic limestone with prominent interbedded chert, limestone and banded ironstone (Ghaap Plateau Formation, Campbell Group) (Figure 2.7).

The Morafe ranch study site, Orange Grove, is situated in the Ae9 land type (Figure 2.5) and is thus characterised by red-yellow apedal, freely drained soils with a high base status, no dunes, an effective depth of less than 450mm (Figure 2.6) and a clay percentage of less than 15% (Department of Environmental Affairs and Tourism, 1997). The geology of the Orange Grove study site can be described as fine and coarse-grained dolomite, chert and dolomitic limestone with prominent interbedded chert limestone and banded ironstone (Ghaap Plateau Formation, Campbell Group), and red to flesh-coloured wind-blown sand with surface limestone of tertiary to recent age (Figure 2.7).

iv. *Topography*

The Ipelegeng study site is situated at 1300m above sea level and the terrain morphology can mainly be described as plains and pans (Department of Environmental Affairs and Tourism, 1997). The Orange Grove study site consists of slightly undulating plains and is located at 1400m above seal level (Figure 2.3).

v. *Vegetation*

The Orange Grove and Ipelegeng study sites both fall within the Kalahari Thornveld and Shrub bushveld (Figure 2.8). The vegetation at the Ipelegeng study site consists of *Acacia erioloba* – *Acacia tortillis* – *Eragrostis rigidior* rocky plains. The Orange Grove study site comprises of *Acacia mellifera* – *Acacia tortillis* – *Tarchonanthus camphoratus* vegetation of the Ghaap Plateau (Smit, 2000).

vi. *Management History*

According to the agricultural extension officers* the Ipelegeng study site has been under communal management since 1980, and the Orange Grove study site has also been under communal management until Morafe ranches were allocated to the farmers during the year 2001.

* Joseph Gabanakosi (Ipelegeng) and Hendrik Sabole (Orange Grove)

Chapter 3: Material and Methods

3.1. Introduction

One of the main aims of the project is to establish and implement monitoring and evaluation systems of the degradation and recovery potential of especially the grass layer in the selected study sites on an ongoing basis. This entails that the orderly collection, analysis and interpretation of the frequency and production of the grass layer and soil characteristics data, must be carried out to evaluate changes in the vegetation composition and production towards meeting the management objectives of the specific communities. The data and results will also be used to promote better management strategies that will meet the objectives of the community in a specific area (*see* 1.4: Aims of the project).

3.2. Selection of Plots

As already mentioned in Sections 1.4 (Chapter 1) and 2.1.1 (Chapter 2), benchmark sites were selected, in collaboration with the agricultural extension officers, to represent rangelands in different states of degradation due to grazing. The agricultural extension officer's choice of benchmark sites thus reflects what they perceive as representations of good, moderate and poor rangeland conditions. In order to determine and compare the change in grass species composition and production, exclosures were erected inside the benchmark sites. The change outside the exclosure could thus be measured against the inside of the exclosure over time.

The survey area, identified as a benchmark site, must be homogenous and representative of the bigger area (Kent & Coker, 1997). The exclosure sizes were thus determined by taking into consideration the species composition, diversity, vegetation structure, as well as the expert knowledge of the agricultural technicians and researchers, in the western region of the North West Province. If the area that needed to be monitored, consisted mainly of a homogeneous grass cover, a plot size (for the exclosure erected inside the benchmark site) of 50m x 50m was sufficiently representative of the bigger area. However, if the tree and shrub component featured significantly, a plot size of 110m x 20m was chosen for these exclosures. The exclosures were then fenced-off with goat-proof fencing.

These benchmarks, representing different conditional states with regard to the extent of degradation at the specific study site, were identified in collaboration with extension officers of the D.A.C.E. In this way the influence of the specific management system and the rest applied inside the exclosures, could also be monitored. These sites were also chosen to train extension workers and land users in applying the specific rangeland improvement system in an effective and correct manner, and to serve an awareness purpose for all land users and members of the community, especially those that participate in the LandCare projects (Figure 3.1).

It is important to note that all the exclosures were erected away from watering points, and that the rangeland wasn't burned as part of a management practice. Accordingly these two aspects wasn't taken into consideration as explanations for changes in the grass species composition and production during this study. Any changes in the grass species composition and production that might surface during the study period can thus mainly be ascribed to the specific management practice being applied, rainfall variation and differences in the soil composition at the different benchmark sites.



Figure 3.1: Selecting benchmark sites in collaboration with extension officers of the DACE (Department of Agriculture, Conservation and Environment).

3.3. Vegetation Sampling Methods

3.3.1. Grass species composition

The grass species composition was determined inside and outside the exclosures by means of a permanently marked (with iron droppers) transect method (Kent & Coker, 1997). A rope, marked off at one-meter intervals, was stretched across the plot inside and outside of the exclosure in the benchmark plot. In the 100m x 20m exclosures the frequency of the grasses was determined by recording the 200 nearest grass species, in a radius of 30cm, at one meter intervals along two 100m transects (Figure 3.2). Survey forms were specifically created for the recording of grass species in the western region of the North West Province, during the grass species compositional surveys. An example of such a survey form is given in annex A.

On the other hand the frequency of the grass species composition in the 50m x 50m exclosures were determined along five 40m transects (Figure 3.3). The minimum number of points required per survey is 200 (Department of Agriculture Conservation and Environment, 2000). The more points done, the smaller the variation and the more accurate the data.

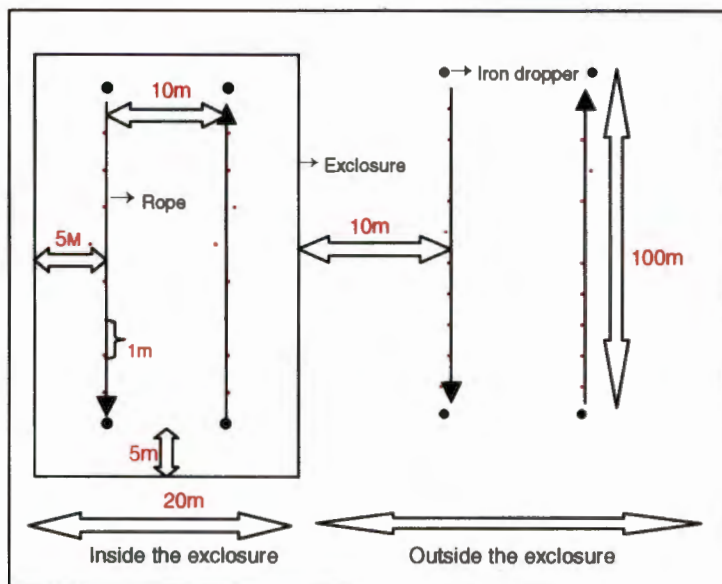


Figure 3.2: Layout for the determination of the grass species composition by means of the transect method in the 100m x 20m exclosures inside the benchmark sites.



Figure 3.3: The grass species composition was determined by means of the line transect method in collaboration with the agricultural extension officers and land users.

As already stated above the nearest plant technique was used, thus the perennial grass species nearest to the specific survey point in a radius of 30 cm was identified and recorded (Kent & Coker, 1997). If the nearest grass species was an annual grass or a forb, it was nevertheless still recorded, but the nearest perennial grass species was then also recorded at the same survey point.

This was done in order to prevent the annual plants from creating a false impression of possible improvement or degradation in the rangeland condition during high rainfall seasons. When the distance to the nearest grass species, whether annual or perennial, exceeded 30cm the survey point was indicated or recorded as a bare patch. In order to eliminate any edge effect the surveys were conducted at least 5m from the fence (Figure 3.2).

3.3.2. Grass production

The grass species inside the exclosures were only being utilized during the winter months (during May, June or July 2001), while the rangeland outside the benchmarks was being grazed throughout the year. In order to keep goats and cattle out of the exclosures, they were fenced with goat proof fencing. The exclosures were grazed before the commencement of the growing season. An effort was made to remove as much of the dry matter as possible from the plot in order to reduce the effect of residual dry matter, which could have influenced the production figures. In order to determine the production and vigor per grass species it was decided to cut the grass per species once a year over a two-year period.

To determine the grass production of the rangeland a quadrat method was applied (Kent & Coker, 1997). A transect, using a rope, was again stretched across the plot. Twenty-five 1m^2 quadrats were thrown out alternately on both sides at every four meters along the rope (Figure 3.4).

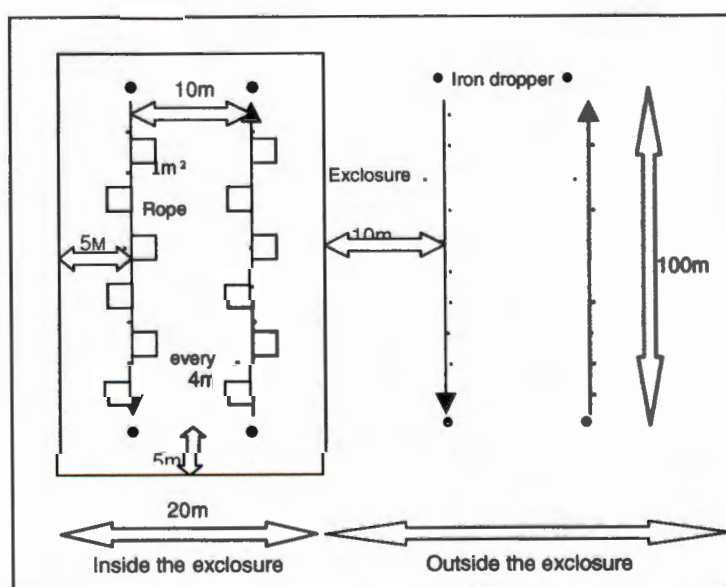


Figure 3.4: A layout for the determination of the grass production by means of a quadrat method in the 100m x 20m exclosures inside the benchmark sites.

The grass in each quadrat were then cut per species by means of sheep shears at a height of approximately 3cm, because this is the height to which cattle will normally graze the grass (Department of Agriculture Conservation and Environment, 2000). Each grass species was also placed in a separate brown paper bag in order to determine the grass production per species (Figure 3.5). Two replications of twenty-five 1m² quadrats were cut.

The grass was only cut inside the exclosures. There will be elaborated on the fact that the production was not also cut outside the exclosures in the section on shortcomings of this study (see Section 5.8, Chapter 5). The data was calculated separately for the two replications. The averages of the two replications were then determined in order to limit variation in the data.



Figure 3.5: Grass production was determined by means of the quadrat method. After being cut each grass species was placed into a separate brown paper bag.

The grass specimens were dried in an oven for approximately 24 hours at 60°C at the Department of Agriculture, Conservation and Environment's facilities in Potchefstroom and Armoedsvlakte (Vrybrug). After the grass specimens were dried, each grass species was weighed separately. The dry matter production (DM) per hectare was then calculated

3.3.3. Soil samples

Soil samples were also taken on the inside and outside of every exclosure. Soil depths at the different study sites were however not determined. Three soil samples were taken randomly across the inside of the exclosure, mixed, and then one representative sample of approximately 1kg was taken. This procedure was also repeated on the outside of the exclosure. The influence of management on the soil composition inside the exclosure is monitored and compared with the soil composition outside the plot over time. Drastic changes in the soil characteristics usually do not take place over the short term, especially in semi-arid rangeland systems. Changes in soil characteristics are therefore not discussed in this study, which took place only over a

two-year period. The results of the soil sample analysis are however given, as they can serve as baseline data for the envisaged long term monitoring of this LandCare project (Annex B).

The soil samples were analysed at the Institute of Soil Climate and Weather (ISCW) in Pretoria in order to determine the chemical and soil particle composition of the soil at each study site. This data will be used to explain differences in the grass species composition and production between the different benchmark sites. The following analysis were carried out:

- The determination of the percentage of carbon (C) present in the soil. It was determined by means of the oxidation with potassiumdichromate, known as the Walkley-Black (W.B) test;
- The soil texture, namely the silt, clay and sand percentage, were analysed by means the standard Bouyoucos method (hydrometer);
- The Cation Exchange Capacity (CEC cmol^+/kg) was established with 1 molar ammonium acetate at pH7;
- Soil resistance (ohm) was determined; and
- The Farmer's Packet, which includes the following analyses:
 - The determination of the calcium (Ca mg/kg), potassium (K mg/kg), Magnesium (Mg mg/kg), and sodium (Na mg/kg) content with 1 molar ammonium acetate at pH 7;
 - The phosphorous (P mg/kg) content by means of the Bray-I extraction; and
 - The soil pH (water), with a 1:2.5 ratio suspension of soil and water.

3.4. Data analyses

3.4.1. Grass species composition

The frequency of occurrence of the different species was calculated by determining the percentage that each species composed of the total grass species recorded during a specific grass species compositional survey.

Rangeland condition assessment techniques used in southern African grasslands are based on estimates of proportional species composition. These estimates are made using amongst others, the nearest-plant approach. This approach, as already mentioned, was used for the purpose of this study.

Grass species were classed into four desirability classes according to research findings of Van Oudtshoorn (1999) and the expert knowledge of agricultural technicians and researchers of the North West DACE. These classes are as follows: highly desirable (HD), desirable (D), less desirable (LD) and non desirable (ND) grass species.

Van Oudtshoorn's (1999) classification of grass species according to their ecological status was used in order to classify the grass species found inside and outside of the exclosures into one decreaser and the three increaser groups. This classification is based on the species' response to grazing impact. The rangeland condition of the

study site was established in each benchmark by the classification of grass species into desirability classes and according to their ecological status.

The changes in the grass species composition inside and outside the exclosures in the different benchmark sites can be compared with one another by employing the Z-index, which is an index of agreement (similarity). The Z-index value is obtained as the sum of the individual species inside and outside an exclosure (Du Toit, 1998). An individual species' Z-value can be calculated as follows:

$$Z = \{[(b \div a) \times 100] \times (a+b) \div \Sigma (a+b)\}$$

According to Du Toit (1998) species which were not recorded, but present in the survey areas should be included and a very low value (e.g. 0.01) should be allocated to them. This will provide a better value of the similarity between the two sites. In this way the reaction of the vegetation to different grazing management systems, or to the rainfall received during different years, can be quantified. This is illustrated with an example at the Austrey 1 benchmark site in Table 3.1.

Table 3.1: Calculation of the Z-index inside and outside the exclosure at the Austrey 1 benchmark site during April 2001. The frequency (%) values of the grass species are re-arranged in columns a (the higher frequency value) and b (the lower frequency value) to facilitate the computation of the percentage value given in column A (b/a) and their sums in column B (a+b). The overall sum is the Z-index value (A x B/ Σ B) indicating the similarity between the grass species composition inside and outside the exclosure.

Species	a	b	A	B	Z-index (%)
<i>Digitaria eriantha</i>	7.6	1.7	22.4	9.3	1.45
<i>Schmidtia pappophoroides</i>	7.2	2.9	40.3	10.1	2.83
<i>Eragrostis lehmanniana</i>	26.9	14	52.0	40.9	14.78
<i>Eragrostis trichophora</i>	13	7.6	58.5	20.6	8.37
<i>Aristida stipitata</i>	14	12.7	90.7	26.7	16.83
<i>Melinis repens</i>	0.7	0.7	100.0	1.4	0.97
<i>Eragrostis rigidior</i>	0.3	0.01	3.3	0.3	0.01
<i>Aristida congesta</i>	19.8	13.8	69.7	33.6	16.27
<i>Chloris virgata</i>	0.3	0.01	3.3	0.3	0.01
<i>Tragus racemosus</i>	0.7	0.01	1.4	0.7	0.01
SUM:				143.9	61.53

The more the Z-index value (%) tends to 100%, the greater the similarity between the grass species composition inside and outside an exclosure, and the more this value tends to 0% the less the similarity. A Z-index value of above 50% thus indicates a high similarity between the grass species composition inside and outside the exclosure, while a Z-index value of below 50% indicates a low similarity. The Z-index values calculated in order to determine the similarity between the grass species composition inside and outside the exclosures of the different benchmark sites, is attached as annex D.

3.4.2. Grass production

In the sweet grasveld areas of South Africa, the area in which this study was carried out, the factor most severely limiting pastoral production, is rangeland deterioration (Danckwerts, 1982). Rangeland deterioration is mainly a result of over-estimating the grazing capacity of the rangeland and incorrect grazing management. Surveys in the Vryburg district indicated that the grazing capacity of the area is overestimated by as much as 100% and that 97% of the farmers do not apply any recognised grazing system (Fourie & Redelinghuys, 1984).

Rangeland is typically heterogeneous and comprises of a mixture of species of varying acceptability to livestock. Accordingly, proportional species composition usually has an important influence on grazing capacity. In the present context, the latter term is used to describe the productivity of the grazeable portion of a unit of vegetation. It is the number of animal units that can be maintained per unit area of land in order to achieve maximized animal production per unit input under consideration, but does not permit soil erosion or changes in the botanical composition that reduce the potential of the vegetation to produce animal products (Danckwerts, 1982). It is usually qualified by the length of the grazing season.

To allow for the natural resources to be maintained in a productive state, it is necessary to establish the current and potential long-term, sustainable grazing capacity of the rangeland. The simplest method of doing this is to use the concept of a large stock unit (LSU). This equates to an animal with a mass of 450 kg and a dry matter (DM) intake of 10 kg/day or 3.65 tons/annum (Tainton, 1999).

Seeing that vegetation community composition has a decisive influence on the productivity and eventually on the grazing capacity expected from grasslands (Snyman, 2000), the proportional production of grass species, divided into the different desirability classes, is considered in order to determine the seasonal grazing capacity at the different benchmark sites. The dry matter (DM) production of the different desirability classes was thus used in order to determine the rangeland condition of the benchmark sites. Forbs were not taken into consideration in determining the seasonal grazing capacity. Three different approaches in calculating the seasonal grazing capacities were used and compared with each other. Each of these approaches is however based on the formula proposed by Moore *et al.* (1985) and Moore & Odendaal (1987):

$$y = d \div [(DM \times f)/r]$$

Where y = grazing capacity (ha/LSU)

d = number of days in a year (365)

DM = total grass DM yield/ha

f = utilization factor

r = daily grass DM required per LSU (intake of 10 kg/day for an animal with a mass of 450 kg)

The utilization factor, expressed as a decimal value, represents that part of the available grass material that can be consumed. The actual consumption of grazing animals is limited by their grazing preferences, losses due to trampling and

environmental factors. The percentage of available dry matter that the animals will actually consume is determined by factors like the desirability of the plant material. However, even when the animals will be able to consume a high percentage of the available dry matter, their intake should be limited to pre-determined levels to avoid overgrazing. According to Smit (2002) the utilization factor may thus vary from 0.20 (20%) to 0.50 (50%), with the average of 0.35 (35%) that is commonly used. The three different approaches used to calculate the seasonal grazing capacities are as follows:

- i. The first approach was used by the Agricultural Pasture Specialist¹ in the western region of the North West Province. In this approach, utilization factors of 0.50 (50%), 0.30 (30%), 0.20 (20%) and 0.10 (10%) were allocated to the highly desirable, desirable, less desirable and non desirable classes of grass species, respectively. All the desirability classes were thus taken into consideration in this approach. The low utilization factor appointed to the non desirable grass species can be explained by the fact that these grass species are very unpalatable. Grazing animals will thus only utilize them if none of the grass species in the other desirability classes are present, seeing that selective grazing to varying degrees is common among grazers (Smit, 2002). By determining the amount of available dry matter production per desirability class, the total amount of available DM production per hectare could be calculated. In order to determine the grazing capacity per LSU at each benchmark site, the available DM yield of the benchmark site is divided by the total amount of DM intake per LSU/annum (3650 kg). The Agricultural Pasture Specialist and agricultural extension officers make use of this approach to calculate and advise land users in the western region of the North West Province with regard to seasonal and long-term management strategies.
- ii. The second approach used to determine the seasonal grazing capacity is according to Smit (2002). Smit (2002), uses utilization factors of 0.35 (35%), 0.2 (20%) and 0.05 (5%) which are allocated to the highly desirable, desirable and non desirable classes of grass species, respectively. The grasses and forbs were classified into four different classes for this study, namely highly desirable, desirable, less desirable and non desirable. Since only three classes are used in this calculation, the desirable and less desirable classes were joined and both were multiplied by the 0.2 utilization factor. Again all the desirability classes were thus taken into consideration, and a low utilization factor was appointed to the non desirable grass species. The total amount of available DM production per hectare, and subsequently the seasonal grazing capacity (ha/LSU) could then be calculated in the same way as described in (i).
- iii. The third approach was used by researchers of the DACE to determine the grazing capacity in areas where an ideal management system is aimed at². The

¹ Personal communication: Dames, R., Dept. of Agriculture: Conservation and Environment: Pasture Section, P.O. Box 807, Vryburg, 8600, South Africa, + +27 53 927 0436 (o), +27 83 564 9672 (c).

² Personal communication: Jordaan, F.P., Dept. of Agriculture: Conservation and Environment: Pasture Science Division, Private Bag X 804, Potchefstroom, 2520, South Africa, + +27 18 299 6702 (o), +27 18 297 7135 (f).

non desirable grass species are not taken into consideration by this method, seeing that it is expected that rangeland subjected to an ideal management system should be in a good condition and accordingly a low percentage of non desirable grass species, which should not be utilized, is anticipated. According to Moore & Odendaal (1987) 25% of the production will be lost because of climatic conditions, trampling, etc., 40% will remain on the rangeland (if sound management practices are followed) and 35% will be available to the animal for consumption. These assumptions are then used by the researchers of the DACE only on the desirable component (Jordaan, 2000). This approach is thus based on the assumption that only 35% of the highly desirable, desirable and less desirable grass species, which can also be described as grasses consisting of a medium desirability, are available for grazing animals. By determining the joint amount of available dry matter production for these three desirability classes, the total amount of available DM production per hectare could be calculated. The seasonal grazing capacity was then determined as described in (i).

In order to obtain much better and more realistic figures to determine the long-term grazing capacity of a benchmark site, long-term data of at least 30 years would be necessary³. The seasonal grazing capacity can thus be used to adjust the long-term grazing capacity of the benchmark site according to the prevailing environmental conditions, and also to plan the fodder flow program for the grazing animals. The Pasture Specialist of the western region of the North West Province suggested the use of the first approach in order to determine the seasonal grazing capacity of the different benchmark sites. Approaches (ii) and (iii) are however used by the Pasture Scientist of the DACE in the North West Province⁴ as well as other scientists in South-Africa, as portrayed by Smit (2002) and Jordaan (2000). All three methods were used to emphasize and illustrate how the different approaches used to determine grazing capacities could vary. The differences that might occur by calculating the seasonal grazing capacities by the three different approaches will be briefly discussed for all study areas. A table of the DM production figures for the different desirability classes and the seasonal grazing capacity, determined by means of the three above mentioned approaches at the different benchmark sites during April 2001 and May 2002, is attached as annex E.

³ Personal communication: Dames, R., Dept. of Agriculture: Conservation and Environment: Pasture Section, P.O. Box 807, Vryburg, 8600, South Africa, + +27 53 927 0436 (o), +27 83 564 9672 (c).

⁴ Personal communication: Jordaan, F.P., Dept. of Agriculture: Conservation and Environment: Pasture Science Division, Private Bag X 804, Potchefstroom, 2520, South Africa, + +27 18 299 6702 (o), +27 18 297 7135 (f).

Chapter 4: Results and Discussion

4.1. Introduction

During the two year period in which the study was conducted, plant surveys were carried out on three occasions. The grass species composition and production were determined twice to the end of the growing season, namely during April 2001 and May 2002. The grass species composition was however also determined once at the commencement of the growing season, during December 2001. The objective for the conduction of these surveys was to determine the survival of grass species after the exclosures were grazed during the winter months.

It is important to note that the conduction of the surveys were dependent on budget constrains, assistance from the agricultural extension officers and the contractors responsible for the erection of the fences for the exclosures at the selected benchmark sites. This means that the vegetation at many of the benchmarks were only surveyed twice, namely during December 2001 and May 2002 (Table 2.2 in Section 2.2.2). These include the vegetation at the benchmark sites of: Heuningvlei A2, C2 and F2 in the Kudumane magisterial district, and Waterfouchè 2, 3, 4, 5 and 6 in the Ganyesa magisterial district.

As already mentioned in section 3.2.2 (Chapter 3), grass production was only cut on the inside of the exclosure in order to serve as an example of how the production would react to the resting applied. Due to the fact that the above mentioned exclosures were not yet finished in April 2001, the production at these benchmarks were only cut during May 2002. Surveys were also not executed at Austrey 4 during April 2001 and at Orange Grove during December 2001. During the discussion these problems will be mentioned again.

Results of each magisterial district will be considered separately. At first the grass species composition results of the benchmark sites in the communally managed rangelands for a specific magisterial district will be discussed, followed by the grass production results.

A summary, where all the communally managed benchmark sites surveyed in the specific magisterial district are compared to each other, will follow. Differences in the soil composition between the benchmark sites will also be discussed under this section in order to explain differences and changes in the species composition and production.

Thereafter results of the Morafe ranch, in the corresponding magisterial district, will be discussed in the same way as the communally managed benchmarks. Every magisterial district will be discussed in the above mentioned manner.

4.1.1. Grass species composition

Seeing that the grasses were classified according to four desirability classes, namely HD, D, LD and ND (Annex C1 and 2), the grass species composition and grass production results are given accordingly. It is however important to keep in mind that the LD grass species can also be described as consisting of a medium desirability (see Section 3.4.2, Chapter 3), especially when the grass production results are discussed. The desirability, grazing value, whether the grass species are annual or perennial, their plant successional status and ecological status are all indicated on the specie list (Annex C1 and 2). The survey forms were also compiled according to the desirability of the grass species (Annex A). Forbs were sampled separately.

According to the grass species reaction to grazing, they could be classified into the following groups with respect to their ecological status (Van Oudtshoorn, 1999):

Decreasers – This group includes grasses that are abundant in good rangeland, but that decrease in number when the rangeland is overgrazed or undergrazed. These grasses are palatable climax grasses such as *Digitaria eriantha* and *Schmidtia pappophoroides*.

Increaser I – Grasses that are abundant in underutilised rangeland are classified into this group. These grasses are usually unpalatable, robust climax species that can grow without any defoliation, such as *Cymbopogon excavatus*.

Increaser II – Grasses that are abundant in overgrazed rangeland falls within this group. These grasses increase due to the disturbing effect of overgrazing and include mostly pioneer and subclimax species such as *Eragrostis lehmanniana* and *Aristida stipitata*. They produce much viable seed and can thus quickly establish on new exposed ground. This group is common in lower rainfall areas, such in the case of this study, which was conducted in a semi-arid to arid area.

Increaser III – This group consists of grasses that are commonly found in overgrazed rangeland. These are usually unpalatable, dense climax grasses such as *Enneapogon scoparius* and *Eragrostis pallens*. These grasses are strong competitors and increase because the palatable grasses have become weakened through overgrazing. In addition, it is possible that they are stimulated by light grazing during overgrazing.

It is however of great importance to take into consideration that the ecological status and desirability of these grasses may vary from one region to the next. In the case of this study area rainfall more often has a greater effect on the grass composition and production than grazing (Van Oudtshoorn, 1999).

4.1.2. Grass production

As already mentioned (see Section 3.4.2, Chapter 3), results of the three approaches used to determine the seasonal grazing capacity of the exclosures at the different benchmark sites are portrayed in Annex E.

If for example the seasonal grazing capacities calculated for the inside of the exclosures at the Austrey 1 and 2 benchmarks sites during April 2001 by means of all

three approaches is considered, the difference in grazing capacity for these two sites when calculated by approaches (ii) (256.1 ha/LSU at Austrey 1 and 81.7 ha/LSU at Austrey 2) and (iii) (173.8 ha/LSU at Austrey 1 and 51.9 ha/LSU at Austrey 2) are less different than when calculated with approach (i) (195.2 ha/LSU at Austrey 1 and 30.8 ha/LSU at Austrey 2). It can thus be seen that the seasonal grazing capacity determined according to approach (i) at the Austrey 1 benchmark site is 6.3 times higher than that of the Austrey 2 site (Annex E). Considering that the DM production values of the highly desirable and desirable grass species at these sites did not differ much during the April 2001 survey, and the lower utilization factors appointed to the less desirable and non desirable grass species, there should not have occurred such a great difference in the seasonal grazing capacities when calculated by approach (i). In applying approaches (ii) and (iii), this difference was much less, namely 3.1 and 3.3 times higher at the Austrey 1 than at the Austrey 2 site, respectively. It seems that approaches (ii) and (iii) provide much more realistic results than results obtained through the application of approach (i). This indicates how approaches of different scientific groups for calculating the grazing capacity can differ. These differences could hold in great implications for the degradation of rangelands, seeing that different recommendations can be made from these calculations which are used to determine the grazing capacity of an area.

Results obtained from approach (ii) generally resulted in poorer seasonal grazing capacities than results obtained from the other two approaches, e.g. the seasonal grazing capacities determined for the Austrey 3 benchmark site during April 2001 according to approaches (i), (ii) and (iii) are 10.2 ha/LSU, 13.4 ha/LSU and 9.5 ha/LSU, respectively. The seasonal grazing capacities obtained by applying approaches (i) and (iii) were in general very similar, e.g. at the Waterfouchè 6 benchmark site (Annex E).

The same tendency in differences in the seasonal grazing capacity values persisted from the results of all three approaches. For the purpose of this study it was thought best to mainly discuss results obtained by means of approach (i). This decision is supported by the fact that this approach is also used in the western region of the North West Province, the area in which this study was carried out. It was thus reasoned that to consist with the current approach would be the least confusing. Although results of approach (i) will mainly be discussed for the purpose of this study, results of the other two methods will also be referred to during the discussion, in order to explain some features of this aspect of the study.

In order to obtain more realistic seasonal grazing capacity values, it is proposed that it should be attempted to rather apply approach (ii) in future studies of the same type. This is proposed, seeing that the seasonal grazing capacity is much lower and if the farmers and land users apply this lower stocking rate, less damage will occur and degraded rangelands would probably recover much quicker.

Part of the objectives of this study was to involve and train the agricultural extension officers, as well as the land users in the specific districts with regard to vegetation sampling, grass species composition and sustainable management practices. The agricultural extension officers, and often land users, helped in the surveying of the specie composition and grass production at the benchmark sites. It also resulted that the agricultural extension officers surveyed some of the benchmark sites alone.

Therefore, during the analysis of all the data, there had to be relied on some data that was not collected personally, which could also have contributed to some discrepancies in the results.

4.2. Ganyesa magisterial district

The two management systems that were chosen in the Ganyesa magisterial district were at the Austrey (communal management) and Waterfouchè (Morafe ranch) study sites (see Figure 2.1, which indicates the location of the different study areas in the three magisterial districts).

4.2.1. Communal grazing management at the Austrey study site

Austrey is a communally managed area in the Ganyesa magisterial district in the western region of the North West Province. It is divided into the Tlagameng FSU, which falls within the Ganyesa ADC. The exclosures at the selected benchmark sites were erected during April 2001 (*see* Table 2.2 in Section 2.2.2 of Chapter 2). The ADC manager and agricultural extension officer responsible for these areas are given in Table 4.1. According to the agricultural extension officer the total area that is communally managed, which includes Austrey and Goodwood, occupies 5200 hectare. The total area is divided into 450–500 hectare paddocks on which the farmers apply a four camp rotational grazing system. According to the Department of Agriculture, Conservation and Environment (2001) the recommended long-term grazing capacity of this benchmark site should be 12 ha/LSU. In the opinion of the agricultural extension officer the current grazing capacity is however nearer to 14–16 ha/LSU.

The rangeland at this study site is being used as grazing for cattle, sheep, goats, horses and donkeys. A committee made up of community members was appointed to deal with the overstocking problem in the area. This was already done during 1997. One of the main problems that they are dealing with, is the uncontrolled number of horses and donkeys. The whole community thus welcomed the implementation of the LandCare project in this area, which includes the selection of benchmark sites and exclosures in certain areas. At the Austrey study site four sites were selected according to their rangeland conditional state (*see* Section 1.4 and 3.2 in Chapter 1 and 3, respectively).

Table 4.1: The ADC manager and agricultural extension officer at the Austrey study site.

District	Benchmark site	Management system	ADC manager	Agricultural extension officer
Ganyesa	Austrey	Communal	Emmanuel Phutiegai Tel: (053) 927 3971 : 083 733 0876	Kenneth Makwati Tel: 072 342 7479 Fax: (053) 927 3971

4.2.1.1. Austrey 1 benchmark site

i. *Grass species composition*

If the grass species composition at Austrey 1 is considered according to the desirability, it is obvious that the desirable grass species dominated inside and outside of the exclosure during April 2001 (Figure 4.1a). This can mainly be ascribed to the high abundance of *E. lehmanniana* at the benchmark site (Figure 4.1d). Seeing that rainfall variability has been identified as a primary determinant of compositional change in southern African savannas (O'Connor, 1995), the drastic increase in the less desirable grass species (inside and outside the exclosure), during December 2001 (Figure 4.1b), can be explained by the above average rainfall from September 2001 till January 2002 (Figure 4.2 b and c). The short period of low rainfall from January to March 2001 could have enhanced the quick response of the rangeland to the high rainfall season from September 2001 to January 2002 at the Austrey 1 study site. Consequently this also led to an increase in the pioneer or sub-climax grass species inside and outside the exclosure, such as *Aristida stipitata* (Figure 4.1e). As the frequency of the grass species also increased, the occurrence of bare ground decreased. The desirable grass species, *E. lehmanniana* and *E. trichophora*, however still dominated during December 2001 (Figure 4.1 b and e).

No marked difference could be observed between the species composition inside and outside the exclosure. During May 2002 the Z-index value at Austrey 1 was 62.6% (Table 4.2). This reflects that the similarity between the grass species composition inside and outside the exclosure remained high during the two consecutive years in which the surveys were carried out.

Table 4.2: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the exclosure at the Austrey 1 benchmark site during April 2001, December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Austrey 1	April 2001	61.5
	December 2001	66.4
	May 2002	62.6

The occurrence of desirable species stayed more or less constant inside the exclosure, namely 34.5% in April 2001, 37.7% in December 2001, and 40.7% in May 2002. It however showed an initial increase in abundance from April 2001 (27%) to December 2001 (36.2%), but decreased again in May 2002 (24.2%) outside the exclosure (Figure 4.1a, b and c).

The less desirable grass species (mostly *A. stipitata*) showed a larger decrease in abundance inside the exclosure from December 2001 to May 2002 than outside the exclosure (Figure 4.1 b and c). *Aristida stipitata* decreased with 14.5% inside the exclosure, while it decreased with only 8.2% outside the exclosure (Figure 4.1 e and f). Seeing that *A. stipitata* is classified as an increaser II specie (van Oudthoorn, 1999) it will accordingly increase in abundance under short-term moderate overgrazing (Bosch & Kellner, 1991).

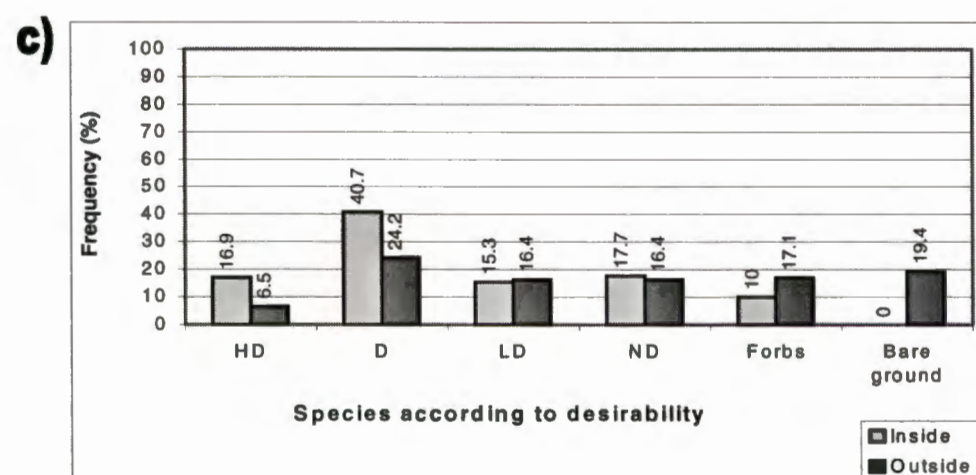
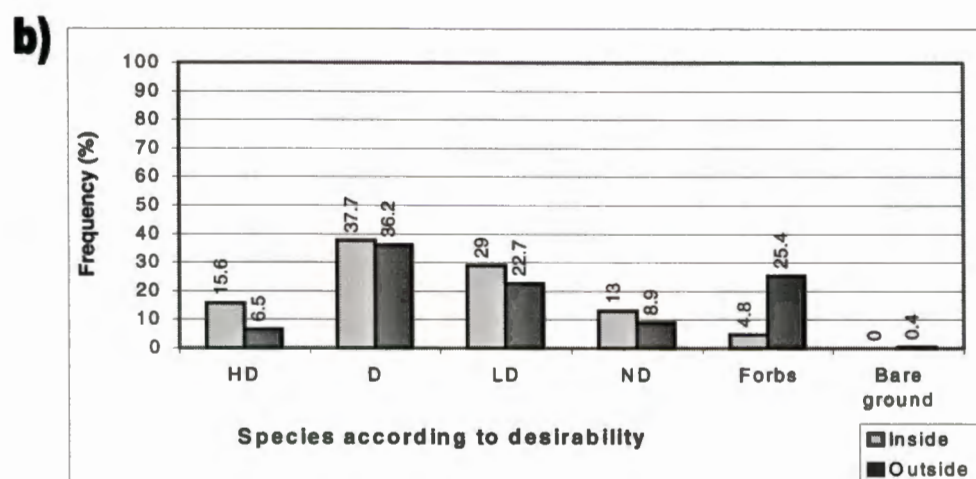
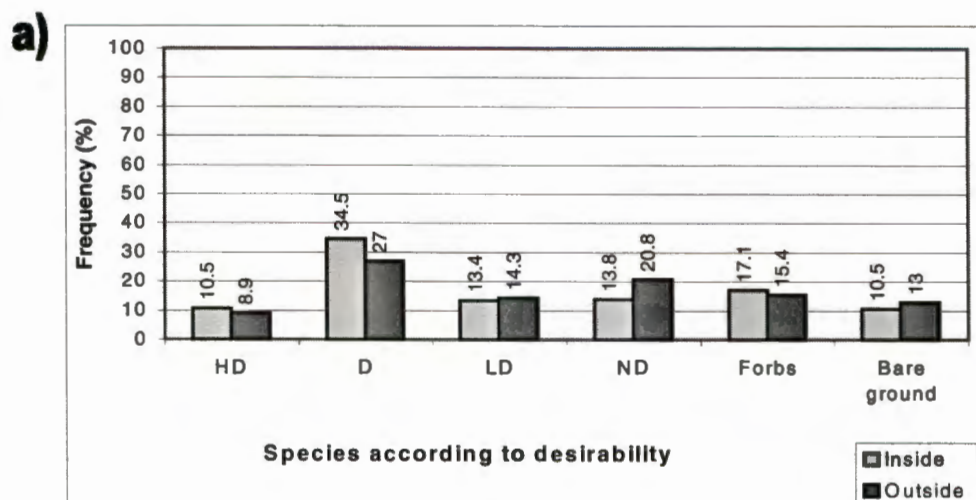


Figure 4.1 a-c: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Austrey 1 benchmark site, during April 2001 (a), December 2001 (b) and May 2002 (c).

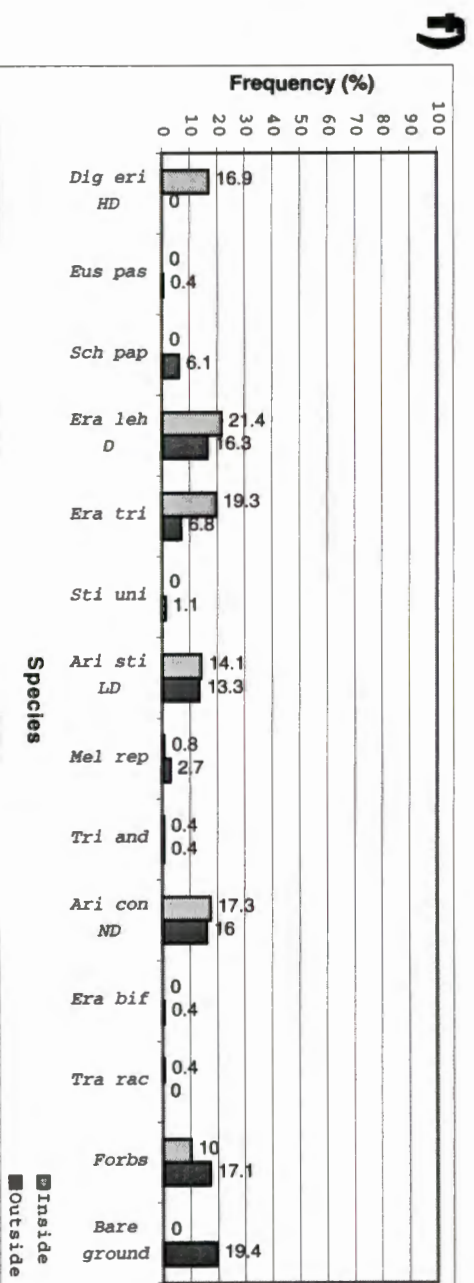
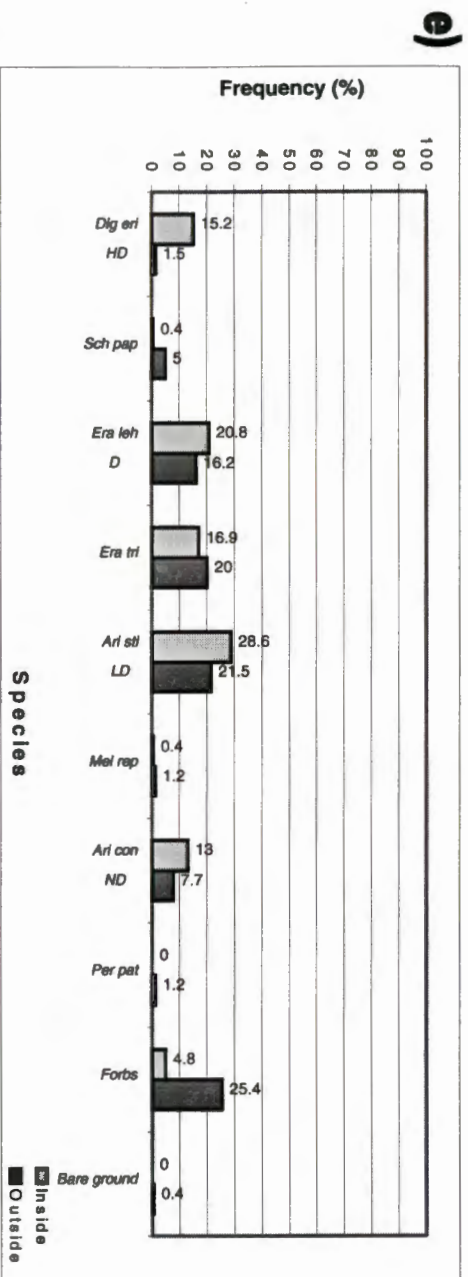
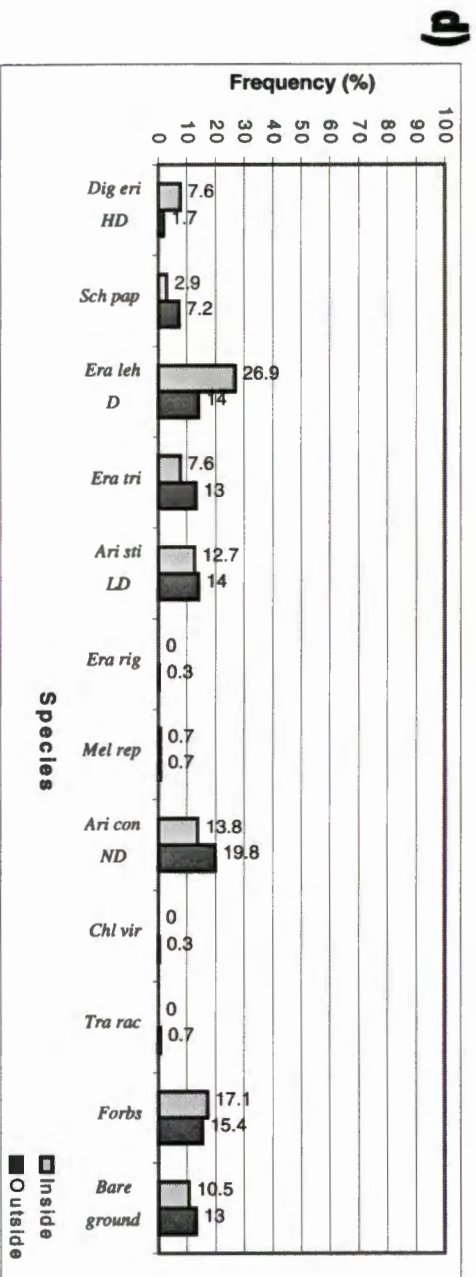
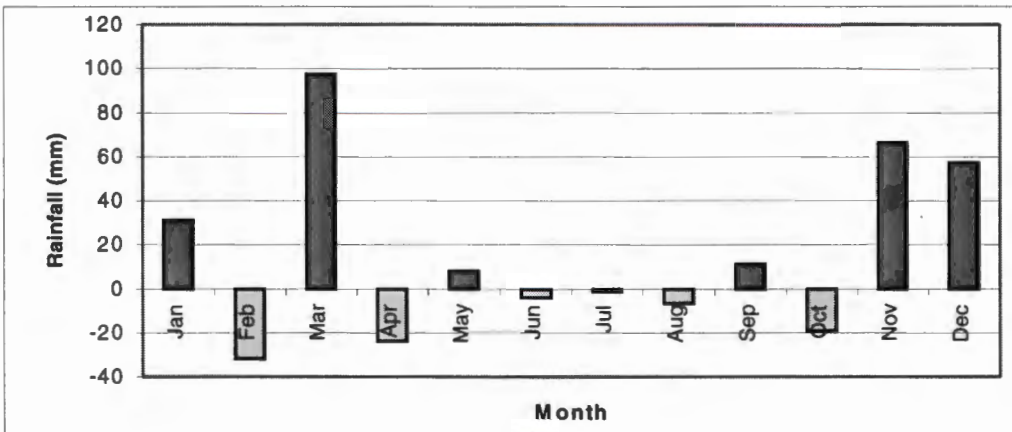
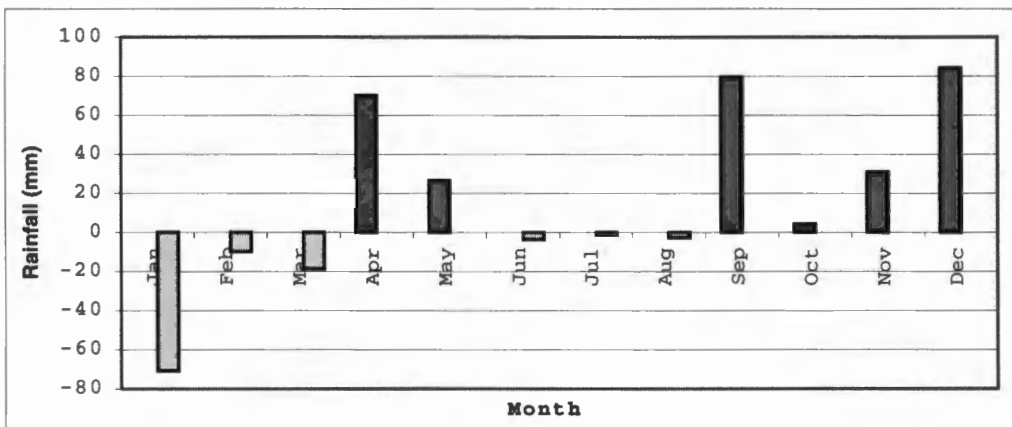


Figure 4.1 d-f: Frequency (%) of grass species inside and outside the enclosure at the Austrey 1 benchmark site, during April 2001 (d), December 2001 (e) and May 2002 (f) (see Annex C1 & C2 for species abbreviations).

a)



b)



c)

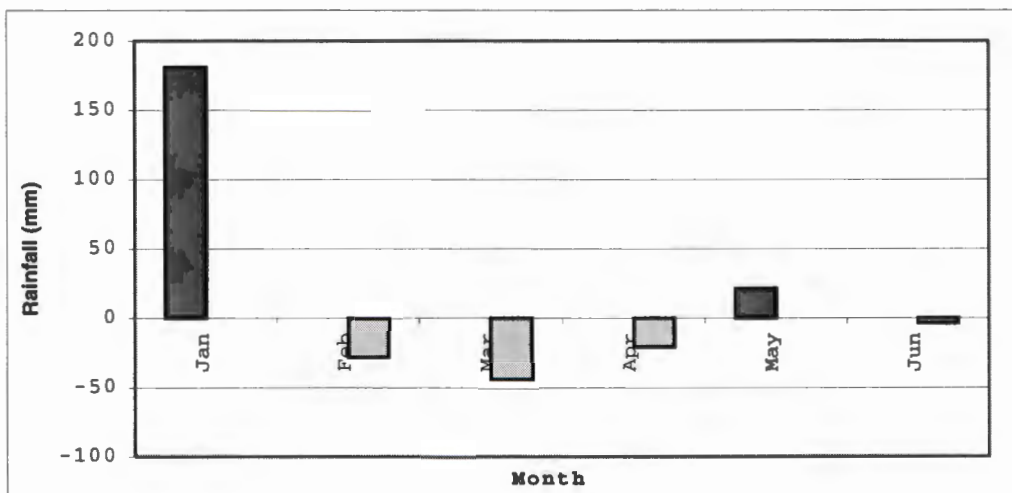


Figure 4.2 a-c: Rainfall deviation from the average rainfall at the Austrey study site during the years 2000 (a), 2001 (b) and 2002 (c).

The fact that the rangeland is being rested inside the enclosure, and could thus not be overgrazed, explains the greater decrease in the frequency of *A. stipitata* inside the enclosure. The relatively high abundance of *A. stipitata* as well as *E. lehmanniana* and *E. trichophora*, which are also classified as increaser II species, therefore indicates that rangeland at this benchmark was being slightly to moderately overgrazed.

An overall increase in the highly desirable grass species inside the enclosure can mainly be ascribed to the increase in the abundance of *D. eriantha* (Figure 4.1 a and c). The frequency of *D. eriantha* increased from 7.6% (April 2001) to 16.9% in May 2002 and decreased from 1.7% to 0% outside the enclosure (Figure 4.1 d and f).

It thus seems that over the short time this surveys were carried out, the rangeland condition inside the enclosure was already increasing while the rangeland condition outside the enclosure is showing signs of deterioration. This can be explained by the tendency of the species composition outside the enclosure shifting towards a less desirable species composition.

The grass species compositional changes on the outside of the enclosure shows a decrease in highly desirable (*D. eriantha*) and desirable (*E. lehmanniana* and *E. trichophora*) grass species, and an increase in the non desirable species (*A. congesta*), forbs and bare ground (Figure 4.1 a, b and c). Even though the better rangeland condition inside the enclosure can be ascribed to the above average rainfall from September 2001 to January 2002, the rangeland condition outside the enclosure still slightly deteriorated in spite of the high rainfall. The continued grazing outside the enclosure could certainly have contributed to this deterioration.

ii. Grass production

The total grass production inside the enclosure at Austrey 1 shows a considerable increase from 203.7kg/ha in April 2001 to 1002.4kg/ha in May 2002 (Table 4.3). Accordingly the seasonal grazing capacity, calculated according to approach (i), also improved tremendously from 195.2 ha/LSU during April 2001 to 21.7 ha/LSU during May 2002. The same improvement could also be observed by calculating the seasonal grazing capacity by means of approaches (ii) and (iii), namely from 256.1 ha/LSU to 30.8 ha/LSU and 173.8 ha/LSU to 23.0 ha/LSU, respectively (Annex E). Seeing that rainfall is the limiting environmental factor determining or influencing sustainable plant production throughout the growing season in semi-arid areas (Snyman, 2000), this increase can mainly be attributed to the above average rainfall in the season from September 2001 to January 2002 (Figure 4.2 b and c). It is important to remember that the production of the forbs was not considered in calculating the seasonal grazing capacities, seeing that the forb species were considered as undesirable and will only be utilised by grazing animals when no or very few other grazing is available. The improvement in the seasonal grazing capacity at this site can thus not be explained by changes in the forb production.

As can be observed in Figure 4.3, the percentage of forbs contributing to the total production decreased from 2001 to 2002. This can also be seen in Table 4.3, where the forbs contributed to 57.9% of the total production in 2001, but only to 24.4% in 2002.

Table 4.3: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Austrey 1 benchmark site during April 2001 and May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
April 2001	203.7	85.7	118	57.9	195.2
May 2002	1002.4	757.9	244.5	24.4	21.7

During May 2002 the highly desirable, desirable and non desirable grass species showed a marked increase in their contribution to the total production (Figure 4.3). This can mainly be ascribed to the seedling recruitment of these grass species that was strongly influenced by the rainfall.

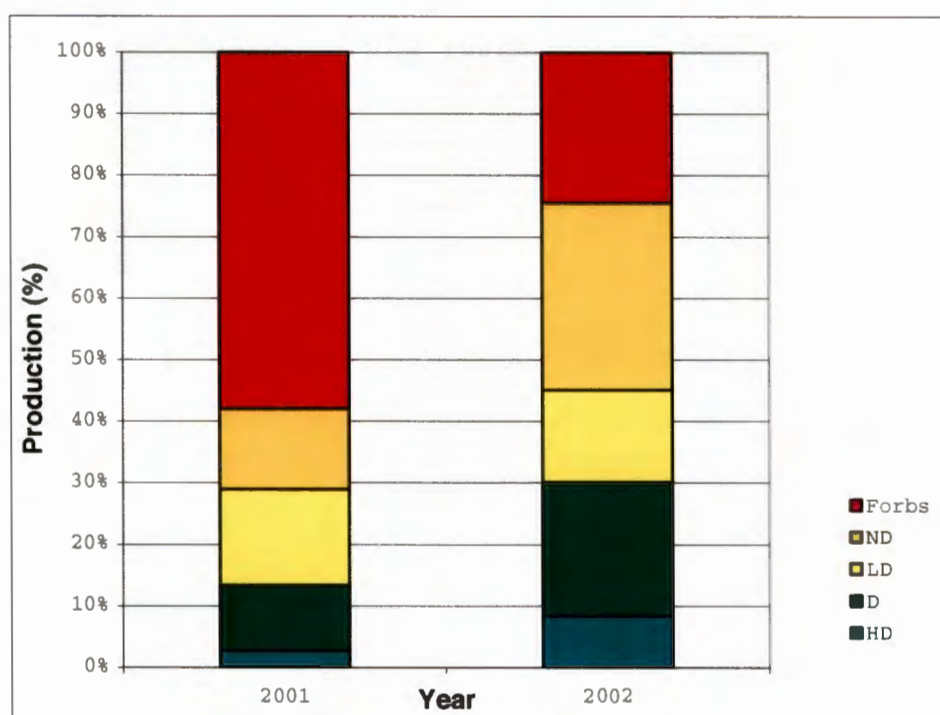


Figure 4.3: The changes in the contributions of the different desirability classes to the total production (%) at the Austrey 1 benchmark site from April 2001 to May 2002.

The increase in the production of non desirable species was caused by the increase in the frequency of *A. congesta* inside the enclosure from 13.8% (April 2001) to 17.3% (May 2002) (Figure 4.1 d and f). *Eragrostis lehmanniana* and *E. trichophora* were the main contributors to the increase in the production of the desirable species, while *D. eriantha* mainly contributed to the increase in the highly desirable grass species production (Figure 4.1 f). *Digitaria eriantha* is classified as a decreaser species and will thus decrease in abundance under conditions of overgrazing (van Oudtschoorn, 1999). The fact that *D. eriantha* increased in abundance indicates that the rangeland condition inside the benchmark is already showing signs of improvement.

Accordingly both, the grass species composition and production, indicates an improvement of the rangeland condition on the inside of the enclosure from April 2001 to May 2002. Therefore the grass production inside the enclosure did not only increase, but it also shows an increase towards a more desirable rangeland condition.

4.2.1.2. Austrey 2 benchmark site

i. *Grass species composition*

During April 2001 the Austrey 2 benchmark site was dominated inside and outside the enclosure by less desirable grass species (Figure 4.4a) such as *Melinis repens*, *A. stipitata*, *Pogonarthria squarrosa* and *E. pallens* (Figure 4.4d). The frequency of the less desirable grass species shows a slight decrease from April to December 2001, while the non desirable species increased in frequency (inside and outside the enclosure) (Figure 4.4b). In May 2002 the frequency of non desirable species, mainly *Perotis patens* (Figure 4.4f), increased even further inside and outside the enclosure, while the abundance of the highly desirable, desirable and less desirable grass species decreased (Figure 4.4c).

The high rainfall during the growing season (Figure 4.2 b and c) has caused an increase in the total grass cover as well as in the frequency of the non desirable grass species (*A. congesta* and *P. patens*), including the forb species, which lead to a marked decrease in bare ground over the two seasons. It can be deduced that during the relative short drought period from January to March 2001 (Figure 4.2b) these shorter-lived species seed production was prolific. Consequently these pioneer and annual grass species dominated the soil seed bank and responded more rapidly to the subsequent high rainfall than the other, perennial, larger tufted grass species (*E. lehmanniana*, *E. trichophora* and *S. uniplumis*).

Perotis patens was the main contributor to the increase in non desirable grass species (Figure 4.e and f). It can thus be deduced that a larger number of *P. patens* seed than *A. congesta* seed accumulated in the soil seed bank. According to De Wet (2001) seed densities are highest in frequently disturbed habitats, and the species most strongly represented in the soil are often those with the shortest life span aboveground. The remarkable response of *P. patens* to the high rainfall, which is described as a annual or poor perennial grass species, is thus in accordance with this fact. Because this increase in the frequency of *P. patens*, a increaser II species, is higher on the outside than on the inside of the enclosure it can be concluded that the rangeland outside the enclosure is being moderately overgrazed.

The desirable, long-lived, obligate seed reproducing grasses (*E. lehmanniana*, *E. trichophora* and *S. uniplumis*) develops only limited amounts of larger seeds (O'Connor, 1994) and did accordingly not respond to the high rainfall season to the same extent as the non desirable species.

The desirable grass species, *E. lehmanniana* and *E. trichophora* (Figure 4.4f) were more abundant inside the enclosure during May 2002 than outside. It comprised 15.9% of the grass species composition in comparison with the 10.3% outside the enclosure (Figure 4.4c). These observations stress the fact that the rangeland inside the enclosure benefits from the rest that is being applied.

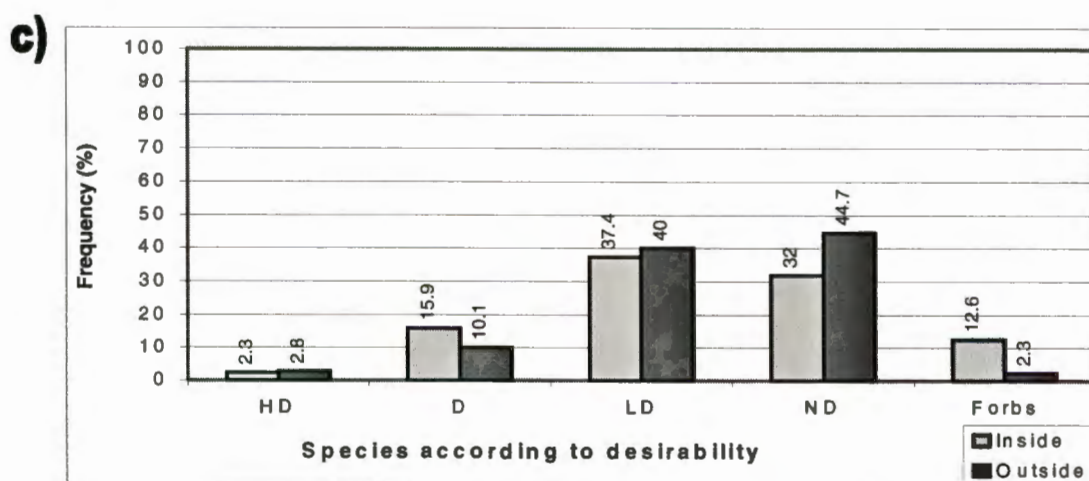
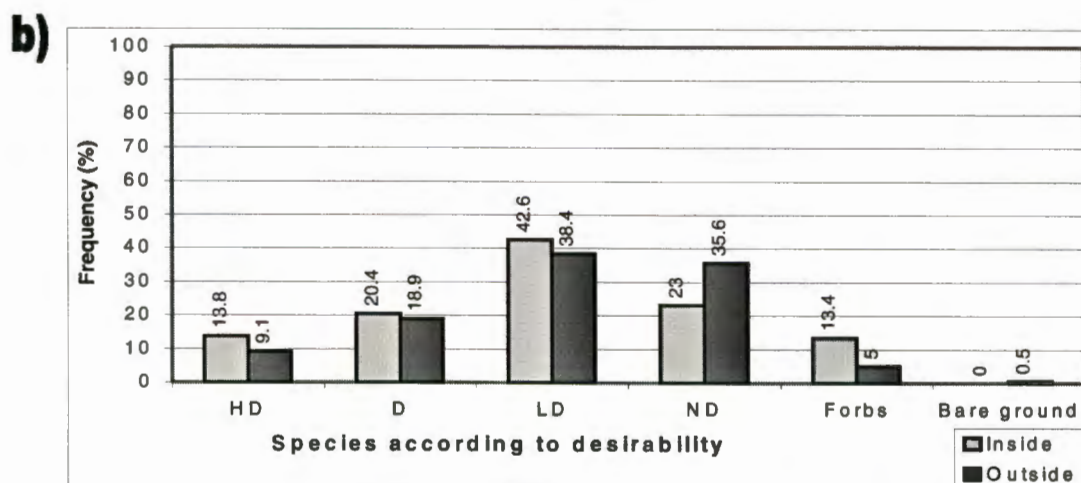
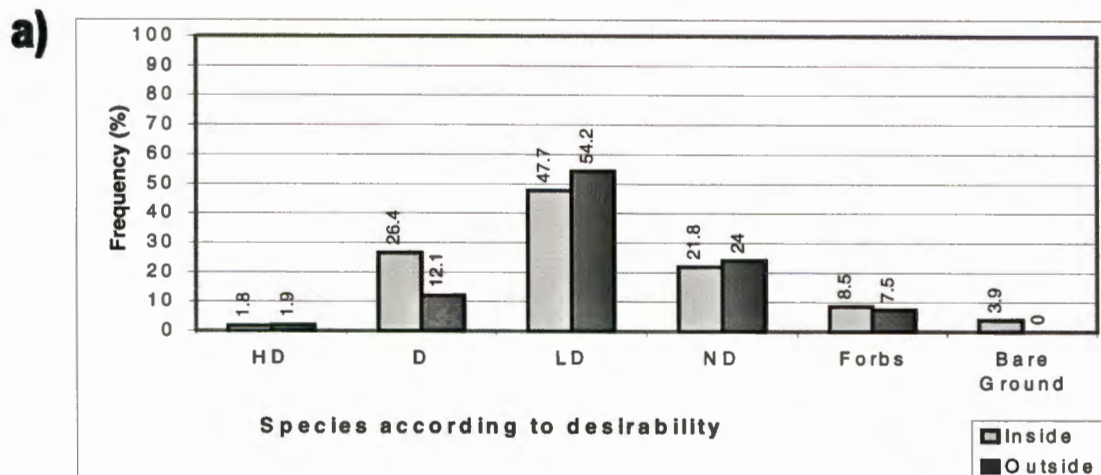
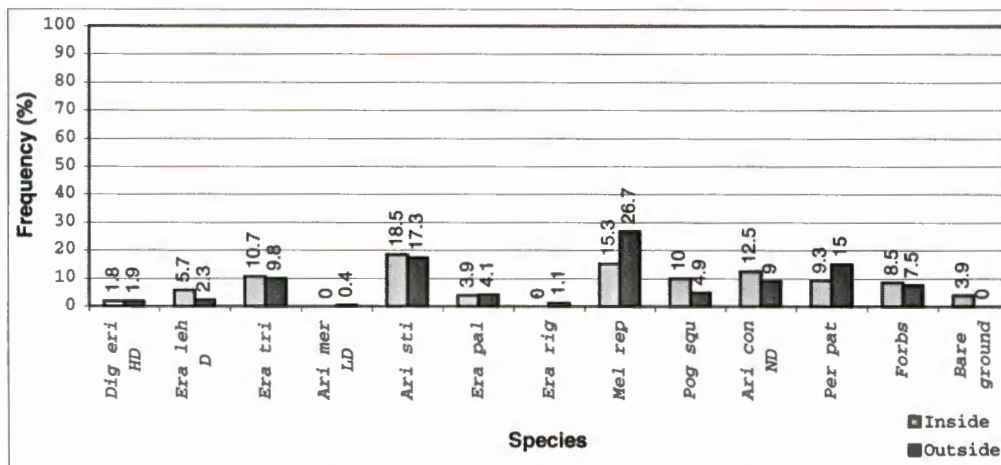
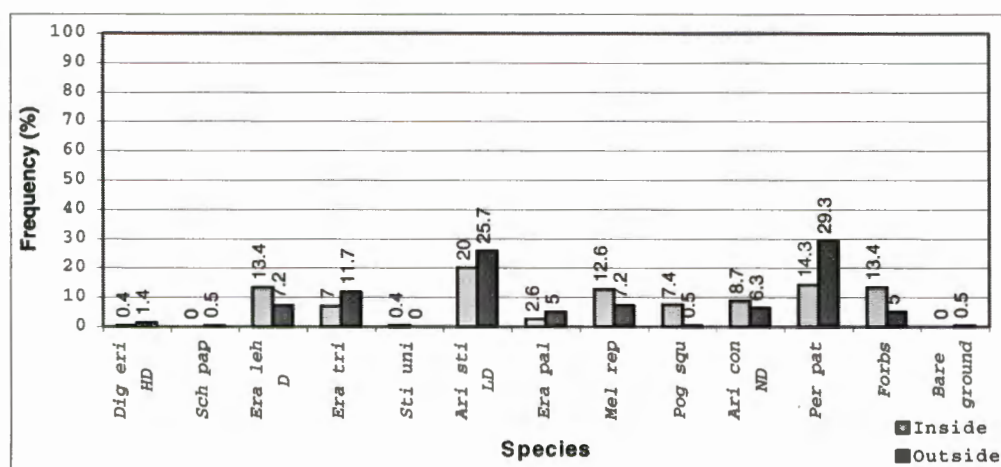


Figure 4.4 a-c: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Austrey 2 benchmark site, during April 2001 (a), December 2001(b) and May 2002 (c).

d)



e)



f)

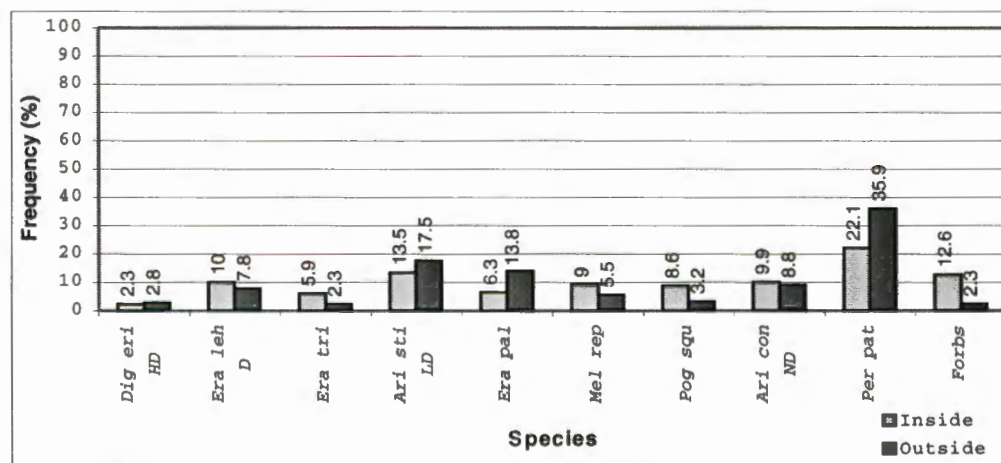


Figure 4.4 d-f: Frequency (%) of grass species inside and outside the enclosure at the Austrey 2 benchmark site during April 2001 (d), December 2001 (e) and May 2002 (f) (see Annex C1 & C2 for species abbreviations).

However, no prominent difference in the grass species composition inside and outside of the enclosure was observed during the two growing seasons. Form the Z-indices at the Austrey 2 benchmark site it is also evident that the similarity in the grass species composition inside and outside the enclosure is still high (Table 4.4). The Z-index values do however show a slight decrease from 69.4% in April 2001 to 64.8% in May 2002.

Table 4.4: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Austrey 2 benchmark site, during April 2001, December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Austrey 2	April 2001	69.4
	December 2001	58.5
	May 2002	64.8

ii. Grass production

In Figure 4.5 a clear increase in the contribution of non desirable grass species, *P. patens* and *A. congesta*, to the total production can be observed. The contribution of the less desirable species (mainly *A. stipitata*, *E. pallens*, *M. repens* and *P. squarrosa*) to the total production shows only a slight increase, while the contribution of the highly desirable (*D. eriantha*), desirable (mainly *E. lehmanniana* and *E. trichophora*) and forb species decreased. This may seem as contradictory to the grass species composition measurements, seeing that the frequency of the highly desirable grass species and forbs increased, while the less desirable grass species decreased in frequency inside and outside the enclosure from April 2001 to May 2002 (Figure 4.4 a and c). From Table 4.11 and Annex E it is however evident that the production of all the desirability classes did indeed increase during the study period. Figure 4.5 must thus merely be viewed as an indication of the change in the contribution of the different desirability classes to the total grass production over the two year study period.

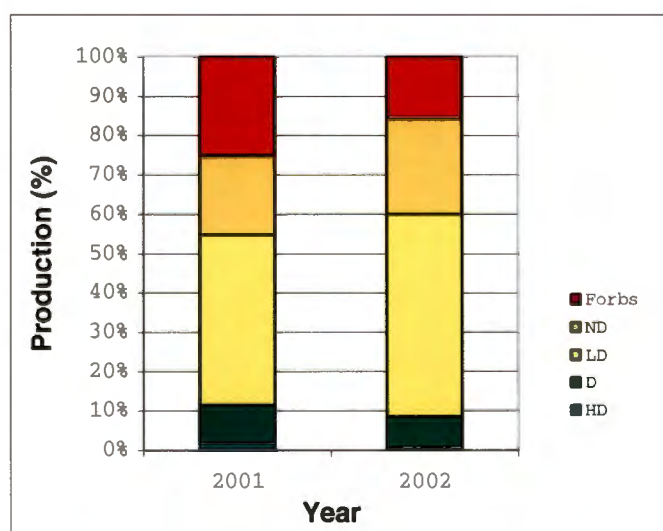


Figure 4.5: The changes in the contributions of the different desirability classes to the total production (%) at the Austrey 2 benchmark site from April 2001 to May 2002.

The total grass production increased considerably, from 366.4 kg/ha to 877.1 kg/ha, through the course of the study period (Table 4.5). Although the production of the forbs shows an increase in production from 2001 to 2002, the percentage it contributes to the total production decreased from 25.2% to 17.6%.

Table 4.5: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contribute to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Austrey 2 benchmark site during April 2001 and May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contribute to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
April 2001	366.4	274	92.4	25.2	30.8
May 2002	877.1	722.9	154.2	17.6	27.1

As can be seen in Table 4.5, the seasonal grazing capacity, determined by means of approach (i), improved from 30.8 ha/LSU during 2001 to 27.1 ha/LSU during 2002. The improvement in the seasonal grazing capacities calculated according to approaches (ii) and (iii) are more prominent, with improvements of 2.6 times, in comparison with the 1.1 times improvement observed when the seasonal grazing capacity is calculated according to approach (i)(Annex E). This improvement can mainly be ascribed to the increase in the production of the less desirable grass species, which can also be described as medium desirable grass species. Although the increase in the production of the less desirable grass species is smaller than that of the non desirable grass species, the utilisation factor, when the seasonal grazing capacity is calculated by means of approach (i), appointed to the less desirable grass species (20%) is higher than the value appointed to the non desirable grass species (10%). It can thus be concluded that the less desirable grass species contributed mostly to the improvement in the seasonal grazing capacity. This improvement in the rangeland condition can be ascribed partly to the preceeding high rainfall season, and partly to the rest that is being applied inside the enclosure.

4.2.1.3. Austrey 3 benchmark site

i. *Grass species composition*

There was no great difference in the grass species composition inside and outside the enclosure at the Austrey 3 site during April 2001 (Figure 4.6 a-f). The Z-indices serves as evidence to this statement, namely that the similarity in the species composition inside and outside the benchmark indicates a steady increase from 63.7% during April 2001, to 74.2% during December 2001, and then to 84.0% during May 2002 (Table 4.6).

Table 4.6: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Austrey 3 benchmark site, during April 2001, December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Austrey 3	April 2001	63.7
	December 2001	74.2
	May 2002	84.0

The abundance of non desirable species was, however, slightly more outside the enclosure during April 2001, with a frequency of 19.2%, than on the inside, with a frequency of 10.3% (Figure 4.6a). Since December 2001 the less desirable species, namely *A. stipitata*, *Brachiaria marlothii*, *E. pallens* and *M. repens*, had a higher frequency inside the enclosure than on the outside (Figure 4.6 b, c, e and f). The species composition of the benchmark site (inside and outside the enclosure) reflected that the rangeland was in a good condition during April 2001, seeing that the highly desirable (*D. eriantha* and *S. pappophoroides*) and desirable grass species (*E. lehmanniana*, *E. trichophora* and *S. uniplumis*) dominated at the benchmark site (Figure 4.6 a and d).

During the above average rainfall season from September 2001 to January 2002 (Figure 4.2 b and c), the abundance of the less desirable species increased considerably (Figure 4.6b). This was mainly due to the increase in the frequency of *A. stipitata* and *M. repens* (Figure 4.6e). It can be concluded that the seed of these two pioneer or sub-climax grass species accumulated in the soil seed bank during the previous lower rainfall season from April 2000 to March 2001 (Figure 4.2 a and b). In response to the high rainfall season during the 2001/2002 growing season, these seeds germinated and the less desirable grass species accordingly increased in frequency. Because of this increase the bare ground patches disappeared.

The desirable species maintained their abundance inside and outside the enclosure from December 2001 to May 2002, while the abundance of the highly desirable and less desirable grass species increased (Figure 4.6b and c). The highly desirable species, mostly *Schmidtia pappophoroides*, occurred in higher frequencies inside (37.6%) than outside (36.2%) the enclosure in May 2002 (Figure 4.6f). During May 2002 there were also greater numbers of less desirable species on the outside of the enclosure (34.8%) than on the inside (24.8%).

The ecological status of *S. pappophoroides* is described as a decreaser species (Annex C1). The high abundance of *S. pappophoroides* suggests that it will dominate in good rangeland and decrease in abundance when the rangeland is mismanaged (Van Oudtshoorn, 1999). Seeing that the rangeland inside the enclosure was rested when *S. pappophoroides* increased in abundance, it can be taken that the occurrence of *S. pappophoroides* indicates that the rangeland is in a relatively good condition.

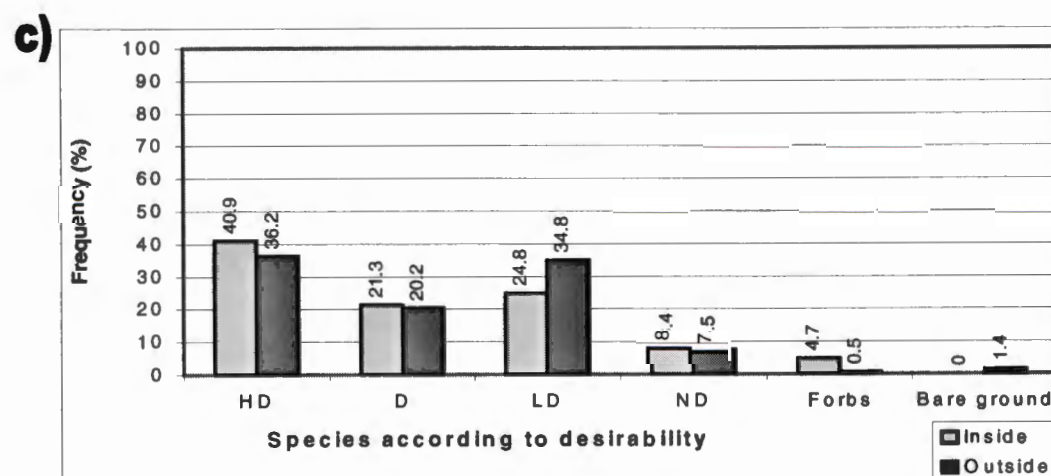
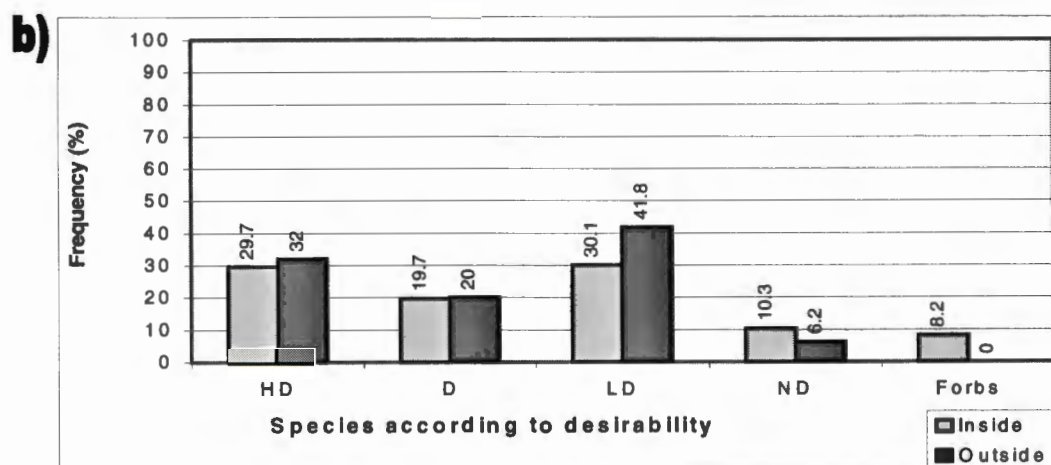
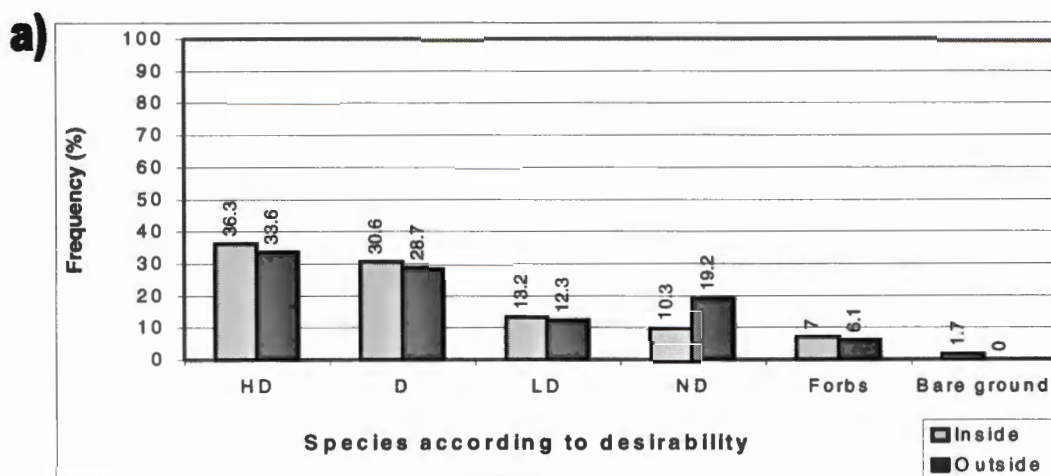


Figure 4.6 a-c: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Austrey 3 benchmark site, during April 2001 (a), December 2001 (b) and May 2002 (c).

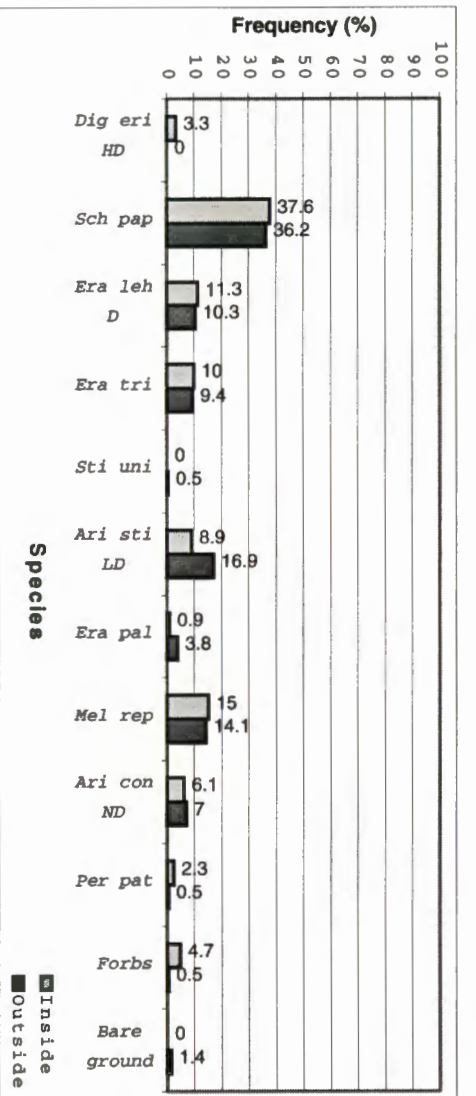
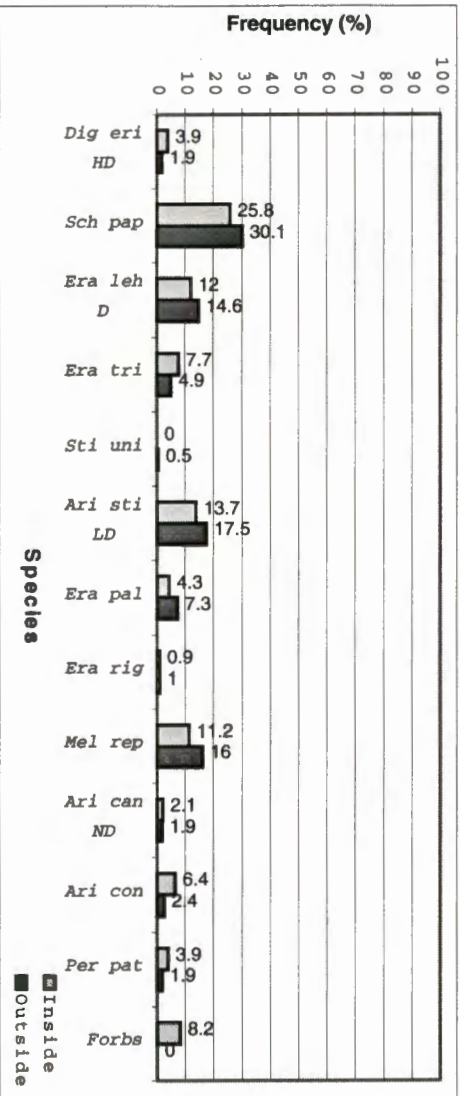
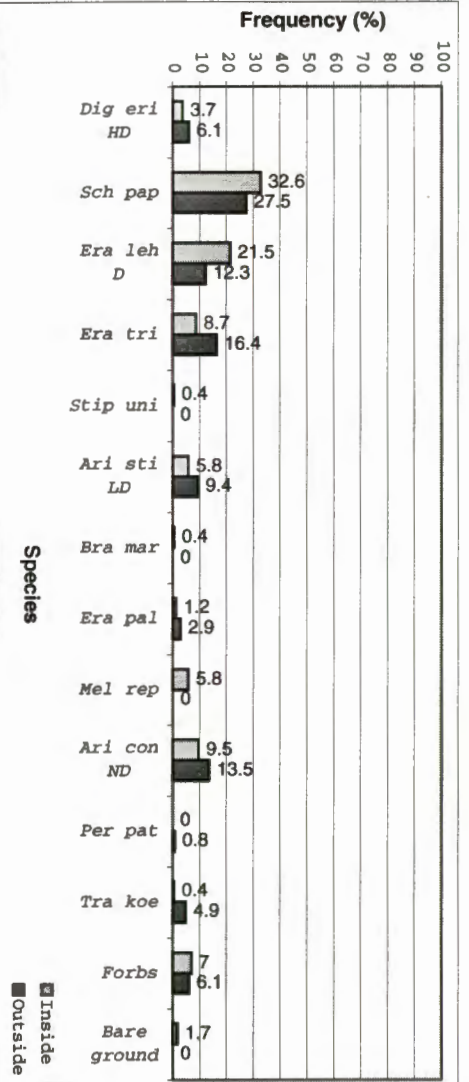


Figure 4.6 d-f: Frequency (%) of grass species inside and outside the enclosure at the Austrey 3 benchmark site during April 2001 (d), December 2001 (e), May 2002 (f) (see Annex C1 & C2 for species abbreviations).

The lower abundance of desirable grass species in December 2001 and May 2002 can be explained by the fact that the seedling recruitment of the less desirable species, mostly pioneer to sub-climax species, was higher in response to the high rainfall. Differences between species in recruitment reflects in part their differences in production and consequent representation in the soil seed bank, as influenced by patterns of grazing selectivity (O'Connor, 1994). In this case the diminution in seedling recruitment of the desirable species, mainly *E. lehmanniana* and *E. trichophora*, could have resulted from the reduction of seed by grazing. The less desirable *A. stipitata* and *M. repens* could thus be grazed to a smaller extent and as a result the number of seeds produced by these species under grazing was greater than that of the desirable grass species. The recruitment of the less desirable species therefore reflects the highest success.

The rangeland condition inside of the enclosure can thus be described as in a slightly better condition than the outside due to the higher frequency of highly desirable and lower frequency of less desirable grass species inside the enclosure.

ii. Grass production

Table 4.7 and Figure 4.7 reflects an increase in the production of the forbs as well as an increase in the percentage (from 7.7% during April 2001 to 26.8% during May 2002) to which the forbs contributed to the total production inside the enclosure. The contribution of the non desirable grass species (mainly *A. congesta* and *P. patens*) to the total production also increased from April 2001 to May 2002 (Figure 4.7).

Table 4.7: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Austrey 3 benchmark site during April 2001 and May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
April 2001	1314.0	1212.8	101.2	7.7	10.2
May 2002	1710.8	1252.8	458.0	26.8	7.9

Although the less desirable grass species increased in their frequency from April 2001 to May 2002 (Figure 4.6 a and c), their contribution to the total production decreased, unlike the production of the highly desirable species, which increased (Figure 4.7). The explanation for this phenomenon is that the dry matter production of the highly desirable species, mostly densely tufted climax or sub-climax grasses, is usually higher than that of the less desirable species, which are mostly loosely tufted sub-climax or pioneer species. At this benchmark site the highly desirable species were mainly represented by *S. pappophoroides*, while *A. stipitata* and *M. repens* contributed mostly to the production of the less desirable species (Figure 4.6f). Snyman (2000) stated that the limiting environmental factor that determines grassland production in the arid and semi-arid areas is rainfall. From this it can be concluded that the increase in the production of all the desirability classes at the Austrey 3

benchmark site (Table 4.11) can mainly be attributed to the high 2001/2002 rainfall season (Figure 4.2 b and c).

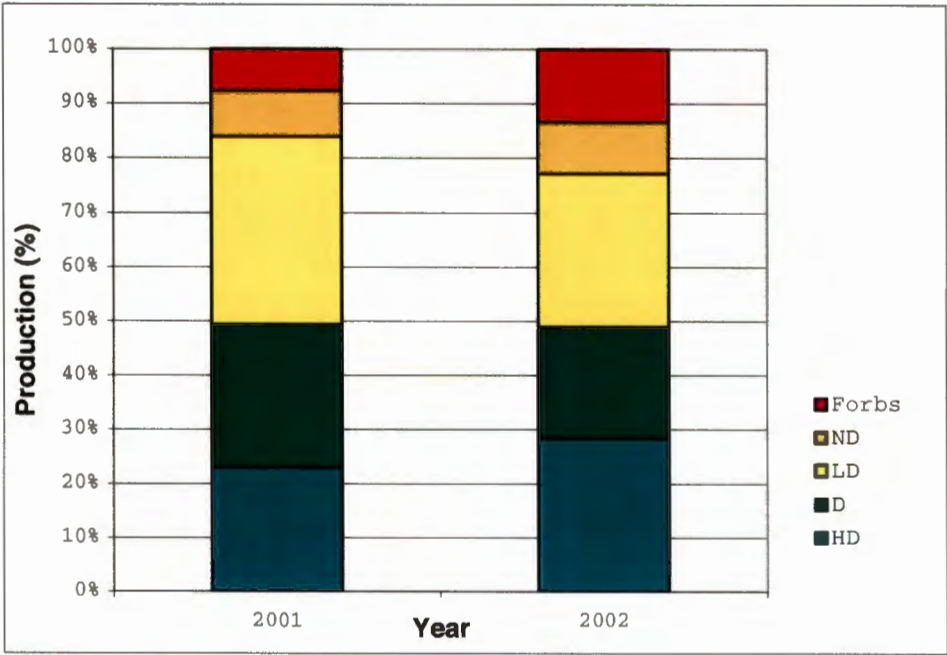


Figure 4.7: The changes in the contributions of the different desirability classes to the total production (%) at the Austrey 3 benchmark site from April 2001 to May 2002.

As can be deduced from the relatively high production figures and the presence of a high abundance highly desirable and desirable grass species during April 2001, this benchmark site was in a relatively good condition since the commencement of the study. This can be ascribed to the fact that the Austrey 3 benchmark site is situated the furthest from the communal village, and consequently also the furthest from the waterpoints. As a result the area in which this benchmark site is located will be less utilised by the grazing animals than the other benchmark sites of the Austrey study area.

The increase in the production of highly desirable species and the total grass production inside the exclosure (from 1314.0 kg/ha during April 2001 to 1710.8 kg/ha during May 2002) gives an indication that the rangeland condition at Austrey 3 improved even further during the course of the study. The improvement of the seasonal grazing capacity, calculated by approach (i), from 10.2 ha/LSU to 7.9 ha/LSU strongly supports this statement (Table 4.7). The seasonal grazing capacities determined by approaches (ii) and (iii) also indicates this improvement, namely from 13.4 ha/LSU in April 2001 to 10.6 ha/LSU in May 2002, and from 9.5 ha/LSU in April 2001 to 7.9 ha/LSU in May 2002, respectively (Annex E).

4.2.1.4. Austrey 4 benchmark site

Due to the initial lack of manpower, plant surveys were only carried out at Austrey 4 since December 2001.

i. *Grass species composition*

Slight to moderate overgrazing leads to an increase in the abundance of unpalatable perennial species (van Oudtshoorn, 1999). This increase is probably due to the stimulation of unpalatable grasses (grazed, but under relatively low grazing pressures) and overgrazing of the palatable perennials (Bosch & Gauch, 1991). This can be observed at the Austrey 4 benchmark site, which is dominated by less desirable grass species during December 2001 and May 2002 (Figure 4.8 a and b). *Aristida stipitata* is the grass specie that contributed mostly to the high frequency of less desirable species on the inside (25.5%) and outside (39.2%) of the exclosure (Figure 4.8 c and d). *Aristida stipitata* is also classified as an increaser II species and will thus increase in frequency under conditions of overgrazing. Hence it could be concluded that the rangeland at this benchmark site was being overgrazed in the past.

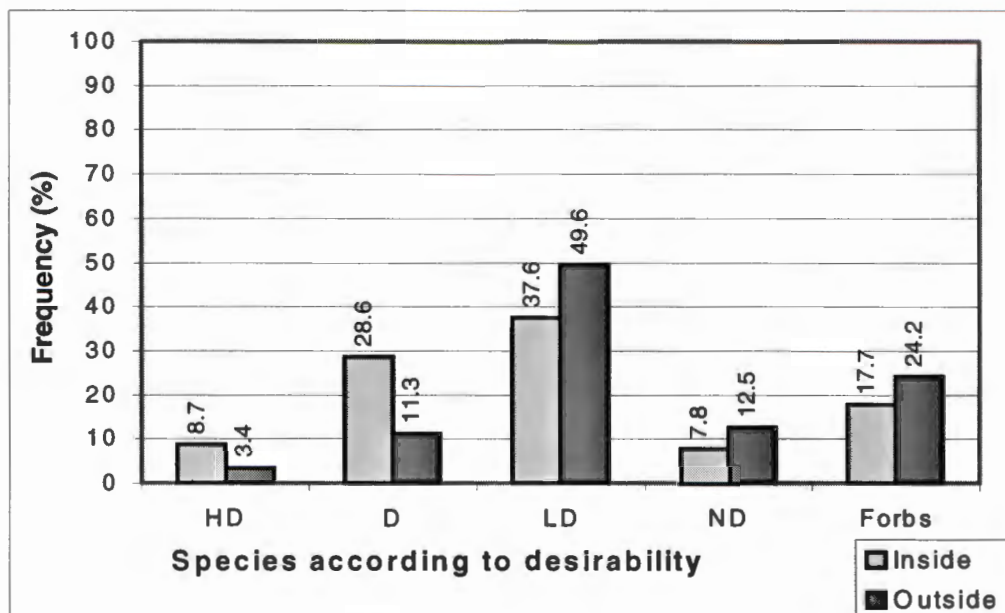
Although the highly desirable grass species were at first only represented by *D. eriantha* and *S. pappophoroides*, the presence of *B. nigropedata* was also noted inside and outside the exclosure during May 2002 (Figure 4.8d). The abundance of desirable grass species, mostly *E. trichophora*, decreased on the inside of the exclosure from December 2001 to May 2002. An increase in the frequency of less desirable and non desirable species was observed inside and outside the exclosure (Figure 4.8 a and b). Outside of the exclosure the non desirable species, such as *A. congesta*, *P. patens*, *Trichoneura grandiglumis* and *E. biflora* (Figure 4.8 c and d), and desirable grass species increased in frequency during the study period. The abundance of the less desirable species remained relatively constant on the outside of the exclosure. The forbs did however decrease in abundance, most likely due to the increased frequency of the non desirable species, which were subsequently recorded to a greater extent than the forb species.

No marked difference can be observed in the abundance of the highly desirable species between December 2001 to May 2002, or between the grass species composition inside and outside of the exclosure. From Table 4.8 it is evident that the grass species composition inside and outside the exclosure increased in similarity from 57.2%, during December 2001, to 63.6%, during May 2002. It can thus be concluded that the short four month period between the two consecutive plant surveys, does not provide enough time for marked vegetation compositional changes to occur.

Table 4.8: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the exclosure at the Austrey 4 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Austrey 4	December 2001	57.2
	May 2002	63.6

a)



b)

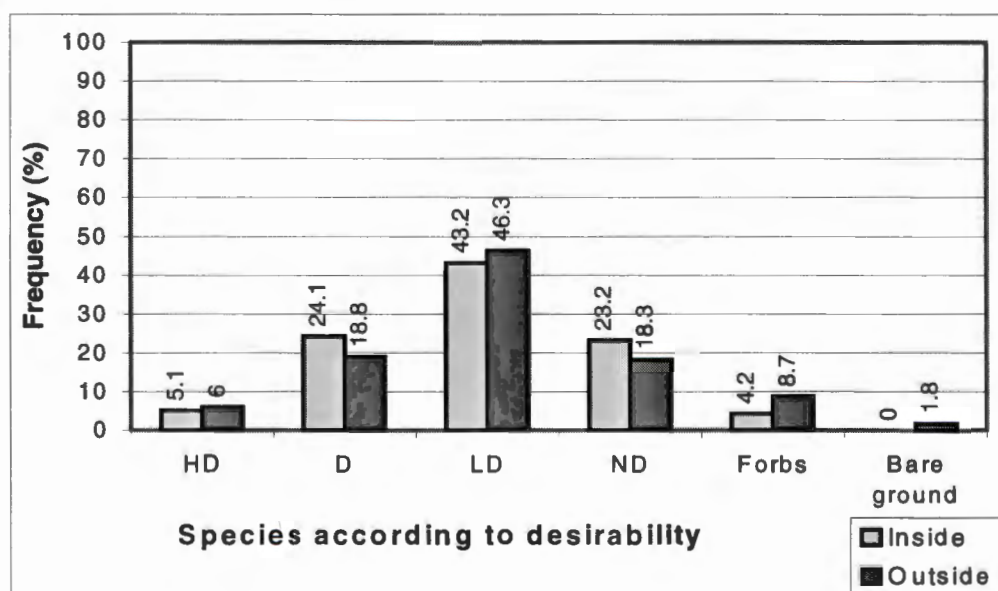


Figure 4.8 a and b: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Austrey 4 benchmark site, during December 2001 (a) and May 2002 (b).

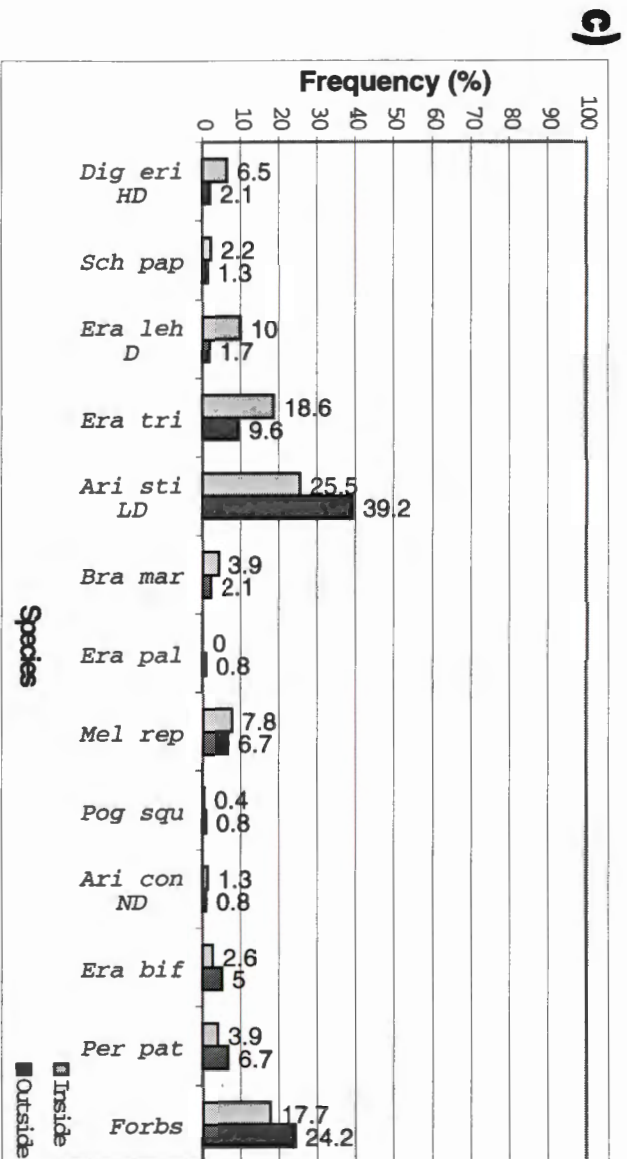


Figure 4.8 c and d: Frequency (%) of grass species inside and outside the enclosure at the Austrey 4 benchmark site, during December 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

ii. *Grass production*

The total grass production at Austrey 4 during May 2002 is 1081.5kg/ha. The seasonal grazing capacity calculated by approach (i) is 18.7 ha/LSU (Table 4.9), while it is 23.3 ha/LSU and 14.5 ha/LSU if calculated by approaches (ii) and (iii), respectively (Annex E).

Table 4.9: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Austrey 4 benchmark site during May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
May 2002	1081.5	795.7	285.8	26.4	18.7

The less desirable grass species, already identified during the determination of the species composition as *A. stipitata*, *E. pallens*, *M. repens* and *P. squarrosa*, contributes the most to the total grass production (Figure 4.9). The less desirable grass species were followed by the production of the desirable grass species (mostly *E. lehmanniana* and *E. trichophora*), non desirable grass species (represented by *A. congesta*, *E. biflora*, *P. patens* and *T. grandiglumis*), forbs, and then the highly desirable grass species, *B. nigropedata*, *D. eriantha* and *S. pappophoroides*. The dry matter production of the forbs contributed to 26.4% of the total grass production.

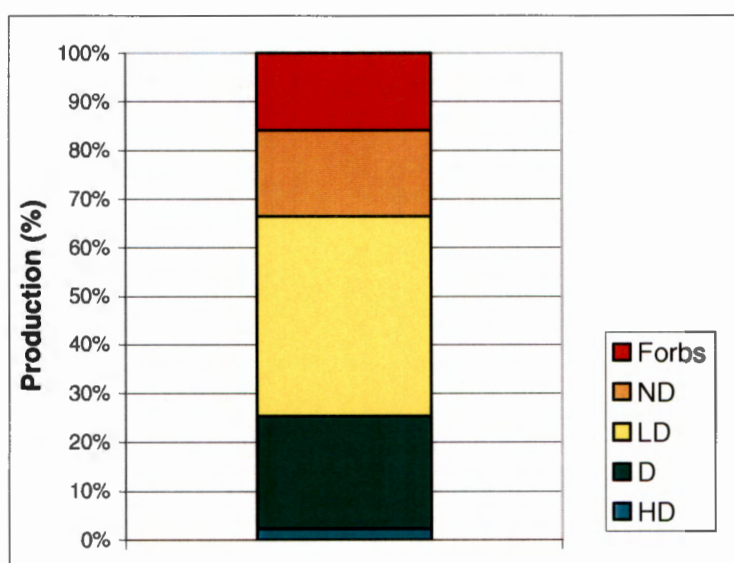


Figure 4.9: Contributions of the different desirability classes to the total production (%) at the Austrey 4 benchmark site during May 2002.

4.2.1.5. Summary for the benchmark sites at Austrey

As already mentioned in Section 3.1 (Chapter 3) the benchmark sites were selected in order to represent rangeland in different conditional states. Initially, as suitable locations for the benchmark sites were identified in collaboration with the specific agricultural extension officers, the enclosure at Austrey 1 was selected to represent rangeland in a poor condition. The enclosures at Austrey 2 and 3 were chosen to represent rangeland in a moderate and a good condition respectively.

Taking the grass species composition into account, Austrey 1 consisted of a better rangeland condition than Austrey 2 since the commencement of the study in April 2001. This can be deduced from the higher abundance of desirable grass species (*E. lehmanniana* and *E. trichophora*) at Austrey 1 (Figure 4.1 a and d) than at Austrey 2, which was in turn dominated by less desirable species, mainly *A. stipitata* and *M. repens* (Figure 4.4a). At Austrey 3 the high frequency of highly desirable (*D. eriantha* and *S. pappophoroides*), desirable and less desirable grass species indicates that this benchmark site consists of the best rangeland condition in comparison with Austrey 1 and 2 (Figure 4.6 a-c). As was already referred to (see Section 4.2.1.3), this can be attributed to the fact that Austrey 3 was situated the furthest from the waterpoints and village, where the grazing animals (goats, sheep, cattle, donkeys and horses) are kept. Accordingly it can be deduced that this benchmark was the least subjected to overgrazing during the past.

The Z-indices determined for these four benchmark sites were all relatively high, indicating that the study period was not long enough in order to detect major differences in the grass species composition between the inside and outside of the enclosures (Annex D). The Z-index values at all four benchmark sites also shows a greater decrease from April 2001 to December 2001 than from April 2001 to May 2002. It could thus be concluded that the grass species composition greatly depends upon the seasonal rainfall variability.

If the total dry matter production in April 2001 is taken into consideration the three benchmark sites clearly represent the different conditional states, with a total production of 203.7kg/ha, 366kg/ha and 1314.0kg/ha at Austrey 1, 2 and 3 respectively (Table 4.10). This can also be explained by the fact that Austrey 1 is located nearest to the waterpoints and subsequently undergoes the most severe grazing pressure in the Austrey study area. The percentage to which the production of the forbs contributed to the total production also reflects a rangeland conditional gradient with the percentage of forbs at Austrey 1 at 57.9%, Austrey 2 at 25.2% and Austrey 3 at 7.7%.

Mainly the climate, management practices employed and soil characteristics will determine the grassland production (De Jager *et al.*, 1980). Seeing that the two year period in which the study was conducted is too short for changes to occur in the soil composition due to a change in the management applied, only the climate and management practices applied can be considered as causes for changes in grassland production.

Table 4.10: The total production (forbs included), grass production (forbs excluded), forbs production and the percentage that forbs contributed to the total production at the Austrey study site, during April 2001 and May 2002.

Date	Benchmark sites	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)
April 2001	Austrey 1	203.7	85.7	118.0	57.9
	Austrey 2	366.4	274	92.4	25.2
	Austrey 3	1314	1212.8	101.2	7.7
May 2002	Austrey 1	1002.4	757.9	244.5	24.4
	Austrey 2	877.1	722.9	154.2	17.6
	Austrey 3	1710.8	1252.8	458.0	26.8
	Austrey 4	1081.5	795.7	285.8	26.4

From Table 4.11 it is clear that the seasonal grazing capacity (determined by approach (i)) at Austrey 1 shows the greatest improvement, from 195.2 ha/LSU in April 2001 to 21.7 ha/LSU in May 2002, of the four benchmark sites. The seasonal grazing capacity increased at all the benchmark sites in the Austrey study area, except at Austrey 4 where the grass production was cut only once during May 2002. At the Austrey 1 benchmark site the production of all the desirability classes increased considerably. It is however evident that the production of the non desirable grass species increased to the greatest extent, with 279 kg/ha. The increase in the production of the less desirable (293 kg/ha) and non desirable (141 kg/ha) grass species contributed mostly to the improvement of the seasonal grazing capacity at the Austrey 2 benchmark site. The Austrey 3 benchmark site shows an improvement in the seasonal grazing capacity mainly due to the increased production of the highly desirable grass species from 302 kg/ha in April 2001 to 486 kg/ha in May 2002. If the seasonal grazing capacities determined by approaches (ii) and (iii) are also taken into consideration, it can be seen that the same trend in the improvement of the seasonal grazing capacities, as was observed by using approach (i), is reflected (Annex E).

The considerable increase in the production figures and the improvement of the seasonal grazing capacity at Austrey 1, 2 and 3 during May 2002 (Table 4.11) can thus be contributed partly to the above average rainfall received in the study area during the growing season (Figure 4.2 b and c). This increase can also be partly ascribed to the fact that rest was applied inside the enclosure and grazing was only allowed during the winter.

It seems as though the rangeland condition (if only the grass production is taken into account) at Austrey 1, with a total grass production of 1002.4kg/ha, improved to such an extent that Austrey 2, with a total grass production of 877.1kg/ha, can now be described as the benchmark site consisting of the poor rangeland condition. The rangeland at Austrey 1, can thus be described as being in the moderate condition. Although the high rainfall figures most probably caused the increase in the dry matter production of the forbs (458kg/ha) at Austrey 3, this benchmark site can still be described as consisting the best rangeland condition in comparison to the Austrey 1 and 2 benchmark sites.

Table 4.11: The dry matter (DM) production figures (kg/ha) for the different grass species desirability classes, and the seasonal grazing capacity determined by approach (i) (ha/LSU) at the Austrey benchmark sites, during April 2001 and May 2002.

Benchmark site	Date	DM production of HD grass species (kg/ha)	DM production of D grass species (kg/ha)	DM production of LD grass species (kg/ha)	DM production of ND grass species (kg/ha)	Seasonal grazing capacity (ha/LSU) determined by approach (i)
Austrey 1	April 2001	6	22	32	27	195.2
	May 2002	83	220	150	306	21.7
Austrey 2	April 2001	6	36	159	73	30.8
	May 2002	4	70	452	214	27.1
Austrey 3	April 2001	302	347	454	110	10.2
	May 2002	486	352	482	162	7.9
Austrey 4	May 2002	25	249	444	192	18.7

The Austrey 4 benchmark site can thus be classified as being in a moderate condition with respect to the other three benchmark sites in the Austrey study area. This can be gathered from its moderately high production figure of 1081.5 kg/ha (Table 4.11), the relatively good seasonal grazing capacity of 18.7 ha/LSU (Table 4.11), and the relatively high abundance of desirable and less desirable grass species at Austrey 4 (Figure 4.8 a and b).

Some of the results of the soil analysis (inside and outside the enclosure) done for these four benchmark sites are conveyed in Table 4.12. According to the soil classification working group (1991), the soil texture at this study site can be described as sand seeing that the soil at all the benchmark sites consist of between 85-95% sand (average sand particle content is 88.5%).

The soil pH of between 5.34-5.47 classifies the soil at Austrey 1 and 2 as strongly acidic, while the soil at Austrey 3 and 4 can be classified as medium acidic because the pH at these sites varies between 5.54 and 5.80. Soils are acidic due to intensive leaching of base elements (Taddese, 2001). This explains the low Cation exchange capacity (CEC) values, with an average value of 3.08 cmol+/kg at these benchmark sites. One of the most important influences of pH on plant growth is its effect on the availability of nutrients for plants (Foth, 1990). As soil acidity increases, potassium (K), calcium (Ca), and magnesium (Mg), which is already present in very low amounts, show less availability as a result of the decreasing CEC.

The moderate and good rangeland conditions at Austrey 4 and 3, respectively, can thus partly be ascribed to their higher pH values. The considerably low phosphorous (P), average of 3.24 mg/kg, and carbon (C), average of 0.24 %, content of the soil indicates that planted pastures should not be established at this study site.

Table 4.12: Some of the results of the soil analyses done for the benchmarks at the Austrey study site (complete set of results can be viewed in Annex B).

Benchmarks	pH	P (mg/kg)	K (mg/kg)	CEC (cmol+/kg)	C (%)	Clay (%)	Silt (%)	Sand (%)
Austrey 1 Inside	5.47	3.11	35.1	3.79	0.26	10	0.1	89.9
Austrey 1 Outside	5.36	3.06	49.6	4.08	0.24	10	2.3	87.7
Austrey 2 Inside	5.47	3.08	30.8	2.95	0.21	10	0.1	89.9
Austrey 2 Outside	5.34	3.26	29.3	2.31	0.21	8	3.3	88.7
Austrey 3 Inside	5.79	3.35	68.8	3.64	0.24	8	4.2	87.8
Austrey 3 Outside	5.68	3.37	70.1	2.82	0.28	8	5.1	86.9
Austrey 4 Inside	5.54	3.25	40.9	2.56	0.24	6	7.3	86.7
Austrey 4 Outside	5.80	3.46	41.7	2.49	0.23	6	3.9	90.1
Average values	5.57	3.24	45.79	3.08	0.24	8	3.3	88.5

4.2.2. Morafe ranch management at the Waterfouchè study site

The Waterfouchè study area is also situated in the Ganyesa magisterial district of the western region in the North West Province. It is divided into the Pomfret ADC and accordingly into the Driefontein FSU (Figure 2.4). This Morafe ranch covers an area of 29 000 hectares and is further divided into sub-units of 600 hectares each. Although twenty-five farmers are currently farming on the Waterfouchè study area, no fixed number of sub-units has yet been allocated to the individual farmers. According to the agricultural extension officer of this area (Table 4.13) the recommended grazing capacity of the area currently is 9ha/LSU. The four camp rotational grazing system is being promoted in order to rest the rangeland. According to a subjective estimation of the land users as well as the agricultural extension officer's opinion, the rangeland condition at this study site is reasonably good and accordingly meets up to their expectations and requirements as good grazing for their livestock.

Table 4.13: The ADC manager and agricultural extension officer at the Waterfouchè study site.

District	Benchmark site	Management system	ADC manager	Agricultural extension officer
Ganyesa	Waterfouchè	Morafe ranch	Robert Gasealahwe Tel: (053) 998 3343 : 072 210 0632	Gert Namelang Tel: (053) 761 0005 : 082 648 1226 Fax: (053) 761 0024

Even though the DACE advises against the keeping of goats and sheep on the Morafe ranches, at the Waterfouchè study site, goats and donkeys are still kept to graze the rangeland together with the cattle. A project committee already exists in the community. The task of this committee is to look after the maintenance of the infrastructure in the Morafe ranch. The exclosures at the Waterfouchè benchmark sites were only erected during April 2001 (*see* Table 2.2 in Chapter 2), and accordingly vegetation surveys during April 2001 could only be conducted at the

Waterfouchè 1 benchmark site, where the enclosure had already been erected. The grass production surveys were only carried out at Waterfouchè 2, 3, 4, 5, and 6 during May 2002, while the grass species composition was determined twice (during December 2001 and May 2002) at these benchmark sites. The grass production data at these sites can thus mainly be used as baseline data for future studies in the same or similar study areas.

4.2.2.1. Waterfouchè 1 benchmark site

i. *Grass species composition*

The grass species composition inside and outside the enclosure at the Waterfouchè 1 benchmark site is mainly characterised by desirable grass species throughout the study period (Figure 4.10 a, b and c). The frequency of the desirable species, mainly *E. lehmanniana* and *E. trichophora* (Figure 4.10d), however increased to the same extent inside and outside the enclosure in December 2001 (Figure 4.10b). This increase after the low rainfall period in the year 2000 (Figure 4.11a) can be ascribed to the very high rainfall season that commenced in September 2001 and lasted until January 2002 (Figure 4.11 b and c). It thus reflects that resting the rangeland inside the enclosure has not yet resulted in a change in species composition. The high occurrence of these two increaser II species indicates that the benchmark site was slightly to moderately overgrazed.

The increase in the frequency of desirable species as well as the forbs during December 2001 led to a decrease in the amount of bare patches both inside and outside the enclosure. The frequency of desirable species decreased only slightly from December 2001 to May 2002, while the percentage bare patches accordingly increased (Figure 4.10c). The decrease in the desirable species frequency (inside and outside the enclosure) can be attributed to the mortality of small individuals which was recently recruited or which fragmented from existing tufts (O'Connor, 1994). The reason for this could be ascribed to the lower rainfall that occurred from February to May 2002 (Figure 4.11c).

No marked differences can be observed between the grass species composition inside and outside the enclosure (Figure 4.10 a-c). This observation is confirmed by the Z-index values determined for the enclosure at the Waterfouchè 1 benchmark site (Table 4.14). Even though the grass species compositions inside and outside shows a slight decrease in similarity from April 2001 (83.6%) to December 2001 (71.0%), the Z-index value increased again to a value of 84.3% during May 2002.

Table 4.14: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Waterfouchè 1 benchmark site during April 2001, December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Waterfouchè 1	April 2001	83.6
	December 2001	71.0
	May 2002	84.3

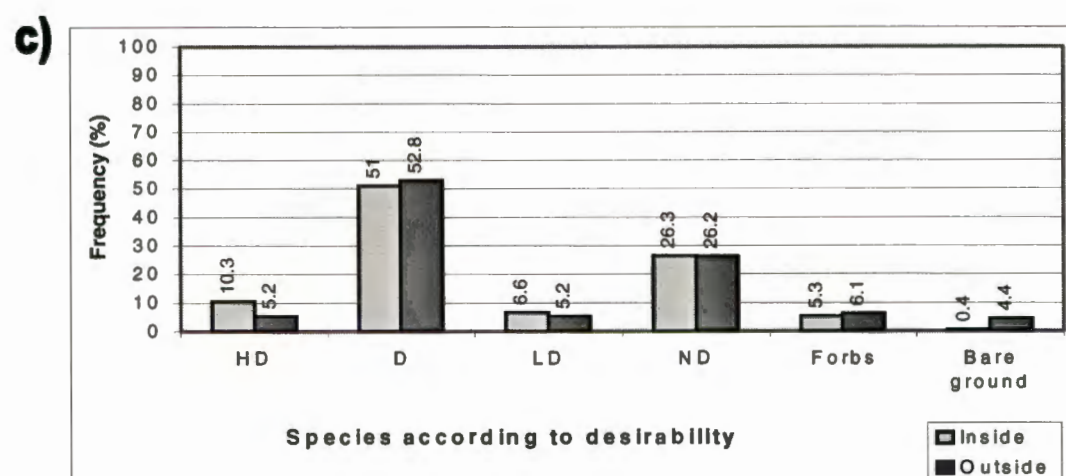
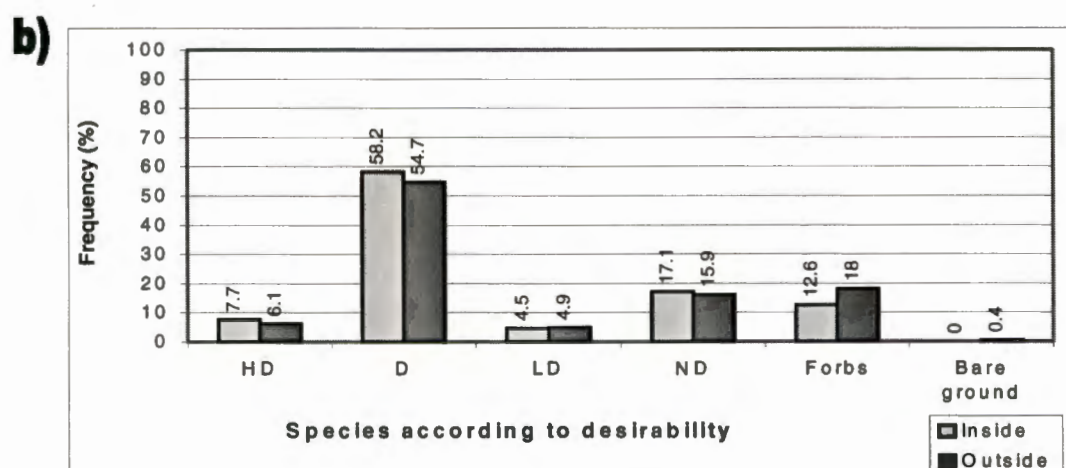
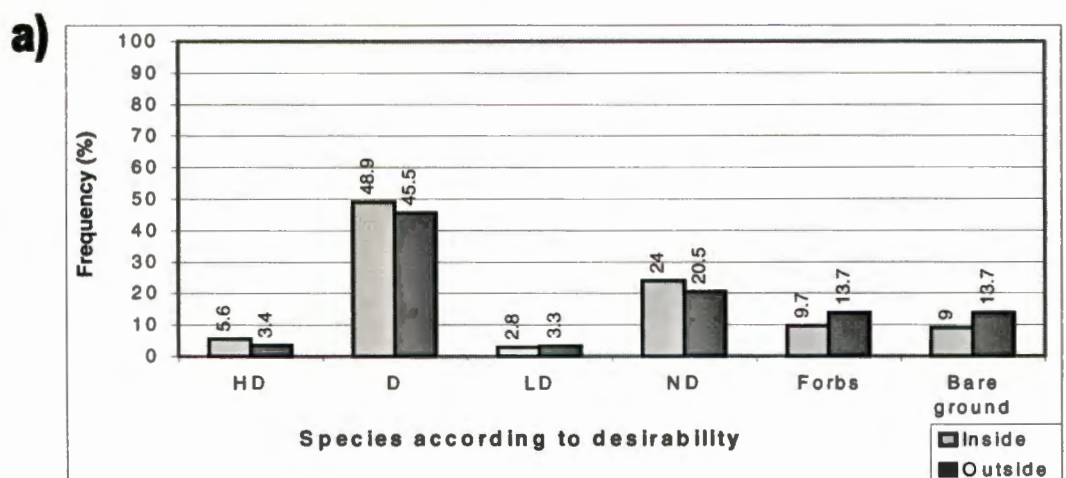


Figure 4.10 a-c: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Waterfouchè 1 benchmark site, during April 2001 (a), December 2001 (b) and May 2002 (c).

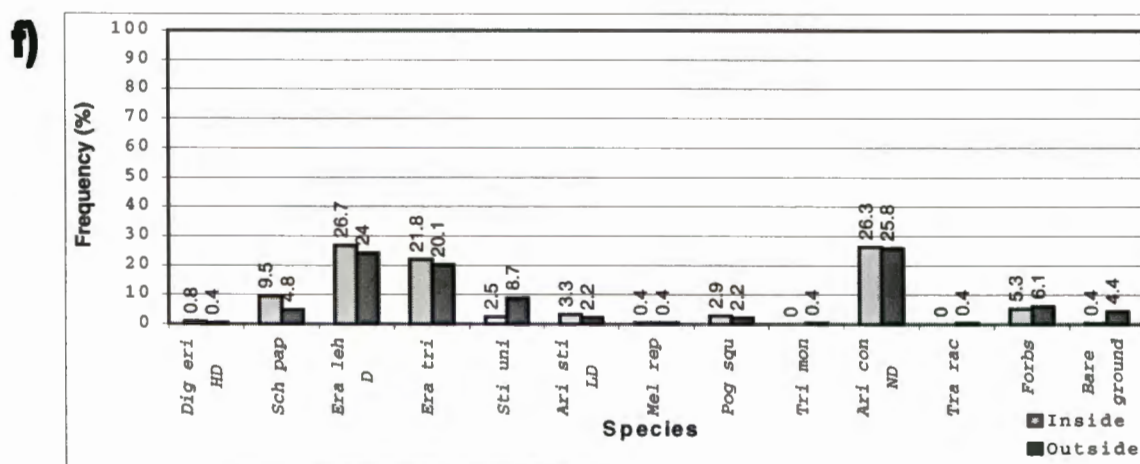
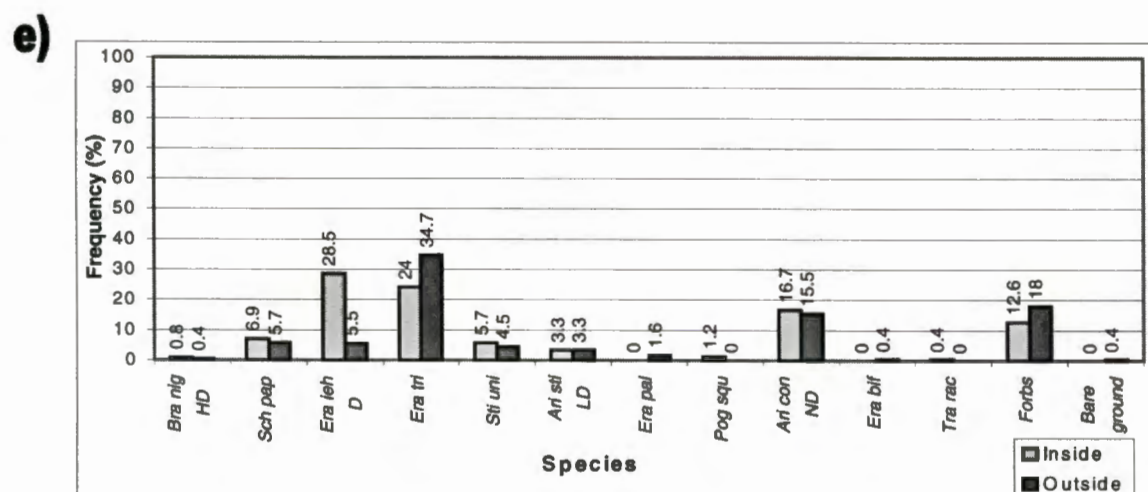
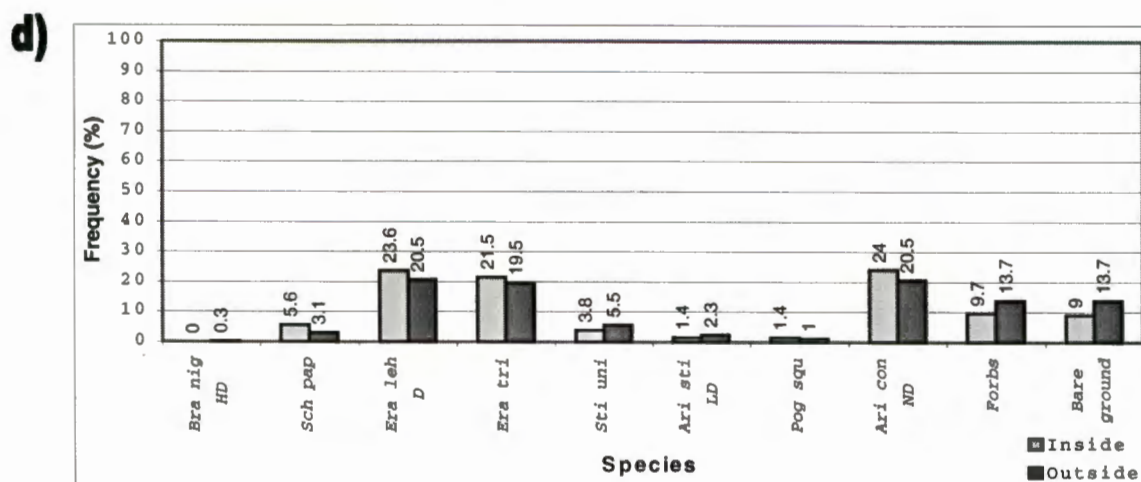


Figure 4.10 d-f: Frequency (%) of grass species inside and outside the enclosure at the Waterfouchè 1 benchmark site during April 2001 (d), December 2001 (e) and May 2002 (f) (see Annex C1 & C2 for species abbreviations).

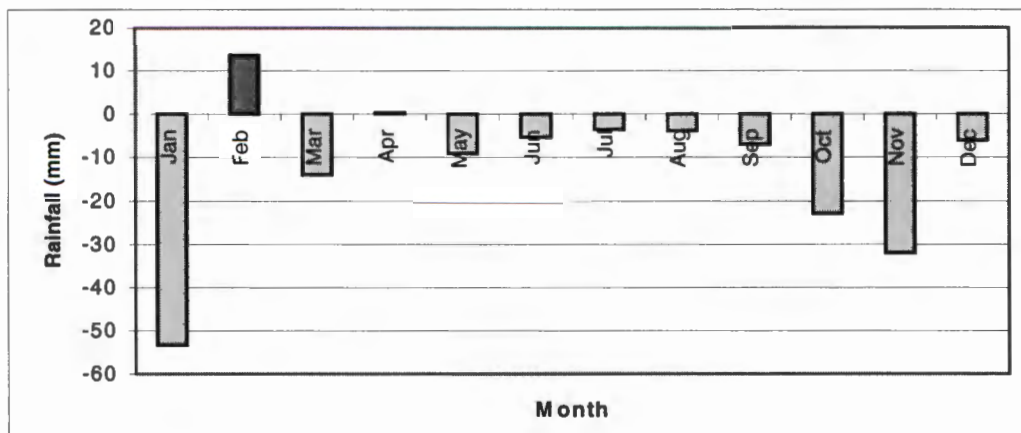
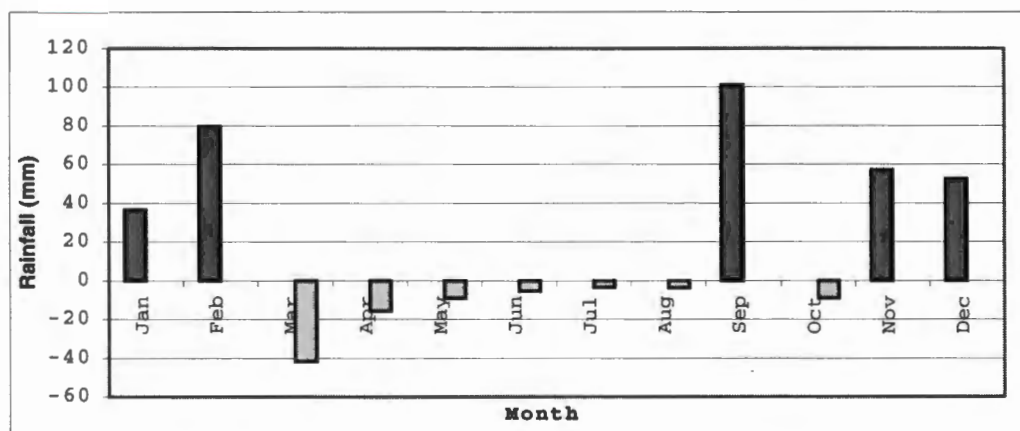
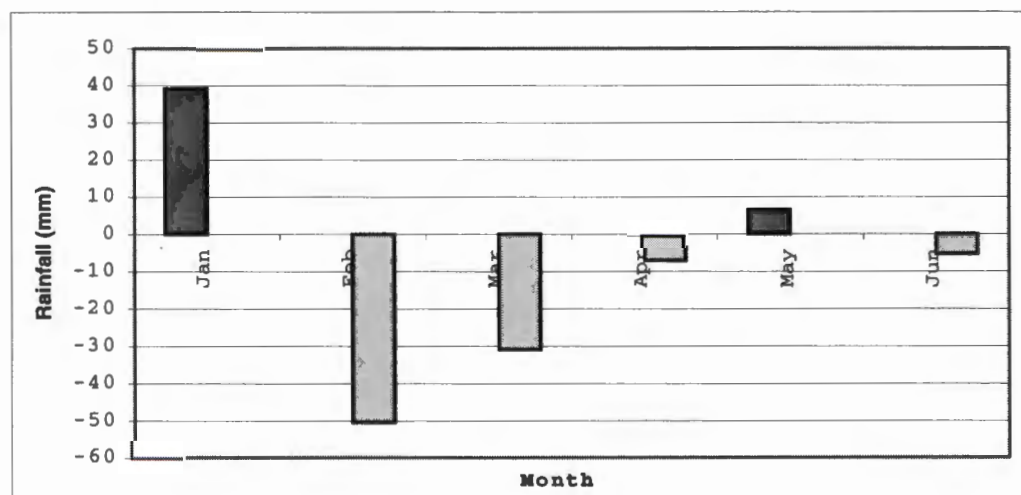
a)**b)****c)**

Figure 4.11 a-c: Rainfall deviation from the average rainfall at the Waterfouchè study site during the years 2000 (a), 2001 (b) and 2002 (c).

These changes in the Z-index value could be explained by Figure 4.10e, which reflects that the frequency of *E. trichophora* increased to a larger extent outside than on the inside of the enclosure, while the frequency of *E. lehmanniana* increased more on the inside of the enclosure than on the outside, during December 2001. In May 2002 these differences were not experienced again (Figure 4.10f). This can be explained according to O'Connor (1994), who states that vegetation compositional changes can only be fully explained in terms of the population processes of the dominant species, because even apparently stable populations exhibit considerable population fluxes.

A slight increase in the abundance of the highly desirable species, such as *B. nigropedata*, *D. eriantha* and, *S. pappophoroides*, as well as the less desirable species, namely *A. stipitata* and *P. squarrosa*, could also be observed throughout the study period (Figure 4.10 a-c). The non desirable grass species decreased in frequency from April 2001 to December 2001 (Figure 4.10 a and b). This can be contributed to the increase in the frequency of the desirable grass species during the growing season, which led to the fact that the non desirable grass species were recorded less during the vegetation surveys. These non desirable species, mainly *A. congesta* (Figure 4.10e), however again increased in abundance, as the desirable species decreased (Figure 4.10c). This can be explained by the lower rainfall figures towards the end of the growing season (February to April 2002).

If only the grass species composition is considered it can be concluded that the rangeland condition of this benchmark site seems to be fairly good.

ii. Grass species production

According to the grass production the highly desirable (mainly *S. pappophoroides*) as well as the desirable grass species (*E. lehmanniana*, *E. trichophora* and *S. uniplumis*) decreased in their contribution to the total grass production from April 2001 to May 2002 (Figure 4.12). The contribution of the less desirable (mainly *A. stipitata* and *P. squarrosa*), non desirable (mainly *A. congesta*) and forb species increased to the total production during this period.

This again seems contradictory to the frequency measurements (see Section 4.2.1.2. i). It is thus important to remember that Figure 4.12 only serves as an indication of the change in the contribution of the different desirability classes to the total grass production, and that the production of all the desirability classes did increase (Table 4.27 and Annex E). One explanation for the fact that the highly desirable and desirable grass species did not contribute as much to the total production during May 2002 as was expected, can be that although they were higher in abundance, their tuft sizes decreased due to the below average rainfall period from February to April 2002 (Figure 4.11c). The highly desirable and desirable grass species thus increased in density, but not in tuft size. The forbs on the other hand increased in size and accordingly gave rise to a greater contribution to the total production because of their higher biomass.

The production of the forbs increased from 28.6 kg/ha during April 2001 to 274.7 kg/ha during May 2002, thus contributing greatly to the increase in the total

production (Table 4.15). As was mentioned before (see Section 4.2.1.1) it is important to keep in mind that forbs were not considered in the seasonal grazing capacity calculations, and changes in the forb production can thus not be used to explain changes in the seasonal grazing capacities.

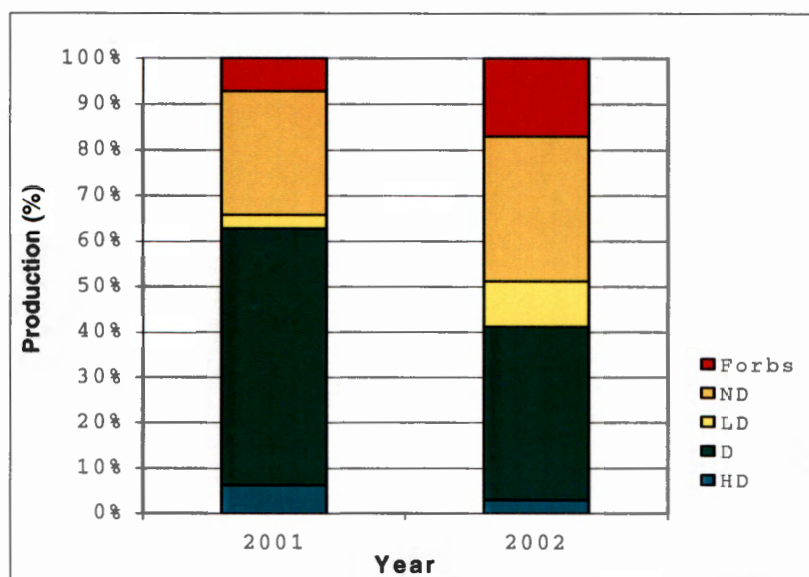


Figure 4.12: The changes in the contributions of the different desirability classes to the total production (%) at the Waterfouchè 1 benchmark site from April 2001 to May 2002.

The non desirable and less desirable species did however show an increase in abundance from April 2001 to May 2002 (Figure 4.10 a and c). It can thus be concluded that the persistent seed bank of the grass species representing these two desirability classes responded to the high rainfall and contributed to the total production accordingly.

The total production inside the enclosure increased from 399.8kg/ha in April 2001 to 1601.1kg/ha in May 2002 (Table 4.15). As can be seen from this data, and according to O'Conner (1991) annual rainfall variation has an important influence on the production of grass species in the savanna region of South Africa. As a result of the increase in the total grass production the seasonal grazing capacity (determined by approach (i)) also improved from 39.1 ha/LSU to 12.6 ha/LSU. The same degree of improvement (31%) can also be observed through calculating the seasonal grazing capacity by approaches (ii) and (iii) (Annex E). In spite of the high rainfall and the fact that the inside of the enclosure was rested, the grazing capacity has not yet recovered to the recommended long-term grazing capacity of 9ha/LSU (see Section 4.1.2). It can thus be concluded that a longer rest period would be necessary for this rangeland to again measure up to its full potential.

Table 4.15: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Waterfouchè 1 benchmark site during April 2001 and May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
April 2001	399.8	371.2	28.6	7.2	39.1
May 2002	1601.1	1326.4	274.7	17.2	12.6

4.2.2.2. Waterfouchè 2 benchmark site

i. *Grass species composition*

According to O'Connor (1991) it should be recognised that the effects of grazing only manifests over long time periods and that climatic effects might eclipse grazing effects over a three-year time period. The four month period between the conduction of the two vegetation surveys (December 2001 and May 2002) is thus too short to detect any definite species compositional changes. Some small variations in the grass species composition did however occur. These variations can mainly be attributed to the rainfall figures. The higher rainfall figures during September and November 2001 caused the higher frequencies in the less desirable grass species and forbs inside and outside the enclosure, during December 2001 (Figure 4.13a) than during May 2002 (Figure 4.13b). The frequency of the highly desirable, desirable and non desirable species increased (inside and outside the enclosure) from December 2001 to May 2002.

Aristida stipitata is the dominant grass species at this benchmark site (Figure 4.13 c and d). The high abundance of this species indicates that the vegetation at Waterfouchè 2 is in a pioneer or sub-climax state. It also indicates that this benchmark site was subjected to short-term moderate overgrazing before the enclosure was erected, seeing that *A. stipitata* is classified as an increaser II species.

As the less desirable species decreased in response to the lower rainfall during February, March and April 2002 (Figure 4.11c), the abundance of the higher desirable species (*S. pappophoroides*) and desirable species, namely *E. lehmanniana* and *S. uniplumis* increased (Figure 4.13 c and d). This could be due to the better and deeper root structure of these species, making it a better competitor, and subsequently causing the decrease in the pioneer and less desirable species.

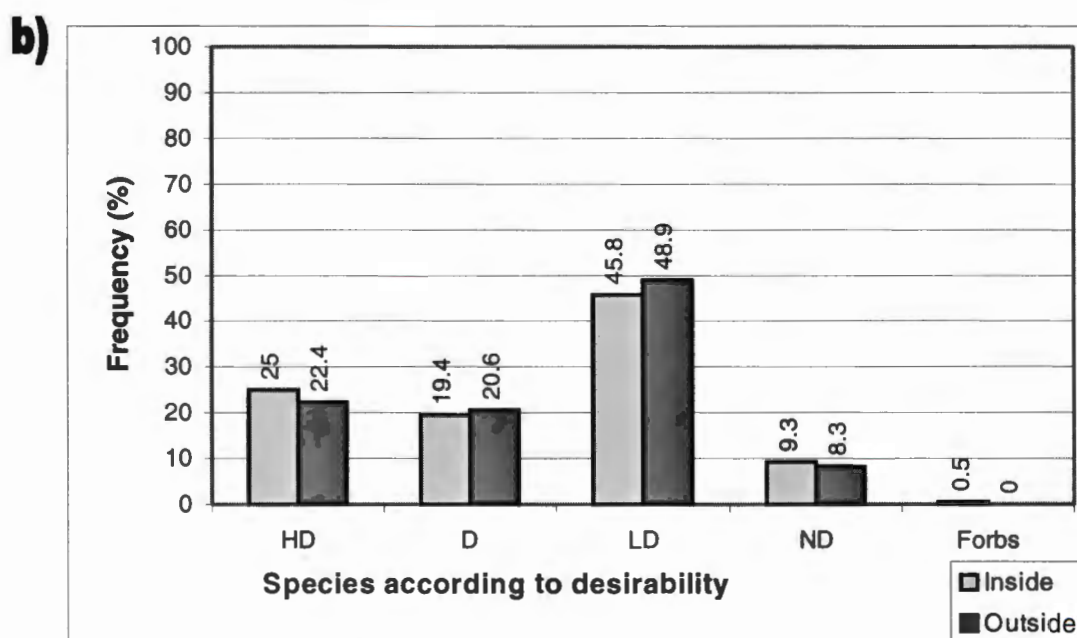
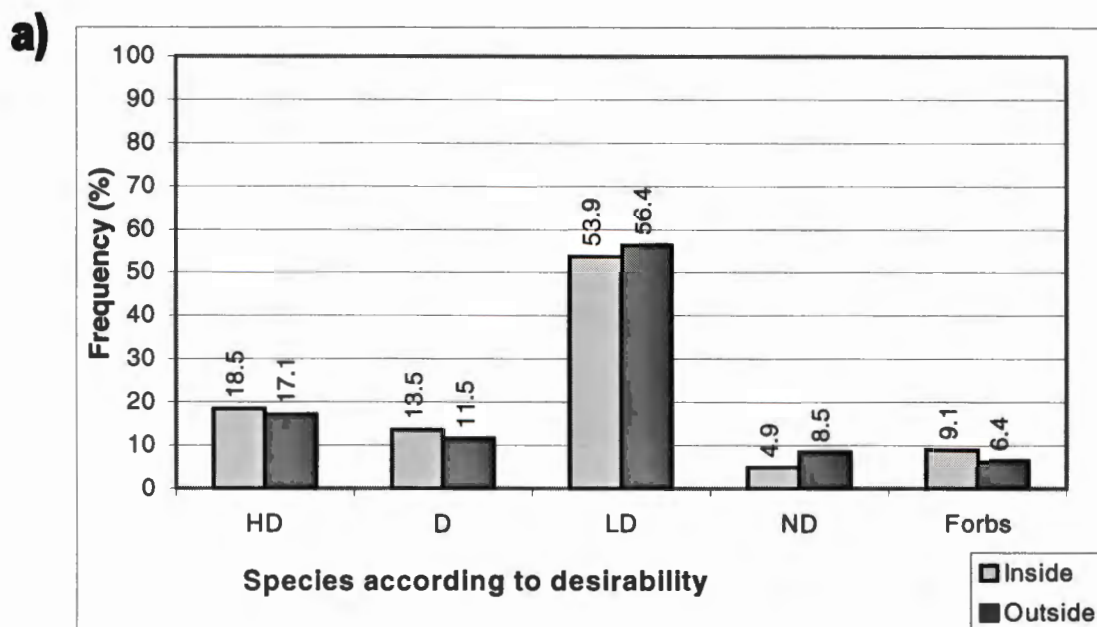


Figure 4.13 a and b: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Waterfouchè 2 benchmark site, during December 2001 (a) and May 2002 (b).

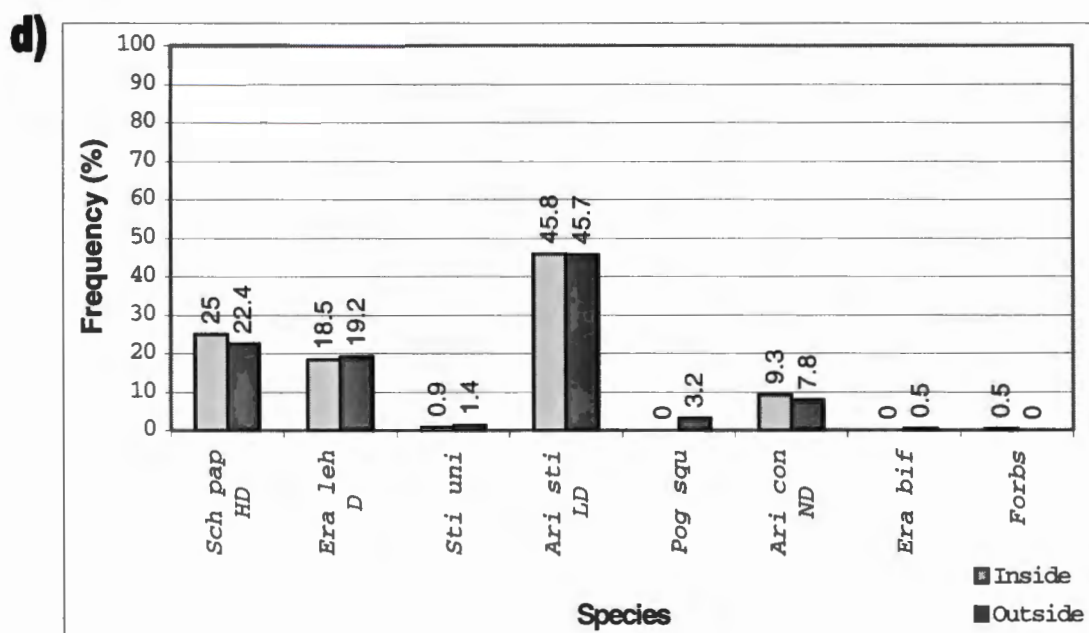
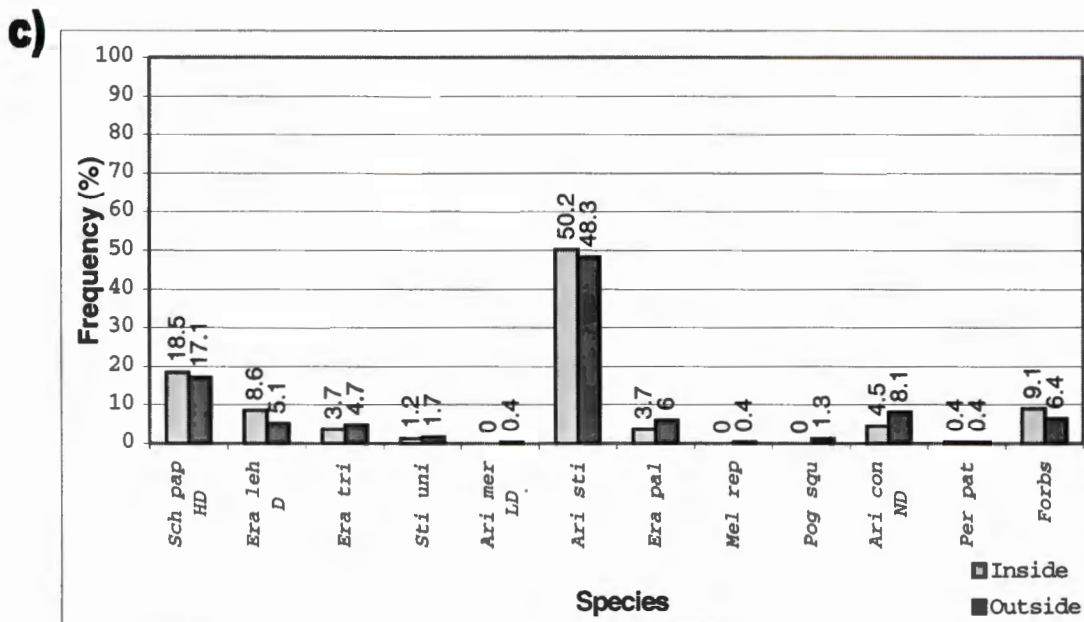


Figure 4.13 c and d: Frequency (%) of grass species inside and outside the enclosure at the Waterfouchè 2 benchmark site during December 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

From Table 4.16 it is clear that the similarity in the grass species composition inside and outside the enclosure is relatively high. The Z-index value even increased from December 2001 (85.9%) to May 2002 (93.1%). Also no marked differences were detected between the species composition inside and outside the enclosure from Figure 4.13 a-d. Accordingly the fact that the study period was too short to detect any prominent changes in the vegetation composition, and that the data of this study will mainly serve as baseline data for the future monitoring of the study site, must be stressed.

Table 4.16: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Waterfouchè 2 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Waterfouchè 2	December 2001	85.9
	May 2002	93.1

iii. Grass production

The total grass production inside the enclosure at the Waterfouchè 2 benchmark site in May 2002 was 1693.9kg/ha (Table 4.17). By means of the utilisation factors allocated to the different grass desirability classes according to approach (i) the seasonal grazing capacity was determined as 9.1 ha/LSU. This value coincides with the recommended long-term grazing capacity of the Waterfouchè study site (see Section 4.2.2). The seasonal grazing capacities that were calculated by approaches (ii) and (iii) are 11.1 ha/LSU and 7.1 ha/LSU, respectively (Annex E).

Table 4.17: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by approach (i), at the Waterfouchè 2 benchmark site during May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
May 2002	1991.4	1693.9	297.5	14.9	9.1

The production of the less desirable grass species, *A. stipitata* and *P. squarrosa*, contributed mostly (946.0 kg/ha) to the total production (Figure 4.14 and Table 4.26). They were followed by the production of the desirable grass species (345.0 kg/ha), *E. lehmanniana* and *S. uniplumis*, forbs (297.5 kg/ha), non desirable grass species (235.0 kg/ha), *A. congesta* and *E. biflora*, and then the highly desirable grass species (169.0 kg/ha), *S. pappophoroides*. The forbs contributed to 14.9% of the total production (Table 4.17).

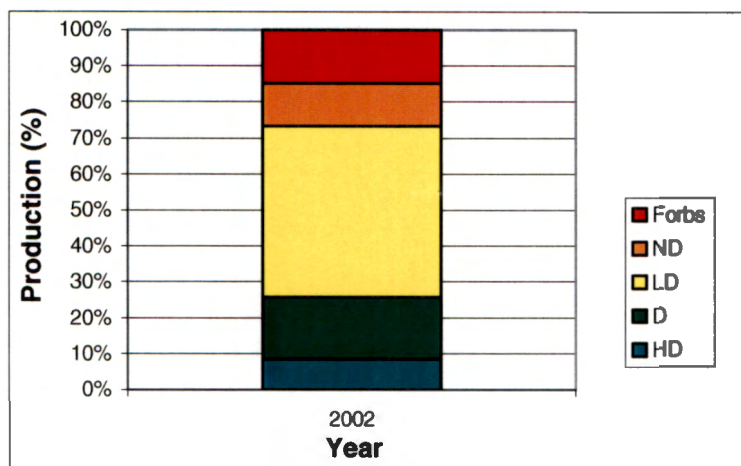


Figure 4.14: Contributions of the different desirability classes to the total production (%) at the Waterfouchè 2 benchmark site during May 2002.

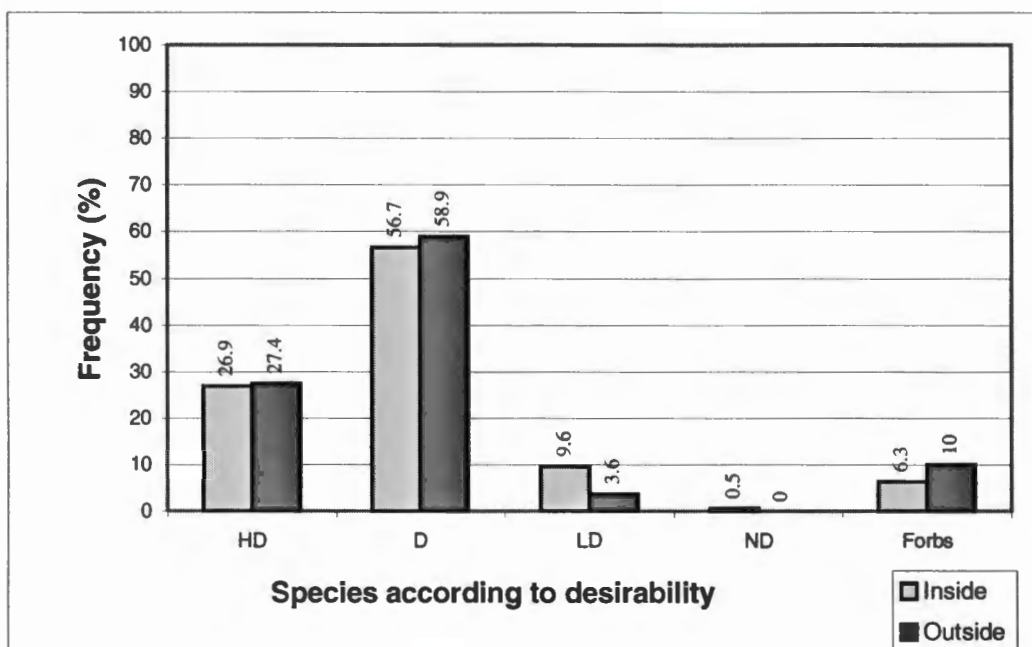
4.2.2.3. Waterfouchè 3 benchmark site

i. *Grass species composition*

The grass species composition at the Waterfouchè 3 site was dominated by desirable grass species inside and outside the enclosure during December 2001 and May 2002 (Figure 4.15 a and b). *Eragrostis lehmanniana*, a sub-climax or climax grass species, contributed the most to the frequency of the desirable species, with a frequency of 44.7% inside the enclosure and 42.9% outside the enclosure during December 2001 (Figure 4.15c). In May 2002 the abundance of the desirable grass species increased even more, mainly due to the increase in the abundance of *S. uniplumis* (Figure 4.15 c and d). This could be explained by the fact that probably a higher amount of *S. uniplumis* seed than that of the other desirable grass species was present in the soil seed bank. The increase in the abundance of the desirable grass species could have led to the decrease in the abundance of the highly desirable, namely *B. nigropedata* and *S. pappophoroides*, and less desirable grass species, *E. pallens* and *A. stipitata*, inside and outside the enclosure. This increase can be attributed to the high rainfall during September, November and December 2001 and during January 2002 (Figure 4.11 b and c).

The desirable grass species, *E. lehmanniana*, *E. trichophora* and *S. uniplumis*, are classified as increaser II species, and thus increase in abundance under short-term moderate overgrazing (Bosch & Kellner, 1991). The increase in the frequency of *S. uniplumis* in May 2002 (with 23.2% inside and 13.4% outside the enclosure, as is reflected in Figure 4.15 c and d) could indicate that the rangeland was slightly overgrazed during the past, and that if sustainable management practises are not maintained, rapid degradation of this area can occur. The slight decrease in the frequency of *S. pappophoroides*, which is classified as a decreaser species, also serves as proof that the benchmark site is slightly being overgrazed.

a)



b)

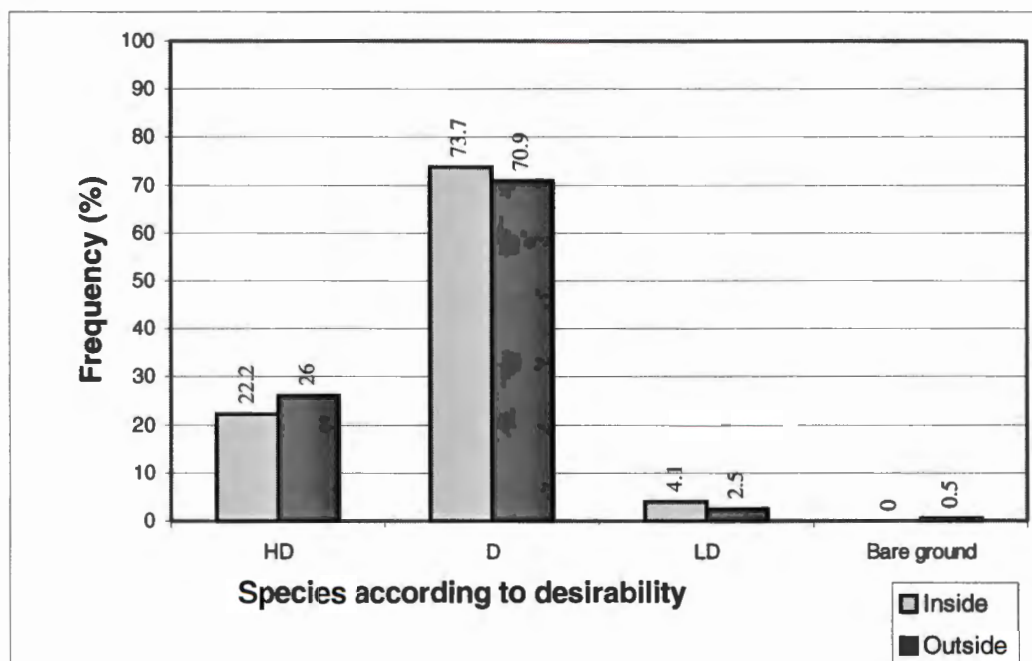
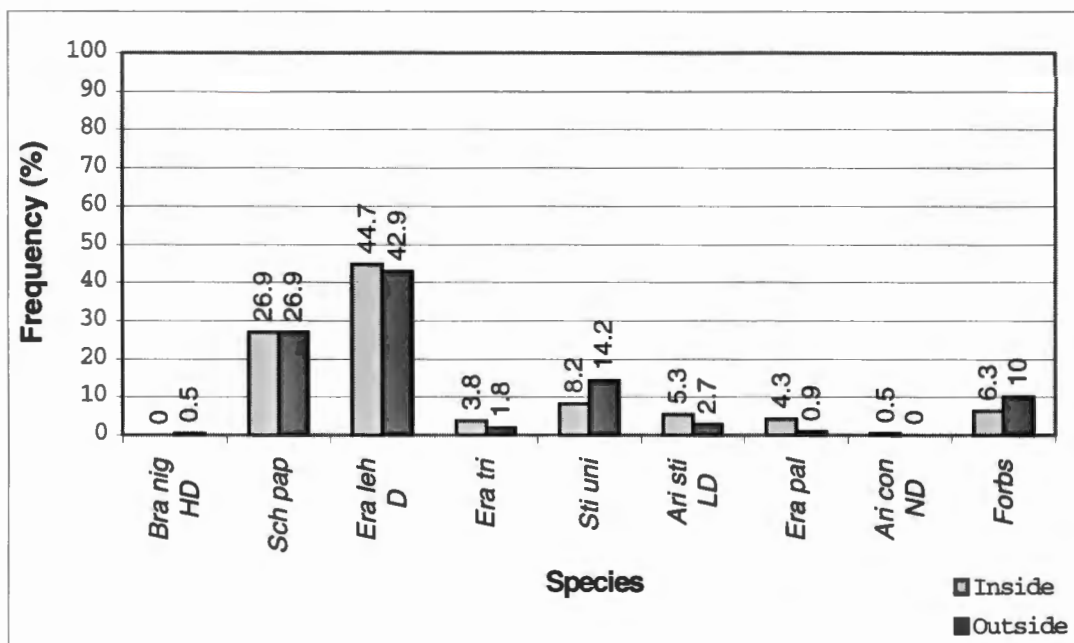


Figure 4.15 a and b: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Waterfouchè 3 benchmark site during December 2001 (a) and May 2002 (b).

c)



d)

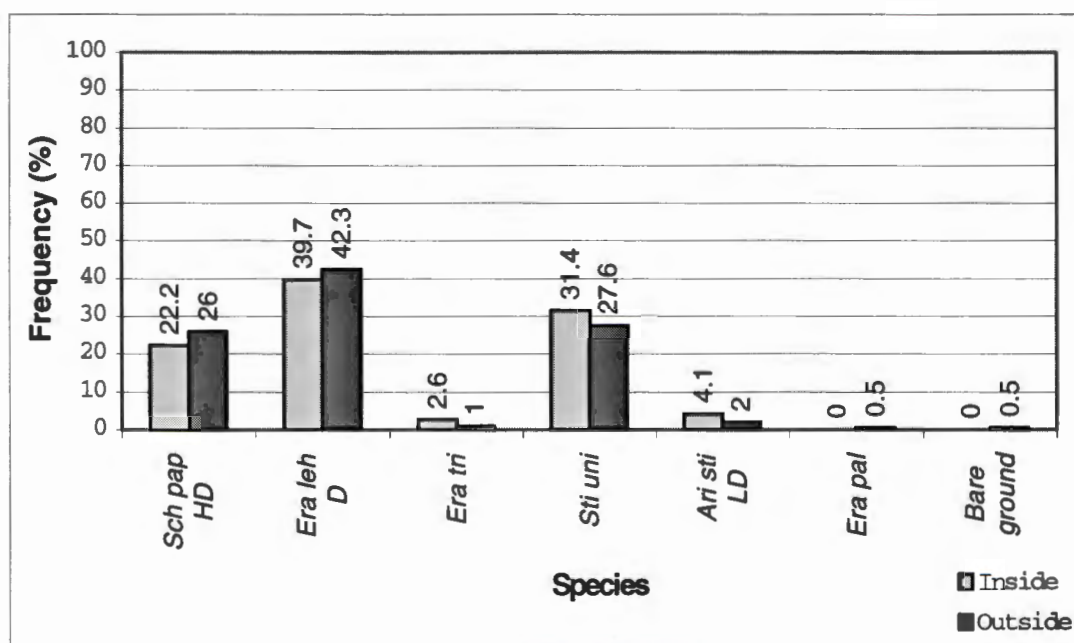


Figure 4.15 c and d: Frequency (%) of grass species inside and outside the enclosure at the Waterfouchè 3 benchmark site during December 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

No marked difference in the species composition between the inside and outside of the enclosure can thus far be observed (Figure 4.15 a-d). The Z-index values support this statement (Table 4.18). These values indicates that the similarity of the grass species composition between the inside and outside of the enclosure is very high, namely 86.4% during December 2001 and 87.4% during May 2002.

Table 4.18: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Waterfouchè 3 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Waterfouchè 3	December 2001	86.4
	May 2002	87.4

iii. Grass production

In accordance with the grass species composition, the desirable grass species (*E. lehmanniana*, *E. trichophora* and *S. uniplumis*) contributed the most to the total grass production (Figure 4.16). These species produced 1584.0 kg/ha DM (Table 4.27). The highly desirable grass species (*S. pappophoroides* and *B. nigropedata*) were the second highest contributors to the total grass production, with a production figure of 448 kg/ha. The forbs and less desirable grass species (*A. stipitata* and *E. pallens*) followed with a DM production of 239.6 kg/ha and 93.0 kg/ha, respectively.

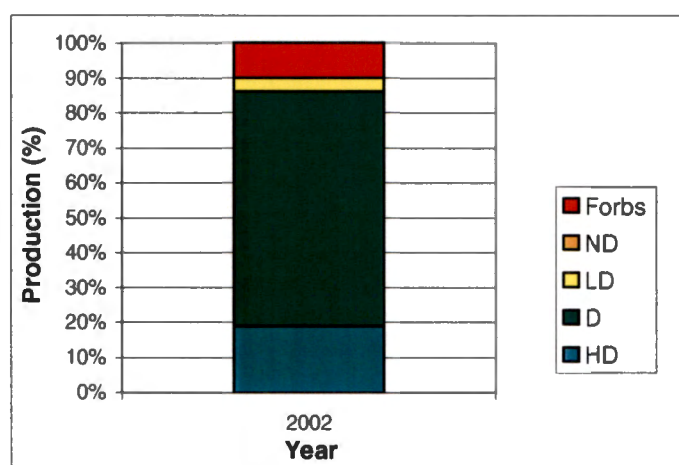


Figure 4.16: Contributions of the different desirability classes to the total production (%) at the Waterfouchè 3 benchmark site during May 2002.

In Table 4.19 it can be seen that the total grass production inside the enclosure is relatively high, namely 2363.8 kg/ha. The seasonal grazing capacity (5.1 ha/LSU), determined by approach (i), is better than the recommend long-term grazing capacity (9 ha/LSU) for the study area. From Annex E it is clear that no matter what method is used to calculate the seasonal grazing capacity, it remains better than the long-term grazing capacity, namely 7.4 ha/LSU according to approach (ii) and 4.9 ha/LSU according to approach (iii). At this benchmark site the forbs composed only 10.1% of the total grass production (Table 4.19).

Table 4.19: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production and the seasonal grazing capacity, determined by means of approach (i), at the Waterfouchè 3 benchmark site during May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
May 2002	2363.8	2124.2	239.6	10.1	5.1

Due to the high total grass production, the good seasonal grazing capacity, the low percentage of forbs present, and the high abundance of the desirable and highly desirable grass species at this benchmark site, it can be concluded that Waterfouchè 3 is in a good condition.

4.2.2.4. Waterfouchè 4 benchmark site

i. *Grass species composition*

A difference in abundance of the desirable grass species inside and outside the enclosure can be observed (Figure 4.17a). The difference can, however, not yet be ascribed to the rest that is being applied inside the benchmark, seeing that the benchmark was only erected during April 2001 and significant species compositional changes could not have taken place after just seven months.

From Table 4.20 it is also evident that the similarity in the grass species composition inside and outside the enclosure at Waterfouchè 4 (75.5%) is less than the similarities at Waterfouchè 1 (84.3%), 2 (93.1%) and 3 (87.4%) during May 2002 (Annex D).

Table 4.20: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Waterfouchè 4 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Waterfouchè 4	December 2001	67.4
	May 2002	75.5

This benchmark site is dominated by desirable grass species (inside the enclosure) as well as less desirable grass species (inside and outside the enclosure) during December 2001 (Figure 4.17a). The main desirable species is *E. lehmanniana*, while *A. stipitata* contributed mostly to the high frequency of less desirable species at this benchmark site (Figure 4.17c). Both these species are classified as increaser II species, and will thus increase in abundance under short-term moderate overgrazing (Bosch & Kellner, 1991).

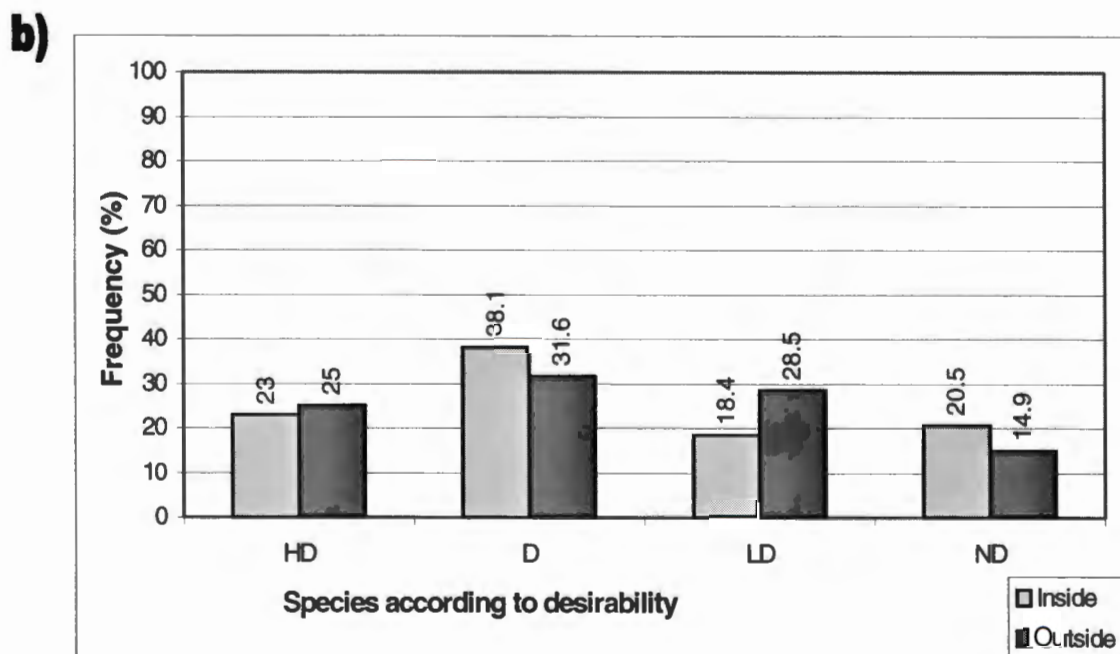
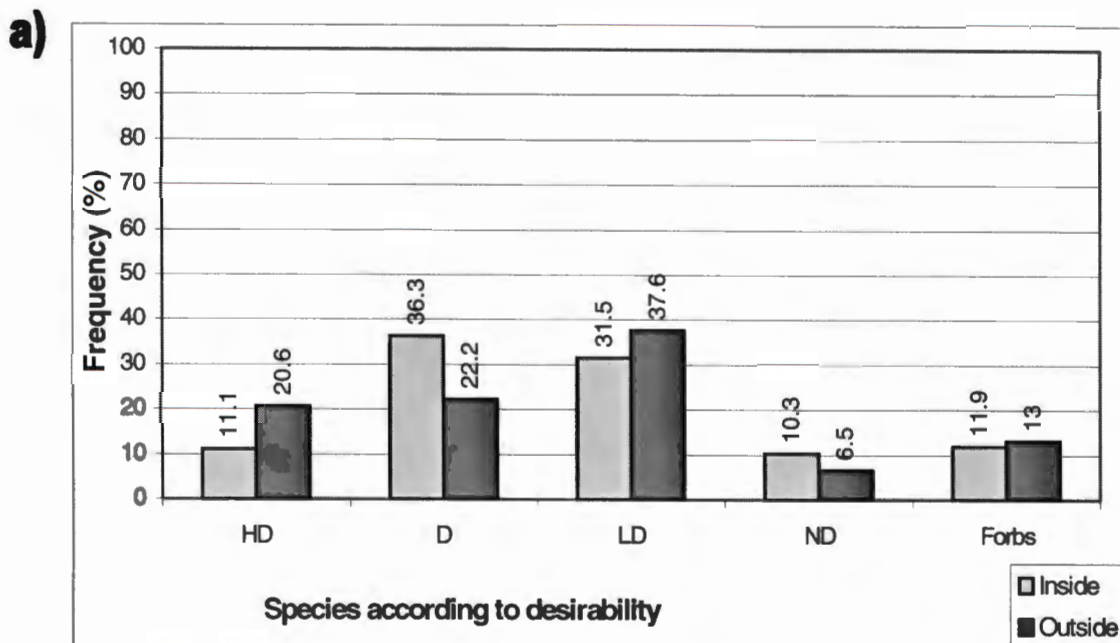
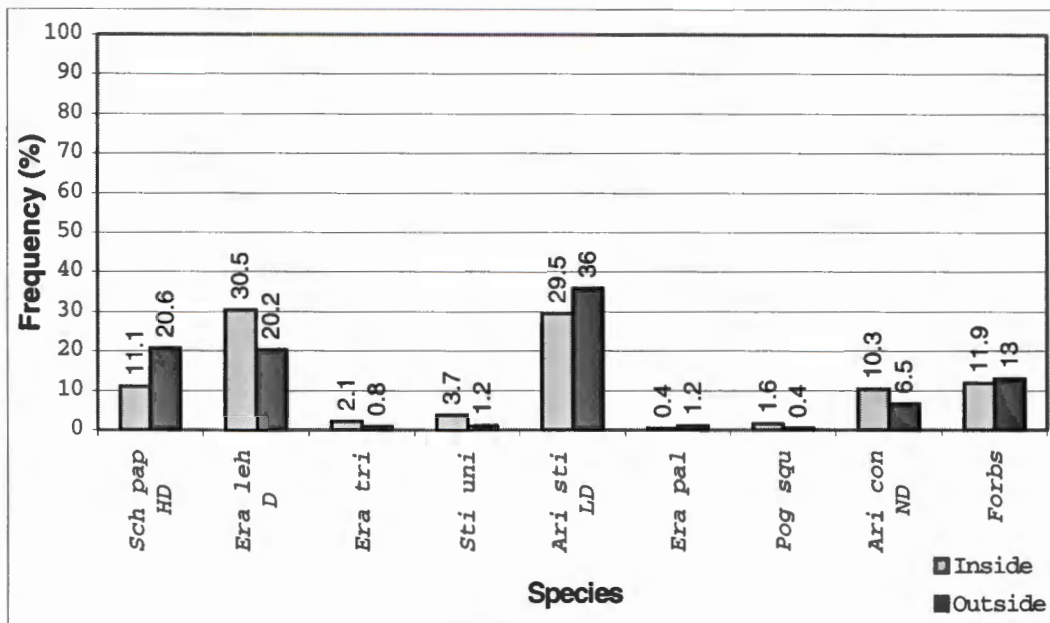


Figure 4.17 a and b: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Waterfouchè 4 benchmark site during December 2001 (a) and May 2002 (b).

c)



d)

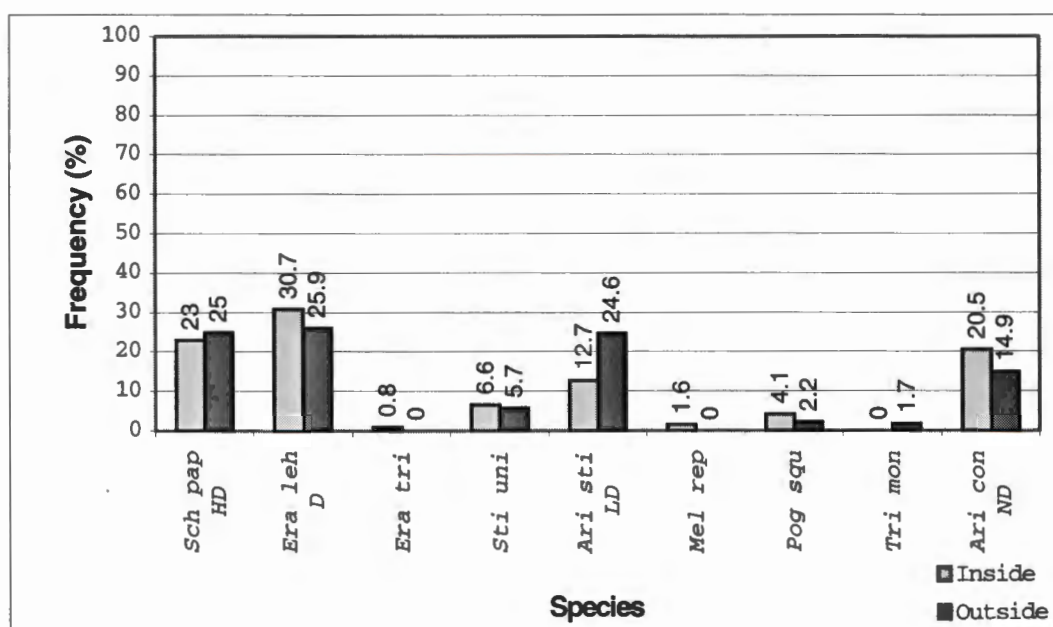


Figure 4.17 c and d: Frequency (%) of grass species inside and outside the enclosure at the Waterfouchè 4 benchmark site during December 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

A small increase in the abundance of desirable species (from 36.3% in December 2001 to 38.1% in May 2002) occurred inside the enclosure. This benchmark site is located far from watering points. Very little grazing therefore occurs at this site, and could have contributed to the greater increase of desirable grass species outside the enclosure (from 22.2% in December 2001 to 31.6% in May 2002).

The frequency of the highly desirable species, *S. pappophoroides*, also shows an increase in abundance inside and outside the enclosure from December 2001 to May 2002 (Figure 4.17 c and d). *Schmidtia pappophoroides*, which is a decreaser species and will decrease in abundance under conditions of overgrazing, have increased to a greater extent inside the enclosure (from 11.1% to 23.0%) than outside the enclosure (from 20.6% to 25%). It can thus be concluded that even though the grazing pressure outside the enclosure is low, the species composition inside the enclosure already inclines to a more desirable composition due to the rest applied.

The abundance of non desirable species, namely *A. congesta*, has however also increased both inside (with 8.6%) and outside (1.9%) the enclosure from December 2001 to May 2002 (Figure 4.17 a and b). This indicates that the persistent soil seed bank of this species responded well to the higher rainfall season in 2001/2002 (Figure 4.11 b and c). The high decrease in the abundance of the forb species from December 2001 to May 2002 could be ascribed to the increase in the grass species density, as well as a possible lack of a persistent soil seed bank. As a result the presence of forbs were not even recorded by means of the nearest point vegetation survey technique during May 2002.

ii. Grass production

The total grass production inside the enclosure during May 2002 at this benchmark site was 1445.2 kg/ha (Table 4.21). The production of the forbs contributed only to a small part of the total production, namely 202.9 kg/ha. This reasonably low production also explains why the forbs weren't recorded during the species compositional survey.

Table 4.21: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Waterfouchè 4 benchmark site during May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
May 2002	1445.2	1242.3	202.9	14.0	11.9

The less desirable grass species (mainly *A. stipitata*) contributed the most to the total production at Waterfouchè 4, namely 531.0 kg/ha (Figure 4.18 and Table 4.27). The DM production of the desirable grass species (*E. lehmanniana*, *E. trichophora* and *S. uniplumis*) contributed to the second highest production figure (368.0 kg/ha), followed by the non desirable species (*A. congesta*) with 205.0 kg/ha, the forbs (202.9 kg/ha), and then the highly desirable species (*S. pappophoroides*) with 139.0 kg/ha. Subsequently the seasonal grazing capacity was determined as 11.9 ha/LSU by

of approach (i), where the utilisation factors 0.5, 0.3, 0.2 and 0.1 were allocated to the different grass desirability classes (see Section 3.4.2, Chapter 3). The seasonal grazing capacities that were calculated with approaches (ii) and (iii) are 15.3 ha/LSU and 10.0 ha/LSU, respectively (Annex E). It can thus be seen that calculations according to approach (ii) results in the poorest seasonal grazing capacities, while results obtained by using approaches (i) and (iii) does not differ much.

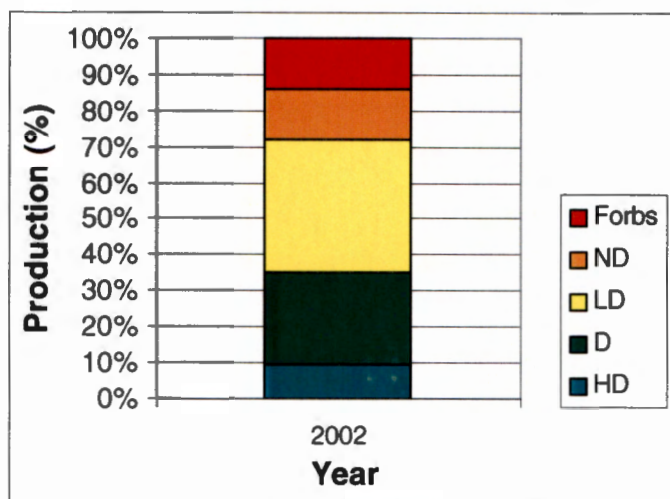


Figure 4.18: Contributions of the different desirability classes to the total production (%) at the Waterfouchè 4 benchmark site during May 2002.

Taking into consideration the relatively high production figures, reasonably good seasonal grazing capacity (determined by approach (i)), as well as the relatively desirable species composition of the benchmark, it can be concluded that the Waterfouchè 4 site is in a moderate to good conditional state.

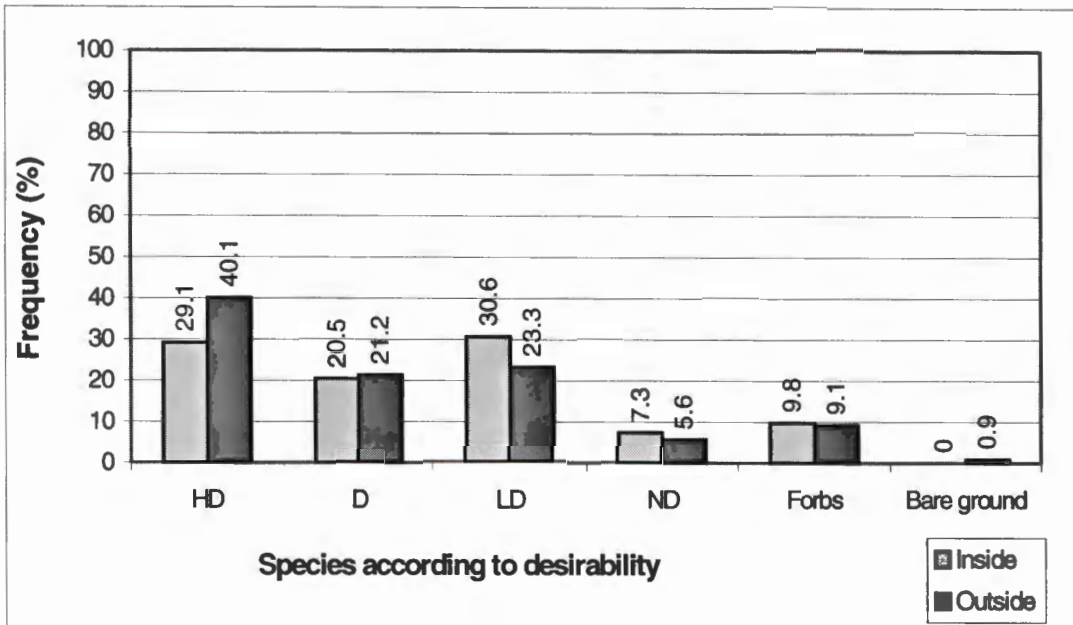
4.2.2.5. Waterfouchè 5 benchmark site

i. *Grass species composition*

This benchmark site is mainly characterised by the highly desirable grass species, *S. pappophoroides* during December 2001 and May 2002 (Figure 4.19 a-d). The abundance of this species was higher on the outside (40.1%) of the exclosure than on the inside (29.1%) at the commencement of the study (Figure 4.19c). Since this difference was observed during the first surveys that were carried out at this study site, the difference can not be ascribed to the implementation of the Morafe ranch management system.

The frequency of *S. pappophoroides*, however, increased from December 2001 to May 2002 (Figure 4.19 a and b). This increase was also more prominent on the inside (from 29.1% to 37.0%) of the exclosure than on the outside (from 40.1% to 43.4%). The period of rest of the grasses inside the exclosure could thus have promoted the increase in the frequency of this desirable grass species.

a)



b)

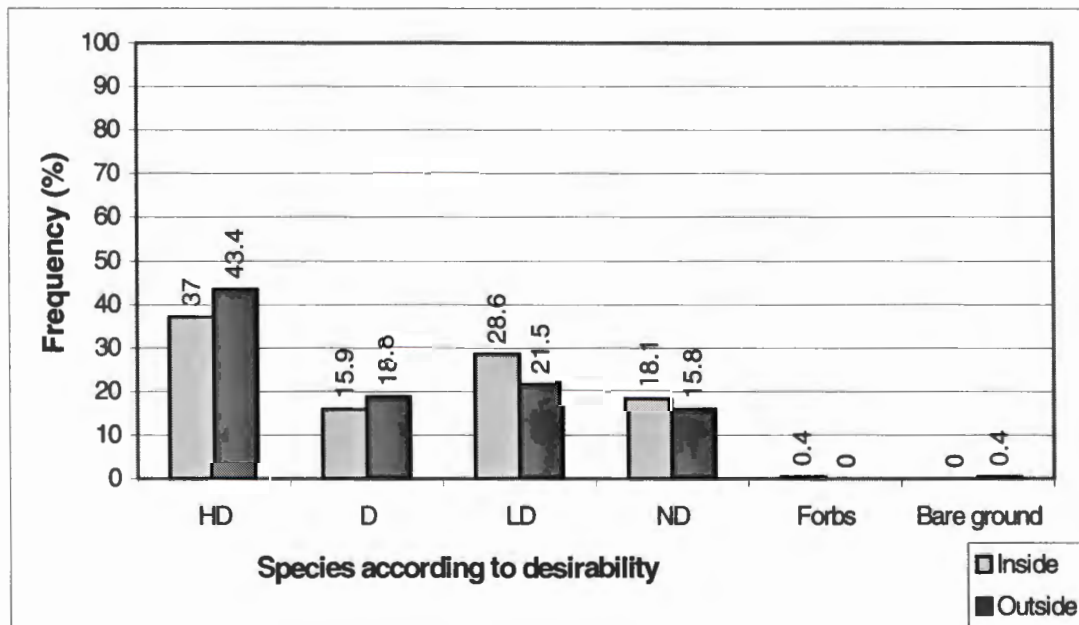
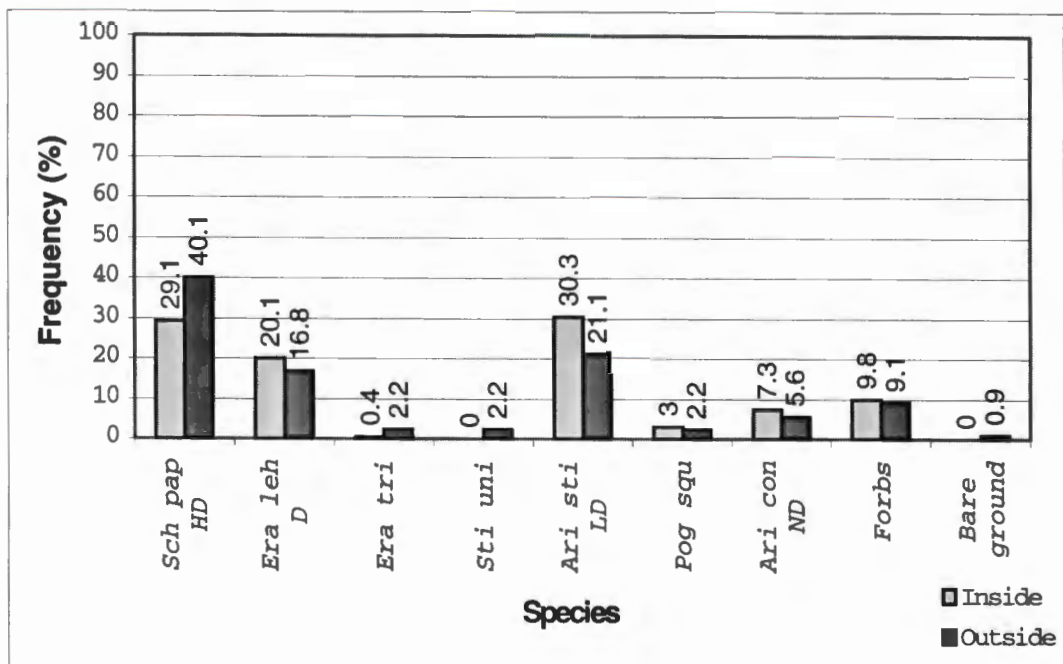


Figure 4.19 a and b: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Waterfouchè 5 benchmark site during December 2001 (a) and May 2002 (b).

c)



d)

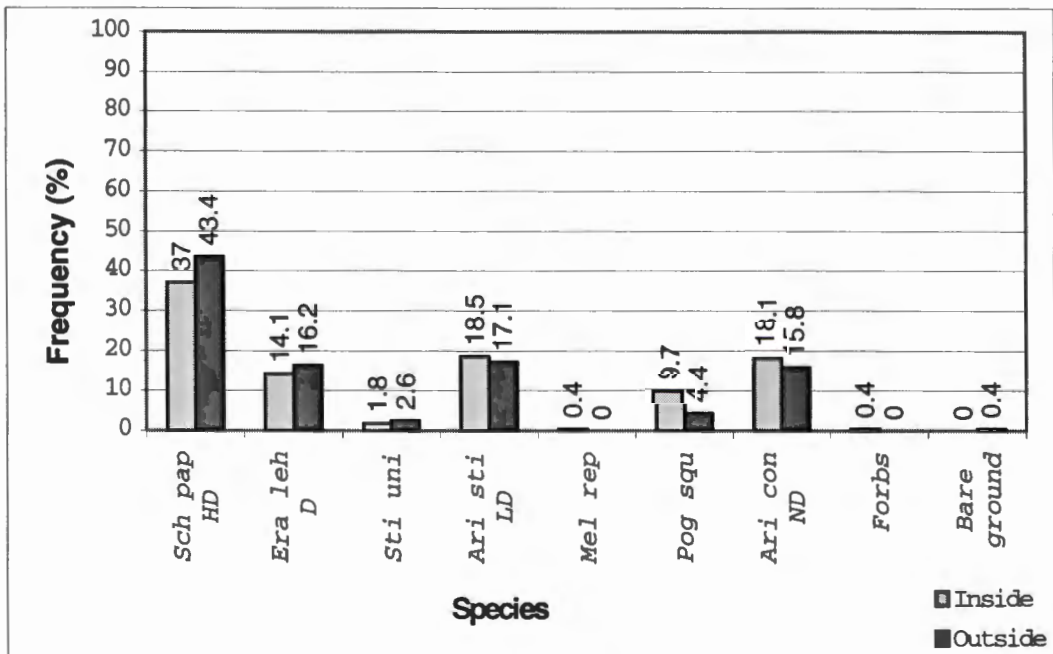


Figure 4.19 c and d: Frequency (%) of grass species inside and outside the enclosure at the Waterfouchè 5 benchmark site during December 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

Even though rest was only applied for a little while (in terms of vegetation dynamics), an overall trend towards a more desirable species composition inside the enclosure of the benchmark site can already be observed. This can be ascribed to the fact that the relatively sandy rangelands recover very quickly, if properly managed (Van Oudshoorn, 1999). According to O'Connor (1991) the long-term data sets for the savanna grasslands of southern Africa suggest that the effect of grazing is contingent upon rainfall. Thus, the high 2001/2002 rainfall season (Figure 4.11 b and c) did contribute to this slight change in species composition.

The Z-indices of the Waterfouchè 5 benchmark site reflects that the similarity between the grass species composition inside and outside the enclosure is relatively high and also increased from 72.6% during December 2001 to 83.9% during May 2002 (Table 4.22). It can thus be concluded that the differences in the species composition mentioned above are not yet significant, and that future follow-up surveys will be necessary in order to determine the long-term influence of the Morafe ranch management system, as well as the influence of rest applied inside the enclosure.

Table 4.22: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Waterfouchè 5 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Waterfouchè 5	December 2001	72.6
	May 2002	83.9

The abundance of the desirable grass species, mostly *E. lehmanniana*, less desirable grass species, mostly *A. stipitata* and *P. squarrosa*, forbs and bare ground patches decreased inside and outside the enclosure from 2001 to 2002, whereas the frequency of non desirable species increased (Figure 4.19 a-d). The non desirable species at this benchmark site was mostly represented by *A. congesta*, which is described as an increaser II pioneer grass species that can effectively stabilise disturbed soil and bare patches, and is therefore a good indicator of overgrazing and other disturbances (Van Oudthoorn, 1999). The increase in the frequency of this species could thus explain the decrease in the percentage of bare ground patches at this benchmark site from 2001 to 2002. The decrease in the desirable, less desirable and forb species is probably due to the increase in the recruitment of *S. pappophoroides* and *A. congesta* seedlings as a result of the high 2001/2002 rainfall season, which subsequently lead to higher recordings in the abundance of these species.

ii. Grass production

Although results from the species compositional surveys indicated that the highly desirable grass species dominated at the Waterfouchè 5 benchmark site, it is clear from Figure 4.20 that the less desirable grass species, with a production figure of 295.0 kg/ha (Table 4.27), contributed most to the total production. The second highest contributor to the total grass production is represented by *S. pappophoroides* (Figure 4.20), which produced 285.0 kg/ha DM (Table 4.27). This coincides with the high frequency values of this species (Figure 4.19 c and d).

The total production at Waterfouchè 5 is 1109.8 kg/ha, and the seasonal grazing capacity, as accordingly determined by means of approach (i), is 13.6 ha/LSU (Table 4.23). The seasonal grazing capacity calculated by approach (ii) was 18.3 ha/LSU, and 14.6 ha/LSU if determined by approach (iii) (Annex E). The forbs contributed only 11.0% of the total production with a production figure of 122 kg/ha.

Table 4.23: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Waterfouchè 5 benchmark site during May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
May 2002	1109.8	987.8	122.0	11.0	13.6

The recommended long-term grazing capacity (9 ha/LSU) is however still better than the seasonal grazing capacities determined by all three methods. Even though the rangeland inside the benchmark site was rested since April 2001 (the inside of the exclosure was only grazed for a short period, that preceded the rainfall season) and received above average rainfall during the 2001/2002 rainfall season, it still could not reach the long-term grazing capacity standard. The seasonal grazing capacity of an area is, however, very variable and depends greatly on the annual rainfall pattern (Snyman, 2000). It can thus be concluded that, according to the production and seasonal grazing capacity during May 2002, this benchmark site is in a moderate conditional state. This also serves as an indication that rangeland should be rested for long time periods in order to reach their full production potential.

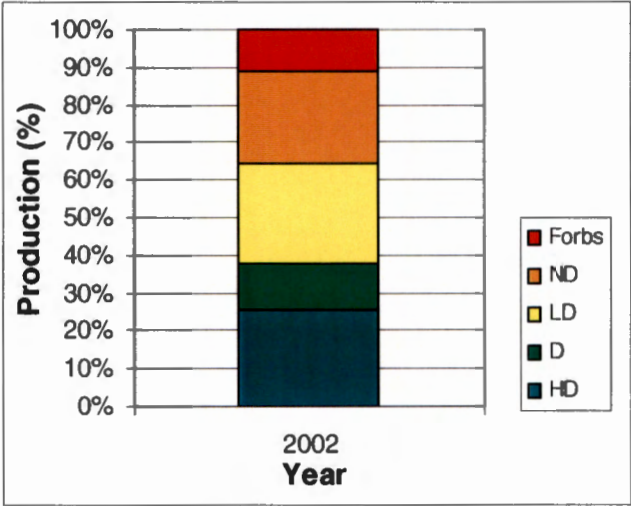


Figure 4.20: Contributions of the different desirability classes to the total production (%) at the Waterfouchè 5 benchmark site during May 2002.

4.2.2.6. Waterfouchè 6 benchmark site

i. *Grass species composition*

The desirable grass species, such as *E. lehmanniana*, *P. schinzii* and *S. uniplumis*, dominated inside and outside the exclosure throughout the study period at this benchmark site (Figure 4.21 a-d). *Eragrostis lehmanniana* was however the dominant species in this desirability class.

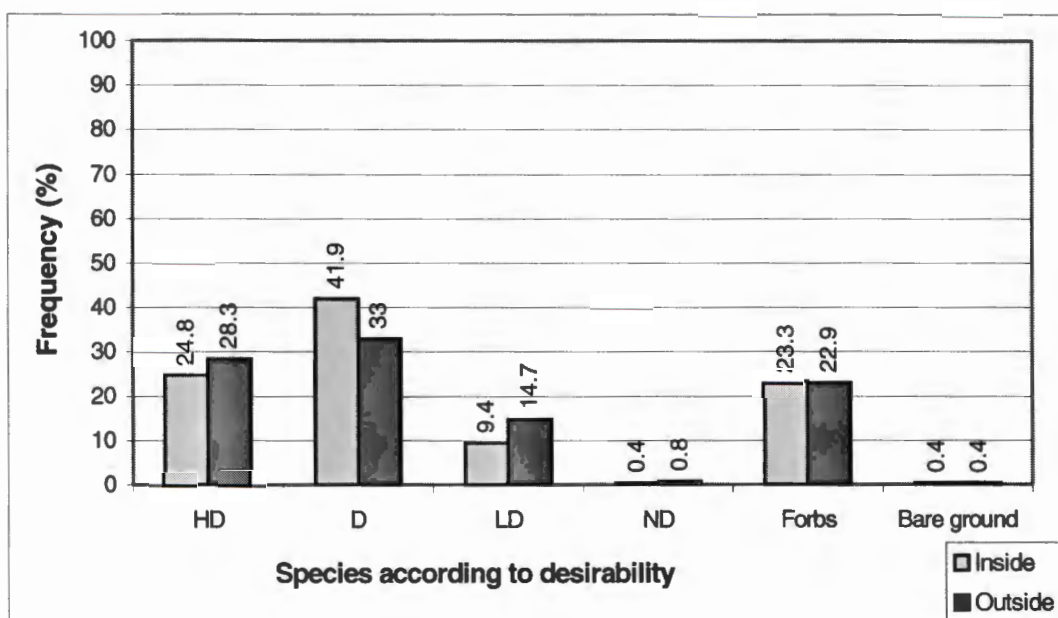
The abundance of the desirable grass species showed a considerable increase from December 2001 to May 2002 (Figure 4.21 a and b). This was mainly caused by the increase in the frequency of *E. lehmanniana*, which is classified as an increaser II species and usually grows in parts where disturbance took place in the past, such as overgrazed rangeland. The increase of this grass species was greater inside the exclosure, with an increase of 17.2%, than outside the exclosure, with an increase of 9.2% (Figure 4.21 c and d). Consequently it can be said that even the relatively short period of rest could have caused the increase of the desirable species, leading to an improvement of the rangeland condition inside the exclosure.

The highly desirable grass species, *S. pappophoroides*, increased both inside and outside the exclosure from December 2001 to May 2002, to approximately the same extent. An increase in the abundance of the less desirable species, *A. stipitata*, *E. pallens*, *M. repens* and *P. squarrosa* was also observed during the study period (inside and outside the exclosure). *Aristida stipitata* contributed the most to this increase (Figure 4.21 c and d).

A large decrease occurred in the abundance of forb species inside and outside the exclosure from December 2001 to May 2002 (Figure 4.21 a and b). The reason for this could primarily be ascribed to the increase in the abundance of the highly desirable, desirable and non desirable species. The percentage of bare ground patches decreased drastically from December 2001 to May 2002 which could also be as a result of the increase in the frequency of these species. It probably also led to an increase of the vegetation cover at the benchmark site.

The fact that the species composition does not show any major differences between the inside and outside of the exclosure, and the increases or decreases of the species occurring both inside and outside the exclosure are similar, indicates that the exclosure had very little effect during the two year study period. Other factors, such as the rainfall pattern, are therefore the most contributing factor to the change in the species composition. Because the inside of the exclosure is being rested, these species will however respond faster, as can be seen in the increased frequency of *E. lehmanniana*.

a)



b)

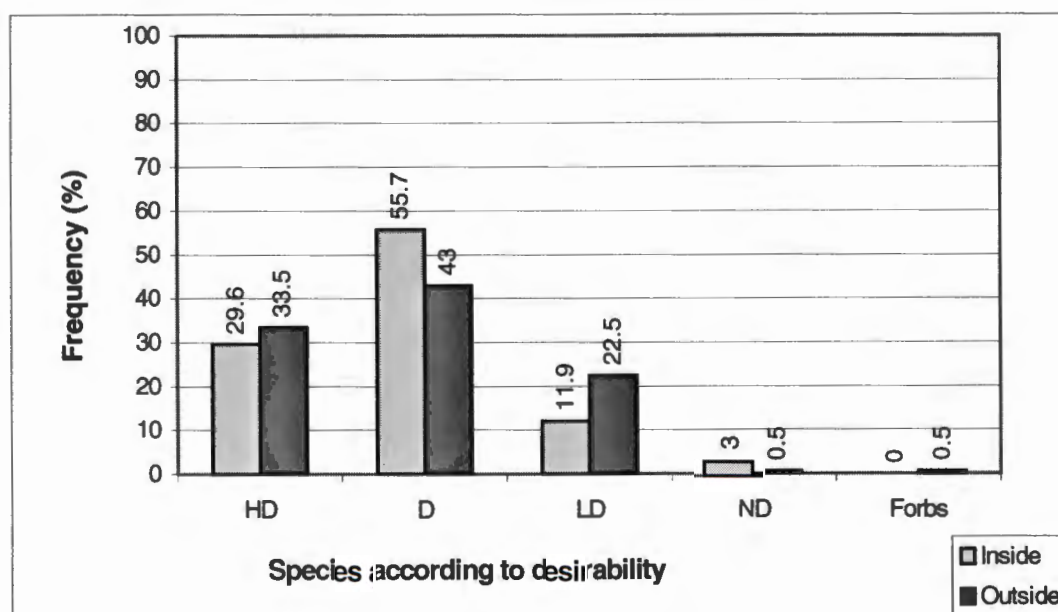


Figure 4.21 a and b: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Waterfouchè 6 benchmark site during December 2001 (a) and May 2002 (b).

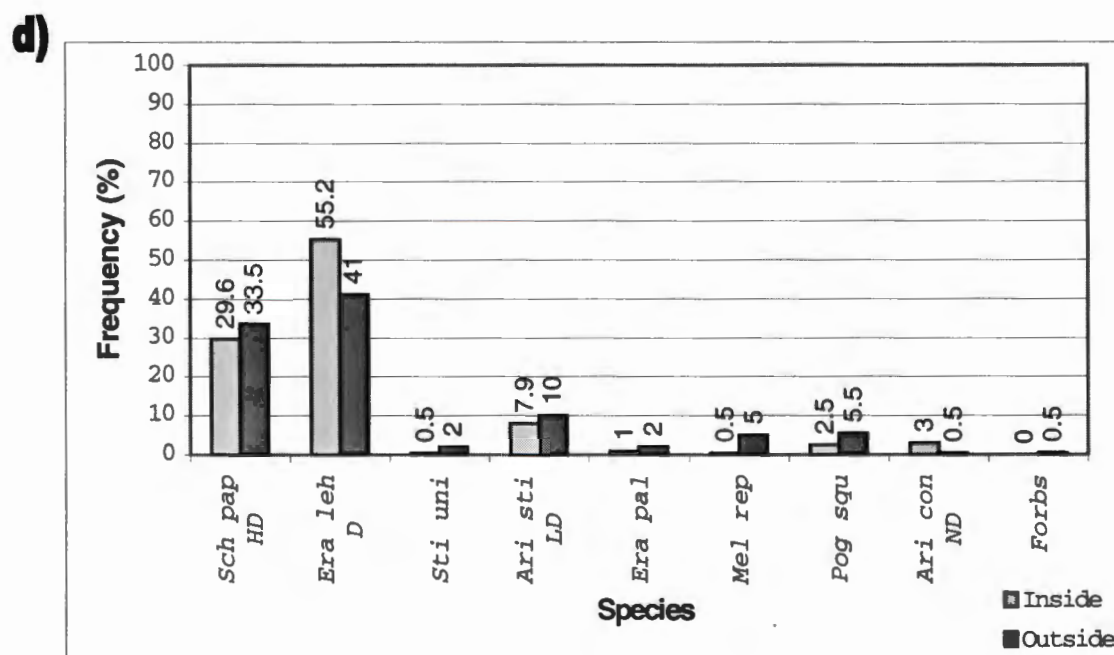
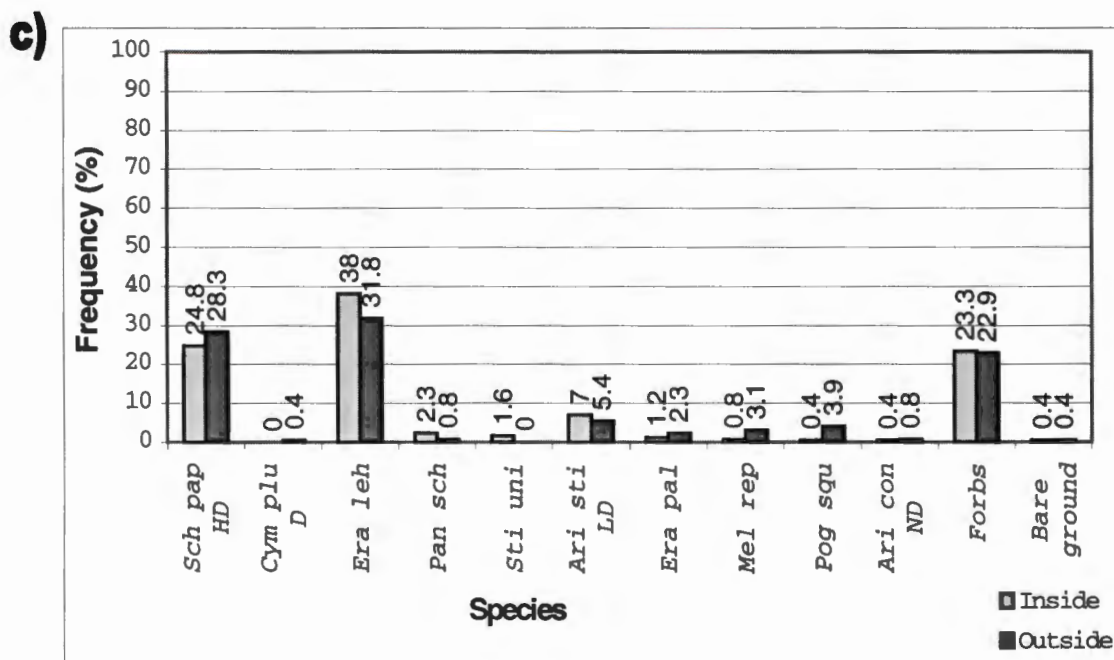


Figure 4.21 c and d: Frequency (%) of grass species inside and outside the enclosure at the Waterfouchè 6 benchmark site during December 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

Although the Z-indices indicates a high agreement in the grass species composition inside and outside the enclosure, this agreement decreased from 77.9% in December 2001 to 74.2% in May 2002 (Table 4.24). In order to determine whether the grass species composition will show a more prominent reaction to the rest applied inside the enclosure, vegetation surveys will still have to be carried out for a number of consecutive years.

Table 4.24: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Waterfouchè 6 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Waterfouchè 6	December 2001	77.9
	May 2002	74.2

ii. Grass production

The total production on the inside of the enclosure at this benchmark site was 1304.3 kg/ha (Table 4.25). By means of the utilisation factor values appointed to the different grass desirability classes according to approach (i), the seasonal grazing capacity was determined as 10.6 ha/LSU. The seasonal grazing capacity determined by approach (iii), 10.8 ha/LSU, is very similar to that calculated by approach (i) (Annex E). By applying approach (ii), a poorer seasonal grazing capacity (14.9 ha/LSU) is obtained for the inside of the enclosure at the Waterfouchè 6 benchmark site.

The forb species production contributes to 23.4% of the total production and is also responsible for the third highest production figures, with a DM production of 305.4 kg/ha (Figure 4.22). The highest production is however produced by the desirable grass species (452.0 kg/ha), mainly *E. lehmanniana*, while the second highest production is produced by the highly desirable grass species, *S. pappophoroides* with 338.0 kg/ha (Table 4.27). The production results correlate very well to the species composition figures described in the previous section.

Table 4.25: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Waterfouchè 6 benchmark site during May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
May 2002	1304.3	998.9	305.4	23.4	10.6

More than half (approximately 62%) of the production is composed of desirable and highly desirable grass species (Figure 4.22). Although the forb species consisted of a reasonably high percentage, the species compositional results reflects a decrease in the forb species frequency and accordingly implies, together with the Z-indices, that the benchmark site tends change toward a more desirable conditional state.

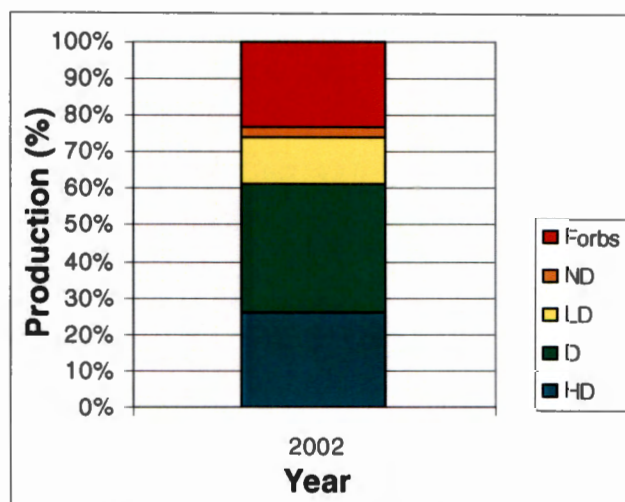


Figure 4.22: Contributions of the different desirability classes to the total production (%) at the Waterfouchè 6 benchmark site during May 2002.

4.2.2.7. Summary of the benchmark sites at the Waterfouchè study site

Results of the grass species composition at the different benchmark sites indicate that the site at Waterfouchè 5 comprised of the highest frequency highly desirable grass species (inside and outside the exclosure) in comparison to all the other sites during May 2002 (Figure 4.19b). Waterfouchè 6 also consists of a reasonably high frequency highly desirable grass species, but this benchmark site is dominated by desirable grass species inside and outside the exclosure (Figure 4.21 a and b). At all six benchmark sites the main contributor to the highly desirable species was *S. pappohoroides*. Seeing that this grass species will decrease in abundance under conditions of overgrazing (decreaser species), it can be concluded that according to the grass species composition, Waterfouchè 5 is the least overgrazed benchmark site in this study area.

The desirable grass species, are mainly represented by *E. lehmanniana*, and dominated at Waterfouchè 1, 3 and 6 (Figure 4.10 a-c, 4.15 a and b, and 4.21 a and b). The highest frequency of this species was found at Waterfouchè 3, with 73.7% inside, and 70.9% outside the exclosure. At Waterfouchè 1 *E. trichophora* also contributed to the abundance of desirable species inside and outside the exclosure throughout the study period (Figure 4.10 d-f). Both species are however classified as increaser II species and an increase in these species will reflect that these benchmark sites have undergone moderate overgrazing in the short term (van Oudtshoorn, 1999).

At all three of the above mentioned benchmark sites (Waterfouchè 1, 3 and 6) an increase in the abundance of desirable species from December 2001 to May 2002 occurred. Seeing that this increase occurred to the same extent inside the exclosures as on the outside, this change can only be ascribed to the above average rainfall over this period (Figure 4.11 b and c).

The Z-indices at all six benchmark sites are above 70% during May 2002, which indicates that the grass species composition between the inside and outside of the exclosures still agrees to a great extent (Annex D). These benchmark sites will thus have to be monitored for a longer time period to be able to detect significant changes in the grass species composition as a result of the rest that is applied inside the exclosures. Seeing that the management in this study area was recently (January 2001) changed from communal management to Morafe ranch management, it would also be interesting to monitor the change in the grass species composition outside the exclosure. This data will thus serve as important baseline data.

From the Z-index values it is also clear that the similarity between the grass species composition inside and outside the exclosures at all the benchmark sites in the Waterfouchè study area (except at the Waterfouchè 6 benchmark site) was less during December 2001 than during May 2002. This can mainly be ascribed to the response of the desirable and less desirable grass species inside the exclosures, *E. lehmanniana* and *A. stipitata* respectively (Figure 4.10 b, e, 4.13 a, c, 4.15 a, c, 4.17 a, c and 4.19 a,c), to the high rainfall. Accordingly it could be deduced that the seed of these grass species accumulated in the soil seed bank during previous periods of moderate overgrazing, seeing that both species are classified as increaser II species and will increase in abundance under such conditions. The recruitment of *E. lehmanniana* and *A. stipitata* were thus slightly higher inside the exclosure and could be ascribed to the rest applied. The higher similarity in the species composition inside and outside the exclosures during May 2002 could be explained by the low rainfall period from February to April 2002 (Figure 4.11c), which probably caused the mortality of many of the seedlings.

In the Waterfouchè study area the highest production (2363.8 kg/ha) was recorded at benchmark site 3, followed by sites 2, 1 (during May 2002), 4, 6 and 5, respectively (Table 4.26). In comparison with the production at the Waterfouchè 1 benchmark during April 2001 all these production figures are reasonably high and, especially the high production figure at site 3, may be as a result of the high rainfall from September 2001 to January 2002 (Figure 4.11 b and c). The high increase in production at the Waterfouchè 1 benchmark site from April 2001 to May 2002 can also be attributed to the high rainfall season. All the exclosures at this study site are situated far from watering points. This, and the fact that the Waterfouchè 3 site is dominated by desirable grass species (Figure 4.16 a and b), which consists of relatively large tuft sizes, could also be given as reasons for the high production at this site.

Considering the production of the forb species, the highest contribution to the total production occurred at the Waterfouchè 6 benchmark site (Table 4.26). If these benchmark sites were arranged according to the percentage of the total production produced by forb species, Waterfouchè 6 would be the highest followed by Waterfouchè 1 (during May 2002), 2, 4, 5, 3 and 1 (during April 2001), respectively. Overall the production of the forb species were very similar, except at the Waterfouchè 5 benchmark site, where the forbs production was very low (122.0 kg/ha).

Table 4.26: The total production (forbs included), grass production (forbs excluded), forbs production and the percentage that forbs contributed to the total production at the Waterfouchè study site, during April 2001 and May 2002.

Date	Benchmark sites	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)
April 2001	Waterfouchè 1	399.8	371.2	28.6	7.2
May 2002	Waterfouchè 1	1601.1	1326.4	274.7	17.2
	Waterfouchè 2	1991.4	1693.9	297.5	14.9
	Waterfouchè 3	2363.8	2124.2	239.6	10.1
	Waterfouchè 4	1445.2	1242.3	202.9	14.0
	Waterfouchè 5	1109.8	987.8	122.0	11.0
	Waterfouchè 6	1304.3	998.9	305.4	23.4

The greatest contributors to the total grass production at the Waterfouchè 1 (613.0 kg/ha), 3 (1584.0 kg/ha) and 6 (462.0 kg/ha) benchmark sites during May 2002 were desirable grass species (Table 4.27). At Waterfouchè 2 (946.0 kg/ha), 4 (531.0 kg/ha) and 5 (295 kg/ha) the less desirable grass species contributed to the highest production.

Seeing that the seasonal grazing capacities were determined by using three different methods of appointing utilisation factors to the different desirability classes, it can be deduced that the seasonal grazing capacities also reflects the present conditional state of the exclosures. However, as rainfall is the limiting environmental factor that determines grassland production and seasonal grazing capacities in the arid and semi-arid areas (Snyman, 2000), it is important to keep in mind that the grass species composition should be the main consideration when rangeland condition is assessed.

From the preceding discussion of the Waterfouchè benchmark sites it was observed that the results of all three methods reflected the same tendency in the seasonal grazing capacities. Only results obtained through approach (i) will thus be discussed now. According to these results it can be concluded the exclosure at Waterfouchè 3 is in the best condition (5.1 ha/LSU), followed by the exclosures at the Waterfouchè 2 (9.1 ha/LSU), 6 (10.6 ha/LSU), 4 (11.9 ha/LSU), 1 (12.6 ha/LSU during May 2002), and 5 (13.6 ha/LSU) sites, respectively (Table 4.27). From the fact that the recommended long-term grazing capacity is 9.0 ha/LSU it is clear that the rangeland condition at the Waterfouchè 1 benchmark site improved greatly. This can partly be ascribed to the response of the grass species to the high rainfall season, the rest applied inside the exclosure, and also to the fact that relatively sandy rangelands recover quickly from overgrazing under the correct management systems (van Oudtshoorn, 1999).

From the species compositional and production results, it can be deduced that all the benchmark sites in the Waterfouchè study area are in a reasonably good condition. The percentage of bare ground patches were also very low. Because of the high abundance of desirable species, the reasonably high abundance of highly desirable species and the high total production figure (2124.2 kg/ha) at the Waterfouchè 3

it can be concluded that this benchmark site consists of the best rangeland condition compared to the other benchmark sites in this study area.

Table 4.27: The dry matter (DM) production figures (kg/ha) for the different grass species desirability classes and the seasonal grazing capacity, determined by means of approach (i) (ha/LSU), at the Waterfouchè benchmark sites, during April 2001 and May 2002.

Benchmark site	Date	DM production of HD grass species (kg/ha)	DM production of D grass species (kg/ha)	DM production of LD grass species (kg/ha)	DM production of ND grass species (kg/ha)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
Waterfouchè 1	Apr 2001	25	226	11	109	39.1
	May 2002	47	613	159	509	12.6
Waterfouchè 2	May 2002	169	345	946	235	9.1
Waterfouchè 3	May 2002	448	1584	93	0	5.1
Waterfouchè 4	May 2002	139	368	531	205	11.9
Waterfouchè 5	May 2002	285	132	295	276	13.6
Waterfouchè 6	May 2002	338	462	166	33	10.6

Waterfouchè 2 on the other hand, can be regarded as the most degraded site with the poorest conditional state. The reason for this is that, although the total production at this site (1991.4 kg/ha) is relatively high, the grass species that contributed mostly to this production is the less desirable *A. stipitata* species. This proves that a high production figure does not mean that the rangeland condition is also good. The production of a specific area can thus be high, but if it only consists of undesirable grass species, it won't be of much value for grazing. Thus, by using benchmark sites 2 and 3 as reference sites in this specific study area the rangeland condition of the other benchmark sites can accordingly be assessed.

According to the soil analyses (inside and outside the exclosure) of the benchmark sites at the Waterfouchè study site (Table 4.28), all sites (with the exception of the inside of the exclosure at the Waterfouchè 5 site and the outside of the exclosure at the Waterfouchè 6 site) consists of soil with a slightly acidic pH (Foth, 1990), namely between a pH 6.0 and 6.5. Seeing that the soil textures at all these benchmark site ranges between 85-95%, the soil can be classified as sand. These soils also consist of a very low Cation exchange capacity (CEC) value. Seeing that good soils consists of a CEC value of between 5 and 20 cmol⁺/kg, the average value of these soils, 2.6 cmol⁺/kg, means that the nutrients, such as potassium, calcium and magnesium, will be less available to the grass species (Taddese, 2001). The soil composition at the different Waterfouchè benchmark sites is very similar, and can therefore not explain any differences in the grass species composition and production between the six benchmark sites.

Table 4.28: Some of the results of the soil analyses carried out for the benchmark sites at the Waterfouchè study site (the complete set of results can be viewed in Annex B).

Benchmarks	pH	P (mg/kg)	K (mg/kg)	CEC (cmol+/kg)	C (%)	Clay (%)	Silt (%)	Sand (%)
Waterfouchè 1 Inside	6.04	3.28	31.2	2.44	0.14	4	1.9	94.1
Waterfouchè 1 Outside	6.14	3.43	38.5	1.83	0.20	4	1.5	94.5
Waterfouchè 2 Inside	6.12	3.29	38.3	2.22	0.18	4	1.9	94.1
Waterfouchè 2 Outside	6.21	3.40	42.3	2.49	0.17	4	2.2	93.8
Waterfouchè 3 Inside	6.16	3.50	33.1	3.09	0.15	4	0.5	95.5
Waterfouchè 3 Outside	6.31	3.52	29.5	3.16	0.15	4	0.4	95.6
Waterfouchè 4 Inside	6.12	3.48	42.3	2.52	0.17	4	0.5	95.5
Waterfouchè 4 Outside	6.04	3.40	35.4	2.33	0.17	4	1.9	94.1
Waterfouchè 5 Inside	5.98	3.20	37.1	3.21	0.17	6	0.2	93.8
Waterfouchè 5 Outside	6.16	3.18	38.4	2.91	0.20	6	0.1	93.9
Waterfouchè 6 Inside	6.06	3.29	52.1	2.70	0.18	6	1.1	93.1
Waterfouchè 6 Outside	5.89	3.19	34.3	2.30	0.19	6	0.1	93.9
Average values	6.10	3.35	37.71	2.60	0.17	5	1.0	94.3

According to O'Connor (1995) grass species of savannas represent a number of different life history types that are expected to differ in their response to rainfall and grazing. Owing to the fact that all the Waterfouchè benchmark sites received the same rainfall, consists of the same soil attributes, and are currently under the same management regimes (Morafe ranch management), the differences in their species composition and production could be ascribed to the fact that they were subjected to different life histories.

4.3. Kudumane magisterial district

The two management systems that were chosen in the Kudumane magisterial district, were at the Maketlele (Communal grazing management) and Heuningvlei (Morafe ranch management) study sites (*see* Figure 2.1 for the location of the different study sites in the three magisterial districts).

4.3.1. Communal Grazing Management at the Maketlele study site

The Maketlele study site is situated in the Allendale FSU, which is located in the Heuningvlei ADC of the Kudumane magisterial district, in the western region of the North West Province (Figure 2.4). The area under communal management at this study site is 2849 hectares and is being managed by nine community members. According to the agricultural extension officer (Table 4.29) a three camp rotational grazing system is currently being applied. This is achieved by dividing the 2849 hectare area into six paddocks. Although the DACE recommends a stocking rate of 10 ha/LSU, the agricultural extension officer determined that the rangeland is approximately 20% overstocked.

Table 4.29: The ADC manager and agricultural extension officer at the Maketlele study site.

District	Benchmark site	Management system	ADC manager	Agricultural extension officer
Kudumane	Maketlele	Communal	James Mokaeng Tel: (053) 773 1981 : 082 927 7931	Andrew Mathe Tel: 082 3428 624 Fax: (053) 773 1778

The animal types currently utilising this rangeland include cattle, sheep, goats, donkeys and horses. As already mentioned, sheep have a greater potential to cause rangeland degradation than either cattle or goats. However this degradation may be minimised, and individual sheep production increased, by stocking sheep in combination with cattle at relatively low ratios (O'Reagain & Turner, 1992). The farmers in this community do not take this fact into consideration, and animal numbers are not being controlled as suggested. The horses and donkeys on the other hand cause great damage to rangeland¹, consume a greater amount of forage than cattle, and do not contribute to the owners economically. This is one of the main concerns at this study site. When a farmer becomes aware of this problem he sells his horses to other community members, causing that this type of problem will persist.

The farmers and community members were very enthusiastic and eager to learn more about sustainable resource management practises. This contributed to the fact that the whole community supported the implementation of the LandCare initiative at this study site. The enclosures (50 x 50 m) at the Maketlele 1 and 2 benchmark sites were already erected during June 1999 (Table 2.2, Chapter 2). Both benchmark sites were surveyed during April 2001, December 2001 and May 2002. As already discussed in

¹ Personal communication: Van Heerden, M., Schoeman Farming, P.O. Box 33, Delmas, 2210, South Africa, + +27 82 388 1016 (c).

the introduction of this chapter (see Section 4.1) the grass production was only cut during April 2001 and May 2002, on the inside of the enclosure.

4.3.1.1. Maketlele 1 benchmark site

i. *Grass species composition*

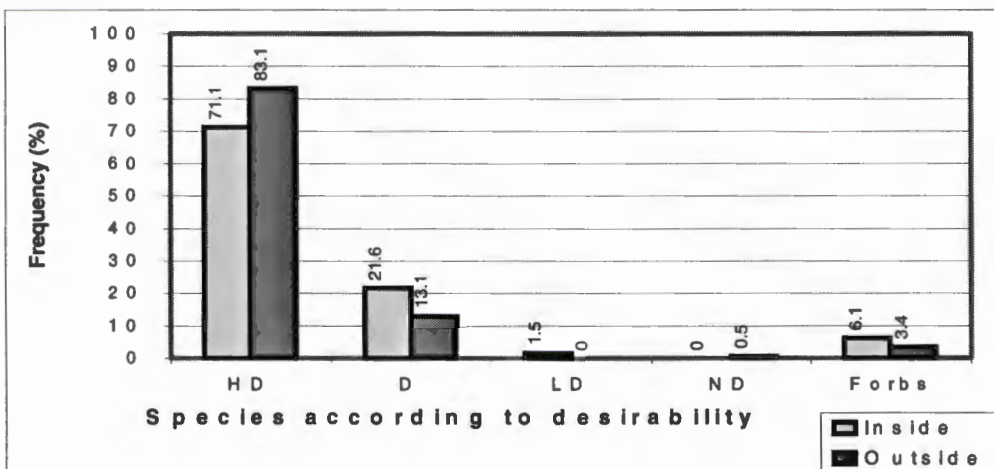
Except for December 2000, the rainfall was very low at the Maketlele study sites, since April 2000 (Figure 4.24 a-c). Seeing that the population dynamics of important savanna grass species appears to be more dependent upon rainfall variability than upon grazing (O'Connor, 1994), it can be deduced that this phenomenon will have a great influence on the vegetation dynamics at this benchmark site.

The Maketlele 1 benchmark site is characterised by a high abundance of highly desirable grasses inside and outside the enclosure throughout the study period (Figure 4.23 a, b and c). These species are represented by *Cenchrus ciliaris*, *D. eriantha*, *S. pappophoroides*, and *T. triandra* (Figure 4.23 d, e and f). The dominant species however is *S. pappophoroides*, which is regarded as a highly palatable climax grass in the sandveld (Roberts & Fourie, 1989) and is classified as a decreaser species. Because of the fact that a decreaser community represents the most preferred community in any ecological area (Tainton, 1988), it can be concluded that the rangeland at this benchmark site is in a good condition.

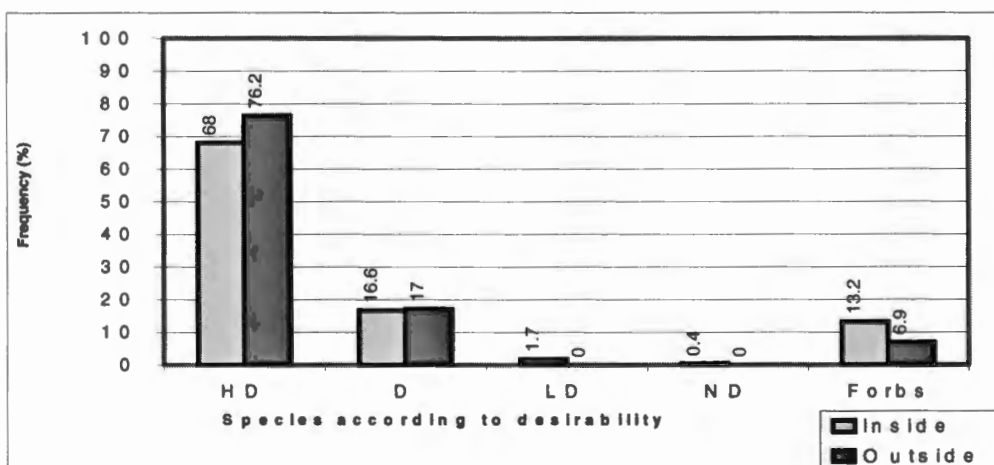
The abundance of *S. pappophoroides* declined from April 2001 to December 2001 inside (with 5.6%) and outside (with 7.4%) the enclosure (Figure 4.23 d and e). This could be attributed to the higher abundances of forb species, inside as well as outside the enclosure. The grasses inside the enclosure were grazed during the winter of 2001. This, together with the low rainfall occurrence could have contributed to the decrease in the highly desirable grass species. Visually their tuft sizes were also much smaller, which could have resulted in a lower basal cover, making the forbs look more prominent and causing the latter to be recorded more frequently during the sampling procedure. The fact that the frequency of *S. pappophoroides* decreased even further inside the enclosure, while it increased outside the enclosure could be due to the fact that the enclosure was possibly overgrazed during the winter of 2001.

From Table 4.30 it is evident that the similarity in the grass species composition inside and outside the enclosure decreased from April 2001 (79.4%) to May 2002 (65.3%). This can also be observed in Figure 4.23 a and c, where the difference in the abundance of highly desirable grass species (from 12% in April 2001 to 22.8% in May 2002) and forbs (from 2.7% in April 2001 to 18.5% in May 2002) increased from 2001 to 2002.

a)



b)



c)

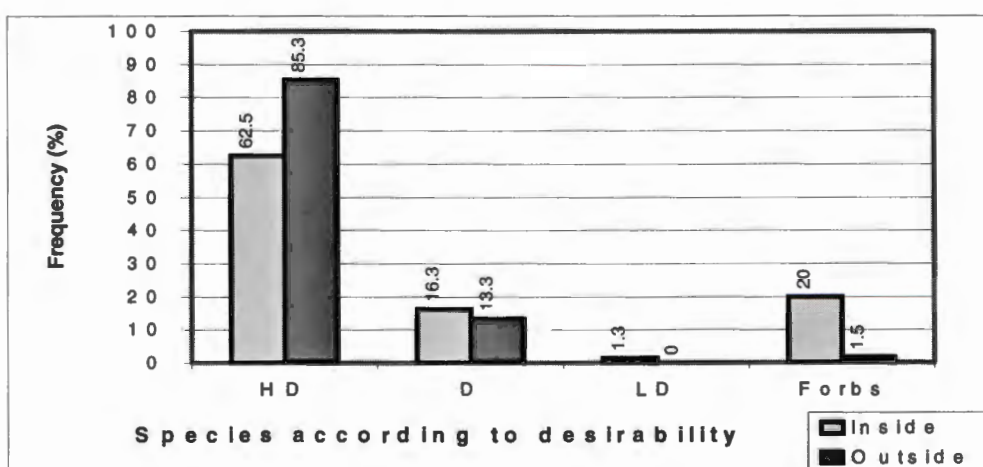
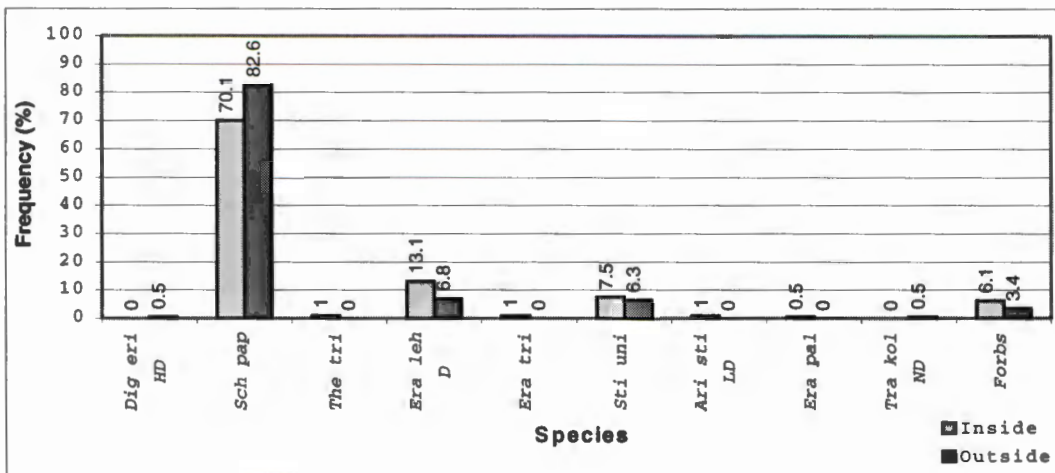
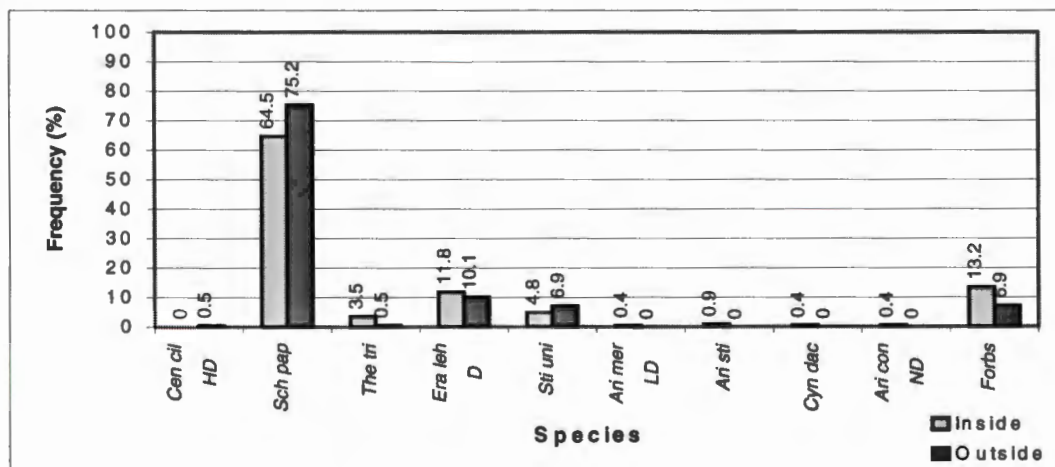


Figure 4.23 a-c: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Maketlele 1 benchmark site, during April 2001 (a), December 2001 (b) and May 2002 (c).

d)



e)



f)

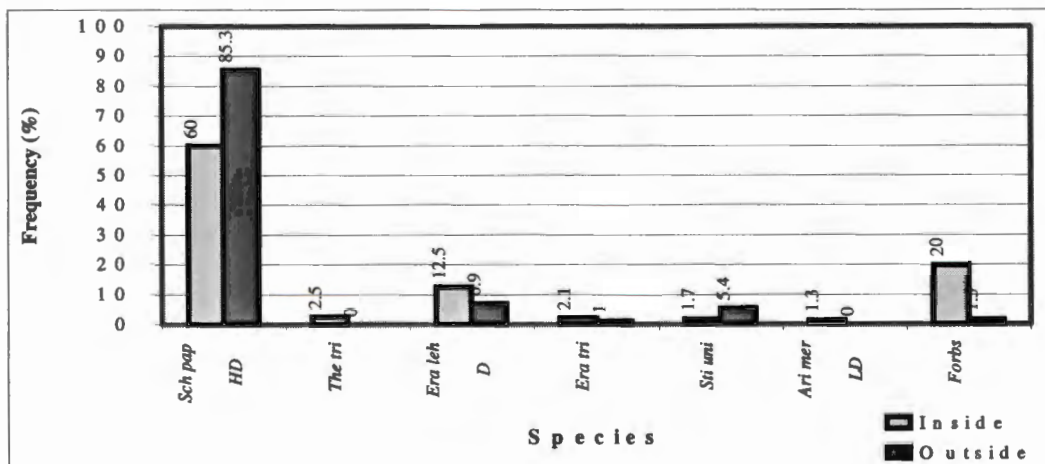
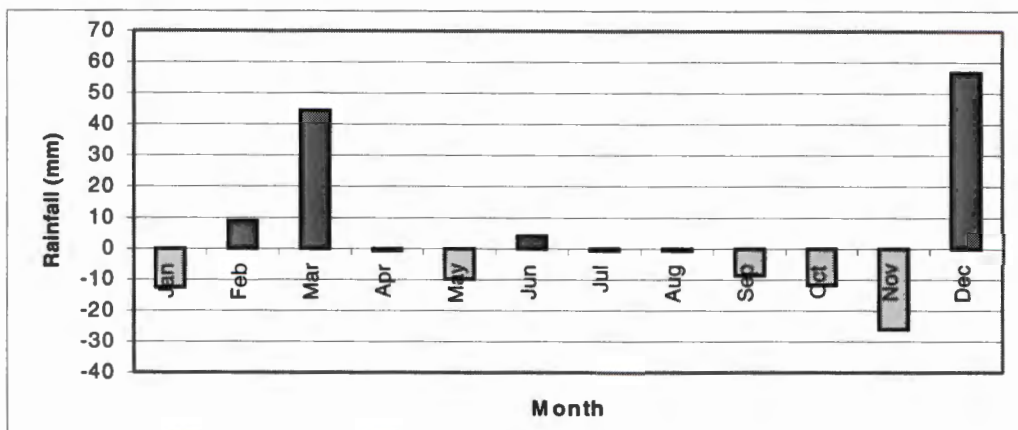
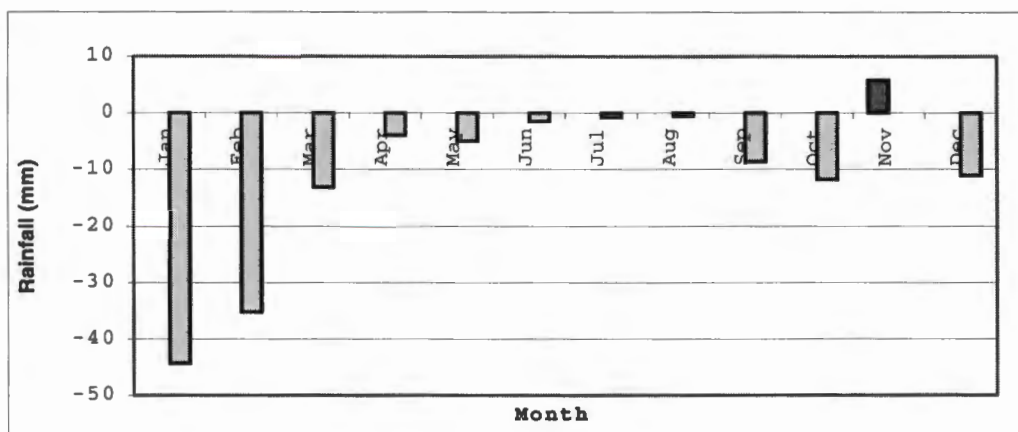


Figure 4.23 d-f: Frequency (%) of grass species inside and outside the enclosure at the Maketlele 1 benchmark site during April 2001 (d), December 2001 (e) and May 2002 (f) (see Annex C1 & C2 for species abbreviations).

a)



b)



c)

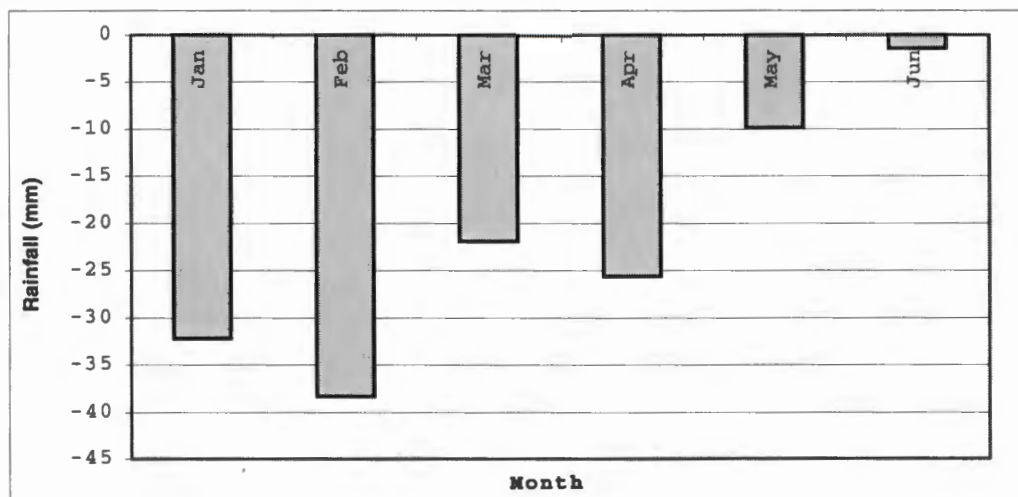


Figure 4.24 a-c: Rainfall deviation from the average rainfall at the Maketlele study site during the years 2000 (a), 2001 (b) and 2002 (c).

Table 4.30: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Maketlele 1 benchmark site, during April 2001, December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Maketlele 1	April 2001	79.4
	December 2001	81.9
	May 2002	65.3

The desirable grass species are the second most abundant species group inside and outside the enclosure at this benchmark site, and are represented by *E. lehmanniana*, *E. trichophora*, and *S. uniplumis* (Figure 4.23d). The relatively low abundance of these increaser II species, and the high abundance of the highly desirable and desirable grass species, is indicative that the rangeland is still in a good condition and was perhaps previously not overgrazed. These species did however decrease in abundance inside the enclosure from April 2001 to May 2002 (Figure 4.23 a and c). This can also mainly be ascribed to the low rainfall during this period (Figure 4.24).

ii. Grass production

From the production data shown in Table 4.31 it can be observed that the production inside the enclosure at the Maketlele 1 benchmark site showed little change from April 2001 (total production of 1182 kg/ha) to May 2002 (total production of 1158.2 kg/ha). The contribution of the forb species to the total production also did not vary much, namely from 231.6 kg/ha during April 2001 to 242.6 kg/ha during May 2002. The total production figures are relatively low if compared to those of the Waterfouchè benchmark sites (Table 4.26), which can mainly be ascribed to the preceding low rainfall seasons (Fig 4.24).

Table 4.31: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Maketlele 1 benchmark site during April 2001 and May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
April 2001	1182.3	950.7	231.6	19.6	8.9
May 2002	1158.2	915.6	242.6	20.9	8.1

The contribution of the highly desirable grass species, mainly *S. pappophoroides*, to the total grass production did however increase inside the enclosure from 2001 to 2002 (Figure 4.25). This serves as an explanation for the improvement in the seasonal grazing capacity (determined by approach (i)), from 8.9 ha/LSU during April 2001 to 8.1 ha/LSU during May 2002, even though the total production shows a slight decrease. The fact that the seasonal grazing capacity is better than the recommended long-term grazing capacity (10 ha/LSU) even though the rainfall was very low, also serve as an indication that this benchmark site is in a good conditional state. The

seasonal grazing capacity calculated by approach (ii) also shows a slight improvement from 12.7 ha/LSU in April 2001 to 11.6 ha/LSU in May 2002 (Annex E). Results of calculating the seasonal grazing capacity according to approach (iii) however remained constant (11.0 ha/LSU) throughout the study period.

The contribution of the desirable (from 290.0 kg/ha to 108.0 kg/ha) and less desirable (from 18 kg/ha to 3.0 kg/ha) grass species to the total production decreased (Table 4.35), while it stayed more or less constant for the forb species (Figure 4.25). The forb production at this benchmark site, 231.6 kg/ha in April 2001 and 242.6 kg/ha in May 2002, is also approximately the same as at the other site, 217.5 kg/ha in April 2001 and 183.8 kg/ha in May 2002, that was sampled for this study (Table 4.31 and 4.33).

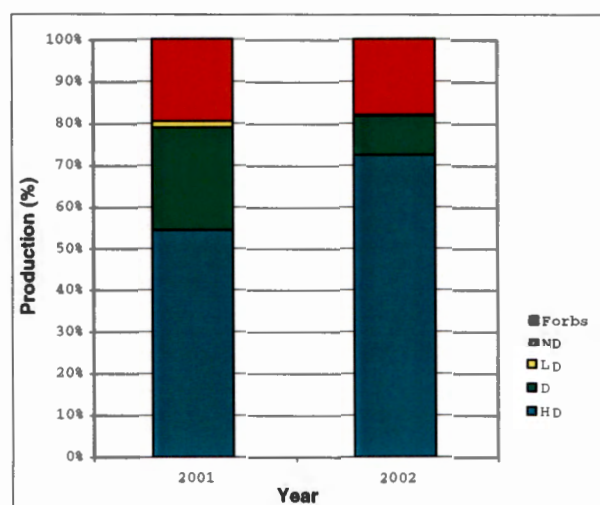


Figure 4.25: The changes in the contributions of the different desirability classes to the total production (%) at the Maketlele 1 benchmark site, between April 2001 and May 2002.

4.3.1.2. Maketlele 2 benchmark site

i. *Grass species composition*

The Maketlele 2 benchmark site was dominated by highly desirable grass species inside and outside the exclosure during April 2001 (Figure 4.26a). The highly desirable species were mostly represented by *S. pappophoroides*. Seeing that *S. pappophoroides* is a decreaser species it proofs that this rangeland is in a relatively good condition. The steady increase in the abundance of *S. pappophoroides* (inside and outside the exclosure) from April 2001 to May 2002 (Figure 4.26 d, e and f), can be ascribed to the fact that it is a drought-resistant grass that can endure heavy grazing (van Oudtshoorn, 1999). Thus, the very low rainfall since April 2000 did not led to the impairment of this highly desirable grass species (Figure 4.24).

Although the exclosure at this benchmark site was already erected in June 1999, no major difference can be observed between the grass species composition inside and outside the exclosure (Figure 4.26 a-c).

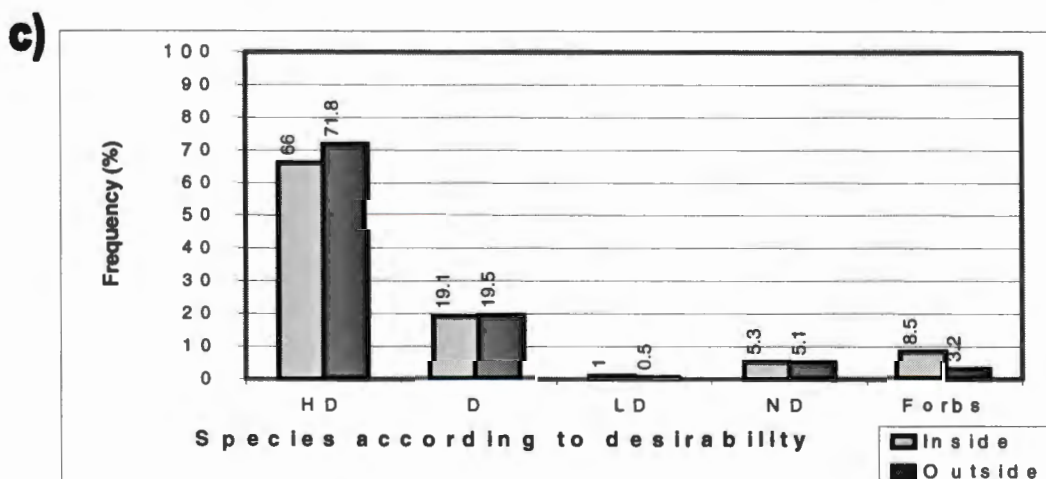
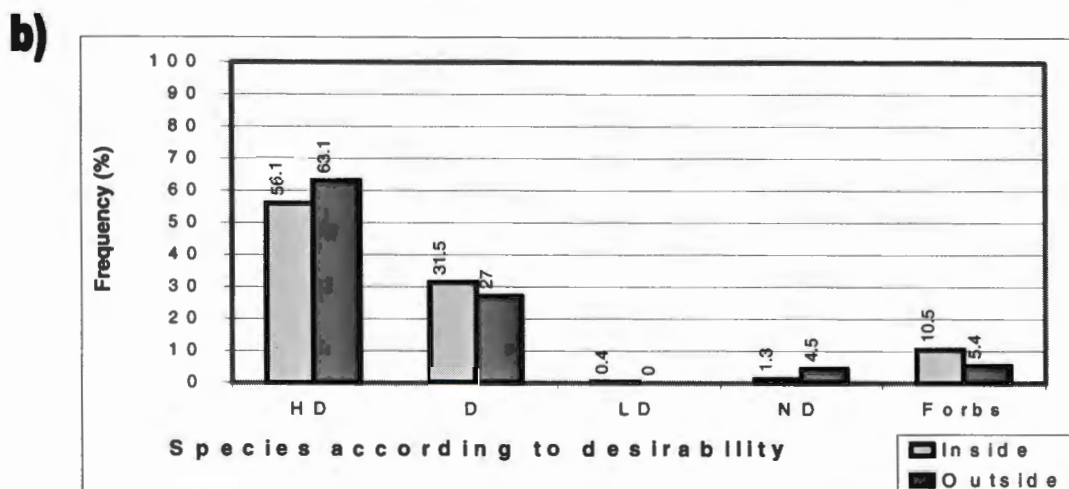
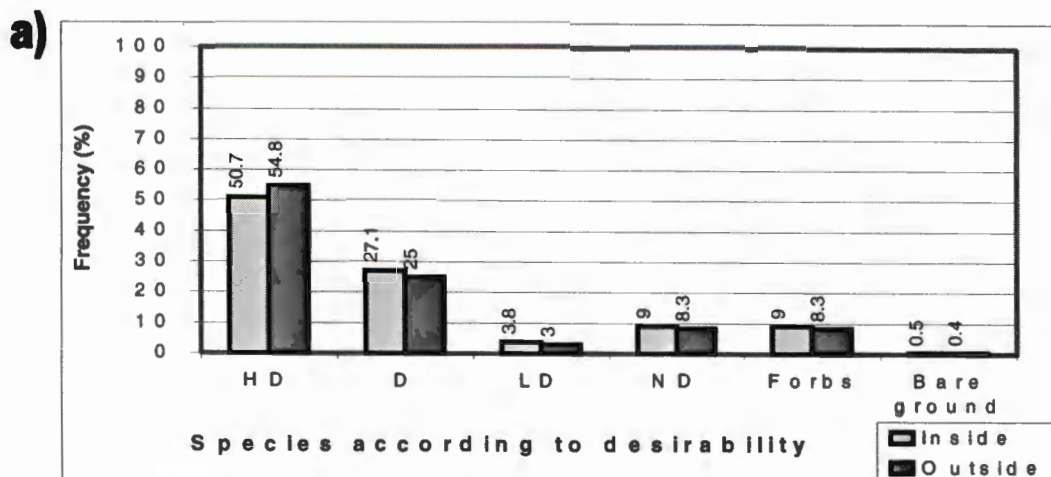


Figure 4.26 a-c: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Maketlele 2 benchmark site, during April 2001 (a), December 2001 (b) and May 2002 (c).

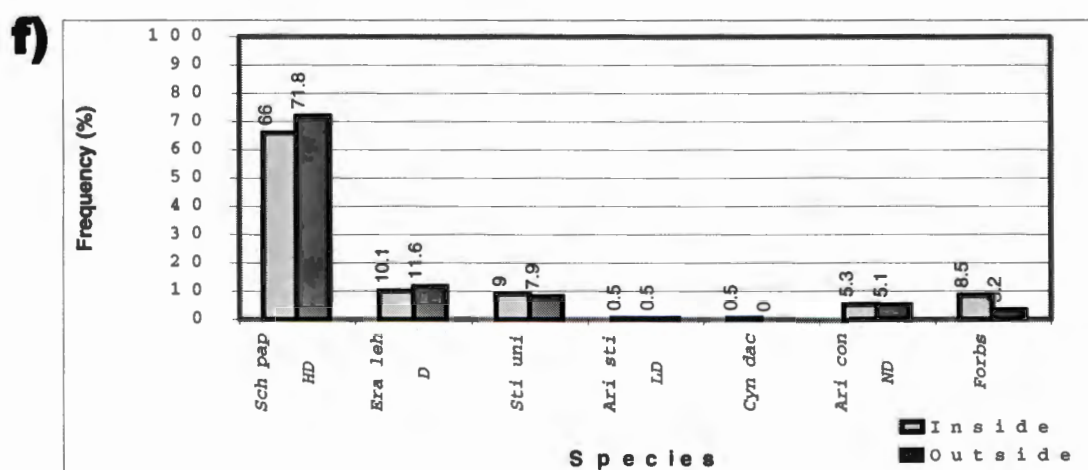
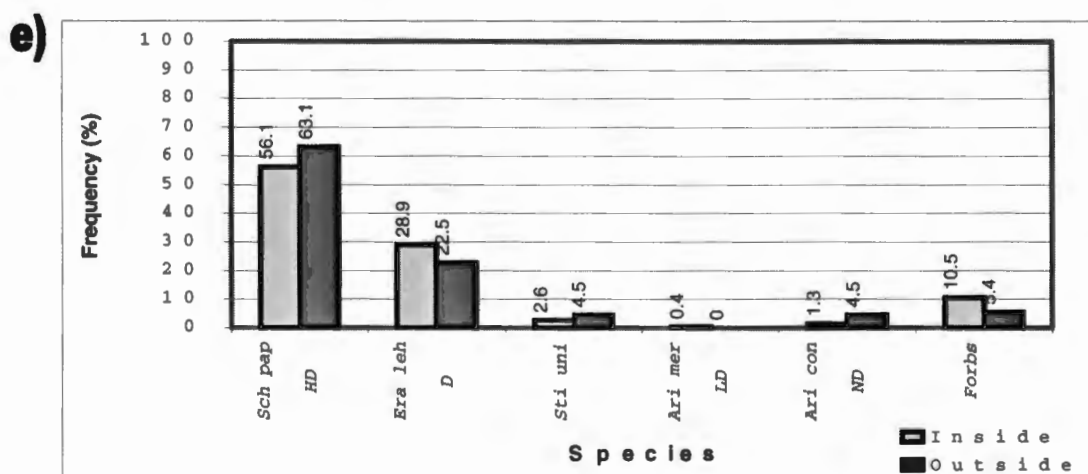
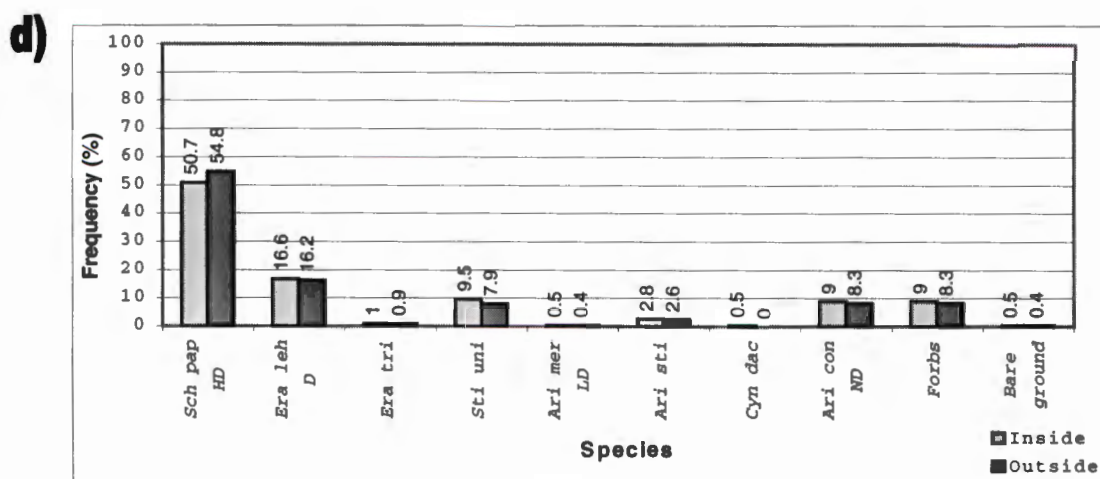


Figure 4.26 d-f: Frequency (%) of grass species inside and outside the enclosure at the Maketlele 2 benchmark site, during April 2001 (d), December 2001 (e), May 2002 (f) (see Annex C1 & C2 for species abbreviations).

According to the Z-indices it is also evident that the similarity in the grass species composition inside and outside the exclosure remained high throughout the study period, namely 92.2% during April 2001, 82.5% during December 2001, and 91.0% during May 2002 (Table 4.32). The effect of resting as demonstrated by the exclosure will only be observed after a few good rainfall seasons.

Table 4.32: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the exclosure at the Maketlele 2 benchmark site, during April 2001, December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Maketlele 2	April 2001	92.2
	December 2001	82.5
	May 2002	91.0

The frequency of the desirable species, mainly represented by *E. lehmanniana* and *S. uniplumis*, showed an overall decrease inside and outside the exclosure from April 2001 to May 2002 (Figure 4.26 a-f). The desirable grass species, *E. lehmanniana*, decreased in abundance from 16.6% in April 2001 to 10.1% inside the exclosure during May 2002, while the frequency of *S. uniplumis* remained relatively constant from 9.5% in April 2001 to 9.0% in May 2002. This decrease in the abundance of the desirable grass species can be contributed to the increase in competition for gaps, caused by the increase in the abundance of the highly desirable *S. pappophoroides*. This highly desirable *S. pappophoroides* populations form dense stands and represent a well established vegetation, and is therefore an effective competitor in this relatively arid environment.

The low percentage of bare ground patches seen at this benchmark site can also be explained by the dense stands of *S. pappophoroides*. The frequency of forb species remained relatively constant (inside and outside the exclosure) throughout the study period.

ii. Grass production

The considerable decrease in the total production inside the exclosure from April 2001 (1559 kg/ha) to May 2002 (906.6 kg/ha) can mainly be ascribed to the low rainfall that persisted throughout the study period (Table 4.33). From Table 4.35 it is evident that these factors led to an overall decrease in the production figures of all the desirability classes at the Maketlele 2 benchmark site.

The low rainfall thus also contributed to a lower recovery of these grass species, as well as to the decrease in the seasonal grazing capacity from 7.7 ha/LSU in April 2001 to 15.6 ha/LSU in May 2002, as calculated by means of approach (i). The seasonal grazing capacities determined by means of approaches (ii) and (iii) indicates a similar proportional decrease (Annex E). The low rainfall season however seemingly favoured an increase of the forbs species production from April 2001 to May 2002. This is explained by the increase in the contribution of the production by the forbs species to 20.3% in May 2002 (Table 4.33). This increase can also be seen in Figure 4.27. The decrease in the seasonal grazing capacity at this benchmark site can not be ascribed to changes in the forb production, seeing that it was not taken

consideration in calculating the seasonal grazing capacities (see Section 3.4.2, Chapter 3).

Table 4.33: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Maketlele 2 benchmark site, during April 2001 and May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
April 2001	1559.0	1341.5	217.5	14.0	7.7
May 2002	906.6	722.8	183.8	20.3	15.6

The increase in the frequency of *S. pappophoroides* inside the exclosure from April 2001 to May 2002 (Figure 4.26 d and f) is also reflected by the increase in the contribution of the highly desirable grass species to the total production from 2001 to 2002 (Figure 4.27). Accordingly the contribution of the desirable grass species, *E. lehmanniana*, *E. trichophora* and *S. uniplumis*, to the total production decreased inside the exclosure from 2001 to 2002.

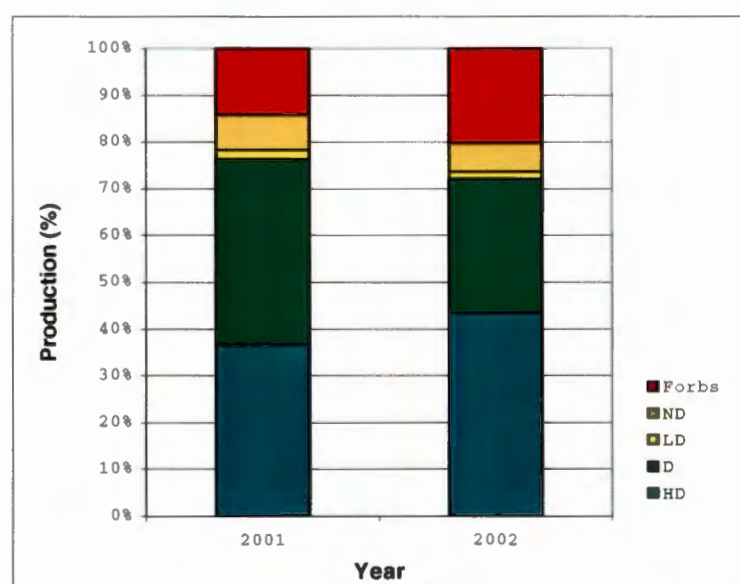


Figure 4.27: The changes in the contributions of the different desirability classes to the total production (%) at the Maketlele 2 benchmark site between April 2001 and May 2002.

4.2.1.3. Summary of the benchmark sites at the Maketlele study site

Since the commencement of the study in April 2001, the grass species composition at Maketlele 1 and 2 was dominated, inside and outside the exclosure, by the highly desirable *S. pappophoroides* species (Figure 4.23 a and d and 4.26 a and d). The abundance of this species continued to increase (inside and outside the exclosure) at

both these benchmark sites throughout the study period (Figure 4.23 a-f and 4.26 a-f). If only the grass species composition is taken into consideration, it can be concluded that the rangeland condition of these two benchmark sites are very similar, and can be regarded to be in a good condition.

Although the Z-indices indicates a high similarity in the grass species composition at both these benchmark sites, it is clear that the similarity was higher at the Maketlele 2 benchmark site, than at the Maketlele 1 benchmark site (Annex D). This can clearly be observed during May 2002, when the similarity between the grass species composition inside and outside the enclosure was 65.3% at the Maketlele 1 benchmark site and 91.0% at the Maketlele 2 benchmark site. This can be ascribed to the high decrease in the abundance of *S. pappophoroides* inside the enclosure at the Maketlele 1 benchmark site, due to the probable overgrazing of the enclosure during the winter.

If the production at Maketlele 1 and 2 is compared, it can be seen that the total production inside the enclosure at the Maketlele 1 site was less than the total production at Maketlele 2 during April 2001 (Table 4.34). During May 2002 the total production at Maketlele 2 (906.6 kg/ha) however decreased to less than the total production at Maketlele 1 (1158.2 kg/ha). The same trend can be observed in the seasonal grazing capacities that were determined by methods (i) (Table 4.35), (ii), and (iii) (Annex E).

Table 4.34: The total production (forbs included), grass production (forbs excluded), forbs production and the percentage that forbs contributed to the total production at the Maketlele study site, during April 2001 and May 2002.

Date	Benchmark sites	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)
April 2001	Maketlele 1	1182.3	950.7	231.6	19.6
	Maketlele 2	1559.0	1341.5	217.5	14.0
May 2002	Maketlele 1	1158.2	915.6	242.6	20.9
	Maketlele 2	906.6	722.8	183.8	20.3

During May 2002 the seasonal grazing capacity at these two benchmark sites indicates that Maketlele 1 consist of a better rangeland condition from the fact that the seasonal grazing capacity, determined by approach (i), at this benchmark site (8.1 ha/LSU) is better than at Maketlele 2 (15.6 ha/LSU). The same tendency is observed when the seasonal grazing capacities were determined by means of approaches (ii) and (iii) (Annex E). The decrease in the total production and the seasonal grazing capacity, as well as the increase in the percentage to which the forbs contributed to the total production at the Maketlele 2 benchmark site, gives an indication that the rangeland condition inside the enclosure deteriorated from 2001 to 2002. However, the grass species composition has the decisive influence on the productivity and seasonal grazing capacity, and eventually on the rangeland condition expected from grasslands (Snyman, 2000).

From Table 4.35 it is evident that the DM production of all the grass desirability classes, except that of the highly desirable grasses, *S. pappophoroides*, at the

Maketlele 1 benchmark site, decreased from April 2001 to May 2002. As already mentioned (see Section 4.3.1.2) these decreases can mainly be ascribed to the low rainfall (Figure 4.24) as well as the grazing of the sites inside the exclosures during the winter season.

The fact that the total grass production at Maketlele 1 did not increase even though the exclosure was already fenced since June 1999, and that the total grass production at Maketlele 2 decreased from 2001 to 2002, proves that changes in species composition and production is not only driven by grazing, but mainly by rainfall variability, especially in arid areas.

Table 4.35: The dry matter (DM) production figures (kg/ha) for the different grass species desirability classes and the seasonal grazing capacity, determined by means of approach (i) (ha/LSU), at the Maketlele benchmark sites during April 2001 and May 2002.

Benchmark site	Date	DM production of HD grass species (kg/ha)	DM production of D grass species (kg/ha)	DM production of LD grass species (kg/ha)	DM production of ND grass species (kg/ha)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
Maketlele 1	April 2001	643	290	18	0	8.9
	May 2002	839	108	3	0	8.1
Maketlele 2	April 2001	557	602	30	114	7.7
	May 2002	294	260	14	56	15.6

As observed in Table 4.36 the pH value of the soil inside and outside the exclosures at the benchmark sites in the Maketlele study site varies between pH 7.69 and 8.16. According to Foth (1990) these soils can be described as slightly alkaline. These relatively high pH values explain the high abundance of highly desirable grass species and also the good rangeland condition. The potassium, calcium and magnesium in the soil will thus be readily available to the plants, even though they are only present in small quantities.

According to the soil classification working group (1991) the soil is classified as sand because of the high percentage of sand particles present in the soil (between 89.7% and 91.6%). The CEC values of the soil at the different benchmark sites are also low, with an average value of 3.45 cmol⁺/kg, and can be attributed to the high sand particle content of the soil. These soils also consist of a very low carbon content, with an average value of 0.27%, as well as a low phosphorous content, with an average value of 3.37 mg/kg.

The soil analyses thus reflects no major differences between the soil composition at this two benchmark sites. These two benchmark sites thus consists of similar soil conditions, received the same rainfall, and were subjected to the same management treatment (the exclosures were rested and only grazed during the winter). Consequently it could be suggested that the different responses of the vegetation to the low rainfall are a consequence of different life histories of the main grass species (*S. pappophoroides*).

Table 4.36: Some of the results of the soil analyses carried out for the benchmark sites at the Maketlele study site (the complete set of results is conveyed in Annex B).

Benchmarks	pH	P (mg/kg)	K (mg/kg)	CEC (cmol+/kg)	C (%)	Clay (%)	Silt (%)	Sand (%)
Maketlele 1 Inside	7.98	3.65	41.1	3.27	0.27	6	2.4	91.6
Maketlele 1 Outside	8.16	3.73	33.1	3.08	0.26	8	0.3	91.7
Maketlele 2 Inside	7.89	3.77	37.6	3.67	0.27	8	2.1	89.9
Maketlele 2 Outside	7.69	3.75	35.5	3.78	0.28	8	2.3	89.7
Average values	7.93	3.73	36.8	3.45	0.27	8	1.8	90.7

4.3.2. Morafe ranch Management at the Heuningvlei study site

The Heuningvlei study site is situated in the Kudumane magisterial district in the western region of the North West Province. This study site is divided into the Heuningvlei FSU that is situated in the Heuningvlei ADC (see Figure 2.4, Chapter 2). The Morafe ranch is managed by 12 farmers. The total area of the Morafe ranch (7200 ha) is divided into sub-units consisting of 1200 hectares each. Each of these sub-units is further divided into four 300 hectare paddocks.

One, two or a group of farmers are appointed to manage one of these sub-units. More than two farmers per sub-unit are allowed, as long as they stay within the recommended long-term grazing capacity of 10 ha/LSU. This implies that only 120 LSU per sub-unit are allowed, and accordingly if the sub-unit is managed by only two farmers each of them are allowed to only own 60 LSU. In order to keep within these limits, the farmers are motivated to sell their calves at an age of nine months. Only a certain percentage of the profit has to be paid to the community. The farmers at this study site were positive with regard to sound management practices and are therefore enthusiastic and committed to the LandCare project.

According to the agricultural extension officer (Table 4.37) a four camp rotational grazing system, where one of the paddocks should be rested for one year, is currently being applied in each sub-unit. Only cattle are allowed to graze the rangeland at this study site, in order to avoid the particularly negative effects that goats and sheep have on rangelands.

Table 4.37: The ADC manager and agricultural extension officer at the Heuningvlei study site.

District	Benchmark site	Management system	ADC manager	Agricultural extension officer
Kudumane	Heuningvlei	Morafe ranch	Shishi Mashishi Tel: (053) 773 1982 : 072 885 5550	Marcus Ndhlapo Tel: 082 665 0497

The exclosures at the Heuningvlei study site were erected during June 2001. Accordingly the grass species compositional surveys were only carried out during December 2001 and May 2002, while the grass species production was cut only once during May 2002.

4.3.2.1. Heuningvlei A2 benchmark site

i. *Grass species composition*

An increase in the abundance of the desirable species occurred inside and outside the exclosure from December 2001 to May 2002, while the abundance of the highly desirable species, *S. pappophoroides*, decreased on the inside and outside the exclosure (Figure 4.28 a-d). Accordingly the highly desirable grass species no longer dominated at this benchmark site during May 2002. The increase in the abundance of the desirable grass species was mainly caused by the increase in the abundance of *E. lehmanniana* inside and outside the exclosure (Figure 4.28 c and d), which thus contributed to the fact that the desirable grass species dominated at the benchmark site during May 2002. The fact that the decreaser species, *S. pappophoroides*, decreased in abundance, while the increaser II species, *E. lehmanniana*, increased in abundance indicates that the benchmark site is moderately overgrazed.

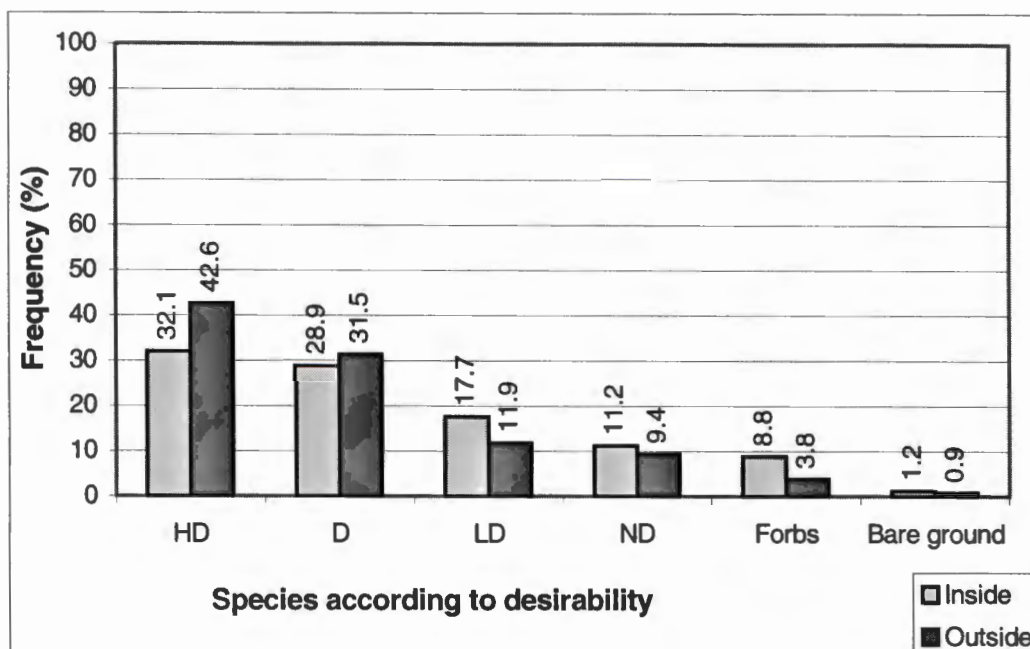
The desirable grass species, *E. lehmanniana*, is described as a valuable grazing grass in the arid parts of this region, and as one of the first grasses that start growing in spring. It can thus be deduced that this grass species was the first to increase in abundance in reaction to the above average rainfall that occurred from September 2001 to February 2002 (Figure 4.29 b and c). Due to the fact that the highly desirable grass species decreased in abundance, it could be concluded that the *S. pappophoroides* population was not yet established very well. On the other hand, the abundance of the less desirable, *A. stipitata*, *M. repens* and *P. squarrosa*, and non desirable, *A. congesta*, grass species stayed relatively constant inside and outside the exclosure from December 2001 to May 2002 (Figure 4.28 a-d). The decrease in the frequency of the forb species inside the exclosure during the study period could have resulted from the increase in the abundance of the desirable grass species.

No major differences between the species composition inside and outside the exclosure could be detected (Figure 4.28 a-d). The high Z-index values also indicates that a high degree of similarity still exists between the species composition inside and outside the exclosure, in fact this similarity increased from 76.8% in December 2001 to 85.1% during May 2002 (Table 4.38). The increase in the Z-index value can mainly be attributed to the decrease in the difference of the abundance in the highly desirable grass species, inside and outside the exclosure, from 2001 (10.2%) to 2002 (0.5%).

Table 4.38: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the exclosure at the Heuningvlei A2 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Heuningvlei A2	December 2001	76.8
	May 2002	85.1

a)



b)

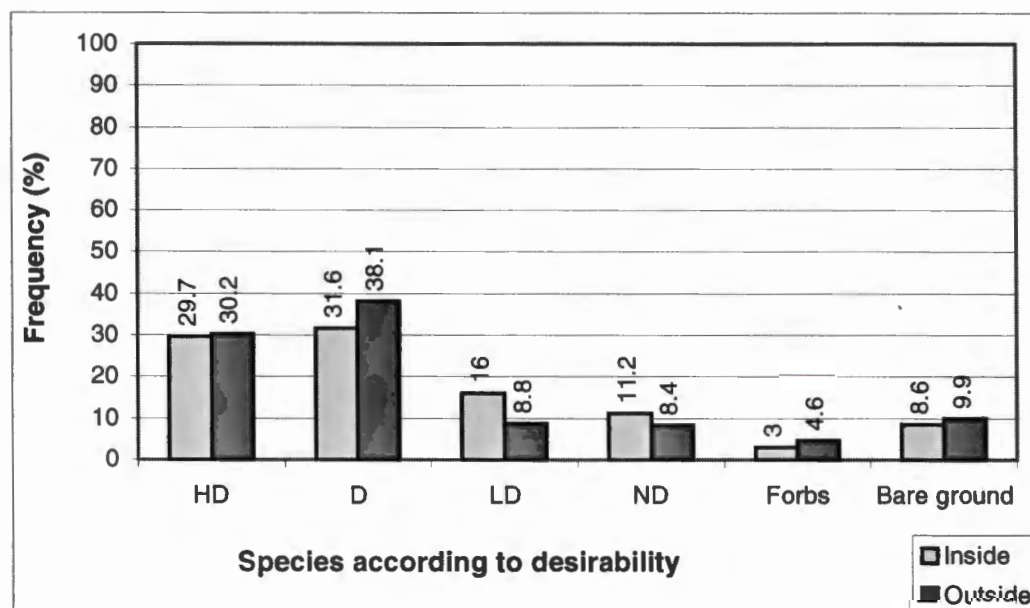
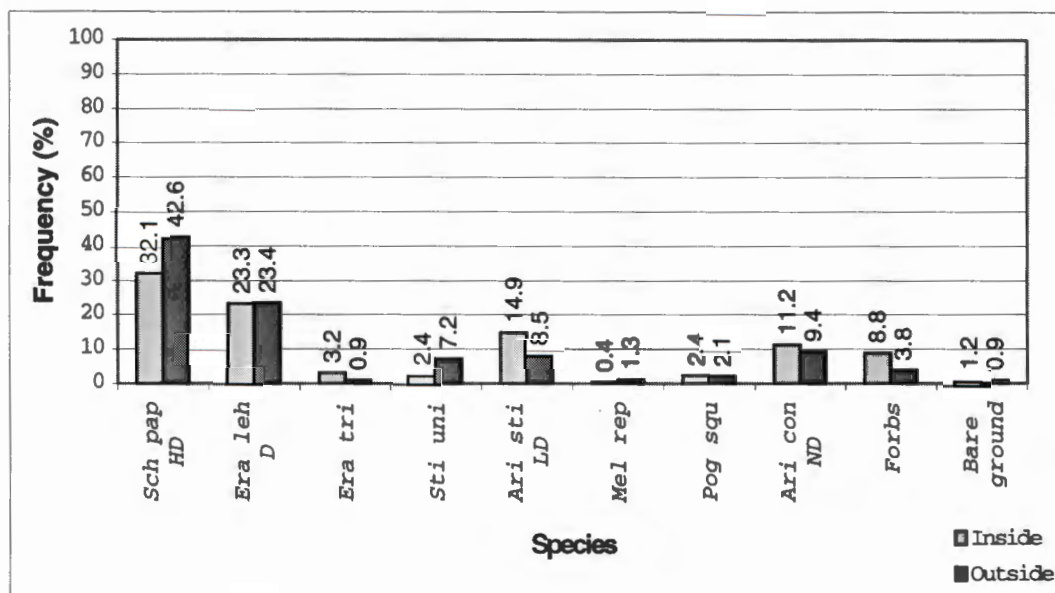


Figure 4.28 a and b: Frequency of grass species according to their desirability inside and outside the enclosure at the Heuningvlei A2 benchmark site, during December 2001 (a) and May 2002 (b).

c)



d)

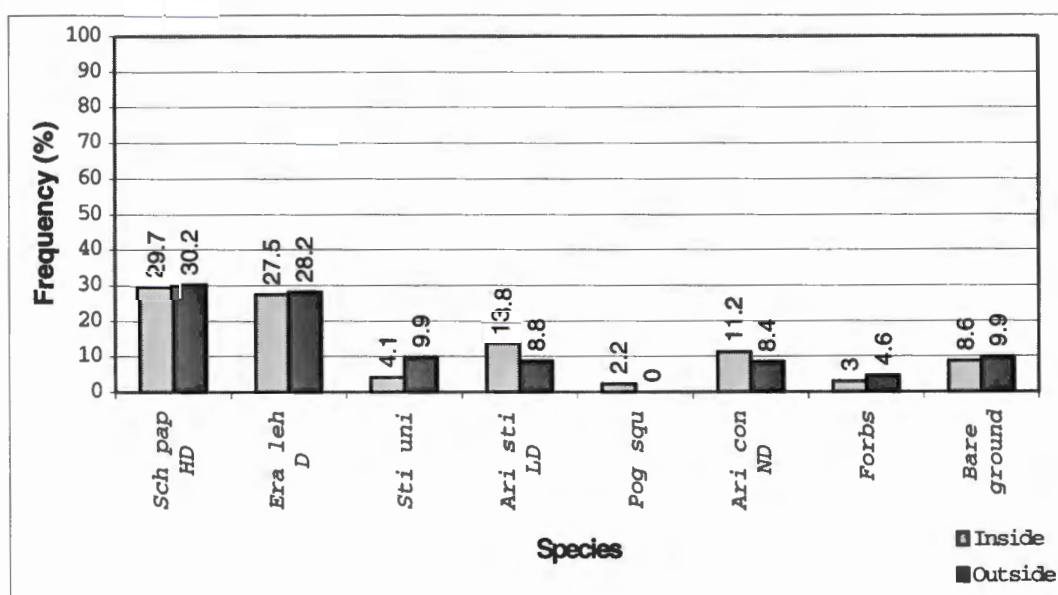


Figure 4.28 c and d: Frequency (%) of grass species inside and outside the enclosure at the Heuningvlei A2 benchmark site, during December 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

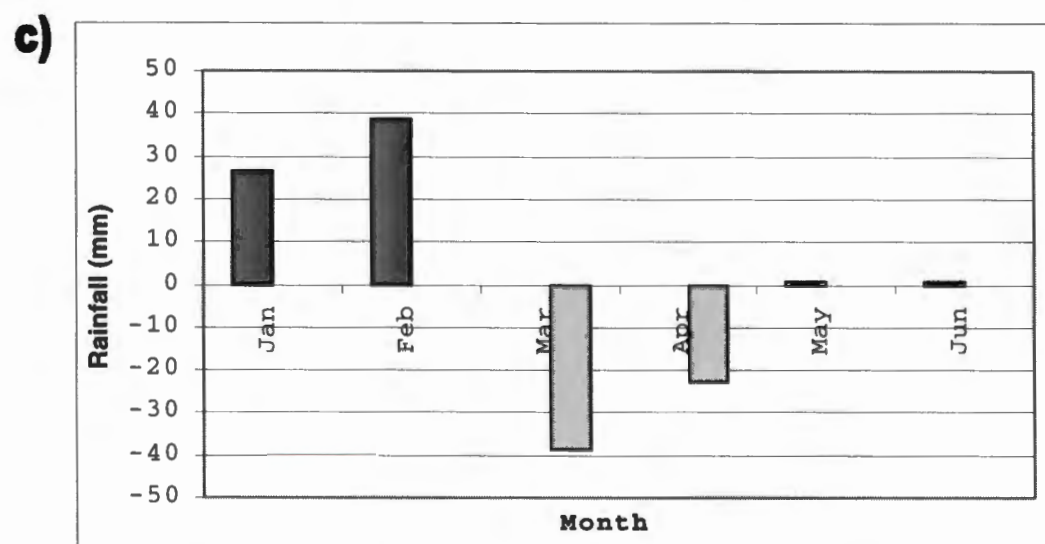
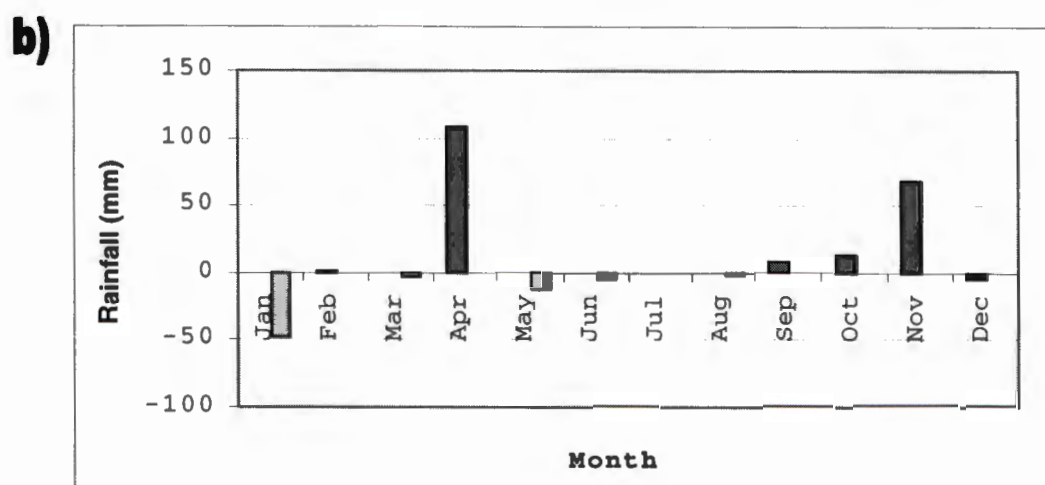
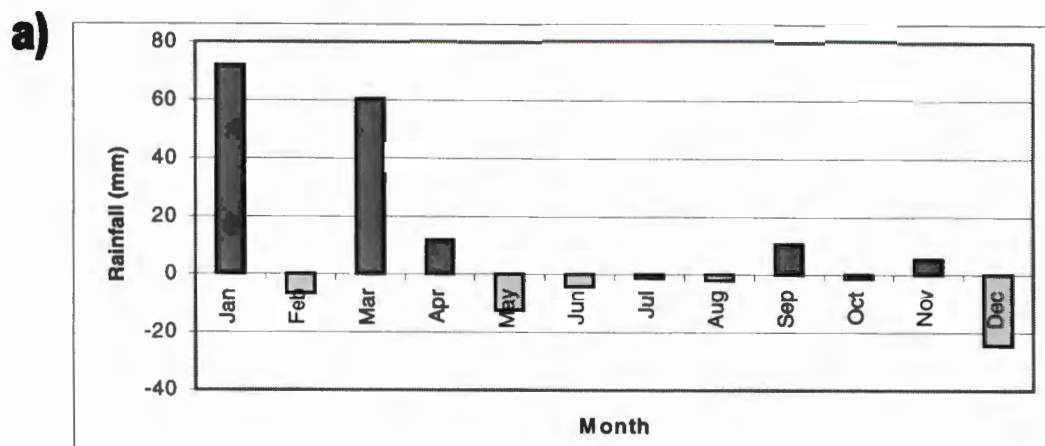


Figure 4.29 a-c: Rainfall deviation from the average rainfall at the Heuningvlei study site during the years 2000 (a), 2001 (b) and 2002 (c).

This large degree of similarity in the grass species composition inside and outside the enclosure during the study period can be ascribed to the fact that vegetation dynamics takes place over much longer time periods. The study period was thus too short to observe any species compositional changes that may have resulted from the change in the grazing regime, especially inside the enclosure where rest was applied. These above mentioned slight changes in the grass species composition thus serve as evidence that annual rainfall variation has an important influence on short duration vegetation compositional changes.

ii. Grass Production

The total grass production inside the enclosure at the Heuningvlei A2 site was 1716.1 kg/ha (Table 4.39). The seasonal grazing capacity, determined by approach (i), was 7.5 ha/LSU during May 2002. This figure is better than the long-term recommended grazing capacity (10 ha/LSU) of this benchmark site. By determining the seasonal grazing capacity by approaches (ii) and (iii), values of 10.6 ha/LSU and 8.1 ha/LSU were obtained respectively (Annex E). These values does not differ much from the seasonal grazing capacity calculated by means of approach (i), and also coincides with the long-term grazing capacity.

Table 4.39: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Heuningvlei A2 benchmark site during May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
May 2002	1716.1	1587	129.1	7.5	7.5

The desirable and highly desirable grass species, *E. lehmanniana* and *S. pappophoroides* (Figure 4.28d), contributed the most to the total grass production inside the enclosure during May 2002 (Figure 4.30), with production figures of 563.0 kg/ha and 480.0 kg/ha, respectively (Table 4.45). The contribution of the desirable grass species to the total production were followed by the production of the non desirable grass species, *A. congesta* (305 kg/ha), the less desirable grass species, *A. stipitata* and *P. squarrosa* (239 kg/ha), and lastly the forb species. The forb species contributed to only 7.5% of the total production with a production of 129.1 kg/ha.

From the high total production figure, the relatively good seasonal grazing capacity, and the fact that the desirable and highly desirable grass species contributed mostly to the total production, it can be concluded that the Heuningvlei A2 benchmark site is in a good conditional state.

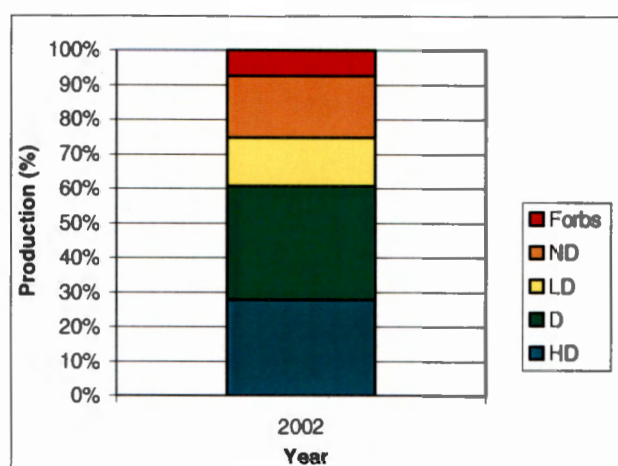


Figure 4.30: Contributions of the different desirability classes to the total production (%) at the Heuningvlei A2 benchmark site during May 2002.

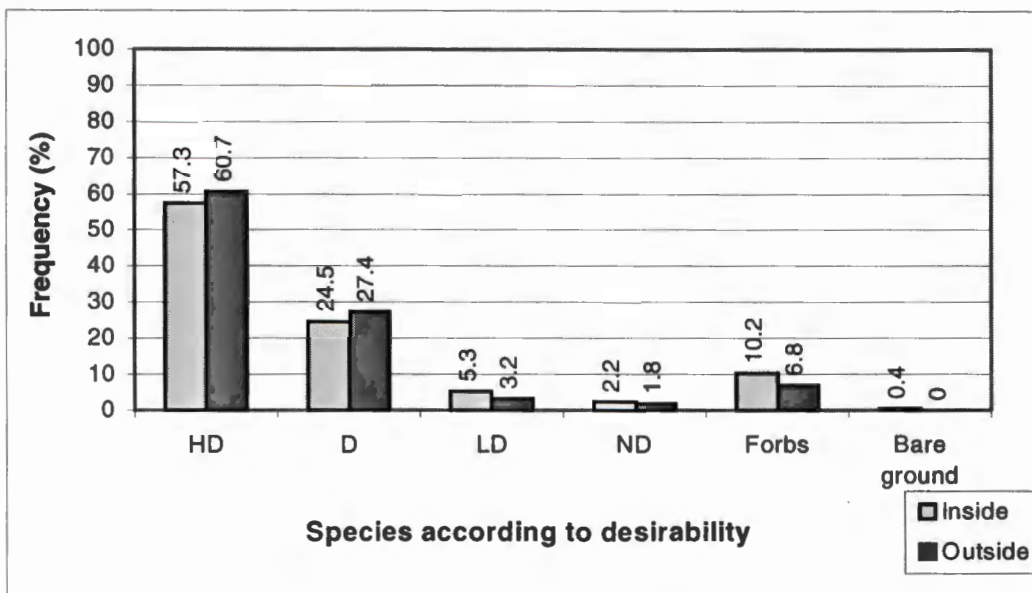
4.3.2.2. Heuningvlei C2 benchmark site

i. *Grass species composition*

This benchmark site is characterised by a high frequency of highly desirable grass species inside and outside the exclosure during December 2001 and May 2002 (Figure 4.31 a and b). The dominant highly desirable grass species is *S. pappophoroides*, a palatable, decreaser species for this sandy rangeland type (Figure 4.31 c and d). This serves as an indication that the rangeland is in a rather good condition. The desirable grass species, *E. lehmanniana* and *S. uniplumis*, are the grass species with the second highest abundances at the Heuningvlei C2 benchmark site inside and outside the exclosure, during December 2001 and May 2002 (Figure 4.31 a-d).

The slight increases in the abundance of the less desirable and non desirable grass species (inside and outside the exclosure) from December 2001 to May 2002, can be ascribed to the higher rainfall from September 2001 to February 2002 (Figure 4.29 b and c). Although the rainfall at this study site was not as high as observed at the Austrey and Waterfouchè study sites (Figures 4.2 and 4.11), it can still contribute to seedling recruitment of especially the pioneer type species, such as the less desirable *A. stipitata* and *P. squarrosa*, and the non desirable *A. congesta* (Figure 4.31d). The frequency of forb species decreased (inside and outside the exclosure) from December 2001 to May 2002, while the bare ground patches increased slightly (Figure 4.31 a and b).

a)



b)

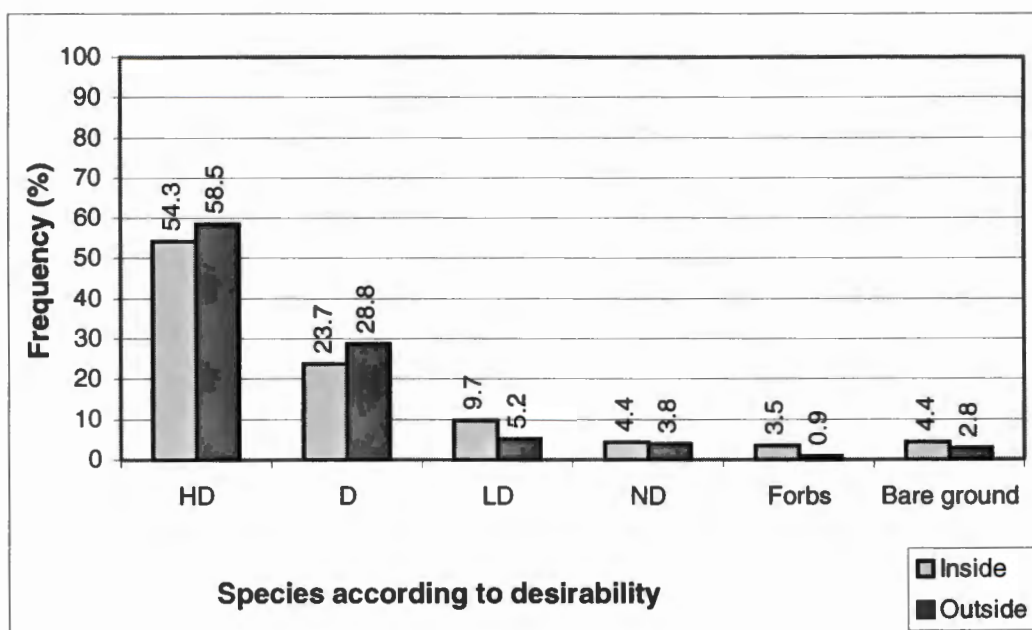
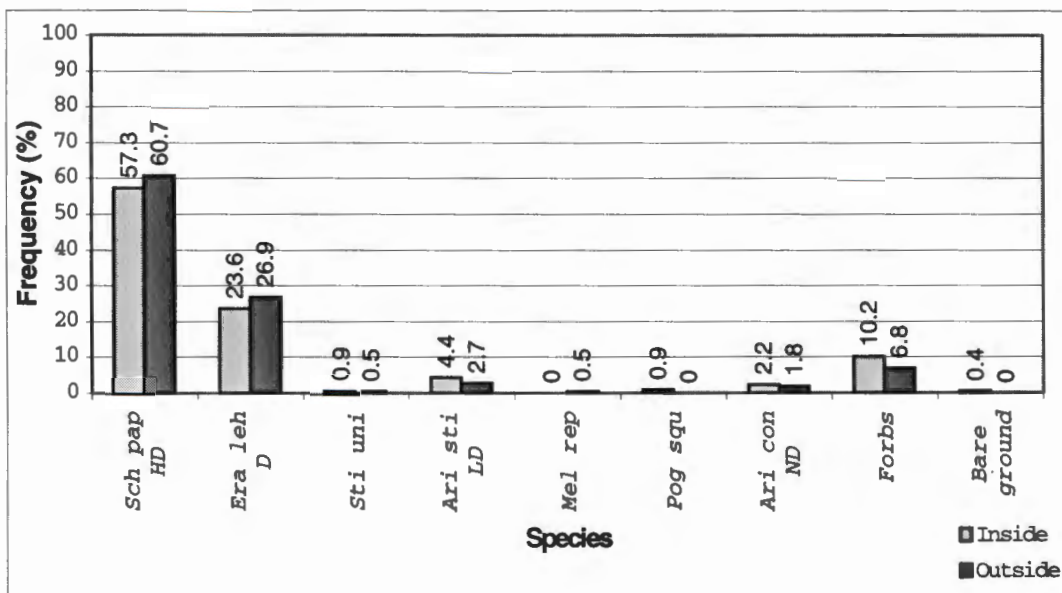


Figure 4.31 a and b: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Heuningvlei C2 benchmark site, during December 2001 (a) and May 2002 (b).

c)



d)

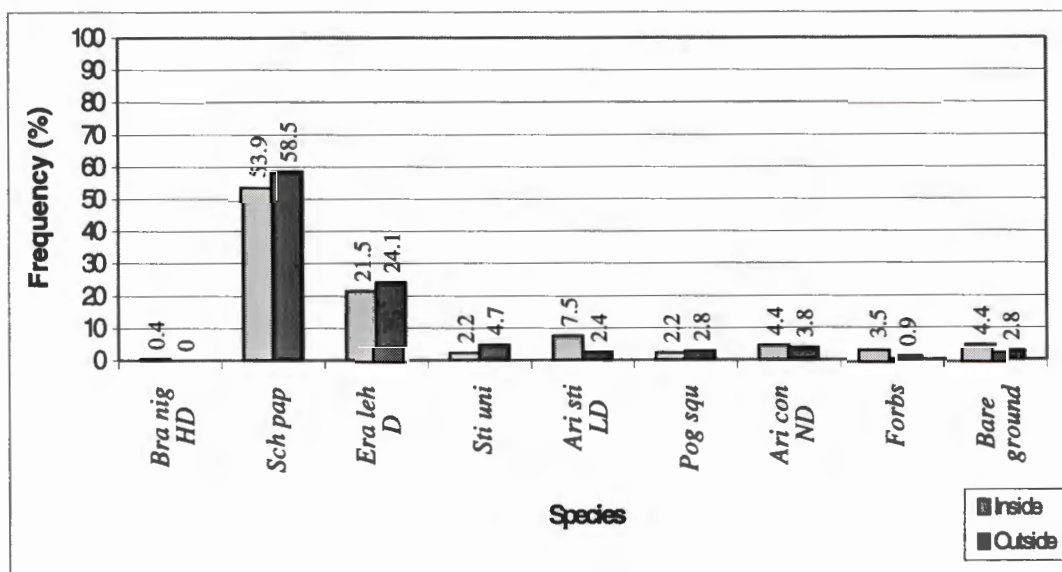


Figure 4.31 c and d: Frequency (%) of grass species inside and outside the enclosure at the Heuningvlei C2 benchmark site, during December 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

From figure 4.31 a-d, it is evident that no great differences can as yet be observed between the vegetation composition inside and outside of the enclosure. The high Z-index values, 90.0% during December 2001 and 85.8% during May 2002, also serve as evidence that the similarity between the grass species composition inside and outside the benchmark is still high (Table 4.40). A slight decrease in the similarity can however be observed from 2001 to 2002, and it can thus be concluded that minor changes in the grass species composition between the inside and outside of the enclosure did occur.

Table 4.40: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Heuningvlei C2 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Heuningvlei C2	December 2001	90.0
	May 2002	85.8

From the high abundances of highly desirable and desirable grass species present at this benchmark site, it can be concluded that Heuningvlei C2 is in a relatively good rangeland condition.

ii. Grass Production

The total grass production inside the enclosure at the Heuningvlei C2 site during May 2002 was 2908.1 kg/ha (Table 4.41). This production figure is relatively high and can mainly be ascribed to the high abundances of the highly desirable and desirable grass species inside the enclosure (Figure 4.31b), which generally consists of large tuft sizes and can accordingly produce a higher amount of DM. The highly desirable grass species contributed mostly to the total production (Figure 4.32), with a DM production of 1972 kg/ha (Table 4.45). As already mentioned *S. pappophoroides* and *E. lehmanniana* were the dominant species of the highly desirable and desirable grass species group during May 2002, respectively.

The seasonal grazing capacity at this benchmark site (determined by approach (i)), 3.1 ha/LSU, is the best of all the benchmark sites that were surveyed for the purpose of this study (Annex E). This can be attributed to the relatively high production of the highly desirable (1972.0 kg/ha) and desirable (528.0 kg/ha) grass species. In determining the seasonal grazing capacity by means of approach (i) the utilisation factors that were appointed to these desirability classes were 0.5 (50%) and 0.3 (30%), respectively. It is thus clear that even if some of the other desirability classes produced the same amount of DM, the seasonal grazing capacity will be lower due to the fact that these grass species are less desirable and are accordingly appointed lower utilisation factors. This is also true for calculating the seasonal grazing capacity by approaches (ii) and (iii) (Annex E). The values obtained through these two methods also reflect a very good seasonal grazing capacity at this study site, namely 4.4 ha/LSU (approach (ii)) and 3.9 ha/LSU (approach (iii)).

The less desirable (*A. stipitata* and *P. squarrosa*) and non desirable (*A. congesta*) grass species, together contributed only to approximately 8% of the total production

inside the exclosure during May 2002, with DM production figures of 181.0 kg/ha and 42.0 kg/ha, respectively (Table 4.45 and Figure 4.32).

Table 4.41: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity, determined by means of approach (i), at the Heuningvlei C2 benchmark site during May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
May 2002	2908.1	2723.0	185.1	6.4	3.1

The forb species contributed only to a small percentage of the total production (inside the exclosure) during May 2002, namely 6.4% (Table 4.41). This is also reflected in figure 4.32 as well as in the species composition figures (Figure 4.31 b and d).

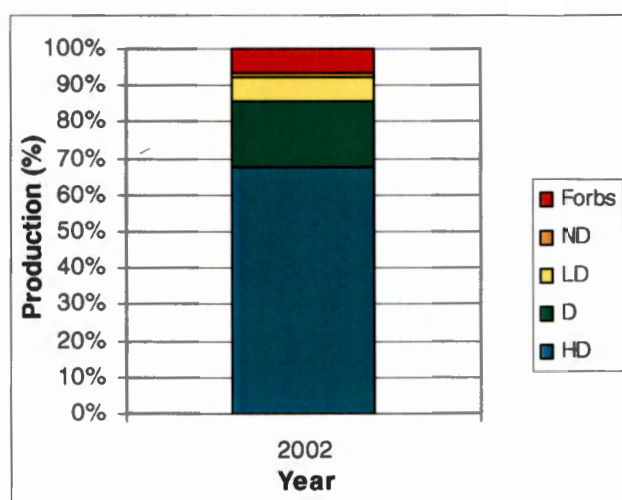


Figure 4.32: Contributions of the different desirability classes to the total production (%) at the Heuningvlei C2 benchmark site during May 2002.

4.3.2.3. Heuningvlei F2 benchmark site

i. *Grass species composition*

The Heuningvlei F2 benchmark site is dominated by the desirable increaser II grass species inside and outside the exclosure, namely *E. lehmanniana* and *S. uniplumis*, during December 2001 and May 2002 (Figure 4.33 a-d). This reflects that the benchmark site is still in a moderately good condition but prone to degradation and a subsequently poor rangeland condition if overgrazing will occur. The latter can be observed in the decrease in the abundance of the highly desirable (*S. pappophoroides*), desirable and forb species, as well as in the increase of bare patches during the study period. The same trend was however observed inside and outside the exclosure. This could be ascribed to the higher grazing pressure that took place before the establishment of the exclosure at the benchmark site.

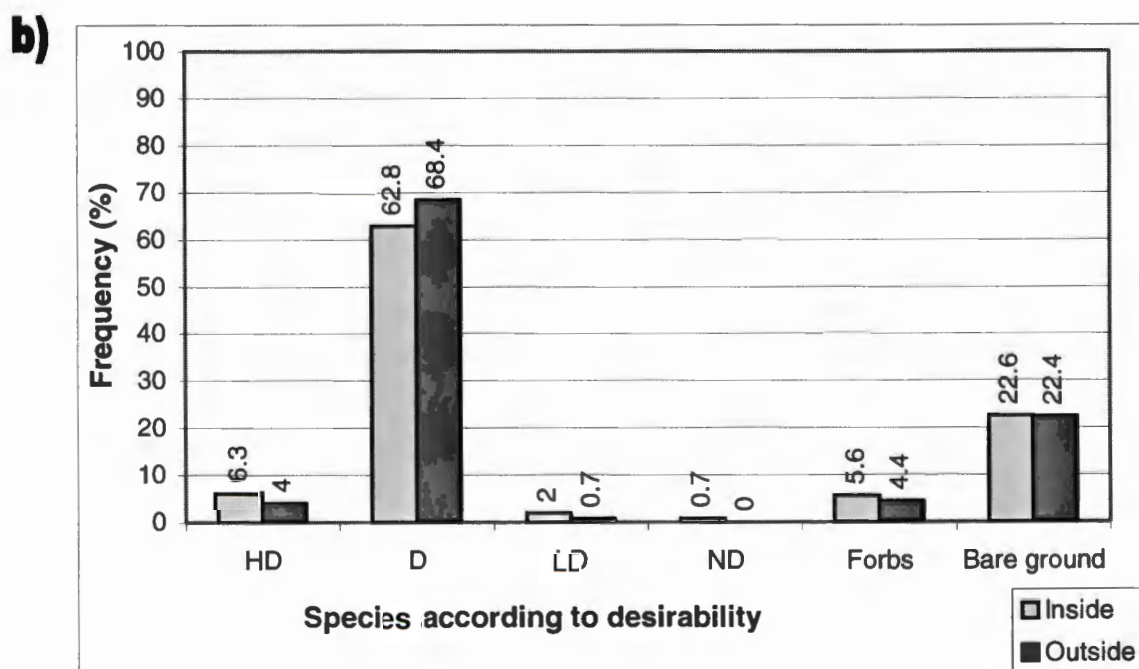
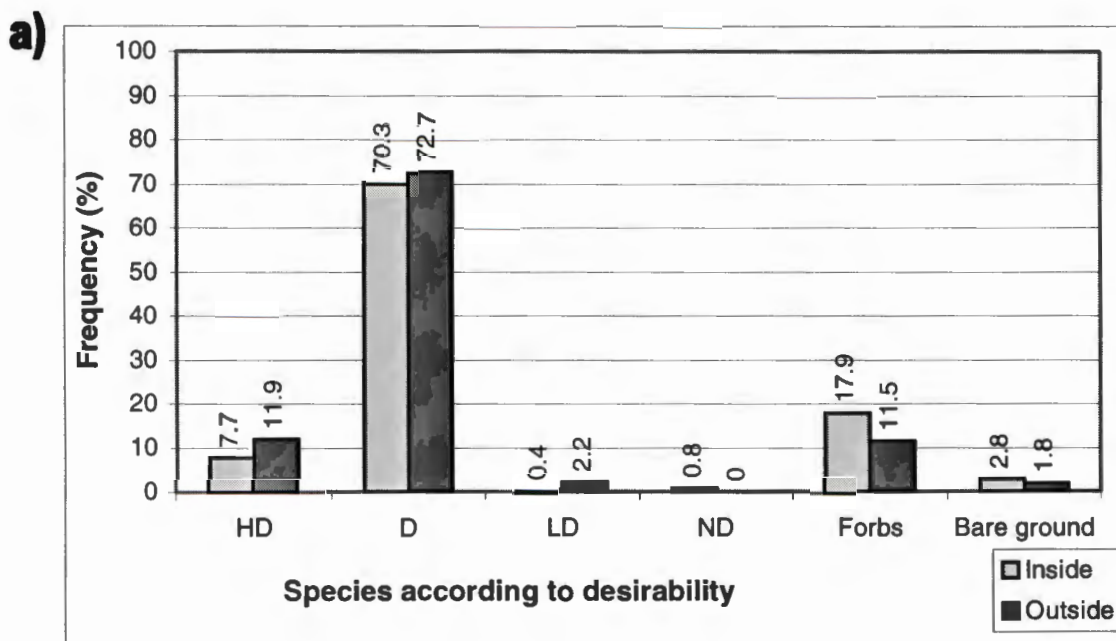
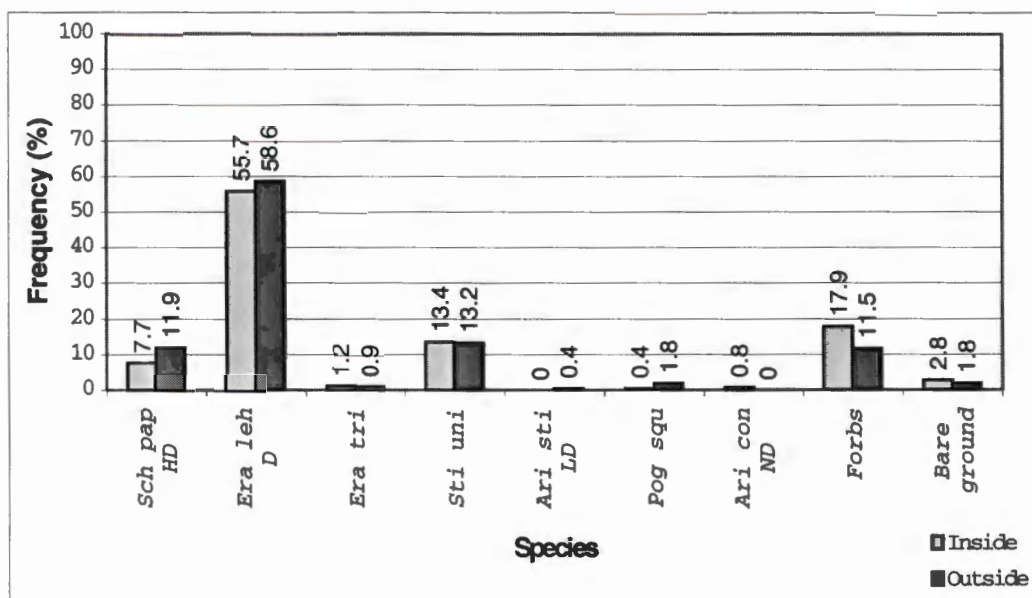


Figure 4.33 a and b: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Heuningvlei F2 benchmark site, during December 2001 (a) and May 2002 (b).

c)



d)

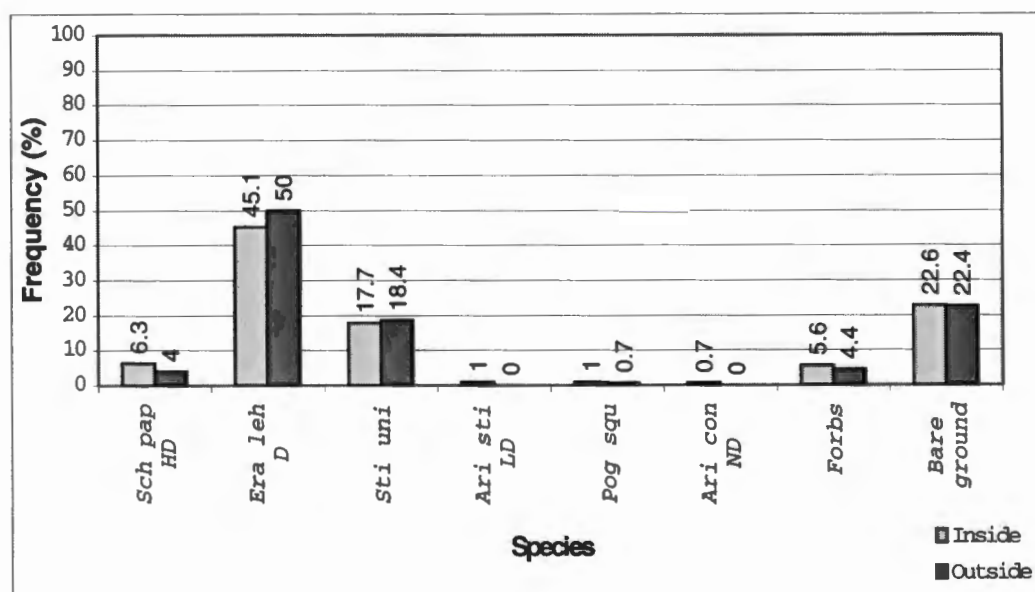


Figure 4.33 c and d: Frequency (%) of grass species inside and outside the enclosure at the Heuningvlei F2 benchmark site during December 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

From the Z-indices it is evident that the degree of similarity between the grass species composition inside and outside the enclosure is still very high (Table 4.42). The Z-index value did however show a slight decrease from 90.1% in December 2001 to 88.5% in May 2002. This can be explained by the slight increase in the difference between the abundance of the desirable grass species, *E. lehmanniana*, inside and outside the enclosure from 2001 (2.9%) to 2002 (4.9%) (Figure 4.33 c and d).

Table 4.42: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Heuningvlei F2 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Heuningvlei F2	December 2001	90.1
	May 2002	88.5

The overall decrease in the abundance of grass species can be described as a result of the lower rainfall during March and April 2002 (Figure 4.29c). It could have occurred that a large amount of seedlings did establish during the higher rainfall period from September 2001 to February 2002 (Figure 4.29 b and c), but due to no follow-up rains the young plants died during the summer months. It is important to keep in mind that savanna grassland communities usually contain species with a range of life history characteristics that are expected to respond differently to environmental influences (O'Connor, 1995). According to O'Connor (1994) a palatable, long-lived obligate seed reproducer developing limiting amounts of larger seeds may for instance become locally extinct under variable rainfall and heavy grazing. This study period was however too short to detect significant responses of grass species to different environmental factors.

ii. Grass Production

The desirable grass species, namely *E. lehmanniana* and *S. uniplumis*, contributed the most to the total, relatively high production of 2069.4 kg/ha inside the enclosure at this benchmark site (Figure 4.43), with a DM production of 1869.0 kg/ha (Table 4.45).

Table 4.43: The total production (forbs included), grass production (forbs excluded), forbs production, the percentage that forbs contributed to the total production, and the seasonal grazing capacity determined by means of approach (i) at the Heuningvlei F2 benchmark site (during May 2002).

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
May 2002	2069.4	1996.7	72.7	3.5	5.9

The forbs had a low production (72.5 kg/ha) and only contributed 3.5% to the total production (Table 4.43). This can be due to the low rainfall (February – May 2002) before the production surveys were carried out, as well as the high abundances of desirable species, giving rise to the conclusion that this benchmark site is still in a moderately good condition. The highly desirable, *S. pappophoroides* (108.0 kg/ha),¹³⁸

less desirable, *A. stipitata* and *P. squarrosa* (16.0 kg/ha), and non desirable, *A. congesta* (4.0 kg/ha), grass species also contributed to the total production during May 2002, but as can be observed from Figure 4.34, only to a small amount.

The fact that the seasonal grazing capacity (determined by approach (i)) of 5.9 ha/LSU is better than the recommended long-term grazing capacity (10 ha/LSU) for the Heuningvlei study site, also serve as proof that the benchmark site is in a moderately good condition (Table 4.43). The seasonal grazing capacities determined by means of approaches (ii), 8.8 ha/LSU, and (iii), 5.2 ha/LSU, are also better than the long-term grazing capacity (Annex E).

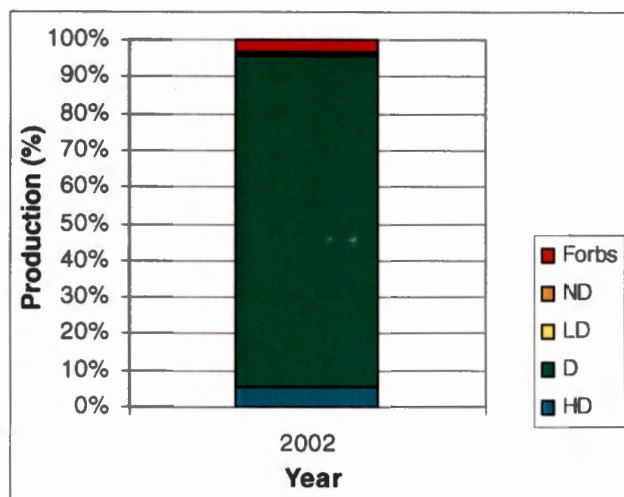


Figure 4.34: Contributions of the different desirability classes to the total production (%) at the Heuningvlei F2 benchmark site, during May 2002.

4.3.2.4 Summary of the benchmark sites at Heuningvlei

At the Heuningvlei A2 and C2 benchmark sites the highly desirable species, *S. pappophoroides*, dominated inside and outside the enclosure, while the desirable grass species, *E. lehmanniana*, dominated at the Heuningvlei F2 benchmark site (Figure 4.28 a-d, 4.31 a-d, 4.33 a-d). The similarity of the grass species composition inside and outside the enclosures at the Heuningvlei study site is still relatively high, as can be seen from the high Z-index values (above 75%) calculated for these benchmark sites (Annex D). It is thus clear that the two year study period was too short to detect marked differences in the grass species composition between the inside and the outside of the enclosure.

The slight deterioration in the vegetation composition at these three benchmark sites during May 2002 can mainly be ascribed to the rainfall variation (Figure 4.29). Consequently the low rainfall figure during March and April 2002 led to an overall decrease in the abundance of grass species inside and outside the enclosure at the Heuningvlei A2, C2 and F2 sites. Thus, the unique responses of recruitment, growth and mortality of the grass and forb species determined the pattern of community change to the rainfall variability.

If only the grass species composition results are taken into consideration, it can be deduced that the Heuningvlei C2 benchmark site is in the best conditional state of the three benchmark sites. This can be deduced from the fact that the abundance of the highly desirable grass species, *S. pappophoroides*, is highest at this benchmark site (inside and outside the enclosure). A good grass species composition, however, does not necessarily reflect a high production. According to Snyman (2000) the grass species composition only has an influence on the productivity and eventually on the seasonal grazing capacity expected from grasslands.

Thus, taking into consideration the production at the three benchmark sites, it can be seen that the highest DM production was produced at the Heuningvlei C2 site (2908.1 kg/ha), followed by the Heuningvlei F2 site (2069.4 kg/ha), and then the Heuningvlei A2 site, with a DM production of 1716.1kg/ha (Table 4.44).

Table 4.44: The total production (forbs included), grass production (forbs excluded), forbs production and the percentage that forbs contributed to the total production at the Heuningvlei study site during May 2002.

Date	Benchmark sites	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)
May 2002	Heuningvlei A2	1716.1	1587.0	129.1	7.5
	Heuningvlei C2	2908.1	2723.0	185.1	6.4
	Heuningvlei F2	2069.4	1996.7	72.7	3.5

The fact that the highly desirable grass species, *S. pappophoroides*, contributed mostly (1972.0 kg/ha) to the highest total production figure (inside the enclosure) at the Heuningvlei C2 benchmark site, thus supports the statement that this benchmark site consists of the best rangeland condition of the three benchmark sites in the Heuningvlei study site.

Even though the total production at the Heuningvlei A2 site is less than that of the Heuningvlei F2 site, this benchmark site is dominated by the highly desirable grass species, *S. pappophoroides* (Figure 4.28 c and d). At the Heuningvlei F2 benchmark site the desirable grass species, *E. lehmanniana* and *S. uniplumis* (Figure 4.33d), however dominated (inside and outside the enclosure), and accordingly it can be said that the Heuningvlei A2 site consists of a better rangeland condition than the Heuningvlei F2 site.

From Table 4.45 it is clear that also according to the seasonal grazing capacity values (determined by approach (i)), the Heuningvlei C2 benchmark site (3.1 ha/LSU) is in the best conditional state in comparison to the Heuningvlei F2 (5.9 ha/LSU) and A2 (7.5 ha/LSU) benchmark sites. The same tendency is also reflected by the seasonal grazing capacities that were calculated by approaches (ii) and (iii) (Annex E).

Table 4.45: The dry matter (DM) production figures (kg/ha) for the different grass species desirability classes and the seasonal grazing capacity, determined by means of approach (i) (ha/LSU), at the Heuningvlei benchmark sites during April 2001 and May 2002.

Benchmark site	Date	DM production of HD grass species (kg/ha)	DM production of D grass species (kg/ha)	DM production of LD grass species (kg/ha)	DM production of ND grass species (kg/ha)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
Heuningvlei A2	May 2002	480	563	239	305	7.5
Heuningvlei C2	May 2002	1972	528	181	42	3.1
Heuningvlei F2	May 2002	108	1869	16	4	5.9

All three benchmark sites however consists of a desirable grass species composition, a high total production figure, and a good seasonal grazing capacity (as demonstrated by all three approaches), and accordingly they all are in a good condition. This serve as prove to the statement of the agricultural extension officer, which was made at the commencement of the study, that all the benchmark sites at this study sites are in a good condition. This could be explained by the fact that the availability of water at the Heuningvlei study site is a serious limiting factor, and accordingly the density of people and cattle at this study site was kept very low until now. Seeing that watering points are currently being erected at this Morafe ranch in order to provide water for the land users and their cattle, it would be interesting to determine the effect it will have on the rangeland condition by means of the continued monitoring of the Heuningvlei A2, C2 and F2 benchmark sites. Therefore, the importance of this baseline data, and the use of exclosures at different benchmark sites in order to determine the effect of the Morafe ranch type of management on the vegetation composition and production over the long term, cannot be stressed enough.

According to the soil analyses of the benchmark sites at Heuningvlei (Annex B), these soils (inside and outside the exclosures) can all be classified as slightly acidic (Foth, 1990). These pH values of between pH 6.35 and 6.60 has a negative influence on the availability of the already low amounts of soil nutrients, in that it decreases the availability of potassium (average value of 28.83 mg/kg), calcium and magnesium in the soil (Table 4.46) (Taddese, 2001). This can also be ascribed to the relatively low CEC, with an average value of 3.81 cmol+/kg. The low abundance of phosphorous, average value of 3.31 mg/kg, potassium, and the other soil nutrients can mainly be attributed to the high leaching of these sandy soils. The fact that the sand content of these soils is considerably high, between 87.5% and 93.6% proves that leaching of the soil at this benchmark site takes place to a great extent. These soils are therefore classified as sand (Soil classification working group, 1991).

Table 4.46: Some of the results of the soil surveys carried out at the Heuningvlei study site (the complete set of results can be observed in Annex B).

Benchmarks	pH	P (mg/kg)	K (mg/kg)	CEC (cmol+/kg)	C (%)	Clay (%)	Silt (%)	Sand (%)
Heuningvlei A2 Inside	6.44	3.51	20.5	5.82	0.16	6	0.4	93.6
Heuningvlei A2 Outside	6.37	3.38	28.7	3.17	0.19	6	0.9	93.1
Heuningvlei C2 Inside	6.35	3.35	38.0	4.22	0.21	6	0.8	93.2
Heuningvlei C2 Outside	6.44	3.25	34.6	4.12	0.16	8	0.9	91.1
Heuningvlei F2 Inside	6.60	3.33	25.9	3.31	0.27	6	0.9	93.1
Heuningvlei F2 Outside	6.24	3.04	25.3	2.22	0.26	10	2.5	87.5
Average values	6.41	3.31	28.83	3.81	0.21	7	1.1	91.9

Seeing that the soil composition at all the Heuningvlei benchmark sites, A2, C2 and F2 does not show major differences, the vegetation composition at these benchmark sites could be compared. Due to this fact, and that these benchmark sites all received the same rainfall and were subjected to the same management system (Morafe ranch management type) during the study period, the differences in the grass species composition and production can only be attributed to differences in the history of grazing at these benchmark sites.

4.4. Taung magisterial district

Two study sites were monitored in the Taung magisterial district, namely the communal managed site at Ipelegeng, and the Orange Grove site managed by the Morafe ranch management system.

4.4.1. Communal grazing management at the Ipelegeng study site

The Ipelegeng study site is situated in the Ipelegeng FSU of the Taung central ADC (see Figure 2.4, Chapter 2). The Taung central ADC is located in the Taung magisterial district of the western region in the North West Province.

Information about the study site that was provided by the agricultural extension officer (Table 4.47) is as follows: The Ipelegeng study site consists of two sections namely 460 hectares of irrigated farmlands and 871 hectares of pasture. The study was only carried out on the natural grazing section. No paddocks have been established up to now and accordingly no specific rotational grazing system is currently being applied. The study site is under the communal management of eight households. The enclosure is erected in a 20 hectare camp, which is currently being grazed by six goats and ten cattle.

Table 4.47: The ADC manager and agricultural extension officer at the Ipelegeng study site.

District	Benchmark site	Management system	ADC manager	Agricultural extension officer
Taung	Ipelegeng	Communal	Simon Tsenkeng Tel: (053) 9941 858/9	Joseph Gabanakgosi Tel: 083 208 4971

The enclosure at this benchmark site was only erected in June 2001. The initial vegetation surveys were carried out during April 2001 in the natural grazing area where the enclosure still had to be erected. Only a single set of vegetation data was thus collected at this benchmark site during April 2001 (Figure 4.35a). During the subsequent surveys carried out in December 2001 and May 2002 the species composition was determined inside and outside the enclosure.

The overall attitude of the community towards the LandCare project was perceived as positive and enthusiastic. The community members were also co-operative and willing to assist with the surveys.

4.4.1.1. Ipelegeng 1

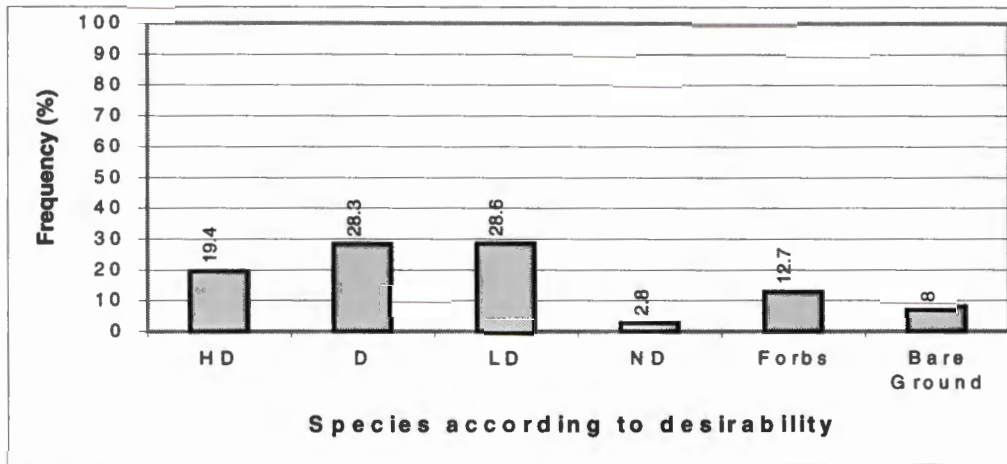
i. *Grass species composition*

The Ipelegeng 1 benchmark site was dominated by desirable and less desirable grass species during April 2001 (Figure 4.35a). *Eragrostis lehmanniana* and *E. trichophora* represent the desirable grass species, while the less desirable grass species are represented by *A. stipitata*, *Cynodon dactylon* and *E. rigidior* (Figure 4.35 d-f). The dominance of these increaser II species (Annex C1 and C2) implies that this benchmark was slightly to moderately overgrazed.

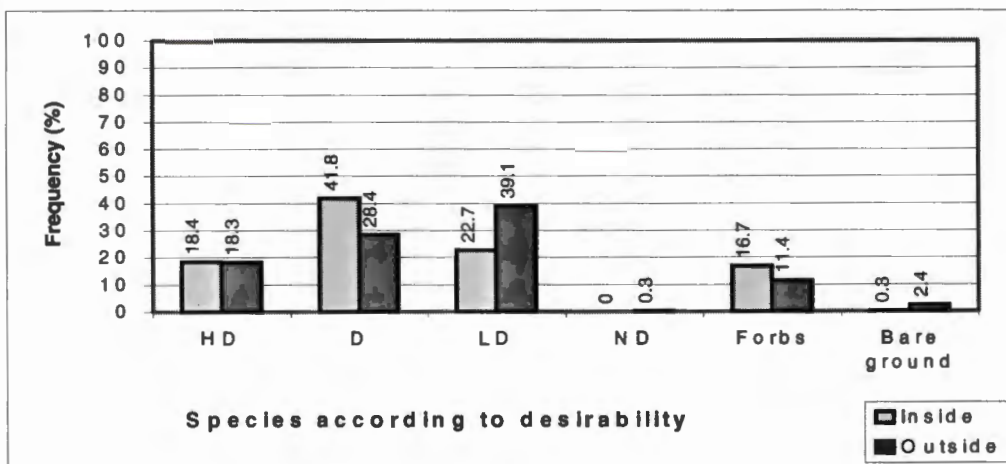
The abundance of the desirable grass species (inside and outside the enclosure), less desirable grass species (outside the enclosure) and the forb species (inside the enclosure) increased from April 2001 to December 2001 (Figure 4.35 a and b). This can be ascribed to the above average rainfall that prevailed from September to December 2001 (Figure 4.36b).

A minor difference between the species composition inside and outside the enclosure can be observed, especially the higher frequency of desirable grass species inside the enclosure, during December 2001 (Figure 4.35b). The abundance of less desirable species, such as *C. dactylon* and *E. rigidior* (Figure 4.35 b and e), were on the other hand lower, on the inside than on the outside of the enclosure during December 2001. The short rest period, together with the above average rainfall, could have led to the more desirable grass species composition on the inside of the enclosure. The lower abundance of desirable grass species outside the enclosure can be attributed to the fact that heavy grazing causes a reduction in the production of seed (O'Connor, 1994). These species could therefore not react on the high rainfall to the same extent than the desirable grass species inside the enclosure, where no grazing took place for at least five months.

a)



b)



c)

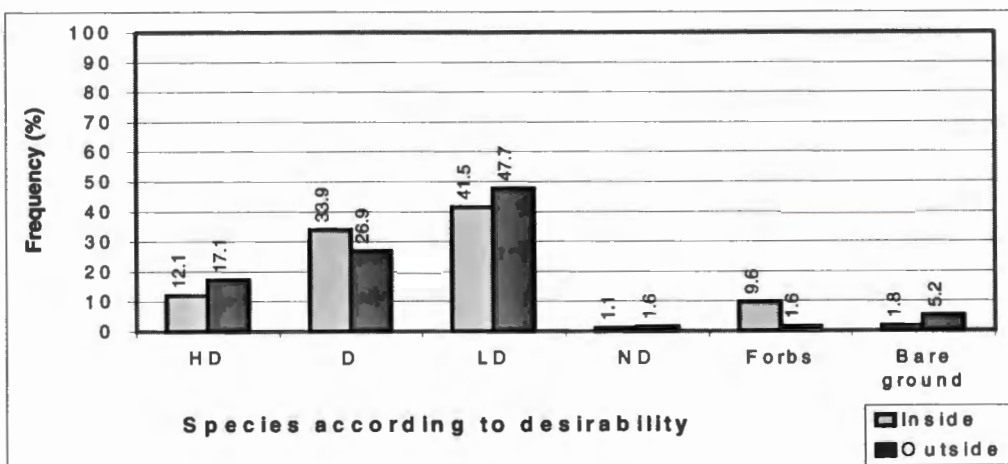
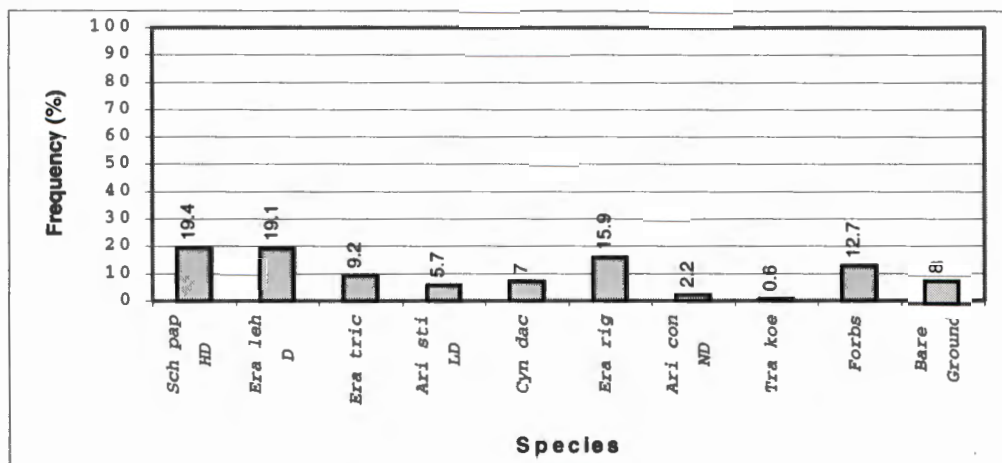
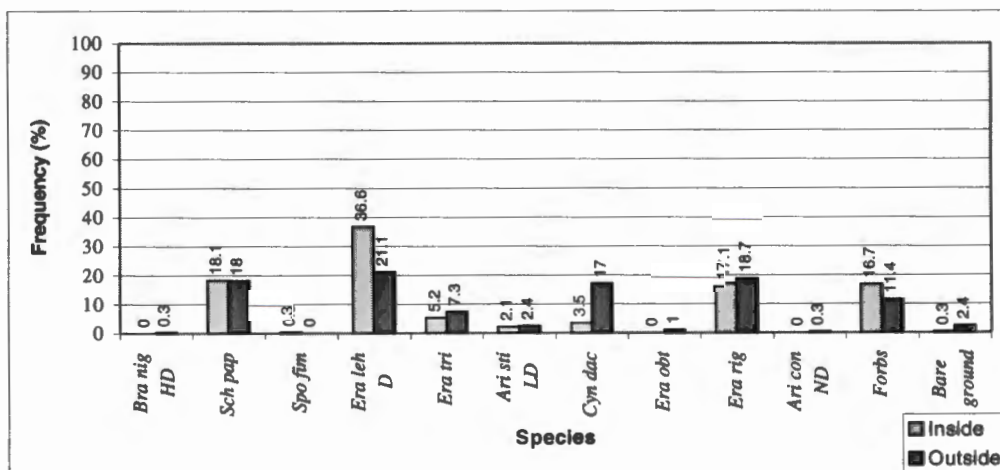


Figure 4.35 a-c: Frequency (%) of grass species according to their desirability inside and outside the enclosure (except during April 2001 where only one set of data was collected, seeing that the enclosure was only erected in June 2001) at the Ipelegeng 1 benchmark site, during April 2001 (a), December 2001 (b) and May 2002 (c).

d)



e)



f)

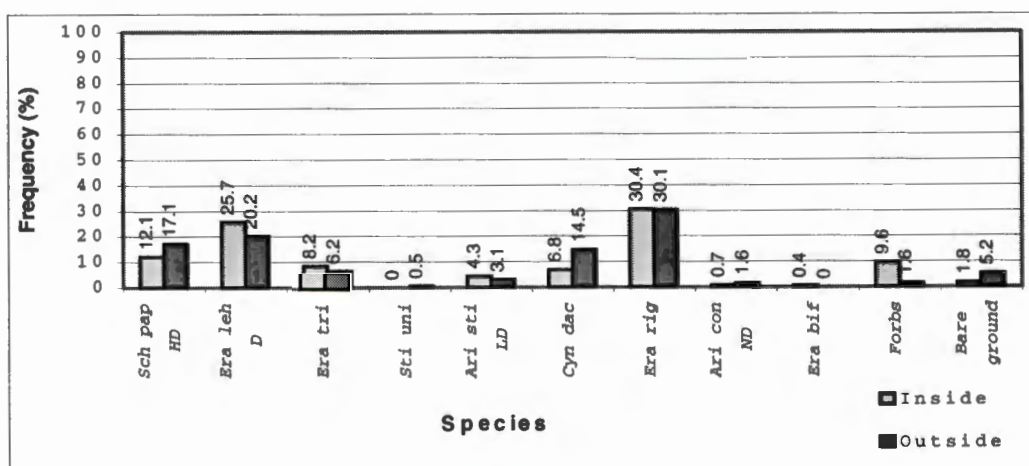


Figure 4.35 d-f: Frequency (%) of grass species inside and outside the enclosure (except during April 2001 where only one set of data was collected, seeing that the enclosure was only erected in June 2001) at the Ipelegeng 1 benchmark site, during April 2001 (d), December 2001 (e) and May 2002 (f) (see Annex C1&2 for sp. abbreviations).

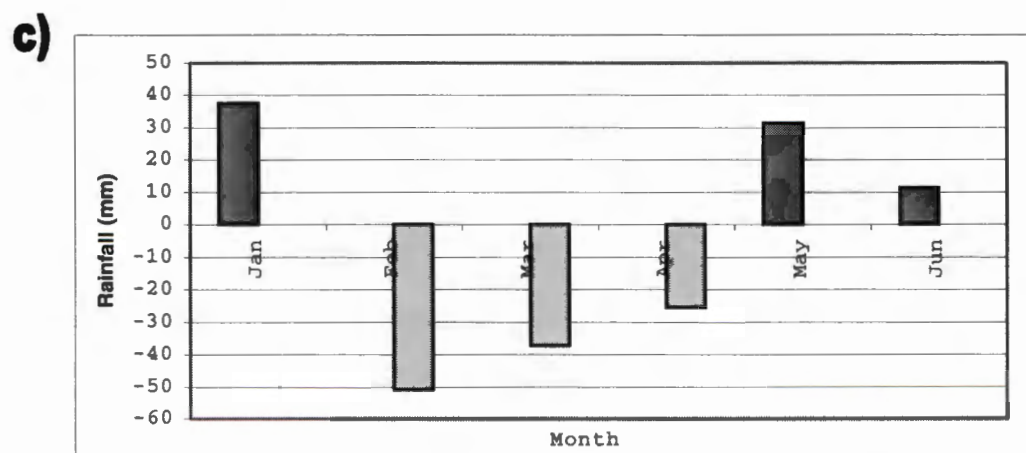
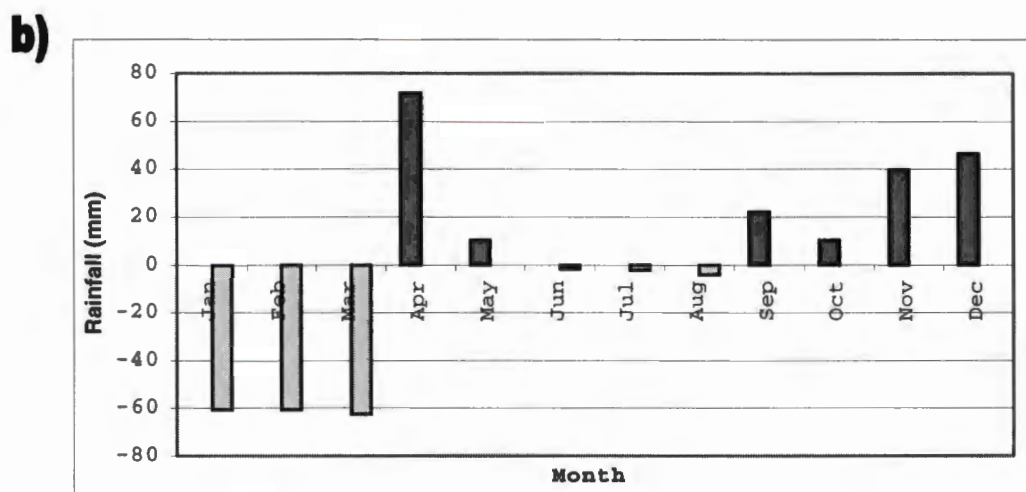
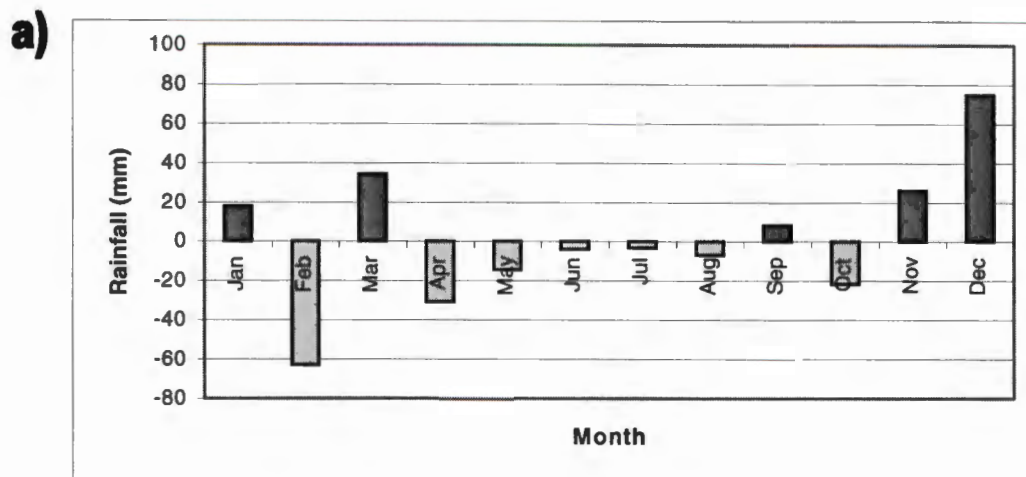


Figure 4.36 a-c: Rainfall deviation from the average rainfall at the Ipelegeng study site during the years 2000 (a), 2001 (b) and 2002 (c).

The abundance of the less desirable grass species increased even more from December 2001 to May 2002, namely from 22.7% to 41.5% inside the enclosure and from 39.1% to 47.7% outside the enclosure (Figure 4.35 b and c). The seedling recruitment of these species was mainly in response to the high rainfall from September 2001 to January 2002 (Figure 4.36 b and c). The less desirable grass species, *E. rigidior*, was the main contributor to this increase, and it can thus be deduced that this species must have had a persistent soil seed bank.

The increase in abundance of the less desirable grass species and the decrease in abundance of the desirable grass species inside the enclosure, occurred to such an extent that the frequency of these species differ less from their frequencies outside the enclosure in May 2002 than in December 2001 (Figure 4.35 b and c). This explains the fact that the similarity in the grass species composition inside and outside the enclosure increased from 70.4 % in December 2001 to 88.7% in May 2002 (Table 4.48). Thus, although small differences in the grass species composition inside and outside the enclosure can be observed, the similarity is still high.

Table 4.48: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Ipelegeng 1 benchmark site, during December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Ipelegeng 1	December 2001	70.4
	May 2002	88.7

The increase in the seedlings of the less desirable grass species, in reaction to the high rainfall season, could have led to a decrease in which the highly desirable grass species, desirable grass species and forb species were recorded during the vegetation surveys of May 2002 (Figure 4.35c). Accordingly this explains the decrease in the abundance of these species inside and outside the enclosure from December 2001 to May 2002. Although the Ipelegeng 1 benchmark site is dominated by less desirable grass species, the abundance of non desirable grass species, forb species and the percentage of bare ground patches are low, and it can thus be concluded that this benchmark site is in a moderate rangeland condition.

ii. Grass Production

The total production at the Ipelegeng 1 benchmark site increased considerably from April 2001 (696.0 kg/ha) to May 2002 (1324.1 kg/ha) (Table 4.49). Although the contribution to the total production by the forbs decreased from 19.5% in April 2001 to 10.9% in May 2002, this contribution was still considerably high, compared to the other benchmark sites previously discussed.

The increase in the total production mostly occurred due to the increase in the production of the desirable (from 149.0 kg/ha in 2001 to 468.0 kg/ha in 2002) and less desirable grass species, also described as medium desirable grass species (from 317.0 kg/ha in 2001 to 563.0 kg/ha in 2002) (Figure 4.37 and Table 4.50).

Table 4.49: The total production (forbs included), grass production (forbs excluded), forbs production, and the percentage that forbs contributed to the total production at the Ipelegeng 1 benchmark site, during April 2001 and May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)
April 2001	696.0	560.0	136.0	19.5
May 2002	1324.1	1180.2	143.9	10.9

As can be observed in Figure 4.35f, this increase in production was mainly caused by the increase in the frequency of the desirable *E. lehmanniana* and the less desirable *E. rigidior* grasses. The contribution of the highly desirable grass species, *S. pappophoroides*, and forb species to the total grass production decreased from April 2001 to May 2002 (Figure 4.37).

Table 4.50: The dry matter (DM) production figures (kg/ha) for the different grass species desirability classes and the seasonal grazing capacity, determined by means of approach (i) (ha/LSU), at the Ipelegeng 1 benchmark site during April 2001 and May 2002.

Benchmark site	Date	DM production of HD grass species (kg/ha)	DM production of D grass species (kg/ha)	DM production of LD grass species (kg/ha)	DM production of ND grass species (kg/ha)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
Ipelegeng 1	April 2001	88	149	317	7	23.9
	May 2002	139	468	563	11	11.3

This increase in the total grass production and the fact that the desirable and less desirable grass species contributed mostly to this increase gave rise to the improvement of the seasonal grazing capacity, determined by approach (i), from 23.9 ha/LSU in April 2001 to 11.3 ha/LSU in May 2002 (Table 4.50). The seasonal grazing capacities calculated by means of approaches (ii) and (iii) also improved 2.1 times, namely from 29.4 ha/LSU in April 2001 to 14.3 ha/LSU in May 2002, and from 18.8 ha/LSU in April 2001 to 8.9 ha/LSU in May 2002, respectively (Annex E). It thus appears as though the rangeland condition inside the enclosure of the benchmark site improved in terms of the total production and seasonal grazing capacities. According to Snyman (2000) these changes in the grass species production and seasonal grazing capacities in arid and semi-arid areas can mainly be ascribed to differences in the annual rainfall pattern.

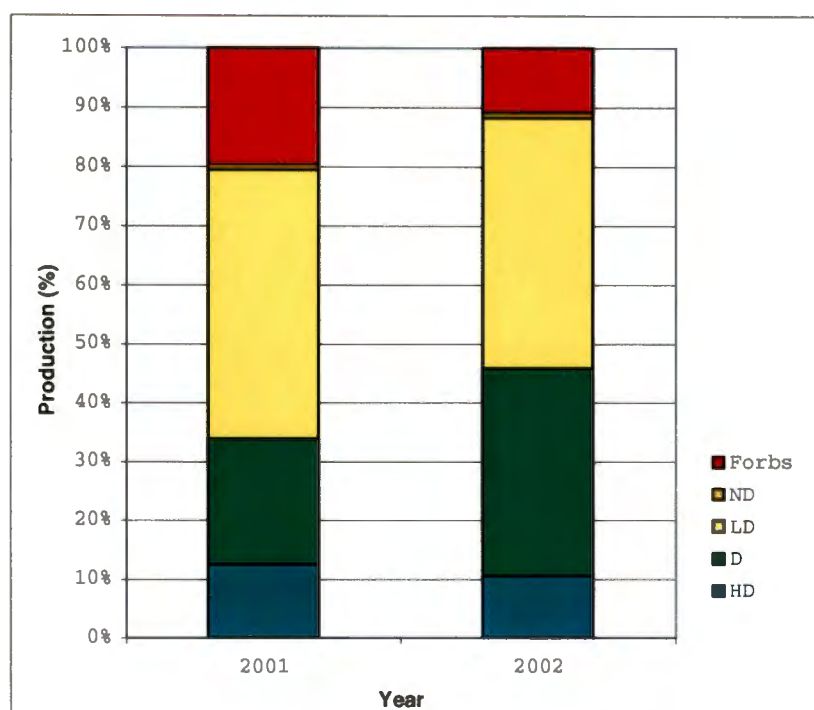


Figure 4.37: The changes in the contributions of the different desirability classes to the total production (%) at the Ipelegeng 1 benchmark site from April 2001 to May 2002.

According to the soil classification working group (1991), the soil texture inside and outside the exclosure at the Ipelegeng 1 benchmark site can be classified as a loamsand type of soil, seeing that it consists of an average sand particle percentage of 83.3%, an average silt particle percentage of 5.7%, and an average clay particle percentage of 11.0% (Table 4.51). The pH 6.10 to 6.21 indicates the soil is slightly acidic (Foth, 1990). As the soil acidity increases, the soil nutrients, namely potassium, calcium and magnesium, show less availability as a result of the subsequent low CEC value (average value of 4.17 cmol+/kg) (Taddese, 2001).

Table 4.51: Some of the results of the soil analyses carried out for the Ipelegeng 1 study site (the complete set of results can be seen in Annex B).

Benchmark sites	pH	P (mg/kg)	K (mg/kg)	CEC (cmol+/kg)	C (%)	Clay (%)	Silt (%)	Sand (%)
Ipelegeng 1 Inside	6.21	3.25	117.7	4.39	0.28	12	6.3	81.7
Ipelegeng 1 Outside	6.10	3.11	115.8	3.95	0.39	10	5.1	84.9
Average values	6.16	3.18	116.8	4.17	0.34	11	5.7	83.3

The fact that this benchmark site is dominated by less desirable grass species can also be ascribed to the fact that the soil is not that fertile. This can be deduced from the low phosphorous and carbon content, as well as the low pH value of the soil.

4.4.2. Morafe ranch Management at the Orange Grove study site

The Orange Grove study site is situated in the Taung magisterial district in the western region of the North West Province. This study site forms part of the Moretele FSU in the Taung North ADC.

Morafe ranches have been appointed to 21 farmers. This study site comprises a total area of 3015 hectares. Due to shortage of watering points at this study site, this Morafe ranch is divided into sub-units of only a 100 hectares each in order for all the farmers to have accesses to the few available watering points. Seeing that the recommended long-term grazing capacity at the Orange Grove study site is 10 ha/LSU, each farmer is only allowed to own 10 cattle.

The enclosure was erected during January 2001. The farmers at this study site were informed and trained in the specific vegetation survey techniques with regard to the implementation of the LandCare project at this study site during January 2001.

Although everybody was enthusiastic regarding the project at that time, the commitment to help during the vegetation sampling was not that good. The reason for this is unknown. It did however influence the vegetation sampling exercise. It was not easy for the responsible ADC manager and agricultural extension officer (Table 4.52) to motivate the land users and agricultural officers. Vegetation sampling was carried out during April 2001 and May 2002.

Table 4.52: The ADC manager and agricultural extension officer at the Orange Grove benchmark site.

District	Benchmark site	Management system	ADC manager	Agricultural extension officer
Taung	Orange Grove	Morafe ranch	Pieter Applegreen Tel: (053) 994 1816	Hendrik Sabole

4.4.2.1. Orange Grove benchmark site

i. *Grass species composition*

The highly desirable grass species, namely *D. eriantha*, *S. pappophoroides*, *Sporobolus fimbriatus* and *Themeda triandra*, dominated inside and outside the enclosure during April 2001 (Figure 4.38 a and c). All of these highly desirable grass species are classified as decreaser species, and are associated with good rangeland (van Oudtshoorn, 1999). According to Tainton (1988) a decreaser dominated community also represents the most preferred community in any ecological area (Tainton, 1988). If only the grass species composition is taken into account, it can thus be concluded and that the rangeland at this benchmark site is in a good conditional state.

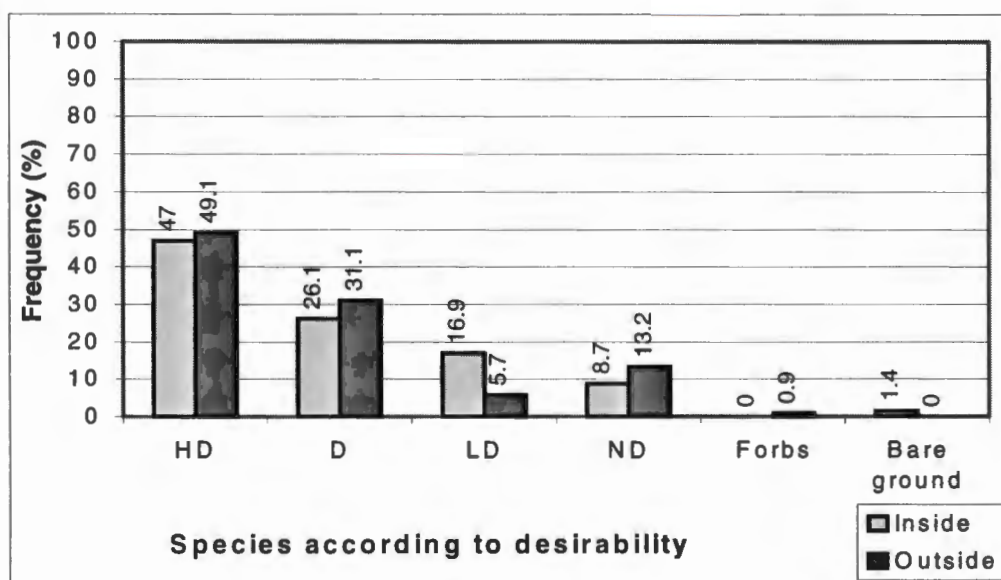
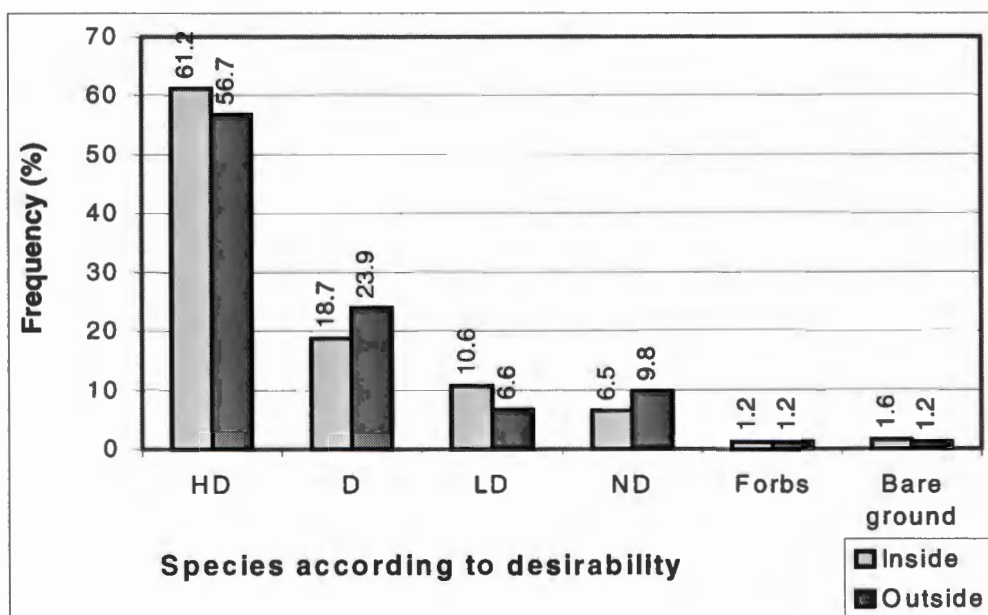
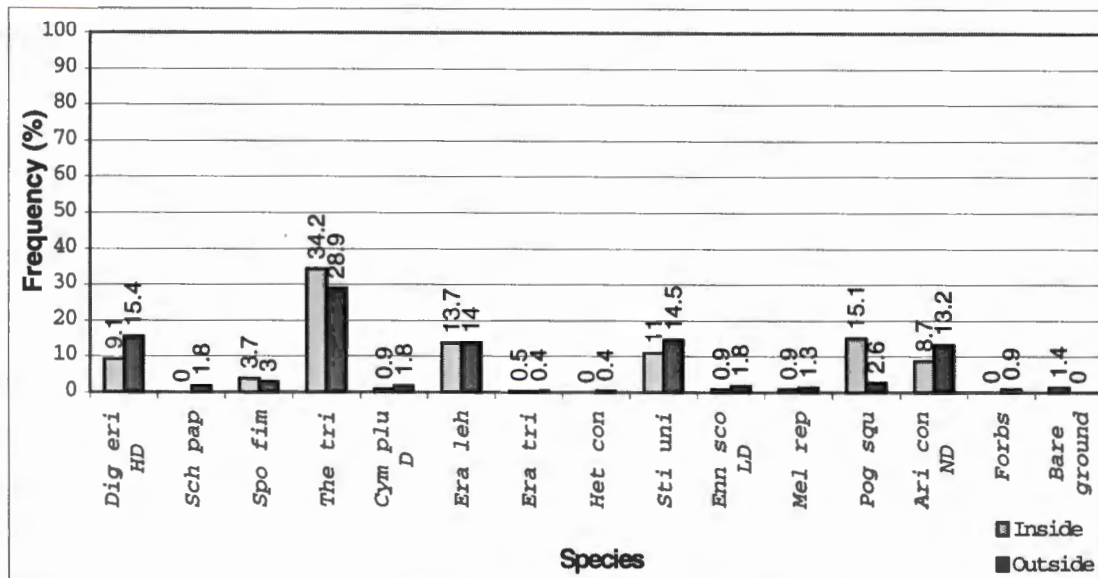
a)**b)**

Figure 4.38 a and b: Frequency (%) of grass species according to their desirability inside and outside the enclosure at the Orange Grove benchmark site, during April 2001 (a) and May 2002 (b).

c)



d)

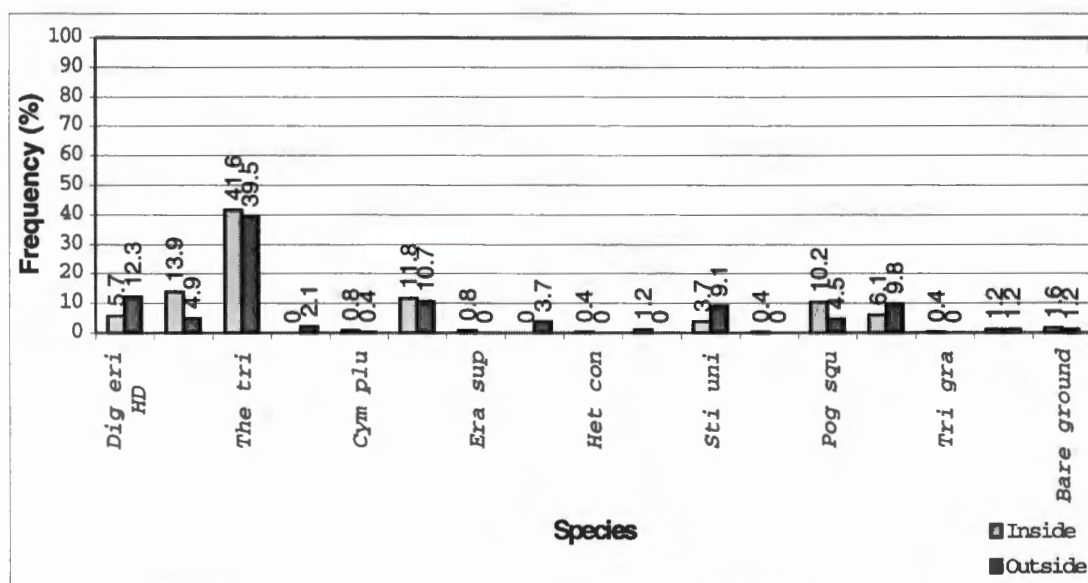


Figure 4.38 c and d: Frequency (%) of grass species inside and outside the enclosure at the Orange Grove benchmark site, during April 2001 (c) and May 2002 (d) (see Annex C1 & C2 for species abbreviations).

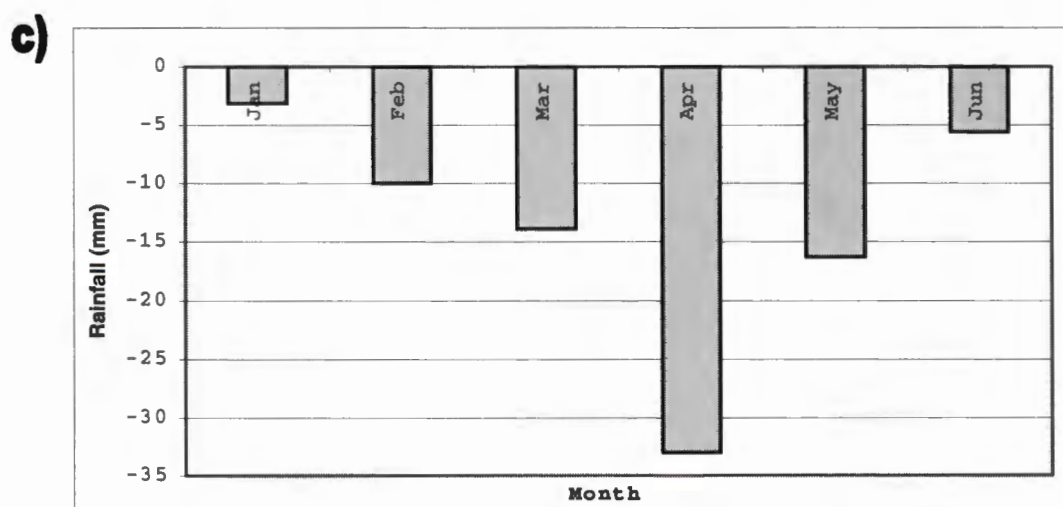
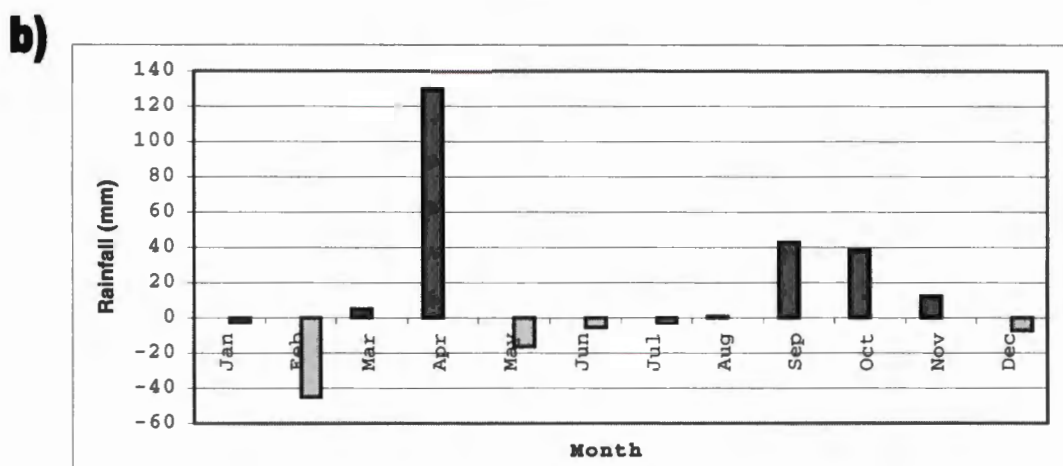
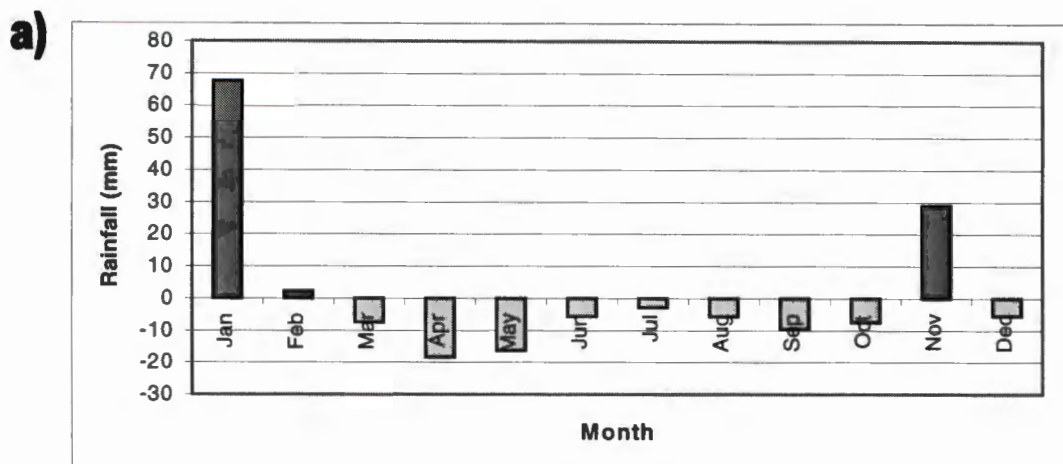


Figure 4.39 a-c: Rainfall deviation from the average rainfall at the Orange Grove study site during the years 2000 (a), 2001 (b) and 2002 (c).

The increase in the frequency of the highly desirable grass species (inside and outside the enclosure) from April 2001 to May 2002 can be attributed to the above average rainfall from September to November 2001 (Figure 4.39b). *Themeda triandra* was the dominant species in this increase with an increase of 7% inside the enclosure and an increase of 11% outside the enclosure (Figure 4.38 c and d).

The desirable grass species, mainly represented by *E. lehmanniana* and *S. uniplumis*, the less desirable grass species, mainly represented by *P. squarrosa*, and the non desirable grass species, such as *A. congesta*, all decreased in abundance (inside and outside the enclosure) from April 2001 to May 2002 (Figure 4.38 a-d). This can be explained by the fact that the well established population of highly desirable grass species minimises the seedling establishment of all the other grass species. This limitation in the recruitment of the desirable, less desirable and non desirable grass species can also be ascribed to the scarcity of gaps in the vegetation due to the high frequency of the highly desirable grass species, *T. triandra*.

No obvious difference could thus far be observed between the grass species composition inside and outside of the enclosure (Figure 4.38 a-d). From Table 4.53 it is however evident that the similarity in the grass species composition inside and outside the benchmark site decreased from 73.3% in April 2001 to 69.4% in May 2002. This can be attributed to the greater difference in the abundance of the highly desirable and desirable grass species between the inside and outside of the enclosure in May 2002, than in April 2001 (Figure 4.38 a and b). It is expected that the improvement in the rangeland condition from April 2001 to May 2002, which was mainly caused by the response of the highly desirable species, was due to the above average rainfall.

Table 4.53: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure at the Orange Grove benchmark site, during April 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Orange Grove	April 2001	73.3
	May 2002	69.4

Only vegetation sampling over the long term will explain if grazing was an important factor with regard to the dynamic changes in species composition between the inside and outside of the enclosure at the benchmark site. It is however important to have this baseline data as part of the long term monitoring study.

ii. Grass Production

The total grass production increased to a considerable amount, namely from 541.9 kg/ha during April 2001 to 1560.9 kg/ha during May 2002 (Table 4.54). The contribution of the forb species to the total grass production decreased from 4.5% to 3.0%. This decrease can also be observed in Figure 4.40.

Table 4.54: The total production (forbs included), grass production (forbs excluded), forbs production, and the percentage that forbs contributed to the total production at the Orange Grove benchmark site, during April 2001 and May 2002.

Date	Total production (kg/ha) – forbs included	Grass production (kg/ha) – forbs excluded	Forbs production (kg/ha)	Percentage forbs contributes to the total production (%)
April 2001	541.9	517.7	24.2	4.5
May 2002	1560.9	1513.8	47.1	3.0

The extent to which the highly desirable grass species, mostly *T. triandra*, contributed to the total grass production indicates a considerable increase, namely from 230.0 kg/ha in 2001 to 765 kg/ha in 2002 (Figure 4.40 and Table 4.55). This, together with the great increase in the total production, attributed to the improvement of the seasonal grazing capacity inside the exclosure (determined by approach (i)) from 20.1 ha/LSU in 2001 to 6.3 ha/LSU in 2002 (Table 4.55). The seasonal grazing capacity determined by means of all three methods indicates an improvement of 3.2 times, e.g. according to approach (ii) it improved from 28.6 ha/LSU in April 2001 to 9.0 ha/LSU in May 2002 (Annex E). Calculating the seasonal grazing capacity by means of approach (iii) shows an improvement from 23.2 ha/LSU in April 2001 to 7.2 ha/LSU in May 2002. From these results it is clear that the seasonal grazing capacity, calculated by all three methods, inside the exclosure during May 2002 is better than the recommended long-term grazing capacity. Consequently the rangeland condition inside the exclosure at the Orange Grove benchmark site improved to a great extent.

Variations in grassland production are primarily due to differences in annual rainfall as well as its distribution (Snyman, 2000). The above mentioned increases in production, and subsequent increases in the seasonal grazing capacities, can thus mainly be ascribed to the above average 2001/2002 rainfall season (Figure 4.39 b and c).

Table 4.55: The dry matter (DM) production figures (kg/ha) for the different grass species desirability classes and the seasonal grazing capacity, determined by means of approach (i) (ha/LSU), at the Orange Grove benchmark site during April 2001 and May 2002.

Benchmark site	Date	DM production of HD grass species (kg/ha)	DM production of D grass species (kg/ha)	DM production of LD grass species (kg/ha)	DM production of ND grass species (kg/ha)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)
Orange Grove	April 2001	230	159	60	68	20.1
	May 2002	765	536	138	75	6.3

The contribution of the desirable grass species, mostly *E. lehmanniana* and *S. uniplumis*, to the total production also increased, while the contribution to the total production of the less desirable grass species, non desirable grass species and forb species decreased from April 2001 to May 2002 (Figure 4.40).

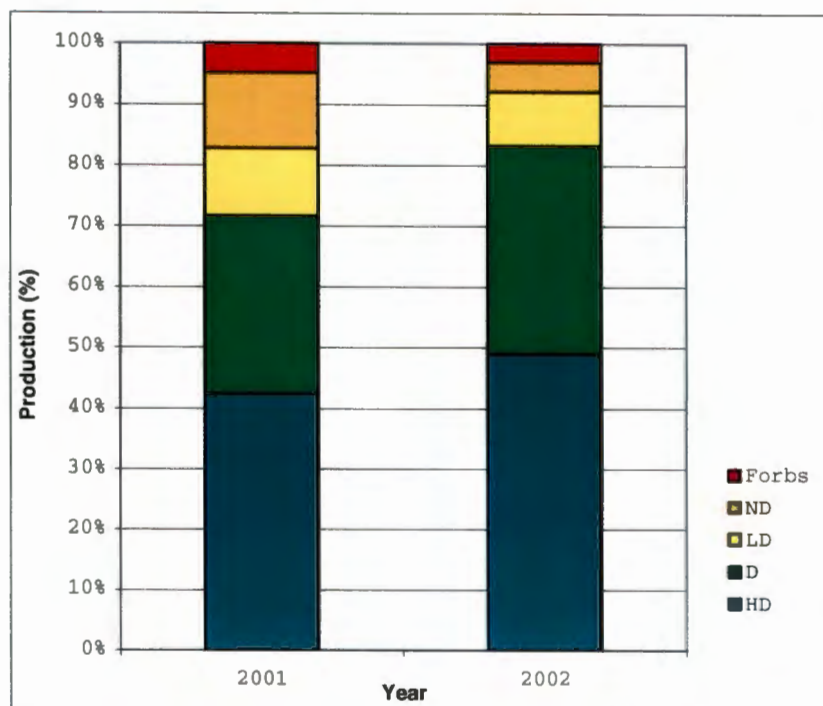


Figure 4.40: The changes in the contributions of the different desirability classes to the total production (%) at the Orange Grove benchmark site, during April 2001 and May 2002.

The soil inside and outside the enclosure at the Orange Grove benchmark site can be classified as sandloam according to the percentage of the soil that is composed of sand, silt and clay (Table 4.56). According to Buys (1991) good soil comprises of a CEC value of between 5 and 20 cmol^+/kg . The fairly high CEC value can be explained by the fact that the percentage of sand particles in the soil is not as high as the CEC values at the other study sites, and by the fact that the pH value is also relatively high (average value of pH 7.5). Following the pH value, the soil can be described as slightly alkaline (Foth, 1990). Potassium, calcium and magnesium are widely available in alkaline soils, and thus the soil can be described as being relatively fertile. This fact thus serves as an explanation for the high abundance of highly desirable grass species present at the Orange Grove benchmark site.

Table 4.56: Some of the results of the soil analyses that were carried out for the Orange Grove study site (the complete set of results is conveyed in Annex B).

Benchmarks	pH	P (mg/kg)	K (mg/kg)	CEC (cmol^+/kg)	C (%)	Clay (%)	Silt (%)	Sand (%)
Orange Grove Inside	7.8	3.46	169.6	9.93	0.85	8	14.5	77.5
Orange Grove Outside	7.2	3.62	123.9	8.88	0.60	10	12.5	77.5
Average values	7.5	3.54	146.8	9.41	0.73	9	13.5	77.5

Chapter 5: General discussion and conclusion

5.1. Introduction

As part of the implementation of the LandCare initiative in the western region of the North West Province, particular the veldcare theme, a long-term monitoring program was initiated in three magisterial districts, namely Ganyesa, Kudumane and Taung (see Section 2.2.1, Chapter 2). Changes in the grass species composition and production in two rangeland management systems namely, Communal grazing and Morafe ranch management, were monitored. Benchmark sites were identified in order to represent rangeland of different conditional states with respect to degradation in each district (see Section 2.2.2, Chapter 2). Exclosures were erected at each benchmark site to determine the effect of rest applied inside the exclosures on the rangeland condition at the different management systems. Eighteen benchmark sites were monitored for the purpose of this study. These sites were monitored by conducting abundance and production vegetation surveys (see Section 3.3, Chapter 3). The line transect method was used to determine the grass species composition (abundance), while the DM production was determined by means of a quadrat method. Production surveys were only carried out on the inside of the exclosures. Soil samples were also taken at each benchmark site. The results of the soil sample analysis are given primarily to serve as baseline data for the envisaged long-term monitoring of this LandCare project. The above mentioned study had the following aims in mind (see Section 1.4, Chapter 1):

1. To establish and implement monitoring and evaluation systems in order to monitor changes in grass species composition and production in two rangeland management systems;
2. To evaluate changes in the rangeland condition by using the benchmark site approach;
3. To create an environmental awareness and train the agricultural extension workers, technicians, and land users; and
4. To use the data and results to serve as baseline data for future LandCare projects to be conducted in the same or other, similar study areas;

Accordingly the aims of this project will contribute to the objectives of the North West Province's LandCare program.

5.2. Ganyesa magisterial district

5.2.1. Austrey benchmark sites

Four benchmark sites were monitored in the communally managed Austrey study site, which falls within the Tlagameng FSU, situated in the Ganyesa ADC (see Figure 2.4 and Section 2.2.2, Chapter 2).

The benchmark sites in this study area are located at different distances from watering points. They were chosen to represent different rangeland conditional states. This was done subjectively and according to the knowledge of the agricultural extension officers. Seeing that grazing animals, especially in these more arid regions of the country, rely greatly on the available water sources, they will not graze far from the watering points. Consequently the rangeland nearer to the watering points will be subjected to higher grazing pressures and is more vulnerable to overgrazing than the rangeland further away from the watering points. Objective vegetation sampling was however used to quantify this selection. From the results obtained through the vegetation sampling during April 2001, the Austrey 1 benchmark site consisted of the poorest, the Austrey 2 and 4 benchmark sites of moderate, and the Austrey 3 benchmark site of the best rangeland condition. This was deduced from the fact that the Austrey 1 benchmark site consisted of the least desirable (especially during April 2001), the Austrey 2 benchmark site of a moderately desirable, and the Austrey 3 benchmark site of the most desirable grass species composition. The reason for this could be the fact that the Austrey 1 benchmark site is situated closest to the watering points and the Austrey 3 benchmark site the furthest.

The rangeland in die good condition (Austrey 3 benchmarks site) was dominated by highly desirable (*D. eriantha* and *S. pappophoroides*) and desirable grass species (*E. lehmanniana*, *E. trichophora* and *S. uniplumis*) in April 2001 (Figure 4.6 a and d). The abundance of the less desirable grass species did however increase mainly as a response to the high rainfall season from September 2001 to January 2002 (Figure 4.2 b and c). The less desirable grass species (mainly *A. stipitata* and *M. repens*) dominated at the benchmark sites that consisted of a moderate rangeland condition (Austrey 2 and 4 benchmark sites), with a subsequent increase in the abundance of the non desirable grass species in response to the above average rainfall (Figure 4.4 a-f and 4.8 a-d). The recruitment of the obligate seed reproducing species was thus clearly related to rainfall.

At the site that consisted of the poorest conditional state (Austrey 1 benchmark site), the desirable grass species dominated, but in lower frequencies than in the better conditional sites (Figure 4.1 a-c). The high abundance of bare ground also contributed to the fact that this benchmark site can be classified as being in the poorest rangeland condition of all the Austrey study sites.

The DM production on the inside of the exclosures at the Austrey 1, 2 and 3 benchmark sites (production was cut only once at the Austrey 4 benchmark site and therefore not considered) increased from April 2001 to May 2002 (Table 4.10). This subsequently also led to an improvement in the seasonal grazing capacities, as determined by approaches (i), (ii) and (iii) (Table 4.11 and Annex E). These improvements could mainly be ascribed to the preceding above average rainfall season and the rest that was applied inside the exclosures, seeing that the soil conditions inside and outside the exclosures at the benchmark sites were very similar (Table 4.12). The improvement in the grazing capacity and total production were however the most prominent at the Austrey 1 benchmark site, where the total production inside the exclosure increased from 203.7 kg/ha (April 2001) to 1002.4 kg/ha (May 2002). This could be ascribed to the fact that this site reacted the greatest to the high rainfall season if compared to the Austrey 2 and 3 study sites. This site is located closest to the waterpoint, and can thus serve as a good example of the

influence that high grazing pressure has on the rangeland condition, and how drastic the rangeland condition can improve in reaction to good rainfall if rest is applied. Accordingly it could be concluded that the life history of grass species seems to hold some promise for predicting their response to grazing and rainfall.

Even from these short-term results it is clear that the DM production of the grass species and forbs show some very prominent changes on the inside of the exclosures since their erection during April 2001 (Table 4.10 and 4.11). The Z-indices, determining the similarity in the grass species composition inside and outside the exclosures, however indicates that no major changes in the grass species composition between the inside and the outside of the exclosures have occurred since the commencement of the study, especially for the Austrey 1 study site (Annex D). This stresses the fact that the study period of two years was too short for vegetation dynamic studies to detect species compositional changes, and that it is vital to continue with the long-term monitoring program that is planned in future as part of this project.

5.2.2. Waterfouchè benchmark sites

Six benchmark sites were surveyed at the Waterfouchè study site, where the Morafe ranch management system was implemented since January 2001. These sites are divided into the Driefontein FSU, that is situated in the Pomfret ADC (see Figure 2.4 and Section 2.2.2, Chapter 2).

As observed in Figure 4.10, 4.13, 4.15, 4.17, 4.19 and 4.21, the Waterfouchè 5 site is dominated by highly desirable grass species, such as *S. pappophoroides*, the Waterfouchè 1, 3, 4, and 6 sites by desirable species, such as *E. lehmanniana*, *E. trichophora* and *S. uniplumis*, and the Waterfouchè 2 site by less desirable species, mainly *A. stipitata*.

It is evident from the Z-index values that the similarity between the grass species composition inside and outside the exclosures at all the benchmark sites in the Waterfouchè study site during May 2002 are all higher than 70% (Annex D). Thus, to determine the effect of rest applied inside the exclosures, as well as the Morafe ranch type of management system on the grass species composition and production of the rangeland a longer study period is necessary. The results of this study will however serve as important baseline data for the long-term monitoring program at these sites. The fact that the grass species compositions at most of the Waterfouchè benchmark sites already tends to a more desirable composition holds the promise of significant results that can be obtained during a long-term monitoring study.

The benchmark sites at this study site are all dominated by highly desirable (*S. pappophoroides*) and desirable grass species (*E. lehmanniana*, *E. trichophora* and *S. uniplumis*), except at the Waterfouchè 2 benchmark site, where less desirable grass species, such as *A. meridionalis*, *A. stipitata*, *E. pallens*, *M. repens* and *P. squarrosa*, has a higher abundance (Figures 4.10, 4.13, 4.15, 4.17, 4.19, and 4.21). The last mentioned benchmark site does however show a tendency towards a more desirable grass species composition, seeing that the abundance of the highly desirable and desirable grass species increased on the inside and outside of the exclosure from December 2001 to May 2002, while the less desirable grass species decreased in abundance (inside and outside the exclosure) during this period (Figure 4.13 a-d).

Concerning the grass species composition it can thus be deduced that these benchmark sites are all in reasonably good conditional states. The high total DM production figures, as well as the relatively good seasonal grazing capacities - that are better than the recommended long-term grazing capacity of 9ha/LSU – supports this statement (Table 4.26 and 4.27). As reference sites to demonstrate different conditional states, the Waterfouchè 3 site can be described to be in a good or “the best” condition, and the Waterfouchè 2 site in a poor or “the worst” rangeland condition in this region (see Section 4.2.2.7, Chapter 4).

As already mentioned in Chapter 2, Section 2.2.1, water is considered to be a key limiting factor for vegetation development and productivity in the North West Province (Department of Agriculture, Conservation and Environment, 2002). Perennial surface water resources are generally scarce, particularly in the arid and semi-arid western region of the Province (Figure 2.3). These facts, as well as the limited number of watering points at the Waterfouchè study site, explains the current relatively good rangeland condition at these benchmark sites. As a result of the scarcity in water sources, the population density of people, and subsequently also the livestock population, is reasonably low in this area. This can however be seen as very fortunate, seeing that the sweet rangeland that occurs in this region is very sensitive to overgrazing, especially when the rangeland is already under stress during low rainfall seasons.

Watering points are however currently being erected throughout the Waterfouchè study site. This will result in a more efficient rotational grazing implementation in the future. It will thus better the control of the rangeland grazing pressure at all four benchmark sites, the basis on which the Morafe ranch grazing system rests on. The importance of the data and results gathered by this short-term study can therefore not be over emphasised, as it will form a very important baseline for determining the changes in species composition and production after the implementation of this higher intensive grazing strategy in the future. A longer study period will indicate the influence of this change in management on the rangeland condition at all six Waterfouchè benchmark sites.

Seeing that the Waterfouchè 2, 3, 4, 5, and 6 benchmark sites were not surveyed since April 2001, the response of the vegetation at these sites to the above average rainfall (Figure 4.11) could not be determined. The Waterfouchè 1 benchmark site shows an increase in the total production from April 2001 to May 2002, due to this high rainfall, to such an extent that its total production figure during May 2002 coincides with that of the other benchmark sites. From these results it could be deduced that when only the production figures are considered, the production at all six these sites responded to more or less the same extent during the high 2001/2002 rainfall season.

Even though the high rainfall led to a considerable increase in the total DM production at Waterfouchè 1, the grass species composition did not react to the same extent. This can be explained by the statement of O'Connor (1995), that a clearer understanding of the environmental factors and population processes primarily responsible for vegetation population and community changes, will only be achieved within the context of long-term field experiments. It could thus be concluded that rangeland, especially in this arid to semi-arid area, must be managed very strictly and cautiously during drought periods in order to prevent the deterioration of the

rangeland in terms of a change in grass species composition towards an undesirable grass species composition. O'Connor (1995) also stated that grazing management during drought episodes is critical for determining the direction of vegetation community change.

The production results indicate that the total production during May 2002 varies from 1109.8 kg/ha at the Waterfouchè 3 site to 2363.8 kg/ha at the Waterfouchè 5 site (Table 4.26). The grass species composition and production at all six benchmark sites thus differ from each other although they were all subjected to the same rainfall condition, similar management systems (Communal management before January 2001, and Morafe ranch management thereafter), and consisted of very similar soil compositions. The past history of management applied at these sites in the long-term (before January 2001) is however not known, which could have had an effect on the differences that currently occur at these sites. As mentioned so many times previously, long-term studies are thus needed to explain vegetation compositional changes in arid and semi-arid environments. This makes this study so important, seeing that these quantitative results can now be used as baseline for such long-term studies.

5.3. Kudumane magisterial district

5.3.1. Maketlele benchmark sites

The two benchmark sites at Maketlele are communally managed and are situated in the Allendale FSU of the Heuningvlei ADC in the Kudumane magisterial district (see Figure 2.4 and Section 2.2.2, Chapter 2).

The rangeland condition at both these benchmark sites could be described as good, especially during April 2001, seeing that the highly desirable grass species, such as *C. ciliaris*, *D. eriantha* and *S. pappophoroides*, dominated on the inside and outside of the exclosures (Figure 4.23 and Figure 4.26, Chapter 4). As in the other study areas, the benchmark sites were chosen by the agricultural extension officer, land users and community members to represent rangeland in different conditional states, i.e. the Maketlele 1 site to represent good rangeland and the Maketlele 2 site to represent a poorer rangeland condition. Through the course of the study period it became clear that the agricultural extension officer and the community members were correct in their opinion, as the Maketlele 1 benchmark site consisted of a better rangeland condition than the Maketlele 2 site during May 2002. This was not only proven by the higher abundance of highly desirable grasses at the Maketlele 1 site, but also by the slight improvement in the seasonal grazing capacity (determined by approach (i)), from 8.9 ha/LSU during April 2001 to 8.1 ha/LSU during May 2002 (Figure 4.23 a and f and Table 4.35). The Maketlele 2 site on the other hand, had a lower abundance of highly desirable grasses and also a poorer seasonal grazing capacity (determined by approach (i)), 15.6 ha/LSU, during May 2002 (Figure 4.26 c and f and Table 4.35). The seasonal grazing capacities determined by approaches (ii) and (iii) reflects the same tendency as when calculated by means of approach (i) (Annex E).

The total DM production at the Maketlele 2 benchmark site also shows a greater decrease, from 1559.0 kg/ha in April 2001 to 906.6 kg/ha in May 2002, than at the Maketlele 1 site, where it decreased only slightly from 1182.3 kg/ha in April 2001 to 1158.2 kg/ha in May 2002 (Table 4.34). Accordingly the Maketlele 2 site could be classified into a poorer rangeland condition than the Maketlele 1 site.

The fact that the benchmark sites at this study area does not show an increase in the total DM production inside the exclosures, as was observed at the Austrey and Waterfouchè 1 benchmark sites, can mainly be ascribed to the very low rainfall that persisted from January 2001 to May 2002 (Figure 4.24 b and c). This, and the fact that the inside of the exclosures was probably overgrazed during winter, could have contributed to these low production figures and the decrease in the abundance of the highly desirable and desirable grass species on the inside of the exclosure at the Maketlele 1 benchmark site.

Although the Z-index values of the Maketlele 1 (65.3 %) and 2 (91.0 %) benchmark sites differ, mainly due to the reasonably high decrease in the abundance of the highly desirable and desirable grasses on the inside of the exclosure at the Maketlele 1 site during May 2002, the similarity of the grass species composition inside and outside the exclosures at both these sites are still very high (Annex D). The fact that these exclosures have been erected for the longest time period in comparison to all the other exclosures of this study, emphasises that the effect of rest applied inside the benchmark sites will only be observed after a few good rainfall seasons, and that a longer study period would thus be necessary.

O'Connor (1995) discounted the notion that changes in species abundance are simply a consequence of rainfall variability without any effect of grazing. He also stated that management should recognise that change in community structure in response to grazing occur both with the onset of drought and during post-drought seasons, due to the influence of grazing on mortality of established tufts and on seedling recruitment. The correct management during periods of lower rainfall, as occurred at this study site, is thus very important, seeing that in this study the history of grazing prior to and during drought rather than following drought, will be an important influence on the change in the grass species composition.

According to O'Connor (1995) the perennial grass species of savannas represent a number of different life history types that are expected to differ in their response to rainfall and grazing. For example, it has been proposed that the longer-lived, obligate seed reproducing, desirable species which annually produce smaller amounts of larger-bodied, poorly dispersed seeds (e.g. *D. eriantha*) are extinction prone, and would be eliminated under sustained grazing in combination with drought. In contrast, shorter-lived, undesirable obligate seed reproducing species, which produce larger amounts of smaller, better-dispersed seeds (e.g. many *Aristida* species), may respond to similar conditions. Following this, and that the availability of seed is a very important constraint on seedling recruitment in years of suitable rainfall, management at this study site, should recognize that a reduction in grazing pressure during and after the low rainfall period is required, if changes towards a more desirable grass species composition is desired in future.

5.3.2. Heuningvlei benchmark sites

Vegetation surveys were carried out at three benchmarks at the Heuningvlei study area. This study area forms part of the Heuningvlei FSU, which falls within the Heuningvlei ADC (see Figure 2.4 and Section 2.2.2, Chapter 2).

Of the three benchmark sites in this study area the Heuningvlei C2 benchmark site was not only dominated by highly desirable grass species, such as *B. nigropedata* and *S. pappophoroides* (Figure 4.28), but also gave rise to the highest total production (2908.1 kg/ha) and best seasonal grazing capacity (3.1 ha/LSU) (Table 4.44 and 4.45). Accordingly this site could be described as being in the best rangeland conditional state within this study area.

The rangeland condition at the Heuningvlei F2 benchmark site can be described as being in a moderately to good condition (see Section 4.3.2.4, Chapter 4), as it was dominated mainly by desirable grass species (*E. lehmanniana*, *E. trichophora* and *S. uniplumis*), and the grass production was poorer (2069.4 kg/ha) resulting in a lower seasonal grazing capacity (determined by approach (i)) of 5.9 ha/LSU (Figure 4.33 and Table 4.43). All three benchmark sites however consists of a mainly desirable grass species composition (Figure 4.28, 4.31 and 4.33), a relative high total production figure (Table 4.44), and good seasonal grazing capacities (determined by means of approach (i), (ii) and (iii)) (Annex E), and can therefore be classified as being in a rather good condition.

This coincides with the statement of the agricultural extension officer, during the commencement of the study, that the rangeland condition at this study site is overall very good, and that it was difficult to select benchmark sites which would represent rangeland in different conditional states. If the sites had to be classified on a gradient from good to poor, the Heuningvlei C2 site can be regarded as being in the best condition, Heuningvlei A2 in a moderately to good, and Heuningvlei F2 site in the poorest rangeland conditional state. The same principles as for the Waterfouchè study sites are relevant here, namely low population densities and only few watering points (see Section 5.2.2).

Only slight changes in the grass species composition inside and outside the enclosure at all three benchmark sites were observed from December 2001 to May 2002, mainly due to the rainfall variability during this period (Figure 4.29). The period of four months between the consecutive vegetation surveys at these sites were however too short to observe marked changes in the grass species composition between the inside and outside of the enclosures, as is reflected by the high Z-index values (Annex D).

Due to the high increase in the total production observed at the Austrey (except at the Austrey 4 benchmark site, where the production was only cut during May 2002) and Waterfouchè 1 benchmark sites due to the preceding above average rainfall season (see Sections 4.2.1.5 and 4.2.2.7, Chapter 4), it can also be deduced that the high production figures at the Heuningvlei benchmark sites can be ascribed to the above average rainfall from September 2001 to February 2002 (Figure 4.29). Since all three sites are situated on similar soils and subjected to the same rainfall and management systems, changes in the grass species composition, as well as differences in the total

production and seasonal grazing capacities, could thus be explained by the past history in grazing pressure at these sites.

Watering points are however currently being erected in each sub-unit of the Morafe ranch in order to supply water to the people and their cattle. In this way rotational grazing, which is the aim of this management system, can be applied more effectively. The sudden introduction of high densities of large mammalian grazers, such as livestock, will have a dramatic influence in the grass species composition at the study site (Olff & Ritchie, 1998). It will therefore be very important and most interesting to monitor the change in abundance of the highly desirable and desirable grass species, and subsequently the rangeland condition, inside and outside the exclosures over the long-term.

5.4. Taung magisterial district

5.4.1. Ipelegeng benchmark site

Only one benchmark site was surveyed in the communally managed Taung magisterial district. This benchmark site is situated in the Ipelegeng FSU that is located in the Taung North ADC (see Figure 2.4 and Section 2.2.2, Chapter 2).

This site is dominated by less desirable grass species, such as *A. stipitata*, *C. dactylon* and *E. rigidior*, also classified as increaser II species (van Oudtshoorn, 1999), and subsequently means that the Ipelegeng 1 benchmark site was moderately overgrazed in the past (Figure 4.35). The similarity in the grass species composition inside and outside of the exclosure is however still very high, as can be seen in the Z-index values calculated for this benchmark site, namely 70.4% in December 2001 and 88.7% in May 2002 (Annex D).

The previous moderate overgrazing at this benchmark site could have led to the increase in the less desirable, prolific seed producing species, such as *A. stipitata*. The high 2001/2002 rainfall season (Figure 4.36) could have favored high levels of seedling recruitment, therefore maintaining a high abundance of this less desirable species especially outside the exclosure, e.g. *E. rigidior*, (Figure 4.35 b, c, e and f). The seed of these species in the soil seed bank was thus abundant. The particular survival strategy, or life history traits of plants, thus determine its success at a particular region of any environmental gradient. If environmental resources or stress levels change in space or time, the species composition will probably also change (McCook, 1994). A longer study period is therefore necessary and could deliver some interesting results.

Even though the abundance of the less desirable grass species increased on the inside and outside of the exclosure, it could be deduced that the rangeland condition on the inside of the exclosure did improve slightly since the commencement of the study (see Section 4.4.1.1, Chapter 4). This conclusion is made due to the fact that, the total production inside the exclosure increased considerably (Table 4.22), and that the seasonal grazing capacity (determined by approaches (i), (ii) and (iii)) inside the

enclosure also improved (Table 4.50 and Annex E) from April 2001 to May 2002. The high 2001/2002 rainfall mainly contributed to this change, especially with regard to the inside of the enclosure, where rest was applied since June 2001, when the enclosure was erected. The effects of rainfall may not only depend on the annual amount, but also on the sequential pattern over years (O'Connor, 1995). This emphasises the fact, that in order to observe the effect of the sequential rainfall pattern on the vegetation at the benchmark site, as well as the effect of rest on the grass species composition and production inside the enclosure, a longer study period would be necessary.

5.4.2. Orange Grove benchmark site

At the Orange Grove study site vegetation surveys were only carried out at one benchmark site. The Orange Grove benchmark site is managed according to the Morafe ranch management system. The site is located in the Moretele FSU, of the Taung Central ADC (see Figure 2.4 and Section 2.2.2, Chapter 2).

This benchmark site is dominated by highly desirable grass species (*T. triandra*), which increased with an abundance of 7.4% inside, and 10.6% outside the enclosure, from April 2001 to May 2002 (Figure 4.38 a-d). Even though this increase could be attributed to the above average rainfall from September to November 2001, these species retained their high abundance throughout the subsequent low rainfall period from December 2001 and until the surveys were again conducted during May 2002 (Figure 4.39 b and c). This could be ascribed to the fact that *T. triandra* forms dense stands (van Oudtshoorn, 1999) and the fact that already well established populations of this species occurred before the commencement of the study.

It could also be deduced that the great increase in the total production from April 2001 to May 2002 (Table 4.54), was mainly due to the increase in abundance of the highly desirable grass species in response to the above average rainfall, but also due to the rest applied inside the enclosure since April 2001. O'Reagain & Turner (1992) supports this conclusion with their statement that range conditions in semi-arid savanna areas recover far more rapidly under resting than under grazing. They attributed this to the large-scale seedling establishment of more desirable species and a reduction in tuft mortality.

As a result of the above mentioned increase in mainly desirable species, the seasonal grazing capacity also improved from 20.1 ha/LSU during April 2001 to 6.3 ha/LSU during May 2002 (Table 4.55). The seasonal grazing capacities determined by means of approaches (ii) and (iii) reflects the same tendency (Annex E). This high abundance of highly desirable grass species, high production, as well as good seasonal grazing capacity, contributed to the good conditional state inside the enclosure of this Orange Grove benchmark site.

As for the study sites at Waterfouchè and Heuningvlei (see Sections 5.2.2 and 5.3.2), only a few watering points are currently near the benchmark site that falls within the Orange Grove study area. This resulted in low grazing intensities by the livestock in and around the benchmark site. Since the implementation of the Morafe ranch management system, watering points are however being erected at this study site in order to provide the farmers and their livestock with water. The effect of this

management system on the vegetation at the Orange Grove study area, and the rest applied inside the exclosures will therefore only be determined by follow-up surveys and a long-term study period. The results of this study therefore only forms a baseline of the long-term monitoring plan as part of the LandCare process.

The Z-index values, calculated for this benchmark site, also emphasises that a longer study period would be necessary (Annex D). These values are still very high (73.3 % during April 2001 and 69.4% during May 2002), which means that the grass species composition, between the inside and the outside of the exclosures, does not yet show significant differences as a result of a change in the management type (Morafe ranch), and rest applied inside the exclosure.

5.5. Comparison between the two rangeland management systems

A general perception exists that communal grazing systems will inevitably lead to overgrazing (Hoffman *et al.*, 1999). The reasoning behind this is that when a farmer adds an additional animal to his herd, he or she receives all the benefits of owning that additional animal, but the costs in terms of overgrazing are shared by all that use the commons. While it is against the group's interest to overgraze, for an individual, the benefits of overgrazing exceed the costs. Overgrazing thus arises out of the conflict between group and individual goals. As long as individuals cannot prevent others from overstocking, everyone has an incentive to overgraze. Those who do not increase their herd size, loose out as a result of the overgrazing of their neighbours. Despite very little research into communal grazing systems in Africa, this reasoning has become widely accepted and has formed the basis of most agricultural development programmes in Africa (de Bruyn *et al.*, 1998).

Even though communal grazing areas are perceived to be in poor condition, recent research shows that large areas are in a good, productive condition and support large herds of grazing livestock (de Bruyn *et al.*, 1998). The question however is whether communal grazing is sustainable?

According to pasture specialists, the rangeland must be fenced into paddocks and the livestock rotated among the paddocks. This practice will allow recovery to the rangeland and certain areas to rest. Without such conservation practice the rangeland will degrade. It is therefore believed that its potential to produce livestock will deteriorate when continuous grazing is practiced (Mentis, 1989).

Following the above mentioned reasoning, a serious effort to implement rotational grazing in communally managed areas are currently being undertaken as part of the LandCare initiative in the North West Province. Fences are erected in the communally managed areas in order to make it possible for the farmers to implement rotational grazing strategies (see Section 2.1.1, Chapter 2). These strategies are also used to educate farmers with regard to the positive advantages of resting their rangeland.

The Morafe ranch system is one of the systems being introduced into formerly communally managed areas, whereby livestock is rotated between four paddocks in

the system. Another, very effective way of demonstrating the effect to resting on the species composition and production, is the establishment of exclosures in certain benchmark sites. In this way, farmers can observe the effect of grazing and resting inside and outside the exclosure within the selected benchmark site. Benchmark sites are established “on site” or “on farm” and represent different rangeland conditional states (due to past history of grazing pressures), as well as types of vegetation and environmental regions. It is expected that “on site” demonstration plots will lead to an increased adoption of sustainable and sound management practices.

According to Turner (2001) the motivation for sustainable resource use is undeniably lowest, and the degradation worst, in the overcrowded former “homeland” areas where resource rights are not clear or secure enough and where land and resource management systems are inefficient, corrupt or non-existent. Turner (2001) also stated that until a comprehensive programme of tenure reform and administrative upgrading is implemented in these areas, there is no prospect of sustainable resource use or of sustainable development. As this is a well known fact throughout South Africa, the LandCare initiative in the North West Province attempts to provide an appropriate tenure reform programme for the former “homelands”. One way to achieve this goal, is to appoint Morafe ranches to willing and enthusiastic farmers (see Section 2.1.2, Chapter 2 for the functioning of these Morafe ranches). Although this could make a major contribution to sustainable development, it is important to remember that conferring private ownership on a land user does not guarantee good environmental behaviour.

The aim of this study was not to compare the communal and Morafe ranch management systems with each other. The establishment of the benchmark sites was only carried out in April 2001 and very little effect of species change could be determined in such a short period of time. Vegetation types, as well as the soil and climatic conditions, also varied considerably between all study areas. This was also proven from results using multivariate analytical techniques. These results are however not included in this thesis.

In spite of the differences in the soil compositions, it was observed that the benchmark sites under Morafe ranch management (the Waterfouchè, Heuningvlei, and Orange Grove benchmark sites) all consisted of good rangeland conditions (see Sections 5.2.2, 5.3.2, and 5.4.2). This could be seen in the fact that highly desirable or desirable grass species dominated at these sites, and that the total production and seasonal grazing capacity inside the exclosures at all these sites were very good during May 2002. The limited amount of available water resources at these study sites, which consequently kept the number of people and their livestock low, most probably explains why no signs of overgrazing was observed at these sites. Past, low stocking rates could also have contributed to the lower grazing impact at these sites. Watering points are currently being erected at all the Morafe ranches to provide water to the farmers and their livestock. However, the two year study period is too short to determine the effect that the implementation of this management system and the subsequent erection of watering points have on the rangeland condition.

The same could not however be said from the benchmark sites situated in the communally managed study sites (i.e. Austrey, Maketlele, and Ipelegeng). Even though it could be concluded that none of these sites were more degraded, seeing that

the rangeland condition at all of them improved to some extent in response to the preceding high 2001/2002 rainfall season (except at the Maketlele study site), the rangeland conditions at these sites varies from good to poor (see Sections 5.2.1, 5.3.1, and 5.4.1). The conditional states of benchmark sites dominated by highly desirable or desirable grass species during May 2002 were classified as good (the Austrey 1 and 3, and the Maketlele 1 and 2 benchmark sites). Conditional states of benchmark sites dominated by less desirable and non desirable grass species during May 2002 were respectively classified as moderately good (the Austrey 4 site) or moderate (the Austrey 2 site). The total production on the inside of the exclosures increased from 2001 to 2002 at all of the communally managed benchmark sites, except at Maketlele 2, where the figures of the preceding rainfall season were below average.

Thus, a clear difference in the conditional states between the communally managed benchmark sites and the benchmark sites where the Morafe ranch management system was implemented recently, exists. As mentioned, this could mainly be attributed to the past history of grazing pressures at these sites, before the commencement of this study. In both cases, under communal and Morafe ranch management, the study period was too short to determine the effect of these management systems on the rangeland conditions.

From this comparison, it is evident that much still has to be learned about rangeland dynamics and sustainability regarding these management systems. Accordingly, the challenge to develop management strategies that will ensure sustainability of resources and satisfy the aspirations and desires of the livestock keepers thusfar, still remain unsolved. These management strategies needs to be socially, economically, technically and economically efficient, providing high quality livelihoods to a large amount of people. Only the continued long-term monitoring of these two management systems can prove if either one of them might be the answer to this challenge.

5.6. General conclusions

Through conducting this study, the following general conclusions can be made.

- At benchmark sites where highly desirable grass species dominated, *S. pappophoroides* was the main representative species. This was especially at the Austrey 3, Waterfouchè 5, Maketlele 1, 2, Heuningvlei A2, C2 benchmark sites (Figures 4.6, 4.19, 4.23, 4.26, 4.28 and 4.31). Where benchmark sites were dominated by desirable grass species, *E. lehmanniana* occurred at high frequencies. This was noted at the Austrey 1, Waterfouchè 1, 3, 4, 6, and Heuningvlei F2 benchmark sites (Figures 4.1, 4.10, 4.15, 4.17, 4.21 and 4.33). The less desirable, *A. stipitata*, was the main representative grass species at benchmark sites that were dominated by less desirable grass species, e.g. at the Austrey 2, 4, and Waterfouchè 2 benchmark sites (Figures 4.4, 4.8 and 4.13). These three grass species, *S. pappophoroides*, *E. lehmanniana* and *A. stipitata*, can thus serve as good indicators of rangeland condition in the Ganyesa and Kudumane magisterial districts, indicating a highly desirable, desirable and less desirable grass species composition, respectively.

- The benchmark sites situated in the Taung magisterial district however differs from the above mentioned observation. The Ipelegeng benchmark site was dominated by less desirable grass species, which were mainly represented by *E. rigidior* (Figure 4.35). The Orange Grove benchmark site, on the other hand, was dominated by highly desirable grass species, mainly represented by *T. triandra* (Figure 4.38). These differences could be ascribed to differences in the topography, soil and geology at the three magisterial districts (see Section 2.2.3, Chapter 2). The benchmark sites in the Taung magisterial district is situated at a higher altitude (1300-1400m above sea level) than the benchmark sites in the Ganyesa and Kudumane magisterial districts (1100-1200m above sea level). The main difference in the soil composition is that the sand particle content of the benchmark sites situated in the Taung district (77%-85%) are less than those of the benchmark sites situated in the Ganyesa and Kudumane magisterial districts (86%-96%). Other differences in the soil compositions at all the benchmark sites can be viewed in Annex B. The geology of the benchmark sites at the Ganyesa and Kudumane districts are mainly described as aeolian sand and are located on Ah land types. On the other hand, the geology of the benchmark sites situated in the Taung magisterial district are described as fine and coarse-grained dolomite, chert and dolomitic limestone, and the Ipelegeng and Orange Grove sites are located on Fc4 and Ae9 landtypes, respectively.
- Although the seasonal grazing capacity was determined by means of three different methods (see Section 3.4.2, Chapter 3), the overall tendency remained the same. It did however become clear that poorer seasonal grazing capacities resulted from determining the seasonal grazing capacity by means of approach (ii) (see Section 4.1.2, Chapter 4). In order for the moderately high degraded benchmark sites (see Figure 1.1, Chapter 1) to recover sufficiently, it is suggested that approach (ii) should rather be used to determine the seasonal grazing capacity in future. If the farmers of the different study sites agree to apply these lower stocking rates, the degraded rangelands would probably recover much quicker. The use of approach (ii) is further promoted by the fact that calculating the seasonal grazing capacity of an area by means of approaches (ii) and (iii) provided more realistic results than approach (i).
- From this study it is evident that annual rainfall variation has an important influence on the vegetation compositional change, total grass production, and subsequently also on the seasonal grazing capacity. The notion that changes in species abundance are simply as a consequence of rainfall variability without any effect of grazing is already discounted by O'Connor (1995) due to the observation that although year-by-year changes due to grazing are small, they are cumulative. It could thus be concluded that changes in the grass species composition and production are dependent on external factors, such as the timing of rainfall events, dry spells, and the interaction of management practices (O'Connor, 1994).
- According to Snyman & Fouché (1993) the relationship between rainfall and grazing capacity is very strong in areas subjected to low rainfall. This relationship could be observed at the Austrey 1, 2, 3, Waterfouché 1, Ipelegeng 1 and Orange Grove benchmark sites. At these benchmark sites the improvement in the seasonal grazing capacities could be mainly attributed to the preceding high rainfall season.

- According to O'Connor (1991) it should be recognised that the effects of heavy grazing are only manifested over a longer time period. Periods of three years and longer are necessary to determine the effects of grazing in areas, especially due to the fact that climatic effects might eclipse grazing effects over a three-year period. In support of this O'Connor (1995) also stated that the minimum length of a study should at least cover the periodicity of climatic influences and ideally, the life-span of plants. It is thus clear that vegetation surveys at the communally managed, and at the study sites under Morafe ranch management, should be carried out over a longer time period than the present two years study. The effect of rest being applied inside the exclosures would also only provide significant results over longer study periods. Accordingly, it is of fundamental importance that a continued and sustained research effort must be aimed at attaining the ability to predict, within reasonable bounds, the short-term and long-term consequences of possible management actions and dynamic variability. It is thus important to achieve a good predictive capacity at different study sites in order to plan and solve problems at ranch level (Teague & Smit, 1992).
- It could be concluded that the availability of seed in the soil seed bank, available moisture and the availability of gaps in the vegetation, influenced the patterns of recruitment in the grass and forb species as reported in this study. More intensive experimentation is however needed to identify the relative importance of these processes at the different benchmark sites.
- The data for this study were collected at the start of the long-term monitoring program to ensure that the influence of the different management systems and rest applied inside the exclosures were comparable over the long-term in terms of grass species composition and production. These results thus serve as fundamentally important baseline data for the continued monitoring of these benchmark sites in future.
- From the results of this study, it could also be suggested that different patterns in the grass species composition and production across benchmark sites at a study site, or across different study sites are at least partly a consequence of the different grazing histories at these sites. These different patterns across regions could also be ascribed to differences in the life history characteristics of the dominant grass species at the different benchmark sites. Additionally, it could be concluded that the availability of seed forms one of the most important constraints on seedling recruitment in years of suitable rainfall. However studies proved that the restraint of grazing will not alone determine changes in the grass species composition and production, but that aspects such as the type of vegetation, growth form and to which degree the soil conditions change, also has an important influence.
- According to Bosch & Gauch (1991) and Henning & Kellner (1994), changes in soil condition are especially important to identify possible thresholds for the processes of degradation. It also facilitates predictions of the recovery potential of vegetation that was degraded to different degrees. This holds important practical implications as it determines whether the degradation trend is reversible by means of normal rangeland management practices, or whether physical reclamation methods will have to be applied to restore the productivity of the land. Results of the soil sample analyses that was given thus also serve as important baseline data,

seeing that these results can be used in future studies at the benchmark sites in order to determine if the rangeland conditions are deteriorating or improving over a longer period of time. Teague & Smit (1992) stated that although plant species composition is influenced by soil properties, such as nutrient status, pH, salinity and texture, the overwhelming factor determining the spatial distribution and productivity savanna rangeland, is soil moisture balance. These findings coincide with the results of this study, as the rainfall pattern was regarded at the main driving force of any vegetation compositional and production changes.

- According to O'Reagain & Turner (1992) range conditions of semi-arid savanna areas recovers more rapidly under resting than under grazing. This could be observed in the improvement of the rangeland condition at all the benchmark sites, except at the sites in the Maketlele study area that was subjected to a very low rainfall during the study period. It could thus be concluded that the rangeland condition inside the exclosures at the different benchmark sites could be used to measure the effects that the different management systems will have on the rangeland condition during future studies.
- The importance of rangeland management during periods of low rainfall was emphasized at the Maketlele benchmark sites. This study site received low rainfall during the study period and subsequently the rangeland condition inside the exclosures did not improve to the same extent that was observed at the benchmark sites of the other study sites. Conclusively the grazing pressures at these benchmark sites should be reduced during and after low rainfall periods if changes toward a more desirable grass species composition are desired.
- The agricultural extension officers and land users helped in the surveying of the species composition and grass production at the different benchmark sites. As a consequence they were simultaneously trained to identify grass species according to their scientific names, and to carry out the specific vegetation sampling techniques in order to determine the grass species composition and production. Through this an environmental awareness was created to such an extent that the land users became even more eager to learn how to manage their land sustainably. Accordingly the agricultural extension officers and land users of the different study sites reflected a positive attitude toward the LandCare initiative in the western region of the North West Province.
- During this project the researchers also learned a great deal from the indigenous knowledge of the land users. As a consequence a positive collaboration between the academic institution (Potchefstroom University for CHE) and practitioners (agricultural extension officers and land users) was created.
- The importance that data should be accounted for scientifically and be verified through quantitative vegetation surveys was emphasized through this study. To achieve this for vegetation dynamic studies the long-term monitoring of study sites is inevitable.

5.7. The success and future of the project as a LandCare initiative

The success of this study could mainly be ascribed to the high degree to which the participation by the agricultural extension officers, land users and communities, during the execution of the vegetation surveys, increased throughout the study period.

Sustainable development requires maintaining or enhancing the health of ecosystems. People must be committed to the governance of resource use and conservation within a framework of efficiency, equity and social justice. They must be motivated to conserve natural resources as they use them, or at least have this attitude even if they do not use the resources. This motivation and attitude towards the natural resource, was attempted in this LandCare project by involving the land users and communities in all stages of the study, including the monitoring and sampling of the vegetation and soil factors at the different benchmark sites.

If people consider their rights to natural resources to be insecure, or if they perceive themselves to be unfairly excluded from some of the nation's natural heritage, they are less likely to use the natural resources sustainably. In situations where land rights are clear and where land administration is democratic and efficient, the motivation to use natural resources sustainably will be stronger (Turner, 2001). As already mentioned (see Section 5.5) an appropriate tenure reform programme for the former "homelands" could thus make a major contribution to sustainable development. According to Turner (2001) no comprehensive tenure programme is however yet in place. He also stated that South Africa's leading initiative for agricultural resource conservation is the LandCare programme. Building on the original international concept of LandCare in the local context, would mean bringing all sectors of local rural society together to develop participation and a sense of ownership in caring for natural resources, especially through the establishment of Morafe ranches. This would mean a leading role for land reform in building the rights that help create care. Turner (2001) however also states that LandCare could thus far not contribute much to land reform, seeing that the LandCare program is focused too much on short-term poverty alleviation through labour-intensive public works.

Taking all of the above mentioned statements into consideration it could be concluded that land reform is not only subjected to the implementation of appropriate tenure reform programs by the authorities, but also to the excepting of these strategies by the land users. Accordingly land reform is subjected to an indefinite time period. In order to observe whether the implementation of the LandCare initiative in the North West Province could give rise to the much needed sense of ownership, and subsequent caring for natural resources, a longer study period, in which the effects of the Morafe ranch management on the rangeland condition, have to be determined. However, if only to be true to the interest and eagerness to learn more about the sustainable management of their land, that was awakened in the land users by this LandCare project, it is imperative that the long-term monitoring of these study areas must be maintained. This project is therefore a good example of a well established awareness raising initiative with regard to sustainable management practices. This awareness and positive attitude that has been created in the two year period of the project will only be sustained and improved, if the project is maintained and monitoring carried out over the long-term. The results of this study can therefore serve as very good baseline and reference data for such long-term monitoring projects.

5.8. Shortcomings to address in future studies of the same type

After the completion of this study, the following recommendations are proposed for future studies of this nature.

- As was mentioned many times throughout this thesis, to obtain better results and determine the effect of the different grazing systems quantitatively, a longer study period is recommended. The continued monitoring of these study sites is also vital to obtain a clearer understanding of the environmental factors and plant population processes primarily responsible for changes in the grass species composition and production.
- Fourie *et al.* (1984) found that basal cover in the arid and semi-arid areas was a better indicator of trends in rangeland condition than botanical composition. According to the author, changes in botanical composition in arid areas are indicative of a more advanced stage of rangeland deterioration. In future studies the basal cover should therefore be used together with the botanical composition when evaluating the rangeland condition at the study sites of this study.
- As stated by work of O'Connor (1995), the importance of the spatial heterogeneity in terms of woody individuals serving as protection for some grass species needs emphasis. The changes in the woody component, especially with regard to bush encroachment and thickening, was done in a separate M.Sc. study conducted at the same time (by Miss Anja Janse van Vuuren also from the Potchefstroom University for CHE). It is thus recommended that the results of the bush encroachment study should be better incorporated and considered in relation to the grass species composition during the future monitoring of these benchmark sites.
- In order to compare the influence of environmental changes and the different management systems on the grass production inside and outside the exclosures, it is recommended that the grass production must also be cut on the outside of the exclosures.
- Seeing that part of the objectives of this study was to involve, train and educate the agricultural extension officers and land users with regard to vegetation sampling, grass species composition and sustainable management practices, they helped in the surveying of the species composition and grass production at the benchmark sites. As the results of these vegetation surveys serve as important baseline data for future studies, it is important that the reliability of data sampled by the agricultural extension workers and land users is assured. To achieve this, it is suggested that intensive training workshops, with regard to species identification and monitoring techniques, be held at each study site before the monitoring exercise commences. In this way consensus can be achieved and many inaccuracies avoided. As a result more reliable data would be obtained.
- The agricultural extension officers and land users should also be motivated to record other data, such as the rainfall, temperature and frost, at each benchmark site. Such data can be used to explain changes in the grass species composition and production more effectively in future studies at these study sites.

- Scientists from other disciplines should also be involved in future studies of this nature. In this way other aspects apart from botany, such as the social, economic, animal husbandry and other biodiversity related sciences, could be incorporated in order to form multidisciplinary research teams, which would be able to conduct more comprehensive studies.

Chapter 6: References

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Annex A: Example of a species compositional survey form

Veld Condition: Species Composition

Locality: Ganyesa

Survey Site: Austrey 1

Date: 04/10/2002

Desirability	Species	Nearest point	Nearest perennial	Total
Highly Desirable	<i>Antheophora pubescens</i>			
	<i>Brachiaria nigropedata</i>			
	<i>Cenchrus ciliaris</i>			
	<i>Digitaria eriantha</i>	III	III III I	14
	<i>Eustachys paspaloides</i>			
	<i>Schmidtia pappophoroides</i>	III III II	III III	22
	<i>Sporobolus fimbriatus</i>			
	<i>Themeda triandra</i>			
	Subtotal	15	21	36
Desirable	<i>Cymbopogon excavatus</i>			
	<i>Cymbopogon plurinodis</i>			
	<i>Eragrostis lehmanniana</i>	III III III I	III IIII	25
	<i>Eragrostis superba</i>			
	<i>Eragrostis trichophora</i>	III	III II	12
	<i>Heteropogon contortus</i>			
	<i>Panicum schinzii</i>			
	<i>Sporobolus ioclados</i>			
	<i>Stipagrostis uniplumis</i>	III III	III III I	21
	<i>Urocloa mosambicensis</i>			
	Subtotal	31	27	58
Less desirable	<i>Aristida meridionalis</i>			
	<i>Aristida stipitata</i>	III III I		11
	<i>Brachiaria marlothii</i>			
	<i>Cynodon dactylon</i>			
	<i>Enneapogon scoparius</i>			
	<i>Eragrostis obtusa</i>			
	<i>Eragrostis pallens</i>	II		2
	<i>Eragrostis rigidior</i>			
	<i>Fingerhuthia africana</i>			
	<i>Melinis repens</i>	III		4
	<i>Pogonarthria squarrosa</i>	III III		8
	<i>Tricholaena monachne</i>			
	<i>Triraphis andropogonoides</i>			
	Subtotal	25		25
Non desirable	<i>Aristida canescens</i>			
	<i>Aristida congesta</i>	III III III I		16
	<i>Chloris virgata</i>			
	<i>Eragrostis biflora</i>			
	<i>Perotis patens</i>	III III III II		17
	<i>Tragus koeleroides</i>			
	<i>Tragus racemosa</i>	III III		8
	<i>Trichoneura grandiglumis</i>			
	Subtotal	41		41
Forbs		III IIII III III		19
Bare Ground		III III III III I		21
Grand Total				200

Annex B: Table of the soil analyses results of soil samples taken inside (I) and outside (O) the enclosures of the different benchmark sites.

Benchmarks	pH	P (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	K (mg/kg)	Na (mg/kg)	CEC (cmol+/kg)	C (%)	R (ohm)	Clay (%)	Silt (%)	Sand (%)
Maketlele 1 I	7.98	3.65	671	14.9	41.1	0	3.27	0.27	4300	6	2.4	91.6
Maketlele 1 O	8.16	3.73	564	18.9	33.1	0	3.08	0.26	4400	8	0.3	91.7
Maketlele 2 I	7.89	3.77	579	27.8	37.6	0	3.67	0.27	4000	8	2.1	89.9
Maketlele 2 O	7.69	3.75	622	42.7	35.5	0	3.78	0.28	4400	8	2.3	89.7
Heuningvlei A2 I	6.44	3.51	134	25.1	20.5	0	5.82	0.16	28000	6	0.4	93.6
Heuningvlei A2 O	6.37	3.38	193	31.7	28.7	0	3.17	0.19	7900	6	0.9	93.1
Heuningvlei C2 I	6.35	3.35	243	37.5	38.0	0	4.22	0.21	8100	6	0.8	93.2
Heuningvlei C2 O	6.44	3.25	208	37.1	34.6	0	4.12	0.16	8000	8	0.9	91.1
Heuningvlei F2 I	6.60	3.33	268	27.8	25.9	0	3.31	0.27	3600	6	0.9	93.1
Heuningvlei F2 O	6.24	3.04	225	34.1	25.3	0	2.22	0.26	4900	10	2.5	87.5
Austrey 1 I	5.47	3.11	61	10.3	35.1	0	3.79	0.26	28000	10	0.1	89.9
Austrey 1 O	5.36	3.06	72	15.9	49.6	0	4.08	0.24	34000	10	2.3	87.7
Austrey 2 I	5.47	3.08	84	17.7	30.8	0	2.95	0.21	24000	10	0.1	89.9
Austrey 2 O	5.34	3.26	79	18.3	29.3	0	2.31	0.21	28000	8	3.3	88.7
Austrey 3 I	5.79	3.35	138	39.9	68.8	0	3.64	0.24	22000	8	4.2	87.8
Austrey 3 O	5.68	3.37	142	33.4	70.1	0.3	2.82	0.28	7800	8	5.1	86.9
Austrey 4 I	5.54	3.25	125	25.2	40.9	0.3	2.56	0.24	9000	6	7.3	86.7
Austrey 4 O	5.80	3.46	143	33.2	41.7	0	2.49	0.23	22000	6	3.9	90.1
Waterfouchè 1 I	6.04	3.28	169	32.6	31.2	0	2.44	0.14	24000	4	1.9	94.1
Waterfouchè 1 O	6.14	3.43	189	26.2	38.5	0	1.83	0.20	8400	4	1.5	94.5
Waterfouchè 2 I	6.12	3.29	124	33.3	38.3	0	2.22	0.18	22000	4	1.9	94.1
Waterfouchè 2 O	6.21	3.40	156	36.8	42.3	0	2.49	0.17	9200	4	2.2	93.8
Waterfouchè 3 I	6.16	3.50	121	35.1	33.1	0	3.09	0.15	9400	4	0.5	95.5
Waterfouchè 3 O	6.31	3.52	140	36.7	29.5	2.1	3.16	0.15	9800	4	0.4	95.6
Waterfouchè 4 I	6.12	3.48	101	28.4	42.3	0	2.52	0.17	30000	4	0.5	95.5
Waterfouchè 4 O	6.04	3.40	112	28.9	35.4	0	2.33	0.17	20000	4	1.9	94.1
Waterfouchè 5 I	5.98	3.20	211	50.6	37.1	0	3.21	0.17	18000	6	0.2	93.8
Waterfouchè 5 O	6.16	3.18	197	38.8	38.4	0	2.91	0.20	6800	6	0.1	93.9
Waterfouchè 6 I	6.06	3.29	147	45.1	52.1	0.1	2.70	0.18	9400	6	1.1	93.1
Waterfouchè 6 O	5.89	3.19	113	31.2	34.3	0	2.30	0.19	34000	6	0.1	93.9
Ipelegeng 1 I	6.21	3.25	296	76.9	117.7	0	4.39	0.28	5400	12	6.3	81.7
Ipelegeng 1 O	6.10	3.11	340	63.1	115.8	0.1	3.95	0.39	22000	10	5.1	84.9
Orange Grove I	7.84	3.46	1747	174.6	169.6	1.5	9.93	0.85	2000	8	14.5	77.5
Orange Grove O	7.21	3.62	1245	141.5	123.9	0	8.88	0.60	3400	10	12.5	77.5

Annex C1: Species list of the highly desirable and desirable grass species, with abbreviations, grazing values and some ecological characteristics.

Grass species and Abbreviations	Desirability	Grazing value	Annual/Perennial	Plant succession	Ecological status
<i>Antheophora pubescens</i> (Ant pub)	Highly desirable	High	Perennial	Climax	Decreaser
<i>Brachiaria nigropedata</i> (Bra nig)	Highly desirable	High	Perennial	Climax	Decreaser
<i>Cenchrus ciliaris</i> (Cen cil)	Highly desirable	High	Perennial	Sub-climax - Climax	Decreaser
<i>Digitaria eriantha</i> (Dig eri)	Highly desirable	High	Perennial	Climax	Decreaser
<i>Eustachys paspaloides</i> (Eus pas)	Highly desirable	High	Perennial	Climax	Decreaser
<i>Schmidtia pappophoroides</i> (Sch pap)	Highly desirable	High	Perennial	Sub-climax - Climax	Decreaser – Increaser II
<i>Sporobolus fimbriatus</i> (Spo fim)	Highly desirable	High	Perennial	Climax	Decreaser
<i>Themeda triandra</i> (The tri)	Highly desirable	High	Perennial	Climax	Decreaser
<i>Cymbopogon excavatus</i> (Cym exc)	Desirable	Low	Perennial	Climax	Increaser I
<i>Cymbopogon plurinodis</i> (Cym plu)	Desirable	Low	Perennial	Climax	Increaser I – Increaser II
<i>Eragrostis lehmanniana</i> (Era leh)	Desirable	Average	Perennial	Sub-climax - Climax	Increaser II
<i>Eragrostis superba</i> (Era sup)	Desirable	Average	Perennial	Sub-climax	Increaser II
<i>Eragrostis trichophora</i> (Era tri)	Desirable	Average	Perennial	Sub-climax	Increaser II
<i>Heteropogon contortus</i> (Het con)	Desirable	Average	Perennial	Sub-climax	Increaser II
<i>Panicum schinzii</i> (Pan sch)	Desirable	High	Annual	Pioneer	Increaser II
<i>Sporobolus ioclados</i> (Spo ioc)	Desirable	Average	Perennial	Sub-climax	Increaser II
<i>Stipagrostis uniplumis</i> (Sti uni)	Desirable	Average	Perennial	Sub-climax	Increaser II
<i>Urocloa mosambicensis</i> (Uro mos)	Desirable	High	Perennial	Sub-climax	Increaser II

Annex C2: Species list of the less desirable and non desirable grass species, with abbreviations, grazing values and some ecological characteristics.

Grass species and Abbreviations	Desirability	Grazing value	Annual/Perennial	Plant succession	Ecological status
<i>Aristida meridionalis</i> (Ari mer)	Less desirable	Low	Perennial	Climax	Increaser II
<i>Aristida stipitata</i> (Ari sti)	Less desirable	Low	Perennial	Pioneer – sub-climax	Increaser II
<i>Brachiaria marlothii</i> (Bra mar)	Less desirable	Low	Annual – poor perennial	Pioneer	Increaser II
<i>Cynodon dactylon</i> (Cyn dac)	Less desirable	High	Perennial	Pioneer	Increaser II
<i>Enneapogon scoparius</i> (Enn sco)	Less desirable	Low	Perennial	Climax	Increaser III
<i>Eragrostis obtusa</i> (Era obt)	Less desirable	Average	Perennial	Pioneer – sub-climax	Increaser II
<i>Eragrostis pallens</i> (Era pal)	Less desirable	Low	Perennial	Climax	Increaser III
<i>Eragrostis rigidior</i> (Era rig)	Less desirable	Average	Perennial	Sub-climax	Increaser II
<i>Fingerhuthia africana</i> (Fin afr)	Less desirable	Average	Perennial	Pioneer - sub-climax	Decreaser
<i>Melinis repens</i> (Mel rep)	Less desirable	Low	Annual – poor perennial	Pioneer – sub-climax	Increaser II
<i>Pogonarthria squarrosa</i> (Pog squ)	Less desirable	Low	Perennial	Sub-climax	Increaser II
<i>Tricholaena monachne</i> (Tri mon)	Less desirable	Average	Perennial	Sub-climax	Increaser II
<i>Triraphis andropogonoides</i> (Tri and)	Less desirable	Low	Perennial	Climax	Increaser I
<i>Aristida canescens</i> (Ari can)	Non desirable	Low	Perennial	Sub-climax	Increaser II
<i>Aristida congesta</i> (Ari con)	Non desirable	Low	Annual/perennial	Pioneer	Increaser II
<i>Chloris virgata</i> (Chl vir)	Non desirable	Average	Annual – poor perennial	Pioneer	Increaser II
<i>Eragrostis biflora</i> (Era bif)	Non desirable	Low	Annual	Pioneer	Increaser II
<i>Perotis patens</i> (Per pat)	Non desirable	Low	Annual – poor perennial	Pioneer – sub-climax	Increaser II
<i>Tragus koeleroides</i> (Tra koe)	Non desirable	Low	Annual	Pioneer	Increaser II
<i>Tragus racemosa</i> (Tra rac)	Non desirable	Low	Annual	Pioneer	Increaser II
<i>Trichoneura grandiglumis</i> (Tri gra)	Non desirable	Low	Perennial	Sub-climax	Increaser II

Annex D: The Z-index values (%) calculated for the similarity in the grass species composition inside and outside the enclosure, at the different benchmark sites during April 2001, December 2001 and May 2002.

Benchmark site	Date	Z-index value (%)
Austrey 1	April 2001	61.5
	December 2001	66.4
	May 2002	62.6
Austrey 2	April 2001	69.4
	December 2001	58.5
	May 2002	64.8
Austrey 3	April 2001	63.7
	December 2001	74.2
	May 2002	84.0
Austrey 4	December 2001	57.2
	May 2002	63.6
Waterfouchè 1	April 2001	83.6
	December 2001	71.0
	May 2002	84.3
Waterfouchè 2	December 2001	85.9
	May 2002	93.1
Waterfouchè 3	December 2001	86.4
	May 2002	87.4
Waterfouchè 4	December 2001	67.4
	May 2002	75.5
Waterfouchè 5	December 2001	72.6
	May 2002	83.9
Waterfouchè 6	December 2001	77.9
	May 2002	74.2
Maketele 1	April 2001	79.4
	December 2001	81.9
	May 2002	65.3
Maketele 2	April 2001	92.2
	December 2001	82.5
	May 2002	91.0
Heuningvlei A2	December 2001	76.8
	May 2002	85.1
Heuningvlei C2	December 2001	90.0
	May 2002	85.8
Heuningvlei F2	December 2001	90.1
	May 2002	88.5
Ipelegeng 1	December 2001	70.4
	May 2002	88.7
Orange Grove	April 2001	73.3
	May 2002	69.4

Annex E: The dry matter (DM) production figures (kg/ha) for the different grass species desirability classes and the seasonal grazing capacity (ha/LSU) determined by means of three different approaches (see Section 3.4.2, Chapter 3) at the different benchmark sites, during April 2001 and May 2002.

Benchmark site	Date	DM production of HD grass species (kg/ha)	DM production of D grass species (kg/ha)	DM production of LD grass species (kg/ha)	DM production of ND grass species (kg/ha)	Seasonal grazing capacity (ha/LSU) determined by means of approach (i)	Seasonal grazing capacity (ha/LSU) determined by means of approach (ii)	Seasonal grazing capacity (ha/LSU) determined by means of approach (iii)
Austrey 1	April 2001	6	22	32	27	195.2	256.1	173.8
	May 2002	83	220	150	306	21.7	30.8	23.0
Austrey 2	April 2001	6	36	159	73	30.8	81.7	51.9
	May 2002	4	70	452	214	27.1	31.3	19.8
Austrey 3	April 2001	302	347	454	110	10.2	13.4	9.5
	May 2002	486	352	482	162	7.9	10.6	7.9
Austrey 4	May 2002	25	249	444	192	18.7	23.3	14.5
Waterfouchè 1	April 2001	25	226	11	109	39.1	59.3	39.8
	May 2002	47	613	159	509	12.6	18.6	12.7
Waterfouchè 2	May 2002	169	345	946	235	9.1	11.1	7.1
Waterfouchè 3	May 2002	448	1584	93	0	5.1	7.4	4.9
Waterfouchè 4	May 2002	139	368	531	205	11.9	15.3	10.0
Waterfouchè 5	May 2002	285	132	295	276	13.6	18.3	14.6
Waterfouchè 6	May 2002	338	462	166	33	10.6	14.9	10.8
Maketlele 1	April 2001	643	290	18	0	8.9	12.7	11.0
	May 2002	839	108	3	0	8.1	11.6	11.0
Maketlele 2	April 2001	557	602	30	114	7.7	11.2	8.8
	May 2002	294	260	14	56	15.6	22.7	18.4
Heuningvlei A2	May 2002	480	563	239	305	7.5	10.6	8.1
Heuningvlei C2	May 2002	1972	528	181	42	3.1	4.4	3.9
Heuningvlei F2	May 2002	108	1869	16	4	5.9	8.8	5.2
Ipelegeng 1	April 2001	88	149	317	7	23.9	29.4	18.8
	May 2002	139	468	563	11	11.3	14.3	8.9
Orange Grove	April 2001	230	159	60	68	20.1	28.6	23.2
	May 2002	765	536	138	75	6.3	9.0	7.2