

**EcoRestore - a Decision Support System  
for the restoration of degraded  
rangelands in southern Africa**

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**B.Sc. Honours**

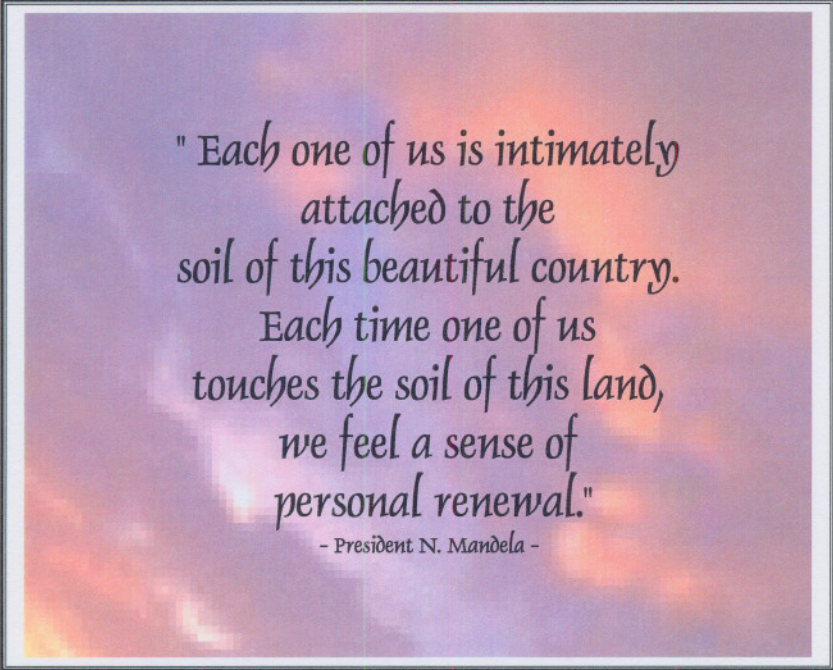
**Dissertation submitted in partial fulfillment of the degree  
MAGISTER SCIENTIAE (BOTANY)  
School of Environmental Sciences and Development,  
Potchefstroom University for Christian Higher Education**

**Potchefstroom**

**November**

**2003**

**Supervisor: Prof. K. Kellner**



*" Each one of us is intimately  
attached to the  
soil of this beautiful country.  
Each time one of us  
touches the soil of this land,  
we feel a sense of  
personal renewal."*

*- President N. Mandela -*

*∞ Dedicated with love to my parents, Steve & Sonja*

*and to my grandparents ∞*

**ECORESTORE - A DECISION SUPPORT SYSTEM  
FOR THE RESTORATION OF DEGRADED RANGELANDS  
IN SOUTHERN AFRICA**

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## ABSTRACT

### *EcoRestore - a Decision Support System for the restoration of degraded rangelands in southern Africa*

Land degradation is a process that causes the reduction in resource potential of natural rangelands and occurs widespread throughout southern Africa. This process is mainly characterized by the loss in vegetation cover, which leads to the occurrence of bare and denuded patches, increased soil erosion, changes in species composition as well as bush encroachment by indigenous and alien invasive plant species in savanna areas.

Degradation of rangelands has drastically extended at an alarming rate during the last few decades with the main causes being overstocking, extended periods of drought, global climate change, overgrazing and general mismanagement of the land. Many researchers, however, feel that rangeland degradation is mainly caused by a combination of changes in land use practices and climate variability.

Land users have, however, been applying a variety of technologies over the years in order to restore affected rangelands and mitigate the effect of degradation. These technologies include passive and active intervention methods, aimed at restoring bare and denuded areas and controlling indigenous bush and alien plant species encroachment. Bush control can be carried out by applying different technologies, involving chemical, mechanical, manual or biological control.

The focal point of this study is on bush encroachment, the factors causing the problem, the possible ways of controlling this phenomenon and lastly the incorporation of such information into a user-friendly Decision Support System (DSS). The Decision Support System comprises of two databases as well as a related expert system. Bush encroachment is a matter of great concern in most southern African countries. This study therefore mainly included data from Namibia and to a lesser extent, South Africa, as the main study areas, seeing that this form of degradation greatly influences the biodiversity of rangelands in both these countries.

The Namibia Agricultural Union (NLU) identified the need for the development of a user-friendly Decision Support System, in which case studies concerning the different bush control technologies could be stored in a database. Restoration technologies, regarding the occurrence of bare and denuded areas, that have been applied by the land users over a period of time and in a specific environment in the past, have been captured in a computerized database and expert system, serving as a Decision Support System (DSS) and user-friendly consulting tool in a similar study, carried out by Mr. Van der Merwe (1997). This DSS was based on CBR (Case Based Reasoning) methodologies by which a number of case studies, that have previously been stored in the database, can be searched by means of an expert system approach to advise the land user concerning the most appropriate solution (action) to similar degradation problems. The DSS developed by Mr. Van der Merwe was never published or made accessible to the land user in a format that could be consulted by either CD-ROM or the internet. Seeing that the NLU identified the need for a similar DSS containing

bush control technologies, it was decided to incorporate both these databases into a single DSS, concerning bush control as well as the restoration of bare and denuded patches. The newly converted DSS is currently known as *EcoRestore* and consists on two databases: *Grass Expert*, which focuses on technologies to reclaim degraded rangelands, and *Bush Expert*, which is more focused on the control of bush encroachment and combating of alien invasives.

As mentioned, this study focussed on the development of the *Bush Expert* database and will therefore only include results, discussions and conclusions of these case studies.

The case studies in the *Bush Expert* database consist of results obtained by means of a questionnaire completed by the land user, in collaboration with the agricultural extension officer, as well as a quantitative vegetation assessment, to determine the success rate of the applied technology.

The *Bush Expert* questionnaire, comprises of questions concerning personal information of the land user (e.g. location of the farm), the situation on the farm before bush control was applied (e.g. information on the environmental factors, such as density of problem trees), as well as the type of control technology applied and the situation of the rangeland after control (e.g. establishment of the herbaceous species).

The quantitative vegetation assessments involved the sampling of the woody and herbaceous components in the area where a specific control technology was applied. The density and height classes of the woody component were determined by means of the belt-transect method. By using the descending-point method, the herbaceous component was surveyed to determine the abundance/ frequency of the annual and perennial grass species.

In order to increase the success of any restoration project, it is important to take the existing indigenous knowledge of local land users, concerning the problem of degradation and mitigation thereof, into consideration. By doing so, the local people and communities have greater control and responsibility over their resources and are able to command a greater range and level of resourcefulness. Taking indigenous knowledge into consideration finally enables the local land users to actively participate in and influence higher-level decision-making processes by which they are affected.

A total of 175 case studies in Namibian and nine case studies in South Africa were surveyed. The Namibian case studies were surveyed in the central and northern arid and semi-arid regions, and South African case studies in a limited location within the Limpopo Province. Only 100 of the Namibian case studies have thus far been incorporated into the *Bush Expert* database.

Multivariate data analyses techniques, analysis of variance and correlation analyses were used to analyse the data obtained from the questionnaires and quantitative vegetation surveys. Results were represented in the form of histogrammes, tables and multivariate analysis ordinations.

From the results obtained for the *Bush Expert* database, it was clear that chemical control technologies were most often applied in Namibian and South African case studies (61%). The herbicides most commonly applied as chemical control technology in Namibia included Grazer (20%) and Savana (15%), whilst in South Africa these included Access (33.3%) and Tordon Super (33.3%). Herbicides were mostly applied by means of aerial application (46%) methods in Namibia and as cut-stump treatment (55.5%) by means of knapsack spraying or with a brush in South Africa.

The dominant woody species causing bush encroachment problems in Namibia were found to be *Acacia mellifera*, *Acacia reficiens* and *Dichrostachys cinerea*, whereas in South Africa these species included *Dichrostachys cinerea*, *Acacia erubescens* and *Acacia karroo*.

The wood of the controlled problem species (dead woody material) is mostly not utilized after control, but rather left on the land to disintegrate and thus contribute to the organic material content in the soil. Dead branches are also used for brushpacking, which forms an ideal micro-climate for the germination and establishment of grass seeds, which serves as an erosion control medium and protects grass seedlings against grazing impacts. Some land users do however produce charcoal from certain controlled woody species, in order to recover some of the input costs of bush control.

The majority of the case study sites (68%) in Namibia occurred within the 300-450 mm short- and long-term rainfall zones and in South Africa the majority of case study sites occurred within the short-term rainfall zone of 550-600 mm (66.6%) and 400-500 mm long-term rainfall zone (55.5%).

Case studies where chemical and manual bush control technologies were applied indicated the highest success rates after control (81.7% and 75.2% respectively). Success rate as an entity was greatly influenced by the type of control technology applied, the density of the problem woody species after bush control as well as environmental variables such as rainfall and soil clay percentage.

No definite trend could be determined concerning the application of a specific bush control technology and a certain problem species. Land users tend to apply a chosen control technology, according to the resources available, such as labour, mechanical implements and finances. The only positive correlation between control technologies and the type of problem species could be found regarding *Dichrostachys cinerea*. This species was mainly chemically controlled by means of the application of certain herbicides.

The most important lesson to be learnt from the surveys completed in the two countries is that it is an absolute necessity to apply a proper after-care programme as a management practice following the initial control of problem woody species. The implementation of after-care determines the final success rate of any applied bush control technology as a restoration practice within a rangeland. Only 11% of the case studies surveyed for Namibia and South Africa indicated the implementation of an after-care programme, which usually involved biological control (e.g. browsing by boer goats or the use of controlled or accidental natural veld fires).

The *EcoRestore* Decision Support System is currently available as an online web-version ([www.puk.ac.za/EcoRestore](http://www.puk.ac.za/EcoRestore)), as well as a CD-ROM version. The CD-ROM version is available in a package containing the CD and user's manual. An example of the package is included in this dissertation.

In consulting the databases through question-and-answer procedures, the best action will be proposed to the land user for future rangeland restoration, either the reclamation of denuded areas or the control of bush encroachment. Since the case studies are based on past and existing experiences and research, the land user will have an indication of the expected outcome, should the same advised technology be applied.

The *EcoRestore* DSS does not only offer a consulting tool for extension workers and technicians, but also creates networking and participation between land users and researchers, both locally and between neighbouring countries. The DSS is linked to other national and international websites and databases, to offer users a wider range of information and technologies with regard to agricultural and conservation practices. Better awareness is created amongst land users concerning the problem of rangeland degradation, which might encourage closer monitoring of the degradation and mitigation processes.

The *EcoRestore* DSS was developed in such a way for it to be as user-friendly as possible, in order to reach as many parties involved in current or future restoration programmes. This study involved the development of the first version of the DSS (Version 1.0) and is thus only the prototype system. It is proposed that the *Bush Expert* database of the *EcoRestore* DSS, will be expanded in future and additional bush control case studies from other southern African countries will be included. The addition of such case studies will ultimately increase the effectivity of this DSS.

**Keywords:** rangeland, degradation, restoration, bush encroachment, DSS, database, land user, indigenous knowledge, control technologies.

## OPSOMMING

### *EcoRestore - 'n Besluitnemings-kundigheidstelsel vir die restourasie van gedegradeerde weiveld in suidelike Afrika*

Degradasie van natuurlike weiveld is 'n proses wat 'n afname in die hulpbronnepotensiaal van die weiveld tot gevolg het en is 'n probleem wat tans wydverspreid in suidelike Afrika voorkom. Hierdie proses word gekenmerk deur 'n verlies aan plantegroeibedekking, wat gevolglik dan lei tot die ontstaan van kaalkolle, verhoogde erosietoestande, 'n verandering in plantspesie-samestellings, asook bosindringing en -verdigting wat hoofsaaklik veroorsaak word deur inheemse en uitheemse indringer plantspesies in savanna gebiede.

Degradasie van natuurlike weiveld het drasties toegeneem gedurende die afgelope aantal dekades. Hierdie toestand in weiveld word hoofsaaklik veroorsaak deur oorbeweidings, verlengde periodes van droogte, globale klimaatsveranderinge, oorbelaeding en algemene wanbestuurs-praktyke. Verskeie navorsers is van mening dat degradasie van natuurlike weiveld die gevolg van 'n kombinasie van meegaande faktore soos grondgebruiks-praktyke en klimaatsveranderinge is.

Grondeienaars en boere pas al vir 'n geruime tyd verskeie restourasie-tegnieke toe om gedegradeerde weiveld te restoureer, om sodoende die effek van degradasie teen te werk. Hierdie tegnieke sluit passiewe en aktiewe bekampings-tegnieke in, wat gerig is op die herstel van kaalkolle en die beheer van bosindringing deur inheemse en uitheemse indringer probleem-spesies. Bosindringing en -verdigting kan hoofsaaklik op een van vier verskillende wyses beheer word, naamlik chemies, meganies, biologies of deur van hande-arbeid gebruik te maak.

Die fokus van hierdie studie is hoofsaaklik op die probleem van bosindringing, die faktore wat daartoe aanleiding gee, asook moontlike beheertegnieke en laastens die samevatting van hierdie inligting in 'n gebruikers-vriendelike besluitnemings-kundigheidstelsel. Hierdie stelsel is saamgestel uit twee databasisse en 'n verwante ekspertstelsel. Bosindringing is 'n belangrike aspek waaraan tans baie tyd en aandag bestee word in verskeie lande in suidelike Afrika. Die hoofstudiegebiede van hierdie studie het hoofsaaklik Namibië en tot 'n mindere mate Suid-Afrika ingesluit, aangesien hierdie degradasieverskynsel die biodiversiteit van natuurlike weiveld in beide lande tot 'n groot mate negatief beïnvloed.

Die Namibiese Landbou Unie (NLU), het die behoefte vir die ontwikkeling van 'n gebruikers-vriendelike besluitnemings-kundigheidstelsel geïdentifiseer. Aangaande die gebruik van verskillende beheer-tegnieke wat gedurende die afgelope paar dekades deur grondeienaars en boere toegepas is, is so 'n stelsel noodsaaklik vir die berging van bosbeheer-inligting en data binne die raamwerk van 'n databasis. Algemene restourasie-tegnieke wat in die verlede toegepas is vir die herwinning van kaalkolle onder bepaalde omgewingstoestande, is reeds gestoor in 'n gerekenariseerde databasis en ekspertstelsel, wat dien as 'n besluitnemings-kundigheidstelsel en ontwikkel is deur Mnr. Van der Merwe (1997). Hierdie data in die stelsel het gedien as 'n konsultasie hulpmiddel vir toekomstige weiveld restourasiepraktyke.

Die kundigheidstelsel was gebaseer op CBR ('Case Based Reasoning') metodologieë, wat die gebruiker in staat gestel het om gevalle studies wat reeds gestoor was, te raadpleeg deur gebruik te maak van die ekspertstelsel-benadering. Hierdie benadering het dit moontlik gemaak vir die gebruiker om die mees toepaslike aanbevelings, ten opsigte van weiveld restourasie-gevalle soortgelyk aan sy of haar eie weiveld se veldtoestand, te raadpleeg. Die kundigheidstelsel wat deur Mnr. Van der Merwe ontwerp is, is nog nooit gepubliseer nie en was ook nie beskikbaar in 'n formaat wat deur die grondeienaar gekonsulteer kon word nie, byvoorbeeld op die internet of as 'n kompakskyf-weergawe.

Aangesien die NLU die behoefte vir die ontwikkeling van 'n soortgelyke besluitnemings-kundigheidstelsel wat geskik sal wees vir die berging van bosbeheer data geïdentifiseer het, is daar besluit om beide hierdie databasisse in 'n enkele besluitnemings-kundigheidstelsel vas te lê. Die ontwikkeling van die nuwe besluitnemings-kundigheidstelsel is gefokus op die insameling van data wat van toepassing is op die tegnieke wat ter sprake is tydens die beheer van bosindringing, asook die herstel van kaalkolle. Die nuwe besluitnemings-kundigheidstelsel staan tans bekend as *EcoRestore* en bestaan uit twee databasisse, naamlik: *Grass Expert*, die bestaande databasis wat konsentreer op die herstel van kaalkolle en *Bush Expert*, wat gefokus is op die beheer van bosindringing in natuurlike weiveld.

Soos reeds genoem, het hierdie studie gefokus op die ontwikkeling van die *Bush Expert* databasis en daarom sal net die resultate en besprekings ten opsigte van die bosbeheer gevallestudies in hierdie verhandeling ingesluit word.

Die gevalle studies vervat in die *Bush Expert* databasis, bestaan uit resultate wat ingesamel is met behulp van vraelyste wat deur die grondeienaar ingevul is, in samewerking met die landbou-voorligters. Kwantitatiewe plantegroei-opnames is ook gedoen om die mate van sukses van 'n toegepaste bosbeheer-tegniek te bepaal.

Die *Bush Expert* vraelys het bestaan uit vrae aangaande die persoonlike inligting van die boer (bv. lokaliteit van die plaas), die toestand van die natuurlike weiveld voordat bosbeheer toegepas is (bv. inligting ten opsigte van omgewingsfaktore en die digtheid van die probleem spesies voor beheer), asook die tipe bosbeheer-tegniek wat gebruik is en die algemene toestand van die weiveld na beheer (bv. hervestiging van grasspesies).

Tydens die kwantitatiewe plantegroei-opnames, is die houtagtige (probleem boomspesies) en kruidagtige (grasspesies en kruide) komponent gemoniteer en geëvalueer in areas waar verskillende bosbeheer-tegnieke toegepas is. Verskeie aspekte van die houtagtige komponent is bepaal deur gebruik te maak van die strook-transek ('belt-transect') metode, soos byvoorbeeld die digtheid van stande en die hoogteklasse van die probleem boomspesies. Die monitering van die kruidagtige komponent, het die bepaling van die frekwensie van spesies deur middel van die dalende-punt metode langs 'n lyn-transek ingesluit. Tydens hierdie opnames is onder andere die toestand van die eenjarige en meerjarige grasspesies gemoniteer.

Die effektiwiteit en suksesvolle implementering van 'n restourasie-projek word grootliks bepaal deur die inagneming van reeds bestaande kennis van grondeienaars en boere in die omgewing wat ter sprake is. Hierdie inligting word al vir 'n baie jare

van een generasie na die ander oorgedra en behels belangrike inligting ten opsigte van die 'tradisionele' ervarings en kennis wat weiveld degradasie aanbetref, asook die beheer daarvan. Plaaslike kennis verkry van die mense wat geraak word deur sulke degradasie-probleme, moet dus altyd in ag geneem word, aangesien dit die betrokkenheid van 'n gemeenskap bevorder. Verder word die verantwoordelikheid van die grondeienaars ten opsigte van die benutting van hul natuurlike hulpbronne ook aangewakker. Deur die gemeenskap en grondeienaars dus te betrek by degradasiebekampings-projekte, word hul ook die geleentheid gegun om hoër vlakke van besluitneming te beïnvloed en hul insette te lewer.

Die eerste 100 gevalle studie opnames van Namibië, is uitgevoer in die sentrale en noordelike gebiede, terwyl die nege gevalle studie opnames in Suid-Afrika, in die Limpopo Provinsie uitgevoer is. Slegs die 100 gevalle studies van Namibië maak tans deel uit van die *Bush Expert* databasis.

Meervoudige data analise tegnieke, asook variansie en korrelasie analises is toegepas tydens die verwerking en statistiese analisering van die data, wat bekom is deur middel van die vraelyste en plantegroei-opnames. Die resultate is voorgestel as histogramme, tabelle en meervoudige analise ordenings-grafieke.

Die resultate wat bekom is vir berging in die *Bush Expert* databasis, het duidelik aangetoon dat die gebruik van chemiese beheermiddels die mees algemene bosbeheer-tegniek was wat toegepas is in beide Namibië en Suid-Afrika (61% van alle gevalle studies). Die chemiese beheermiddels wat mees algemeen toegedien is tydens chemiese bosbeheer in Namibië, het Grazer (20%) en Savana (15%) in gesluit. In Suid-Afrika is die chemiese middels genaamd Access (33.3%) en Tordon Super (33.3%) die algemeenste gebruik. Chemiese middels is in Namibië hoofsaaklik toegedien deur gebruik te maak van 'n vastevlerk-vliegtuig of helikopter, terwyl die middels in meeste van die Suid-Afrikaanse gevalle deur middel van rugsakspuite of kwaste toegedien is aan die oorblywende stompe van beheerde probleem-spesies.

Die dominante houtagtige probleemspesies in Namibië het *Acacia mellifera*, *Acacia reficiens* en *Dichrostachys cinerea* ingesluit, terwyl *Dichrostachys cinerea*, *Acacia erubescens* en *Acacia karroo* die dominante Suid-Afrikaanse probleemspesies verteenwoordig het.

Die hout van die beheerde probleem-spesies is meestal nie vir enige spesifieke doel aangewend na bosbeheer-tegnieke toegepas is nie. Die dooie plantmateriaal is gewoonlik agtergelaat in die beheerde area, waar dit dan na die ontbindings-proses in die grond opgeneem word as addisionele organiese materiaal. Dooie takke is ook gebruik om in gedegradeerde gebiede uit te pak as 'n moontlike wyse om erosie te voorkom, te dien as ideale mikro-klimaat vir die ontkieming en vestiging van grassaad, asook vir die beskerming van gras-saailinge teen moontlike beweidings impakte. 'n Beperkte aantal grondeienaars benut egter die plantmateriaal deur houtskool te vervaardig, wat dan verkoop word om sodoende van die aanvanklike bosbeheer-kostes te verhaal.

Die meerderheid van die Namibiese gevalle studie areas het voorgekom in die 300-450 mm kort- en langtermyn-reënval sone (68%), terwyl die meeste van die Suid-

Afrikaanse gevalle studie areas in die 550-600 mm korttermyn- (66.6%) en 400-500 mm langtermyn-reënval sones (55.5%) voorgekom het.

Die grootste sukses is behaal by die gevalle studies waar chemiese beheer (81.7% sukses) toegepas is, of waar arbeid as beheertegniek gebruik is (75.2% sukses). Daar is bevind dat die mate van sukses van bosbeheer as geheel, hoofsaaklik beïnvloed is deur die tipe beheer-tegniek wat toegepas is asook deur 'n verskeidenheid van faktore, soos die keuse van beheer-tegniek, die digtheid van die probleem spesie-stande na bosbeheer, asook omgewingsfaktore soos reënval en die klei-inhoud van die grond in die studie area.

Geen duidelike tendense kon afgelei word uit die data-analises, betreffende die toepassing van 'n bepaalde tegniek vir die beheer van spesifieke probleemspesies nie. Grondeienaars was geneig om enige moontlike beheer-tegniek toe te pas na aanleiding van die hulpbronne tot hul beskikking. Hulpbronne wat 'n groot rol gespeel het was hoofsaaklik die beskikbaarheid van die nodige fondse, meganiese implemente en werkers. Die enigste geval waar 'n positiewe korrelasie wel aangetref is tussen die beheer-tegniek en die beheerde probleem-spesie, is waar die probleem spesie *D. cinerea* aangetref is. Hierdie spesie is hoofsaaklik deur middel van chemiese middels beheer in meeste van die gevalle studies.

Na afloop van die studie betreffende die verskillende beheer-tegnieke wat toegepas word vir bosbeheer in Namibië en Suid-Afrika, is die belangrikste gevolgtrekking wat gemaak kan word, dat die implementering van 'n behoorlike nasorg-program in die vorm van opvolg-beheer van uiterste belang is vir optimale resultate in bosbeheer. Hierdie opvolg-beheer moet mettertyd na afloop van die aanvanklike beheer tegnieke toegepas word in die natuurlike weiveld, om 'n hoër mate van sukses ten opsigte van bosbeheer te verseker.

Die *EcoRestore* besluitnemings-kundigheidstelsel is tans beskikbaar as 'n web-weergawe op die internet ([www.puk.ac.za/EcoRestore](http://www.puk.ac.za/EcoRestore)), asook in vorm van 'n kompakskyf. Die kompakskyf-weergawe is beskikbaar in 'n pakket wat die kompakskyf en 'n gebruikers-handleiding insluit. 'n Voorbeeld van so 'n pakket is ingesluit in hierdie verhandeling.

In die proses van konsultasie van die kundigheidstelsel deur middel van vraag-en-antwoord prosedures, word die mees toepaslike aanbevelings ten opsigte van 'n bepaalde probleem-situasie aan die gebruiker verskaf, hetsy die herstel van kaalkolle of die beheer van bosindringing of -verdigting. Aangesien die gevalle studies gebaseer is op bevindinge uit die verlede en ook bestaande bevindinge en navorsingsresultate, kan die gebruiker 'n beraamde skatting van die moontlike resultate van 'n bosbeheer tegniek maak, sou hy of sy 'n soortgelyke voorgestelde tegniek toepas in 'n geaffekteerde weiveld.

Die *EcoRestore* besluitnemings-kundigheidstelsel dien nie net as 'n konsultasie hulpmiddel nie, maar bewerkstellig ook kommunikasie onderling tussen die groeideienaars en navorsers, asook tussen verskeie aangrensende lande in suidelike Afrika wat dieselfde degradasie-probleme ondervind. Die stelsel is ook gekoppel aan ander nasionale en internasionale web-tuistes en databasisse. Op hierdie manier verkry die gebruiker ook toegang tot addisionele inligting aangaande ander landbou

en bewaringspraktyke. Verhoogde bewuswording ten opsigte van die probleem van degradasie vind ook onderling plaas tussen grondeienaars en kan lei tot moontlike verbeterde monitering van die toestand van degradasie en restourasie in natuurlike weiveld in suidelike Afrika.

Die *EcoRestore* besluitnemings-kundigheidstelsel is ontwikkel met die doel om dit so gebruikers-vriendelik as moontlik te maak, sodoende word so veel as moontlik verskillende partye betrek in bestaande en toekomstige restourasie-praktyke. Hierdie studie was ten doel om die eerste weergawe van die kundigheidstelsel die lig te laat sien, wat dus as prototipe sal dien (Weergawe 1.0). Moontlike toekomstige uitbreiding van die *Bush Expert* databasis as deel van die *EcoRestore* besluitnemings-kundigheidstelsel sluit die inkorporasie van addisionele bosbeheer gevalle studies in, wat verkry is vanaf die lande wat reeds betrokke is, sowel as ander lande in suidelike Afrika. Die inkorporasie van kwalitatiewe gevalle studies van hierdie aard, sal lei tot die verdere toename in die effektiwiteit van die stelsel.

**Slutelwoorde:** natuurlike weiveld, degradasie, restourasie, bosindringing, besluitneming-kundigheidstelsel, tradisionele kennis, beheer-tegnieke.

## ACKNOWLEDGEMENTS

**I would sincerely like to express my appreciation towards the following persons, without whom I would not have come to this stage of the study and my life:**

**My Heavenly Father and Creator of all**, for the privilege to experience His glorious creations of all the earth and for strengthening me each day anew with health and opportunity to live the life I love and become the person He intended me to be.

∞ ∞  
*The real voyage of discovery  
consists not in seeking new landscapes,  
but in having new eyes..."*  
- Marcel Proust -  
∞ ∞

**My parents**, for your unconditional love, never-ending support, the opportunities you have given me in life and for ALWAYS believing in me.

My mentor and supervisor, **Prof. Klaus Kellner**, for always sharing his expert knowledge concerning rangeland restoration, for all the opportunities and experiences and most of all his patience, perseverance and guidance. It is a privilege to work with someone as dedicated as you.

**Oom Nico de Klerk**, for his determination and encouragement, the sharing of information and great collaboration during this project. Thank you for all the great adventures in the beautiful country of Namibia (a word of gratitude also to his wife, Tannie Andri, for her repeated hospitality).

All my **colleagues and work friends**, for their interest and motivation every single day. I would like to extend my sincere thanks to Prof. Sarel Cilliers for the constant encouragement, prayers, positive input and attitude, which tends to rub off on the people around you.

My **special friends** (Daléne, Marina, Welmarie and Christi) that are close to my heart, for their inexhaustible love and understanding and for being there through all the ups-and-downs.

All the **persons involved in this study**, on the Namibian side (Oom Bessie Bester, his colleagues and the farmers that conducted the surveys) for your input and dedication. To Loraine van den Berg and Lehman Lindeque for their assistance during the South African surveys.

I would like to thank the following people individuals for the parts they played in this project: **Riaan Strauss** for his constant helping hand and advice, **Debbie Visser** for the printing of the *EcoRestore* CD-covers and manuals, **Rassie Louw** for printing the CD's, **Quinton Alexander** for the mapping of survey areas, **Marie Smith** and **Sandra du Plessis** for their help concerning the statistical analysis, **Hendrine Krieg** for assisting in poster-design and proof-reading the *EcoRestore* manual and **Franci Jordaan** for editing done on certain aspects of the dissertation.

**Arnaud le Roux** for the expertise, information and help in locating the survey sites within the Limpopo Province. The **farm owners and managers** in the Limpopo Province (Tony Morton, Wikus Stemmet and Andries (Boeta) Schutte) and Namibia for their hospitality and willingness to assist and for allowing the researchers to conduct the surveys on their land.

**Miles Sowden, Jopie Dullaart and Daniël van Niekerk** for the hours put in to help develop and structure the *EcoRestore* Decision Support System.

All the parties involved in helping me obtain information and data concerning the different aspects of this study (personnel at the Ferdinand Postma Library, NBRI in Namibia, Chris Richter and my KOVSIE-friends).

And last but not least, the **funding institutions**, without which none of the work done in this study would have been possible:

Potchefstroom University for Christian Higher Education (PU for CHE)

National Department of Agriculture in South Africa (NDA) and the

Namibian Ministry of Environment and Tourism (MET).

## ACRONYMS AND ABBREVIATIONS

The following list includes all the important acronyms and abbreviations used throughout this dissertation. Each acronym or abbreviation will be declared in full, where mentioned for the first time within the text.

AEZ - Agro Ecological Zone  
AGIS - Agricultural Geo-referenced Information System  
ANOVA - Analysis of Variance  
ARC - Agricultural Research Council  
ARDSS - Arkansas River Decision Support System  
AREC – Agricultural Resource and Economics (University of Arizona)  
Bio - Biological bush control technology (personal abbreviation used for statistical analysis purposes)  
BIOTA - Biodiversity Monitoring Transect Analysis in Africa  
BMPs - Best Management Practices  
CBR - Case-Based Reasoning  
CD-ROM - Compact Disc-Read Only Memory  
CDSS - Colorado's Decision Support Systems  
Ch - Chemical bush control technology (personal abbreviation used for statistical analysis purposes)  
CIRAN - Centre for International Research and Advisory Networks  
cm – centimetre  
CRDSS - Colorado River Decision Support System  
DCA - Detrended Correspondence Analysis  
DEA - Directorate of Environmental Affairs (Namibia)  
DEAT - Department of Environmental Affairs and Tourism (South Africa)  
DMP - Desert Margins Program  
DSS - Decision Support System  
DWAF – Department of Water Affairs and Forestry (South Africa)  
EDSS – Environmental Decision Support System  
EIA - Environmental Impact Assessment  
EMS - Environmental Management Services  
ENPAT - Environmental Potential Atlas  
ERI - Ecological Restoration Institute  
ETTE - Evapotranspiration Tree Equivalents  
FAO – Food and Agriculture Organization of the United Nations  
FHFA - Fairly Homogeneous Farming Area  
GIS - Geographical Information System  
GPS - Geographical Positioning System  
ICT - Information and Communication Technologies  
IECA - International Erosion Control Association  
IK - Indigenous Knowledge  
IT - Information Technology  
LSU- Large Stock Unit  
m - metre  
Mc - Mechanical bush control technology (personal abbreviation used for statistical analysis purposes)  
MET - Ministry of Environment and Tourism (Namibia)

Mn - Manual bush control technology (personal abbreviation used for statistical analysis purposes)

MOST - Management of Social Transformations Programme

MVA - Multi-Variate Analysis

NAU - Namibian Agricultural Union

ND - Natural die-back (disease caused by the fungi *Phoma glomerata*)

NBI - National Botanical Institute

NDA - National Department of Agriculture (South Africa)

NGO - Non- Governmental Organization

NNF – Namibian Nature Foundation

NPS - Non-Point Source (pollutants)

NRMS - Natural Rangeland Management Systems

PCA - Principal Component Analysis

PDA - Provincial Department of Agriculture

PM & E - Participatory Monitoring and Evaluation

PU for CHE - Potchefstroom University for Christian Higher Education

RDA - Redundancy Analysis

RGDSS - Rio Grande Decision Support System

SADC - Southern African Development Community

SENWES - Sentraal-Wes Co-operation

SER - Society for Ecological Restoration

SPDSS - South Platte Decision Support System

SSU - Small Stock Unit

TK - Traditional Knowledge

UN - United Nations

UNCBD - United Nations Convention on Biological Diversity

UNCCD - United Nations Convention to Combat Desertification

UNCED - United Nations Conference on Environment and Development

UNEP - United Nations Environmental Programme

UNESCO - United Nations Educational, Scientific and Cultural Organization

UNFCCC- United Nations Framework for the Convention on Climate Change

VAT - Value Added Tax

WfW - Working for Water Programme

WATERSHEDSS - WATER, Soil, and Hydro-Environmental Decision Support System

WOCAT - World Overview of Conservation Approaches and Technologies

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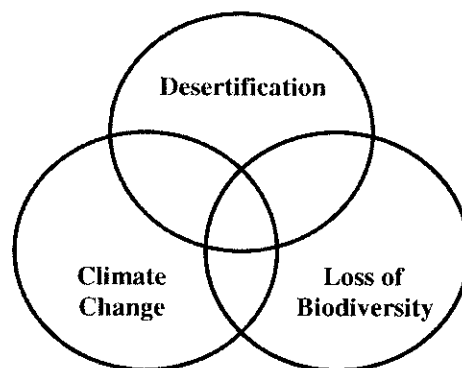
# CHAPTER 1

## INTRODUCTION

This chapter will mainly consist of the general aspects concerning this study. Aspects that will be discussed include: additional information on the problem of degradation or desertification as experienced by land users in southern Africa during the past few decades; intervention methods applied by land users in order to restore degraded rangelands; the role of indigenous or traditional knowledge in the whole process of recuperating degraded rangelands; the main aims of the study, as well as the origin and importance of the new Decision Support System (DSS) that has been developed to aid land users in the restoration of their land.

### 1.1. BACKGROUND

The United Nations Conference on Environment and Development (UNCED) Earth Summit in Rio de Janeiro that took place in 1992 ushered in a new era of awareness and global deliberations on environment and development issues (UNCED, 2003). One of the key areas for African delegates at the Earth Summit was the twin issue of drought and desertification (UN, 2003). The conference agreed on an action plan for sustainable living, known as Agenda 21. Three inter-related environmental issues, each of global concern (Figure 1.1) became the subject of an international convention (Hoffman & Ashwell, 2001).



**Figure 1.1:** Three inter-related key environmental issues to take into consideration in rangeland conservation (Hoffman & Ashwell, 2001; UNCED, 2003).

Koala *et al.* (1994), as quoted by Hambly (1996), stated the following statistics on desertification on earth. Desertification is estimated to involve most of the world's drylands: 3.6 billion hectares of land in total, or 25 percent of the world's surface area. This includes 73 percent of the world's rangelands, 47 percent of rain-fed agricultural land, and 30 percent of irrigated cropland. Desertification affects some 900 million people globally. According to Hoffman *et al.* (1999), the United Nations Convention to Combat Desertification (UNCCD, 1995) acknowledges that about 30% of the total land area of the world is affected by desertification, including 73% of the drylands of Africa.

The United Nations (UN) definition of 'affected drylands' uses the ratio of mean annual rainfall to potential evapotranspiration, which should be between 0.05 and 0.06 (UN, 2003). Nearly 91% of South Africa is arid, semi-arid or dry sub-humid and falls broadly within the UNCCD definition of 'affected drylands', which is also one of the most crucial elements of the UNCCD. Only approximately 1% of the surface area of South Africa may be defined as humid, while approximately 8% is considered hyper-arid (Hoffman *et al.*, 1999).

South Africa is very susceptible to climate change, and contributed about 1.2% to global warming in 1990 (State of the Environment, 2003a). 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 has been degraded, and only 6% is under formal protection (State of the Environment, 1999).

Five percent of soils are affected by water erosion, and the average soil loss is 2.5 tonnes per hectare per year, with a maximum of 60 tonnes per hectare per year. This is more than eight times the rate of soil formation, and clearly unsustainable (State of the Environment, 2003a). The main climatic components for South Africa ranges from deserts to super-humid regions. The annual rainfall distributions for the six main components are indicated in Table 1.1. Most of the areas that are prone to degradation, are bolded within the table.

**Table 1.1** : Annual rainfall distribution and climatic classification in South Africa.

<b>Rainfall (mm)</b>	<b>Classification</b>	<b>Percentage of land surface</b>
<200	Desert	22.8
<b>201-400</b>	<b>Arid</b>	<b>24.6</b>
<b>401-600</b>	<b>Semi-arid</b>	<b>24.6</b>
601-800	Sub-humid	18.5
801-1000	Humid	6.7
<1000	Super-humid	2.8

(FAO, 2003).

Efforts to address desertification and drought have been a lengthy process due to a variety of institutional, political, economic and logistical problems (UNCCD, 1995). Two of the most crucial requirements for desertification abatement, as outlined by the UNCCD, are the improvement of information systems to review and measure ecological, economic and social consequences of desertification and the transformation of results and recommendations to policymakers into action-oriented programmes (Hambly, 1996).

The 1994 United Nations Convention to Combat Desertification (UNCCD, 1995) is to be implemented in southern Africa through various national and sub-regional action programmes. The Convention's approach to combating desertification (and mitigating the effects of drought) emphasizes the importance of local action by local people and communities. Clearly, the war against desertification is won or lost at the local level (Barnard, 1998). The Convention also recognizes that effective local action will not be possible unless local rural people and communities,

- Have greater control and responsibility over their local resources.
- Are able to command a greater range and level of resourcefulness, and
- Are able to actively participate in and influence higher-level decision-making processes by which they are affected (Krugmann, 1996).

South Africa is ranked as the 3rd most biologically diverse country in the world (State of the Environment, 1999). However, exploitative use of natural resources, and conversion and fragmentation of natural habitats, contributes to South Africa also having the highest concentration of threatened species, and high extinction rates (Esler *et al.*, 2002). Poverty alleviation, population stabilisation, and formalisation of the production of plants and animals for medicinal and horticultural markets, will go a long way to reducing pressures on scarce biological resources (State of the Environment, 2003a).

The South African Minister of Environmental Affairs and Tourism, Mohamed Valli Moosa, when interviewed at the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002 said the following: "We have the obligation to our children, and our children's children, to secure the only planet we have and make that planet a place in which they can and want to live. This is not an easy goal, because making countries operate more sustainable, encounters many obstacles. This will be a summit at which countries, rich and poor, try to bridge the differences and come up with solutions." (Moosa, 2002).

The World Summit held in 2002 in Johannesburg, focused on six main themes that are crucial to eradicating or alleviating poverty world-wide, these include: education, water, energy, health, technology and food security. The environment forms the 'green thread' that runs through all these issues (Moosa, 2002).

The content of the WSSD 2002 in general focused on the needs of the developing world, e.g. the links between poverty, environment and human development. In order to build a truly sustainable way of life, an integration of action in the following key areas is imperative: economic development and equity; conserving natural resources and the environment; and social development (DEAT, 2002).

The Conservation of Agricultural Resources Act (43/1983) (CARA) is an act of the National Department of Agriculture and makes provision for the conservation of the natural agricultural resources of South Africa through:

- Maintaining the production of land.
- Combating and preventing erosion.
- Preventing the weakening or destruction of the water sources.
- Protecting the vegetation, and

- Combating weeds and invader plants.

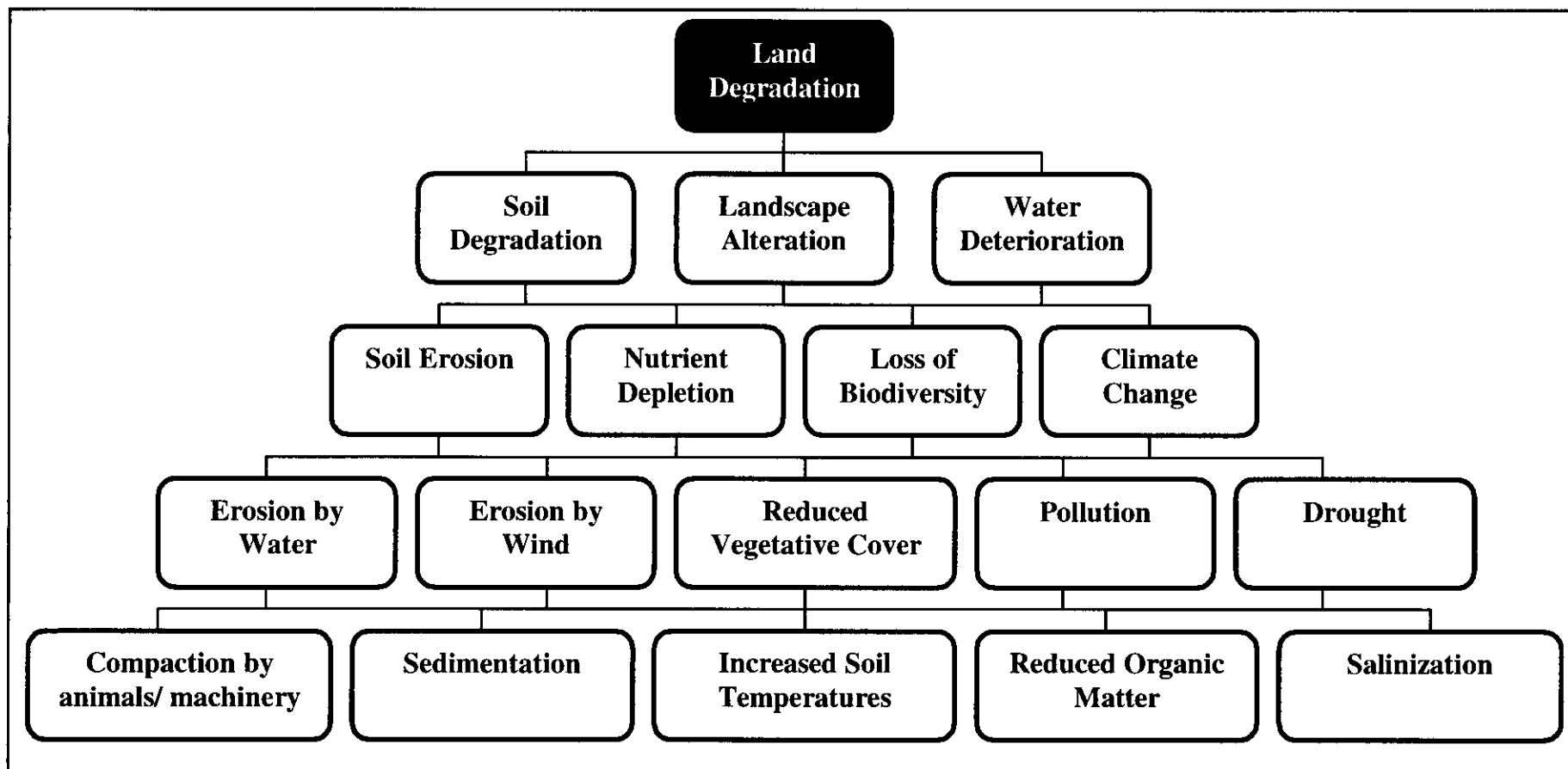
All the recent policies, international conventions, and community-based initiatives being carried out at present are aimed at improving conservation and more sustainable use of natural resources in the future (State of the Environment, 1999).

The combating of desertification throughout southern Africa is of great importance when considering the conservation of natural rangelands and mitigation of current degradation situations. The unique, traditional, local knowledge (Indigenous Knowledge- IK) existing within and developed around the specific conditions of stakeholders (men and women) indigenous to a particular geographic area, should be taken into consideration and be implemented at all costs. This form of knowledge is built up and passed on from one generation to another throughout the years and prove to be very useful when considering rangeland restoration (UNESCO, 2003).

## **1.2. LAND DEGRADATION**

Land degradation should be viewed as an 'umbrella' term, covering many ways in which the quality and productivity of land may diminish from the point of view of the land user, thus it indicates the temporary or permanent decline in the productive capacity of the land (Stocking and Murnaghan, 2001).

According to Figure 1.2, as taken from Stocking and Murnaghan (2001), land degradation components can be subdivided into four main hierarchical levels, each connected to the other through different degradation factors. The three main environmental components affected during land degradation include soil degradation (e.g. erosion), landscape alteration (e.g. agricultural practices such as croplands) and water deterioration (e.g. decrease in water quality due to urbanization and pollution). These factors in turn lead to erosion, nutrient depletion, loss of biodiversity as well as climate changes. Furthermore contributing factors are added, such as erosion being caused either by wind or water, due to a loss in vegetation cover and periods of drought, which in turn can lead to sedimentation and compaction. All of these components are interrelated to one another and complete the land degradation picture.



**Figure 1.2:** Schematic representation of the different components of land degradation (Stocking & Murnaghan, 2001).

Land degradation incorporates the water, soil and vegetation resources of an area and includes an oversupply of hydrological and ecological processes. This condition characterizing the deterioration of rangelands occur as a result of the disruption of the normal functioning of the above-mentioned processes (Hoffman *et al.*, 1999; Stocking & Murnaghan, 2001). Exploitation of resources can lead to deforestation and bush encroachment. These processes change the vegetation structure, and the type and number of animals that can be supported. Collection of plant material for the medicinal and horticultural trades, reduces the abundance of certain species in the wild, and has led to extinction of some (UNEP, 1991).

Continuous degradation of already degraded land may in time lead to desertification of the rangeland. *Desertification* refers to land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors, including climatic variations and human activities (UNEP, 1991). Patches of degraded land erupt separately, sometimes as far as thousands of kilometres away from the nearest desert. Gradually the patches spread and join together, creating desert-like conditions (UNCCD, 1995). Combating desertification in natural rangelands has recently become a priority in large parts of southern Africa, as the deterioration of rangelands as a forerunner of desertification, already occupies large parts (Coetsee, 1992; Sombroed, 1993, Hoffman & Ashwell, 2001; UNCCD, 1995).

Growing population pressure and the resulting increase in demand for food and energy coupled with the retention of traditional but no longer ecologically appropriate land-use systems, leads to over-use of natural resources (Wöhl, 1993).

In short, land degradation is the reduction in resource potential of a rangeland and several main types of degradation can be characterized:

- 1) *Loss of vegetation cover*, as result of overgrazing by livestock, leaving behind bare and denuded patches (Ludwig *et al.*, 1990; Sombroed, 1993; Esler *et al.*, 2002);
- 2) *Bush encroachment or bush thickening*, as result of the increase in cover of indigenous trees and shrubs in savanna regions (Brown & Archer, 1999);
- 3) *Alien plant invasions* (DWAF, 2003);
- 4) *Change in species composition* of the vegetation, mainly caused by selective grazing patterns of livestock (Jacobs, 1991);

- 5) The *non-rotation* of crops leads to an imbalance of nutrients in the soil, which causes its exhaustion, segmentation, and exposure to erosion (Shidiwah, 1993);
- 6) *Salinization* of soil due to the development of irrigation (chemical aspect of soil degradation), as well as inappropriate use of water, contributes to an increase of land surfaces sterilized by salt, another aspect of desertification (Wöhl, 1993; Van Tonder, 2003);
- 7) *Deforestation*, as result of the removal of trees and shrubs by people for domestic energy or construction purposes in forest regions (Barnard, 1998);
- 8) *Frequent droughts* caused by below average rainfall occurrence (Sombroed, 1993; Dean *et al.*, 1996);
- 9) *Soil degradation* influencing the physical (e.g. crusting, compaction and erosion caused by trampling and hoof action of livestock, Figure 1.3 ) and biological (e.g. loss of soil micro and macro-organisms) components of soil in rangelands (Ludwig *et al.*, 1990; Jacobs, 1991; Harris *et al.* 1996). According to Hoffman *et al.* (2000) soil degradation appears to be more tightly coupled to the land tenure system than veld degradation itself.
- 10) Repeated occurrence of *fire events* induces the invasion of alien species as well as bush encroachment/ thickening. The competitive influence of the herbaceous layer is greatly reduced due to the repeated removal of the grass component from the rangeland ecosystem and carbon dioxide is released from fire and thus favours woody species growth (C3-plants) (Andreae, 1997; Török *et al.*, 2003; Ward, 2003b).
- 11) Other forms of rangeland degradation, which usually involves the clearing of a rangeland for the planting of *agricultural crops*, or *mining pollution* (Hoffman & Ashwell, 2001).



**Figure 1.3 :** Examples of trampling, hoof action and crust forming around a watering point.

Expansion of agricultural activities into unsuitable areas, together with poor land-use practices (such as over-use of agro-chemicals, monoculture, ploughing along a slope), result in soil degradation and erosion (State of the Environment, 1999). Rapid population growth and inappropriate government policies in the past, encouraged cultivation in unsuitable areas, and use of poor agricultural methods to produce sufficient food.

According to Leleka (1993), an increased use of marginal lands for crops and grazing has occurred throughout southern Africa during the past few decades, due to population growth and pressure. Thus giving rise to the degradation of soil conditions, which is mostly caused by inappropriate agricultural practices (Leleka, 1993) and poses a serious problem in the sense that it is not easily reversible (Sombroed, 1993). All these factors lead to further deterioration of rangelands and a decrease in the productivity of the land in general (Harris *et al.*, 1996).

A study has been carried out by Zeidler *et al.* (2002) in order to determine the effect of land-use intensity on range condition, whereby the vegetation, soil and termite parameters were investigated as possible indicators of the rangeland condition. Soil fertility parameters provided the most interesting results, with indication that nitrogen limitation is more critical under high land-use and grazing pressure. Organic carbon levels are generally low, but were reduced to critical levels under high land use intensity. Nutrients such as phosphorus and nitrogen are conserved in the system, whereas organic carbon

losses are high and inputs low. It was also found that the effect of termite activity plays an important role in maintaining range condition (Zeidler *et al.*, 2002).

According to Moore (1960) tribal nomadism is a practice that is not that commonly applied in certain countries anymore, particularly in semi-arid regions, thus leading to the increasing prevalence of confining, or at least not controlling the movement of animals in such areas. This might possibly be one of the factors responsible for the occurrence of so-called "man-made deserts".

Climate change plays an important role in the degradation and desertification processes of rangelands. Scientists have convincingly shown that human activities around the world are increasing the atmospheric concentration of many greenhouse gasses (e.g. carbon dioxide, methane, nitrous oxides and chlorofluorocarbons). Greenhouse gasses absorb and trap the energy of sunlight within the earth's atmosphere, causing it to warm up (Gifford & Howden, 2001; NBI, 2001). Thus the generalization can be made that any human-induced climate changes in drylands likely have exacerbated desertification processes (Balling, 1993).

Global climate change is a far less visible risk that threatens the biodiversity of especially faunal life forms, than those risks resulting from habitat transformation caused by agriculture and urbanization. South Africa is signatory to the United Nations Framework Convention on Climate Change (UNFCCC). The aim of this international agreement is to 'avoid dangerous [human] interference in the climate system' (UNFCCC, 2003).

Each plant species or biome occurs within a particular climatic range. Some of the climatic factors that limit plant distribution include rainfall amounts and seasonality, as well as minimum and maximum temperatures in summer and winter months. Predictions based on climatic factors alone, represent a first approximation of possible future plant distributions. When actually taking into consideration the other factors that could restrict plant distributions, it raises concern that these factors could actually restrict these distributions even further, than the climate change-based predictions (NBI, 2003). According to climate models, within 50-100 years the biomes as we know them, will have been reduced to 35-55% of their present area. Thus all the biomes throughout southern Africa will be greatly influenced by climate change factors (Van Jaarsveld & Chown,

2001; NBI, 2001). In essence, under global climate change scenarios those species unable to survive climate change will die out, at least locally (Esler *et al.*, 2002).

From the above mentioned problems concerning climatic changes and the influence thereof on the vegetation, it is evident that these changes up to now and in the future can prove a great threat to the general well being and condition of any ecosystem. Changes such as these can thus lead to the occurrence of land degradation and desertification processes in the end.

A detailed description of bare and denuded areas, bush encroachment or thickening and alien invasive species as forms of land degradation which leads to a loss in biodiversity, will be given in the following section. These three aspects are mainly emphasized due to its importance within this project.

### **1.2.1. Bare and denuded areas**

Bare and denuded areas indicate patches where the long-term loss of natural vegetation is evident (Esler *et al.*, 2002). The deterioration of the physical, chemical, biological and economic properties of soil occur mostly where the influence of soil and water erosion is evident (UNCCD, 1995; UNEP, 1991). The development of large denuded patches can be ascribed to the degradation processes, which includes aspects such as drought, combined with the overgrazing of vegetation (Kellner & Bosch, 1992). Bare patches are probably the most common and obvious symptom of weakened veld in a natural rangeland (Snyman, 2003). This is usually accompanied by a loss of topsoil and organic matter as well as the formation of a hard crust which causes water runoff and drought risks to increase (Du Preez & Snyman, 1993; Sharma, 1998; Snyman, 1999a; Snyman, 1999b; Van Oudtshoorn, 1999).

Overgrazing is the repeated intensive utilisation of the grass plant at high grazing frequency, which leads to the exhaustion of the reserve nutrients in the roots. The plant's root system becomes weak; it struggles to absorb water effectively and later dies off. The most palatable grasses are usually the first to be overgrazed, followed by the less palatable grasses. This pattern continues until only the annual and unpalatable perennial grasses remain or bare areas start occurring due to overgrazing and loss in vegetative cover, which also leads to soil erosion (Snyman, 1998). Lower lying parts of a rangeland

are usually the first to be overgrazed. These areas are normally wetter and soils are more fertile, resulting in more palatable and highly nutritious grass (Van Oudtshoorn, 1999).

According to Dean *et al.* (1995), the expansion of degraded patches in rangelands (Figure 1.4) are also caused by trampling (hoof action of grazing animals), contributing to a loss of vegetation cover, which reduces the rainfall infiltration with increased surface water runoff, as well as soil loss (Snyman, 1986; Snyman & Fouché, 1991; Snyman, 1998; Snyman, 1999b).

The maintenance of established stands of palatable grass species and the sustaining of livestock management systems and rates of stocking within rangelands is complicated by the high frequency and irregularity of droughts which increase grazing pressures, without change in stock numbers (Moore, 1960).

Although not always accepted by rangeland managers and scientists, the issue of equilibrium and non-equilibrium paradigms concerning pastoral ecosystems in Africa also needs to be considered when addressing the problem of degradation. Such ecosystems have always been seen as potentially stable (equilibrial) systems, which tend to become non-equilibrial and destabilized due to overgrazing and overstocking of pastoral lands. Non-equilibrial ecosystems are often still persistent, but the system dynamics are influenced by abiotic rather than biotic factors and there is little evidence of degradation (Ellis & Swift, 1988). The ecosystem and pastoral inhabitants are relatively stable in a non-equilibrial ecosystem in response to major stresses such as severe droughts and other factors.



**Figure 1.4:** An example of a rangeland in the process of degradation, characterized by bare and denuded patches.

### 1.2.2. Bush encroachment and thickening

The two terms, "bush encroachment" and "bush thickening" are very closely related, differing only slightly in meaning. In general, both refer to the increase of the woody component, which poses a higher degree of competition for the herbaceous component in the rangelands.

*Bush encroachment* refers to the invasion of an undesirable plant into an area where it previously did not occur. It could also be stated as the conversion of grassland dominated vegetation type to one that is dominated by woody species (Trollope *et al.*, 1990; Enviroteach, 1996; Hoffman & Ashwell, 2001; Smit *et al.*, 1999; Tainton, 1999; EcoGuard, 2001; State of the Environment, 2003b). *Bush thickening* on the other hand is seen as the phenomenon of increasing tree and shrub density, or the aggregation of existing undesirable plants in grassland and savanna regions where woody species already occur naturally (Smit *et al.*, 1996; Brown & Archer, 1999; Hoffman & Ashwell, 2001; EcoGuard, 2001).

Both these processes contribute to an increase in land degradation throughout southern Africa. Bush encroachment is also the term most commonly used in the literature and amongst land users, seeing that the difference between the two terms is not generally known to all and a clear distinction cannot easily be made. For the purpose of this dissertation there will only be referred to the term *bush encroachment*, in order to prevent possible confusion, due to the fact that these two terms are so closely related and are caused by the same environmental degradation factors.

Bush in an un-encroached state, occurring in relatively average densities in rangelands however prove to be to the advantage of the farming practice and environment in general. *Acacia* species, such as *A. karroo* proved to be such an advantageous species in a case study carried out in the Stutterheim district in South Africa. According to Mr. N. de Ridder (Botha, 2003a), the occurrence of this species in the veld, increased the amount of nitrogen in the soil, due to its nitrogen-binding ability, the trees also served as a form of shade for livestock and restricted the loss of water underneath the trees. Thus problem woody species occurring at average to low densities in rangelands can be an advantage to a farming practice. Many farmers and rangeland managers, however, tend to

believe that the occurrence of any thorny tree species (which have the ability to cause bush encroachment) is to the disadvantage of the farming practice (Botha, 2003a).

In general trees, more specifically leguminous trees and shrubs such as *Acacia* species are important in establishing areas of enhanced soil fertility (Smit, 1999; Rodríguez-Echeverría & Pérez-Fernández, 2003). The soil nutrient content and enrichment underneath the canopies of such trees are much higher than underneath non-leguminous tree species. Higher concentrations of not only nitrogen, but also soil organic matter, phosphate, potassium, magnesium and calcium are to be found underneath the canopies of leguminous trees and the pH tends to be higher and electrical resistance lower than in inter-canopy areas in savannas (Smit, 1999; Rossi & Villagra, 2003).

According to the PPRI (ARC- Plant Protection Research Institute) (Klein, 2002), both indigenous and alien plants can become problematic concerning bush encroachment. Both these groups of plants contribute to an increase in rangeland degradation.

According to the Conservation of Agricultural Resources Act (43/1983) (CARA<sup>1</sup>), Regulation 16, *bush encroachment* is a term used for 'stands of plants (specified as bush encroachment indicators) where individuals are closer to each other than three times the mean crown diameter'. These indicator species concern only landowners in rural areas and are covered in Regulation 16 of CARA. They are thus not outlawed, but instead sound management practices are recommended to prevent or control these species (CARA<sup>1</sup>). These practices include uprooting, felling, cutting, controlled application of herbicides, livestock reduction and the correct management and protection of rangelands. Currently 44 species are listed as indicators of bush encroachment in South Africa and can be seen in Annexure 1 (CARA<sup>1</sup>; Von Breitenbach *et al.*, 2001; Van Wyk & Van Wyk, 1997).

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<sup>1</sup> **CARA Legislation Made Easy. Undated document.** Basic contents, explanations and guidelines concerning the amended Regulations 15 and 16 of the Conservation of Agricultural Resources Act. Published and distributed by the National Department of Agriculture, Pretoria, South Africa.

According to Brown & Archer (1999), species contributing to bush encroachment are indigenous trees or shrubs that are usually in equilibrium with their environment, but become unnaturally abundant as a reaction to the deterioration of the surrounding natural environment (Figure 1.5).

Bush encroachment is one of the most serious conspicuous results of imbalances in savanna (bushveld) ecosystems and globally reduces the profitability and biodiversity of such areas (Kraaij, 2002). Along with various other factors, this poses a serious threat to the financial efficiency of livestock farming practices in affected areas (Mugasi *et al.*, 2000; Botha, 2003b). It has a profound effect on the productivity of the herbaceous component of a rangeland, involving mainly available soil water as the primary determinant of production. It also accentuates the effects of drought and often gives rise to pseudo-droughts (fodder shortages during normal or dry years) (Meyer, 1997a).

Hoffman *et al.* (1999), found that the problem of bush encroachment appears to be most acute in the North West, Northern Cape, Eastern Cape and Northern Provinces of South Africa and although it is a widespread phenomenon, only a few species are perceived as problem elements. These include both thorny and non-thorny woody species. The most important one of these are a suite of thorny small-leaved *Acacia* and other leguminous species, found throughout most of southern Africa (Hoffman & Ashwell, 2001; Ward, 2003a).



**Figure 1.5:** Bush encroachment as a form of rangeland degradation.

The cause and increase of bush encroachment, involving dominance of unpalatable woody species within natural rangelands, especially the savanna and grassland biomes can mainly be ascribed to the following factors:

- *Mismanagement of grazing practices* (e.g. overgrazing and overstocking).
- *A lack of sporadic hot brush-killing fires, or the misuse of fire* (e.g. prevention of natural veld fires).
- *Absence of browsing animals* (e.g. boer goats and game).
- *Selective mechanical damage to trees* caused by mega-herbivores (e.g. elephants), which cause trees to become multi-stemmed bushes dominating the encroached area as dense thickets at lower height classes.
- *Lower than average annual rainfall*, followed by one or two seasons of high or sufficient rainfall.
- *Decrease in game numbers* that used to roam the savannas and restriction of natural migration patterns of these animals together with the conversion of such areas to livestock farming enterprises during the past 100 years.
- *Historic atmospheric CO<sub>2</sub> enrichment*, caused by a high burning rate of fossil fuels and use of CFC's, thus inducing the global warming effect

(Moore, 1960; Van Vegten, 1983; Fourie, 1986; Du Toit, 1991; Enviroteach, 1996; Lange *et al.*, 1997; Smit, 2001a; EcoGuard, 2001; Botha, 2003b; Archer, 2003; ERI, 2003).

In the face of climate change and growing demands for agricultural productivity, future pressures on grassland ecosystems will intensify (Watkinson & Ormerod, 2001). According to the NBI (2001), frost helps to maintain the Grassland biome by killing seedlings of many trees and shrubs that would otherwise grow there. As the climate warms up however and frost becomes less frequent and woody plants may be able to invade grasslands, transforming them into savanna. Increasing CO<sub>2</sub>-levels support higher photosynthetic fixation rates of C<sub>3</sub>-plants (most woody species) and might lead to a change in the competitive interactions of some species (Salisbury & Ross, 1992; Archer *et al.*, 1995; Reckling, 1995; Gifford & Howden, 2001; Bond, 2003). This effect can also be caused by the indirect temperature-related responses caused by atmospheric CO<sub>2</sub>-fluctuations (Barbour *et al.*, 1987; Burrows, 1999). Woody plants need to absorb more carbon in the form of carbon dioxide to convert it into building materials such as

cellulose, than grasses do, thus higher levels of CO<sub>2</sub> in the atmosphere will stimulate the growth of trees and shrubs (NBI, 2001).

Many researchers however feel that bush encroachment may mainly be caused by changes in land use practices, rather than changes in climate and environmental factors (Hoffman & Ashwell, 2001; Moleele *et al.*, 2002).

Du Toit, (1991); Meyer (1997a); Smit & Rethman (1998b) and EcoGuard<sup>2</sup> (2001) stipulate the consequences of bush encroachment to be as follows:

- Competition between trees accentuates droughts in the grass layer.
- Poor grass production, due to the woody component competing for water and soil nutrients.
- Poor grass species composition, explosion of unpalatable annual grass species occurs.
- Bare soil, which leads to sheet erosion and eventually the formation of gullies ('dongas').
- Effective rainfall available to the herbaceous component degrades.
- Land which loses its ecological and economic value

When one plant species is removed out of the ecosystem, it is usually replaced by another plant species (e.g. woody species), which in most cases is less desirable. Bush encroachment therefore involves the natural replacement of the herbaceous cover by an undesirable woody component (Bester & Reed, 1997b; Mouat *et al.*, 2003). This process has become a big concern with land users throughout the whole of southern Africa (Hoffman & Ashwell, 2001). Competitive interactions between the woody and herbaceous components of savannas, involving mainly available soil water (e.g. from rainfall), as the primary determinant of production, have been reported worldwide (Dye & Spear, 1982; Seghieri *et al.*, 1994; Smit, 1999b).

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<sup>2</sup> **EcoGuard Distributors (Pty.) Ltd.** A company specializing in the development and distribution of environmentally compatible products for selective bush control and alien weed control in forestry, agriculture, conservation, rangeland and industrial areas. Contact details: P.O. Box 98634, Sloane Park, 2152, South Africa. Tel: +27-(0)11-463-6057, Fax: +27-(0)11-463-6462. Website: [www.ecoguard.co.za](http://www.ecoguard.co.za) (Regional offices: Nelspruit, Merrivale and Warmbaths).

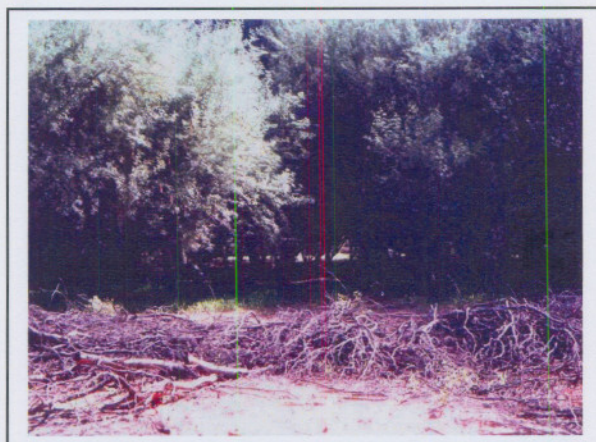
Certain indigenous woody species, such as *Acacia mellifera*, *Dichrostachys cinerea* and *Colophospermum mopane*, tend to be problem woody species, causing bush encroachment in certain overgrazed and mismanaged areas. This then leads to a decrease in the production of the herbaceous layer and carrying capacity, as well as an increase in the erosion potential, which leads to a negative impact on optimal animal production (Belsky *et al.*, 1989; Bester, 1998; Smit, 1999b; Directorate of Environmental Affairs Namibia, 2003; Ward, 2003a).

According to Donaldson (1967) *Acacia mellifera*-seedlings do not establish during each growing season, but seedling-establishment occurs in cycles during seasons characterized by above average rainfall. Scholes (1990) supports this point of view and concludes that the re-establishment period of woody seedlings are shortened by high rainfall occurrence and in turn extended by an occurrence of low rainfall.

It is very important to note that woody species causing bush encroachment are not the cause of the problem, but merely one of the *symptoms* of poor land management (Klein, 2002). A dramatic increase in bush densities can thus be seen as a major indicator of degradation and changes in density status are therefore symptomatic of changes to ecosystem structure and function (Mouat *et al.*, 2003).

### **1.2.3. Alien invasive plant species**

Alien species is another matter of concern, seeing that alien species become aggressively invasive and commonly compete with and replace indigenous and desirable species, already existing in certain areas (SER, 2002). An *alien* plant species is one that was introduced into an area, where it did not previously occur, through human activities. Such exotic species include *Acacia mearnsii*, *Solanum mauritanium* and various *Prosopis* spp. e.g. *Prosopis glandulosa* (Figure 1.6) (Bromilow, 1995; Henderson *et al.*, 1987; Henderson, 2001; Van Rooyen; 2001). Alien invasions have an adverse impact on land productivity and on the biodiversity and sustainability of natural ecosystems, as well as the services they provide to society. Alien plants use greater quantities of scarce water resources, however not all these exotic species are harmful to an environment (Hoffman *et al.*, 1999; State of the Environment, 1999).

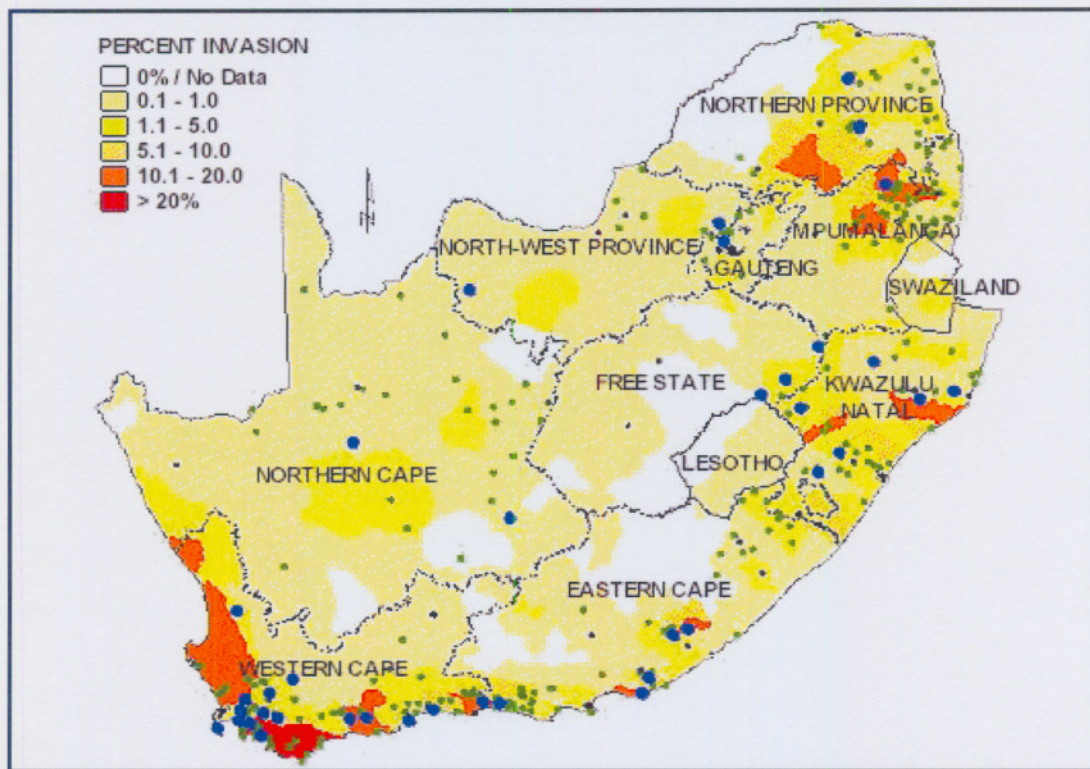


**Figure 1.6:** *Prosopis glandulosa* as an example of alien species invasion.

Over 8% of South Africa has been invaded by alien vegetation, and millions of hectares are affected by bush encroachment (State of the Environment, 1999; DWAF 2002).

Working-for-Water (WfW) is a national programme, initiated by the Department of Water Affairs and Forestry (DWAF) in 1995. This programme focuses on the eradication of alien invasive species in South Africa (DWAF, 2003). Figure 1.7 indicates the percentage of alien plant invasions in all of the provinces in South Africa.

The suppressive effect of bush encroachment or alien invasives on herbaceous production, and thus on grazing capacity, is often the major reason why clearing of woody plants is considered as a management option (Smit *et al*, 1996). The main aim of bush control practices therefore involves the removal of the woody species, which will result in the increase of the herbaceous production and ultimately the grazing capacity of the rangeland.



**Figure 1.7:** Working-for-Water (WfW) map indicating the percentage alien plant invasion in each province in South Africa (DWAF, 2003).

The introduction of alien plant species (either by accident, where seeds of the plants could cling to the hide of livestock when imported from foreign countries, or by a planned action due to the possible import of certain species for its aesthetical value in gardening or as a fodder species used in livestock farming practices) has serious implications for soil-water availability (Haigh, 2001). In total, South Africa's forestry plantations use about 3% of the available surface water, and alien plants use 7% of the available surface water annually (State of the Environment, 2003a).

In a study compiled in the north-central United States, where the vulnerability of certain habitats to invasion by alien plant species is considered, it was indicated that habitats characterized by a high native species richness were more vulnerable to invasion by alien species than species-poor habitats (Stohlgren *et al.*, 2002). Concerning alien species invasion, this pattern of establishment can most probably also be extrapolated to the situation in southern Africa.

#### 1.2.4. Land tenure systems

According to the Ecological Research Institute (ERI) (ERI, 2003), ecosystem changes indicated by degradation are mostly caused by livestock grazing, (overgrazing or selective grazing), fire suppression, drought, woodcutting (for domestic use) and some forms of recreation. Several of these ecosystem changes include:

- Decreased cover of grasses and wildflowers.
- Decreased wildlife diversity (vertebrate and invertebrate).
- Increased densities of small or stunted trees.
- Increased old-growth trees mortality rates due to competition with thickets of small trees.
- Increasing threats to property.

Two main land tenure systems exist in southern Africa, namely commercial and communal. Communal rangelands are defined as those areas where agriculture is largely subsistence-based and rangelands are generally communally owned and managed, as opposed to individual or freehold ownership (Propp, 2001). People living in communal rangeland areas are in effect financially sustained by income earned outside the communal area, but sustainable agriculture land use is however vital for the economic and social development in such areas (Everson & Hatch, 1999). Commercial tenure systems on the other hand implicate the highest possible production of livestock, primarily for financial income purposes (Hoffman & Ashwell, 2001).

Due to overstocking often occurring in both commercial and communal systems, where the stocking rate is usually exceeded, sound management practices should be implemented in order to sustain the rangeland condition and prevent further degradation (Everson & Hatch, 1999).

A study completed as rapid appraisal of the status of land degradation in South Africa indicated that communal areas appeared to be consistently more eroded than commercial areas, while alien plants and bush encroachment problems were often more acute in commercial areas (Hoffman *et al.*, 2000).

It is thus clear that degradation through bush encroachment, alien invasion and/ or the occurrence of bare and denuded areas, has become a serious problem in southern Africa. The challenge however is to successfully restore these degraded areas in the short- and long-term.

For the purpose of this study, only commercial farming systems have been investigated.

Different land use practices are exercised on commercial rangelands within the arid and semi-arid areas of southern Africa. These land use types include livestock farming (large- and small stock) as well as game ranching (Grossman *et al.*, 1999). Due to low or below average rainfall occurrences and a general shortage in water supplies needed for irrigation purposes (Drewes *et al.*, 2000), crop farming and cultivated pasture practices are not commonly exercised within arid and semi-arid rangeland areas.

Game ranching has become a common practice throughout southern Africa, especially in the arid and semi-arid regions. Many farmers have converted their farming practices or land uses, from cattle farming to game ranching due to prevailing drought periods (lack of sufficient water and grazing for cattle), as well as bush encroachment problems in areas where overstocking and overgrazing of livestock occurs (Meyer *et al.*, 2001).

Game ranching implies the commercially orientated stocking and use of game. As such, the objectives of, and approach to veld management on a game ranch, will differ from those in a nature conservation area. On the game ranch, production-related considerations will dictate management, as higher vegetation production to serve as fodder for the herbivores will be needed. In nature conservation on the other hand, prevailing paradigms such as the maintenance of biotic diversity and natural ecological processes, will take precedence (Grossman *et al.*, 1999).

The following section will concentrate on the possible solutions offered in order to reverse or alleviate the effect of land degradation in rangelands throughout southern Africa. These solutions are referred to as restoration technologies. The restoration of degraded rangelands will be discussed as introduction, followed by detailed descriptions of restoration technologies.

### 1.3. ECOLOGICAL RESTORATION OF DEGRADED RANGELANDS

*Sustainable land use* refers to the continued utilization of natural rangelands without degrading this environment to such an extent, that restoration practices need to be implemented. It involves keeping the land in good order by supplying the physical, chemical and biological inputs required for its long-term maintenance. Sustainability of land use depends both on the properties of the resource, as well as the way it is managed (UNEP, 1991; Harris *et al.*, 1996).

Ecological restoration means *regaining the natural characteristics of ecosystems* that have been damaged by humans through overuse, pollution or neglect and returning the area to the state it previously existed, prior to degradation (Cairns, 1995; Harris *et al.*, 1996; Bakker & Berendse, 1999; ERI, 2003). According to The Society for Ecological Restoration (SER, 2002), *ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.*

Ecologically based restoration is the most effective approach. This will help to re-establish the ecological integrity, or completeness of the rangeland in the long-term, by returning it to a more productive state (by implementing intervention methods), while protecting human communities (Ludwig *et al.*, 1990; McDonald, 2000). It is an approach, linked to sustainable use by humans, which is informed by science and establishes as its primary goal to be the restoration of an ecosystem to its fully functional state (Clewel *et al.*, 2000). For ecological restoration to proceed by means of scientifically sound practices, it must be rooted in the best knowledge available, with carefully reasoned analysis, checked against factual evidence (Ehrenfeld, 2000; ERI, 2003).

While restoration technologies themselves are a form of disturbance, one of their primary purposes is to forestall the much greater negative impacts of overgrazing, overstocking and erosion. The latter can cause widespread die-off of native plants and landscape-scale introduction of invasive species (De Groot *et al.*, 1992).

Restorationists use the best ecological science available to understand and reverse the source of damage, restoring the diverse native plant and animal communities, reinstating

natural disturbance regimes such as natural veld fires and developing harmonious relationships between people and the land (State of the Environment, 2002; ERI, 2003).

Important measures of the vulnerability of a rangeland to consider when land degradation has occurred and restoration is opted for, are:

- **Sensitivity**, is the *degree to which a land system undergoes change* due to natural forces, human intervention or a combination of both. Some places are more likely to be sensitive to change - for example, steep slopes, areas of intense rainfall or highly erodible soils (Stocking & Murnaghan, 2001).
- **Resilience**, refers to the property that allows a land system to absorb and utilize change, including resistance to a stress factor. It refers to the ability of a system to *return to its pre-altered state, following change* (Walker, 1980). The natural resilience of an environment may be enhanced by the diversity of the land management practices adopted by land users. Degraded land is less resilient than undegraded land, especially concerning aspects such as the ability to recover from further stresses, such as drought. This will thus lead to further degradation (Stocking & Murnaghan, 2001). According to Ludwig *et al.* (2001), resilience refers to the ability of an ecosystem to remain in its current state (resist change) and return to the previous state (recover) if disturbed.
- **Resistance**, describes an ecosystem's ability to *maintain its structural and functional attributes* in the face of stress and disturbances (SER, 2002).
- **Stability**, indicates the ability of an ecosystem to *maintain its given trajectory* (developmental pathway of an ecosystem) in spite of stress and fluctuating conditions. It denotes dynamic equilibrium, rather than stasis (Walker, 1980; Trollope *et al.*, 1990).

Since ecological restoration of natural ecosystems attempts to recover as much historical authenticity as can be reasonably accommodated, the reduction or elimination of alien species at restoration project sites is highly desirable (SER, 2002). In the case of bush control as restoration practice, concerning alien invasive as well as undesirable

indigenous species, care should be taken to cause the least possible disturbance to indigenous and desirable species as well as the soil substrate (De Beer & Jordaan, 2001).

According to Stocking & Murnaghan (2001), factors affecting land users in the process of rangeland restoration include the following:

- *Land tenure* - security of land tenure affects land users' willingness to invest resources in land improvement and protection against degradation.
- *Poverty* - to a great extent indirectly influences the way in which land users manage their rangelands. It reduces the options available by ruling out some conservative practices, because they require too much investment of land, labour or capital. Poverty similarly tends to encourage farmers to rather focus on immediate needs, rather than those whose' benefits may materialize only in the long term, e.g. the effect of rangeland restoration practices.
- *Pressure on land* - a growing human population puts greater demands on land. Farms are split into ever- smaller units as land is shared out among family members. An indirect effect of land pressure, is the requirement for more extensive infrastructure.
- *Labour availability* - is usually the most limiting constraint of rangeland managers. Competition for available labour is especially intense between laborious activities and off-farm employment that can bring immediate returns. The prevention of land degradation involves the investment of labour for maintenance, both at the initial stages and on an ongoing basis. Land users often overcome labour shortages by gradually implementing conservation measures and spreading the work over several seasons or years. However in a situation where labour is already a scarce resource, it may not be possible to supply the additional labour required to avoid degradation processes or to undertake conservation of already degraded rangelands.
- *Economic incentives* - are economic instruments such as subsidies and other incentives from the government, which may distort land users'

priorities. Application of restoration technologies within natural rangelands often stimulate the granting of economic incentives from the government or Non-Governmental Organizations (NGOs), which could aid in the proper and successful application of these technologies.

- *Appropriateness of introduced restoration technology* - where land users have had previous negative experiences with restoration technologies, they are understandably reluctant to adopt new conservation plans.
- *Economic viability of restoration technologies* - field assessments and restoration technologies are usefully supplemented by relatively simple cost-benefit analysis techniques. This is done, by obtaining information concerning costs of restoration technologies (e.g. mechanical implement, grass seed and labour costs) and then calculating estimated total costs by using certain formulae such as those used in Müller & Archer (2001).

In arid and semi-arid rangelands, the benefits from applying restoration technologies will be lower than areas with sufficient and regular rainfall patterns. Therefore, only low cost and highly beneficial treatments will be cost-effective, which restricts the types of technologies that a land user will be willing to undertake (Ludwig *et al.*, 1990).

Rangeland managers, scientists, conservationists and land users have been applying a variety of restoration technologies over different periods of time and at various environmental conditions, in order to combat or halt the process of degradation and desertification. Technologies have mostly been applied on a trial-and-error basis, which are often not documented or quantitatively assessed. The results and experiences of these attempts (or so called 'case studies') are also not available to other users with similar problems in different environments (Van der Merwe & Kellner, 1999).

In this dissertation, the two main problems of degradation that are addressed through application of restoration technologies, include bare and denuded areas, as well as bush encroachment. The main focus in this study was however on the latter aspect. In order to reverse the effect of degradation on natural rangelands, many restoration technologies have been developed, applied and researched in the past (Milton, 1995; Van der Merwe, 1997; De Wet, 2001; Van den Berg, 2002; Van Heerden, 2002). According to Bradshaw

(1996), three essential matters need attention when considering the restoration of degraded areas: (1) remodelling the physical aspects of the habitat; (2) remodelling the chemical aspects, nutrients and toxicity; (3) and replacing missing species or removing undesirable exotics.

The focus in the following section will be on the different possible restoration technologies (applicable for bare and denuded areas or bush control) that exist and can be applied in order to halt or reverse the degradation processes within rangelands.

### 1.3.1. Restoration technologies

Restoration practices in the form of *bush control technologies* can be divided into *selective* and *non-selective* bush control technologies (Milton, 1995; Esler *et al.*; 2002). Selective bush control involves selective eradication of the problem species by thinning the stands of bush, resulting in only certain trees and woody components being controlled (problem species causing encroachment). According to Fuhlendorf (1999) and EcoGuard (2001), the advantages of *selective bush control* include:

- Improved seasonal leaf cover on trees.
- Increased grass production.
- Improvement in grass species composition.
- Grass basal cover improvement.
- Regaining economical and ecological value of the degraded land.

Several disadvantages also exist for the application of selective bush control technologies. These will however not be discussed in this dissertation. The advantages of selective bush control greatly exceeds the disadvantages and selective control is therefore a much more favoured or desirable control technology, though not always more affordable to apply (Arnaud le Roux, personal communication<sup>3</sup>).

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According to Richter (1991) and Smit *et al.* (1999), *non-selective bush control* entails the 'overall' or total clearing of all woody species occurring in an area, e.g. by applying herbicides by means of spraying with an aeroplane.

According to Richter (1991); Smit *et al.* (1999); Grobler *et al.* (2000); Hoffman & Ashwell (2001) and De Beer & Jordaan (2001), four main bush control methods exist and are actively applied by land users to eradicate problem woody species causing encroachment:

- 1) Chemical control methods.
- 2) Mechanical control methods.
- 3) Manual control methods.
- 4) Biological control methods.

The above mentioned bush control technologies will be discussed in detail in Chapter 5 (Results and Discussion) of this dissertation.

In areas where tree densities are very high and increased herbaceous production should be desired, the first action that may be required will be the thinning of the trees to some predetermined density (Meyer, 1997a). According to Smit *et al.* (1996), tree thinning (selective clearing) or clearing (total clearing), by means of mechanical or chemical methods, will result in immediate changes between woody and herbaceous plants. In selectively controlling problem bushes or trees, the grass component automatically gains an advantage within the ecosystem, as more groundwater becomes available to grasses in the topsoil layers. The moisture can now effectively be utilized by grasses and other herbaceous plant species with shallower root systems than that of trees and bushes. The latter disposing of a vertical root system distribution. The herbaceous biomass increases and mature woody-plant growth is reduced by competition from the grass-dominated herb layer (Knoop & Walker, 1985). Figure 1.8 clearly illustrates the difference between an area where bush control was applied to one where no control has taken place.



**Figure 1.8:** An aerial photograph representation indicating the difference between bush control and no bush control in an encroached area.

Some of the purposes of *restoring bare and denuded patches* in a rangeland include covering of the soil surface and preventing runoff of water (Van Oudtshoorn, 1999). According to Snyman (1991), the overall aims of rangeland restoration concerning bare and denuded areas, include: increased water infiltration into the soil; improvement of vegetation cover and density; reducing runoff of water; and improving the micro-climate and water balance for plants that eventually will help to control erosion.

Should grazing have been the main problem causing degradation, livestock numbers should be controlled and grazing systems (e.g. rotational grazing) implemented in order to prevent further rangeland degradation. In general, the aims of livestock control are to allow palatable grass species to set seed, provide more micro-environments suitable for germination, protect seedlings and to avoid the overgrazing of re-growth following rain or fire (Moore, 1960).

Restoration of bare and denuded patches or areas within a degraded rangeland can firstly be divided into active or passive intervention technologies.

*Passive restoration technologies* comprise the removal or exclusion of stress factors, which caused original degradation of the rangeland, such as overstocking. This allows natural succession to set in and passive improvement of the rangeland condition to take place (Milton & Dean, 1996; Tainton *et al.*, 1999). *Active restoration technologies* (Esler *et al.*, 2002) include the following:

- 1) Mechanical or manual disturbance of the soil surface (e.g. ploughing the land or using a hand implement to loosen the crusted soil surface) (Snyman, 1999b; Van der Merwe & Kellner, 1999). Moore reported as early as 1960, that the implementation of mechanical restoration treatments successfully retained runoff water, causing a beneficial change in botanical composition. Mechanical restoration methods are aimed at providing a suitable micro-environment for natural regeneration from the soil seed bank (Moore, 1960).
- 2) Revegetation of the degraded or denuded land, by for example oversowing (re-seeding) with a grass seed mixture, grass sod-planting or the re-planting of seedlings (Snyman, 1999b; Tainton *et al.*, 2000; Van den Berg, 2002; Barac *et al.*, in prep.).
- 3) Creating gabions<sup>4, 5</sup> or contours ('keerwalle') in order to stop the flow of runoff water. These gabions are usually constructed with stone packs or wire mesh strips filled with organic material (Figure 1.9a). These structures retain soil, trap seed and provide the ideal micro-sites for the germination of seed, by increasing the moisture status of the soil (Esler *et al.*, 2002). Plants such as grasses, usually establish more easily along such 'protective' contours (Van Oudtshoorn, 1999).
- 4) The action of brushpacking (Figure 1.9b), whereby branches of woody shrubs or trees are packed along the slope or onto bare patches, in order to intercept runoff water and increase water infiltration (Boateng, 2002). These 'funnels' formed by the branches also serve as favourable micro-environments for grass seedlings to establish successfully (Barac *et al.*, in prep.). Brushpacking

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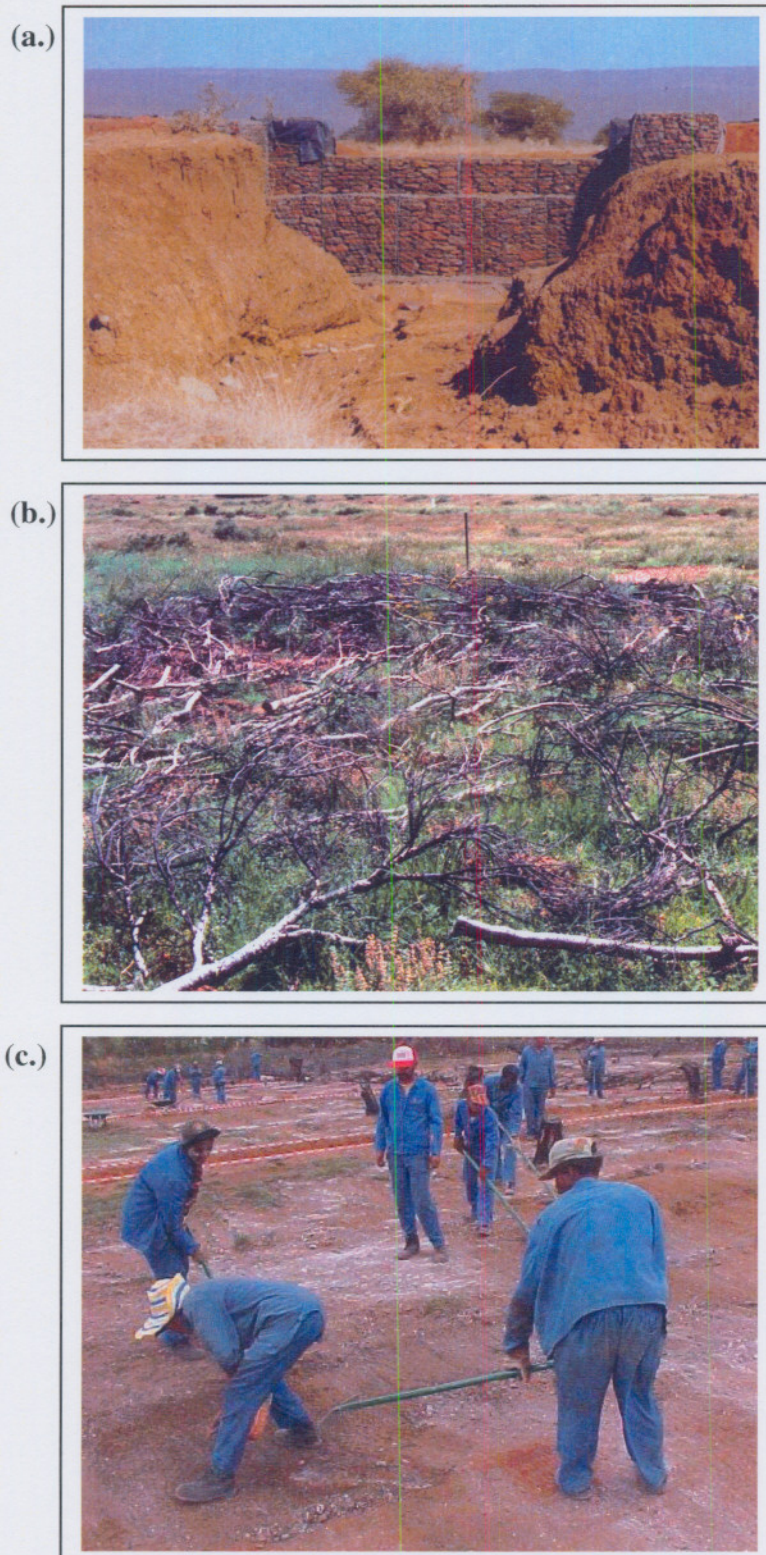
<sup>4</sup> **Land Rehabilitation Systems**. Contact details: Unit 9, Citrus Industrial Park, Citrus Street, Honeydew Johannesburg, South Africa. Tel: +27-(0)11-794-5220, Fax: +27-(0)11-795-2990. Website: [www.lrs.co.za](http://www.lrs.co.za)

<sup>5</sup> **International Erosion Control Association (IECA)**. Contact details: P.O. Box 133, Kya Sands, 2163, Johannesburg, South Africa. E-mail adres: [ieca@ananzi.co.za](mailto:ieca@ananzi.co.za) . Website: [www.ieca.org](http://www.ieca.org)

practices are also effective in protecting the seedlings against wind, high temperatures, direct sunlight as well as against the impact of grazing, especially in areas from which herbivores (game) cannot be restricted (Van Oudtshoorn, 1999).

- 5) In order to ameliorate the soil in denuded and bare areas, inorganic (e.g. lime) (Shainberg *et al.*, 1989) (Figure 1.9c) and organic material supplements (Darwish *et al.*, 1995; Harris *et al.*, 1996; Mukoyo, 2000) can be added to improve the physical and chemical characteristics of the soil, its water-holding capacity and to restore micro-nutrient deficiencies (Brady, 1974; Obi & Ebo, 1995; Whalen *et al.*, 2000; Sørensen, 2001). Animal manure or mulch remains a most valuable soil organic resource that is rich in carbon compounds (Mengel & Kirkby, 1987). Beneficial effects of an increased soil organic matter are: improved soil structure (aeration of soil) and increased water holding capacity; increased capacity of the soil to buffer changes in pH; increased cation exchange capacity (CEC); and reduced phosphate fixation (Ngolwe & Fleissner, 2002).

When restoring degraded rangelands, it is very important to keep in mind that should any remnants of plants that formed part of the ecosystem prior to degradation have remained, they should be 'saved' and all resources should be directed at them. The reason for this is, that the dead plant material serves as a form of organic matter and sometimes N-source to the soil and thus indirectly benefit the growth of remaining or newly established plants. Remaining plants also serve as a microclimate or soil stabilizers in which new seedlings can establish during restoration. It is thus more effective to rehabilitate a damaged plant community with some capacity for recovery than to attempt to construct a new one from scratch (McDonald, 2000).



**Figure 1.9 a-c:** Examples of active restoration technologies:  
(a.) Gabions; (b.) Brushpacking and  
(c.) Addition of lime as an inorganic soil supplement.

According to Harris *et al.* (1996), restoration often fails. This can be ascribed to factors such as:

- 1.) Failure to implement all aspects of the restoration or reclamation plan.
- 2.) Inadequate understanding of the ecosystem process, which is the goal of the work programme.
- 3.) Inadequate study site surveying (e.g. focusing on just one issue to the exclusion of others).
- 4.) The lack of proper resources and funding needed to implement a successful restoration programme over longer time frames.
- 5.) Inexperienced personnel, lacking sufficient training in restoration technology application or monitoring of an affected site. This could also be due to the lack in appropriate guidance in matters concerning the problem.

One of the greatest reasons for restoration failures is the lack of proper involvement or co-operation of the affected community or land user in a project. The needs of the people indigenous to an area, who are directly affected by the ecological decline of a rangeland, are often not taken into consideration when restoration programmes are implemented. These people however dispose of a great deal of knowledge concerning the environment, as they have lived in it for many years. This form of information and experience is most often not acknowledged by scientists and implementing agencies. In other words, these indigenous people at grass roots level with their important knowledge have to be considered and empowered to ensure ownership of a specific project or strategy that has to be implemented in an area. This is especially true for the rural poor communities and areas with communal land tenure systems.

#### **1.4. THE ROLE OF INDIGENOUS KNOWLEDGE (IK)**

According to Kellner & Bosch (2003), resolving the problems facing the world's rangelands, requires the ability of both land managers and policy-makers to make wise management decisions. In turn, wise decision-making is dependant on the quality and availability of relevant knowledge. It should be recognized that years of experience have provided land managers with a wealth of knowledge on management strategies that fit their local conditions.

According to the UNCCD (2003), *traditional knowledge* refers to the knowledge, innovations and practices of indigenous and local communities and people around the world. The knowledge is based on experience gained over the centuries and adapted to the local culture and environment; it is transmitted orally from one generation to the next. Traditional or indigenous knowledge is collectively owned and mainly of a practical nature and transmission thereof takes on the form of stories, beliefs and community laws.

UNESCO (2003) refers to indigenous knowledge as 'traditional' or 'local' knowledge, embedded in the community and as being unique to a given culture, location or society. The term refers to the large body of knowledge and skills that has been developed outside the formal educational system, which enables communities to survive.

Seeing that the term 'local', 'traditional' and 'indigenous' are so closely related within the context of knowledge sharing and in order to prevent confusion, there will be referred to this entity as 'indigenous knowledge' for the remainder of this dissertation.

It is therefore important to recognize the wealth of knowledge and years of experience of all the stakeholders including land users, about resolving the problem of rangeland degradation and the implementation of restoration technologies (Seely, 1998). This includes practices to address problems such as bush encroachment and the reclamation of bare and denuded areas. Participatory Monitoring and Evaluation (PM & E) of several restoration practices, is central to integrating external and indigenous knowledge in the rangeland degradation setup (Waters-Bayer, 2003).

Through generations, farmers have accumulated knowledge and experience based on what they see works well for their own situation by means of innovation, experimentation and adaptation (UNESCO, 2003). This indigenous knowledge (IK) is now well recognized as a valuable commodity, tried, tested and adapted for local environments and accepted by local people (Stocking & Murnaghan, 2001).

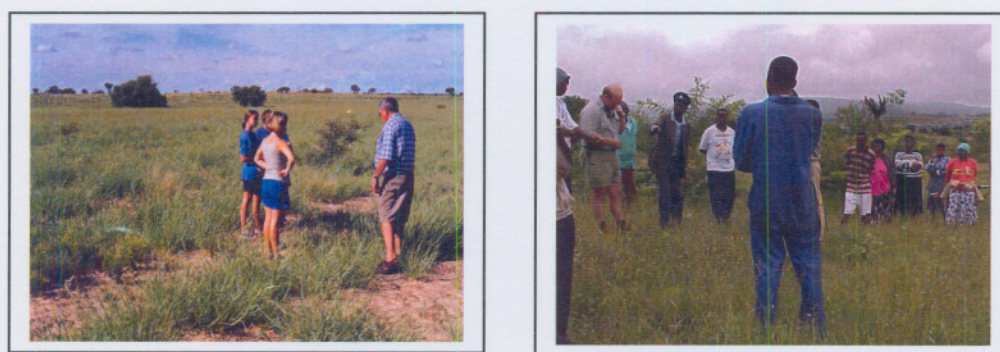
Today, there is a growing appreciation for the value of indigenous knowledge, seeing that it is valuable not only to those who depend on it in their daily lives, but also to the growing modern industry and agriculture (UNCCD, 2003).

Indigenous knowledge can make a significant contribution to the sustainable development of southern Africa. However, the contribution of indigenous and local communities to the conservation and sustainable use of biological diversity, goes far beyond their role as natural resource managers. Communities and land users with extensive knowledge of their local environments (Figure 1.10), are most directly involved with conservation and sustainable use (Masuku- van Damme & O' Donoghue, 2002; UNCCD, 2003).

Ever since the process of desertification was first recognized, scientific expertise has been in the forefront of attempts to reduce or reverse its impact. More recently the importance of involving indigenous knowledge and people experiencing and being directly affected by aspects, such as desertification has been acknowledged. Science and community action can connect, but they cannot do so without proper levels, degrees and types of participation from both sides of the equation (scientists and local communities) (Seely, 1998).

The international community has recognized the close and traditional dependence of many indigenous and local communities on biological resources, notably in the preamble to the Convention on Biological Diversity, which has been ratified by 178 countries from around the world (UNESCO, 2003). The Conference of Parties has established a working group specifically to address the implementation of Article 8(j) and related provisions of the Convention.

Article 8(j) states: " Each contracting party shall, as far as possible and as appropriate: Subject to national legislation, respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities, embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application, with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge innovations and practices." (UNCCD, 2003).



**Figure 1.10:** Sharing of indigenous knowledge and community participation.

Indigenous knowledge can be gained from two types of land users, 1.) first of all that of the commercial or private land owner and 2.) secondly, from the land user in a communal area or tribal ground. Both, however very rich in terms of indigenous knowledge and the use thereof, indigenous people living on tribal or communal ground as well as subsistence farmers in commercial farming areas, rely on the land for most of their basic livelihoods. Their knowledge is often based on very simple survival strategies not only to live from the land, but also looking after it in order to keep it in a sustainable condition for generations to follow.

It is evident that IK is closely related to survival and subsistence, and it provides a basis for local-level decision making in:

- Food security.
- Human and animal health.
- Education.

- Natural resource management.
- Various other community-based activities (UNESCO, 2003).

The following paragraph reflects the actual situation in the rural, poor and mostly communally managed areas throughout southern Africa. More specific, this was a case study on the Shona people of Zimbabwe in Buhera West, where interviews were conducted with the elders of the tribe in order to determine the transfer of indigenous knowledge. An elder was questioned as to how he acquired the knowledge that he had of the land (eg. how to determine the fertility of a particular type of soil, by looking at the species of trees growing in an area). When asked this question the elder replied: "We learned from our fathers. When I say 'fathers' I mean all the elders who were in the village. They were our fathers. We asked them many questions. Besides, before a boy could be considered for marriage, he was required to demonstrate that he was able to look after a wife and children by clearing a piece of land, planting it, and then harvesting enough grain to fill a granary." Sadly enough the same elder, when asked whether he still used this knowledge, he answered by counter-asking where he could possibly apply this knowledge now, as nobody would want to hear anything (concerning land use knowledge) from an old man like him anymore (Mararike, 1996).

Data gathering on local indicators in Buhera West showed that indigenous knowledge emerges from a complex process, which involves socio-economic, cultural and biophysical factors. It appears to take place on the basis of existing conceptual frameworks and procedures. The everyday life of most people in Buhera West is dominated by the pragmatic motive: to solve life-threatening problems. The question is however whether this is "necessary knowledge" or "discretionary knowledge"? This distinction is based on custom and habits as well as physiological criteria. If knowledge is known to satisfy certain physiological needs, then it may be considered necessary; if knowledge has been based on custom and habits, but does not necessarily satisfy physiological needs, then it is discretionary (Mararike, 1996).

Due to urbanization near most rural areas, most of the indigenous young people in communal areas are not interested in living from the land anymore and transferring knowledge about these practices, seeing that they are lured to the cities and towns to make a living there instead. This poses a great threat concerning the age old tradition of sharing of indigenous knowledge for these people living in communal areas and thus the 'survival' of knowledge sharing in itself (Propp, 2001).

According to Stocking & Murnaghan (2001), restoration technologies developed by scientists on research stations, may prove to be inappropriate when introduced to land users, since research plots rarely mirror the actual conditions pertaining to the rangeland. Technologies may for instance take too much land out of production or it may require too much labour to apply certain restoration technologies. Introduced technologies may also be socially or culturally unacceptable as, for example, fenced paddocks for rotational grazing on communal land.

The need has arisen, to document and capture indigenous knowledge information concerning technologies applied by land users, which are suitable to certain needs, in order to control and reverse the process of rangeland degradation in southern Africa. Extension tools needed to be developed in order to facilitate information transfer (e.g. computer-based decision support systems which include economical viability models), particularly information related to decision-making on assessing, reducing and preventing rangeland degradation, specifically referring to the restoration of denuded as well as bush encroached areas (Ludwig *et al.*, 1990).

Grassroots indicators, play a very important role in the process of detecting change in the natural environment. "Grassroots indicators" can be described as *measures or signals of environmental quality or change formulated by individuals, households and communities, and derived from their local systems of observation, practice and indigenous knowledge*. Grassroots indicators may well have a substantial role to play in the monitoring and evaluation of degradation, as well as in the efforts to reverse land degradation, by incorporating indigenous knowledge to develop a suitable restoration workplan within a commercial farming or tribal community (Hambly, 1996).

Wise decision-making is dependant on the quality and availability of relevant knowledge. Local and indigenous knowledge can serve as a valuable basis for interpreting information and data, and for solving problems identified by land users and scientists. This knowledge is however not always well documented or easily accessible to other land users in the same area that may be experiencing the similar problems, e.g. bush encroachment. It is very important to also conserve natural resource systems, local knowledge and long- and short-term experiences. Thus linkages need to be established between traditional knowledge of land-use management systems and modern scientific methods and technology (Kellner & Bosch, 2003).

An appropriate extension tool system, ideal for the transfer and sharing of knowledge concerning aspects, such as restoration technologies that are obtained through trial-and-error basis, is that of a Decision Support System (DSS). Such a system is made up of different databases containing information on subjects such as combating of rangeland degradation or control of bush encroachment.

According to UNESCO (2003) one of the best methodologies to obtain important indigenous knowledge information, is by constructing and implementing a questionnaire, which should be completed by the land users themselves. In this way 'lessons learnt' and locally obtained experiences in the process of restoration of degraded rangelands can be captured and incorporated into a DSS in order to serve as reference for future restoration applications.

Each type of documented experience derived directly from the field, increases the knowledge base with 'actual' rather than 'theoretical' experience. This valuable source of knowledge needs to be safeguarded for the future to promote better decision-making (WOCAT, 2003).

In conclusion it can be said, that the importance of the knowledge of local and indigenous people, should never be underestimated or excluded during the decision-making processes and the implementation of e.g. restoration programmes. Such knowledge could form the basis of a restoration programme and also give the local people a feeling of ownership. It will also increase active participation and local

action by the local people in such a programme, which will lead to a more successful restoration programme.

The following chapter will serve as an introduction providing background information concerning the application of a DSS and inter-linked databases, with specific reference to the use of these systems within the rangeland degradation situation. Regular references will be made throughout the text on how this information is applicable to the restoration of bush encroached rangelands.

## CHAPTER 2

### DECISION SUPPORT SYSTEM DEVELOPMENT

Chapter 2 includes an elaboration on the importance of knowledge-sharing regarding rangeland restoration in southern Africa, with special reference to the development and use of a DSS aimed at aiding land users, by encouraging monitoring of rangeland condition over time and sharing of experiences or successes concerning restoration aspects. Additionally the expected outputs of the DSS, at present and in the future, will also shortly be discussed.

#### 2.1. INTRODUCTION

A *Decision Support System (DSS)* is an information system programme application that analyzes data and provides its users with useful decision-oriented information whenever a decision-making situation arises (Stuth *et al.*, 1991). In particular, decision support systems are usually designed to support unstructured decisions, that is, those decision-making situations that cannot be predicted in advance (Willits, 1992; Whitten & Bentley, 1998).

A DSS may present information graphically and include an expert system or artificial intelligence. In short it is a 'system used to support managerial decisions' (Power, 2003b). Decision Support Systems (DSSs) cover a wide variety of systems, tools and technologies. The term DSS is inclusive of many types of information systems that support decision-making (Willits, 1992). A decision support database focuses primarily on the production of information required to make tactical or strategic decisions at middle- and high-management levels (Ludwig *et al.*, 2001). Decision support, provided by a Decision Support System (DSS), typically requires extensive data manipulation in order to produce or extract information from historical data or indigenous knowledge (e.g. concerning restoration of degraded rangelands), to formulate a possible solution and control decisions. As DSS information can be based on historical data e.g. consisting of , successful applications of restoration technologies applied in the past, the data retrieval time factor is not likely to be as critical as it is for the transactional database. Additionally, the DSS information tends to be based on complex data derived from many sources, such as questionnaires and on-site surveys. In order to make such complex data

more easily retrievable, DSSs favour database design by means of data warehouses (Rob & Coronel, 2000).

A DSS is based on the reality that the information needed to support unstructured decisions, has already been captured by management information systems. The DSS provides the decision maker (land user) with tools to access that information and analyse it to make a decision. In general, a DSS provides one or more of the following types of support to the decision maker:

- Identification of problems or decision-making opportunities.
- Identification of possible solutions or decisions.
- Access to information needed to solve a problem or make a decision.
- Analysis of possible decisions, or of variables that will impact a decision.
- Simulation of possible solutions and their likely results.

Although DSSs has an unquestionably important role in modern rangeland management operations, it is important to keep in mind that the *manager (e.g. restoration scientist)* must initiate the decision support process by asking the appropriate questions. The DSS exists to *support* the manager; it does *not* replace the management function. If the manager fails to ask the appropriate questions and/ or does not make the correct inputs, problems will not be successfully identified and solved, and opportunities (e.g. to improve the rangeland condition), will be missed. In spite of the very powerful DSS presence, the human component (programmer or developer of the DSS) is still at the centre of this DSS technology (Rob & Coronel, 2000). The effectivity of a DSS mainly depends on the quality of the data gathered at the operational level. In this study, data was gathered 'on-site' by means of questionnaires and vegetation surveys in areas where certain restoration technologies have been applied e.g. revegetation of denuded and bare patches or bush control (Rob & Coronel, 2000; Power, 2003a).

A DSS consists of four main high-level components:

- A **data store** component, which basically is a DSS database.
- The **data extraction** and **data-filtering** component that is used to extract and validate the data taken from the operational database and the external data sources.

- The **end user query tool**, which is used by the data analyst to create the queries that access the database. This tool either accesses the operational database or the DSS database (questionnaires).
- The **end user presentation tool**, which is used by the data analyst to organize and present the data. This tool helps the end user (land user) select the most appropriate presentation format, such as a summary report or graphs (Rob & Coronel, 2000). In the case of the DSS used in this study, results and actions are represented mostly in the form of a summary report (individual case studies and photographs) and to a lesser extent as graphs.

The DSS developed for the purpose of this study, mainly consists of a *database(s)* as well as an *expert system*. A **database**, as one of the most integral parts of a DSS, consists of interrelated files. The records in each file must allow for relationships to the records in other files (Whitten & Bentley, 1998).

**Expert systems** are an extension of the decision support system. It is an information system application that captures the (indigenous) knowledge and expertise of a decision maker (land user or scientist) and then simulates the 'thinking' of that expert for those who have less expertise. Such systems are to a certain extent difficult to construct, since intelligent questioning demands deep insight into the situation at hand (Straach & Truemper, 1999). Expert systems are implemented with artificial intelligence technology, often called expert system shells, which capture and simulate the reasoning of the experts who use the data and information (Whitten & Bentley, 1998; Willits, 1992). The matter of artificial intelligence and its role in the DSS development will be discussed in detail in section 2.2 of this chapter.

Expert knowledge is a combination of theoretical and practical knowledge about a certain subject to the problem at hand, such as rangeland degradation. This kind of knowledge is a combination of a theoretical understanding of the problem and a collection of heuristic problem-solving rules that are experienced and has proven to be effective in a certain domain. Expert systems, as said, are thus constructed by obtaining this (indigenous) knowledge from a human expert and coding it into a form that a computer may apply to similar problems (Willits, 1992).

The primary people involved in building an expert system are the *knowledge engineer*, the *domain expert* and the *end user* (Luger, 2002). In comparing these role-players with those responsible for the different aspects involved in this study, the knowledge engineer would be the computer specialist responsible for the construction and programming of the DSS<sup>1</sup>. The domain expert would be represented by the person<sup>2</sup> being an expert in the field of rangeland restoration practices. The end user would refer to the farmer or land user experiencing a degradation problem within the rangeland on his farm, which could also dispose indigenous knowledge concerning rangeland restoration successes.

Although some expert system programmes are written in which the designer is the source of the domain knowledge, it is far more typical to see such programmes growing out of a collaboration between a domain expert such as an environmental scientist and a separate artificial intelligence specialist (DSS programmer or developer). The domain expert provides the necessary knowledge of the problem domain through a general discussion of his or her problem-solving methods, by demonstrating those skills on a carefully chosen set of sample problems (described as case studies in this study). The artificial intelligence specialist (will be elaborated on in section 2.2. of this chapter), is responsible for implementing this knowledge in a user-friendly programme that is both effective and seemingly intelligent in its behaviour. Once written, such a programme needs to be refined in its expertise through a process of giving it example problems to solve ('calibrating'). This process is repeated until the programme has achieved the desired level of performance (Luger, 2002).

### ***Artificial Intelligence (AI)***

*Artificial Intelligence (AI)* may be defined as the branch of computer science that is concerned with intelligent behaviour (Luger, 2002). It is also the collection of problems and methodologies studied by artificial intelligent researchers. The two most fundamental concerns of AI researchers are *knowledge representation* and *search*. The knowledge representation addresses the problem of capturing in a formal language, e.g. one suitable for computer manipulation.

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<sup>2</sup> Researchers, agricultural extension officers and land managers from Namibia and South Africa that participated in this study.

### *Knowledge representation*

Artificial intelligence research embraces the primary concern of finding an effective way to understand and apply intelligent problem solving, planning and communication skills to a wide range of practical problems (Luger, 2002). The heart of the expert system, based on artificial intelligence, is the *knowledge base* (Starfield *et al.*, 1990). The latter contains the knowledge of a particular application domain, which consists of both *general knowledge* (general information concerning the rangeland, e.g. rainfall and location) and *case-specific* information (detailed information on the degradation problem experienced, e.g. density of species within the site) (Luger, 2002).

In developing a DSS such as the *EcoRestore* DSS by means of AI, a case-based reasoning approach was used, to act as basis for this user-friendly tool (Inference Corporation, 1990). Case-based reasoning refers to the 'solving of problems or making recommendations by *remembering* previous similar situations' (CBR Express, 1993). This is exactly what the *EcoRestore* DSS is aimed at, to provide the land user with possible solutions or options concerning bush control technologies, which is made possible by the case-based reasoning component of the DSS, referring to 'previously stored' cases contained in the database of the DSS, of which the situations coincide with the current problem experienced.

*Case-Based Reasoning (CBR)* uses an explicit database of problem solutions to address new problem-solving situations. It is a powerful strategy that experts use to reason from cases, examples of past problems and their solutions. These solutions may be collected from experts through the knowledge engineering process or may reflect the results of previously search-based successes or failures (case history, including the land user's knowledge concerning successful bush control practices). Computer programmers often use the same basic programming structure in adapting an old programme to fit a new situation with similar structure. The ability to reason from cases is fundamental to human intelligence (Whitten & Bentley, 1998).

CBR offers a number of advantages for the construction of expert systems. Knowledge acquisition can be simplified if we record a human expert's solutions to a number of problems and let a case-based reasoner select and reason from the appropriate case. In the case of the *EcoRestore* DSS, 'matching' is done, to give the most appropriate solution.

The current problem experienced by a user, is 'matched' with a case study in the database, which concur most accordingly to certain aspects, such as rainfall, vegetation type or problem previously experienced. As a case-based reasoner (computer programme) acquires more cases, it becomes more intelligent, better able to solve a variety of target problems, thus the more cases the larger the database and the more effective the system becomes. The case-based reasoning approach includes several advantages for the design of expert systems and therefore has been considered for the development of the *EcoRestore* DSS.

#### *Search component*

The *search* component, which forms part of the fundamental concerns of AI researchers, is a problem-solving technique that systematically explores a space of problem states, e.g. successive and alternative stages in the problem-solving process. This space of alternative solutions can be searched to find a final answer to the problem, such as the control of bush encroachment or the restoration of degraded and denuded rangelands.

Expert systems that ask questions intelligently are needed for many applications. Such systems are difficult to construct since intelligent questioning, which is part of *dialogue control*, demands deep insight into the situation at hand (considerable knowledge about degradation and possible solutions on how to solve the problem, by means of restoration technology implementation) (Straach & Truemper, 1999). This kind of information contained in such expert systems and databases of a DSS, can thus be searched for a possible solution to the problem experienced (Starfield *et al.*, 1990).

## **2.2. THE ROLE OF DECISION SUPPORT SYSTEMS AND DATABASES IN NATURAL RANGELAND MANAGEMENT SYSTEMS (NRMS) IN THE CONTEXT OF THIS STUDY**

### ***Use of Decision Support Systems and databases in practice***

Decision Support Systems and databases are used and applied worldwide to assist people in decision-making, concerning important aspects such as rangeland management and restoration. These systems can be operated in many different divisions within the natural sciences. In the following paragraphs, a number of such examples of DSS and database use, both nationally and internationally, will be mentioned and shortly discussed.

One of the initiatives that make use of Decision Support Systems in practice in South Africa is e.g. *AGIS* (Agricultural Geo-referenced Information Systems), which is a cross-sectoral initiative between several Agricultural role-players including: the National (NDA) and Provincial Departments of Agriculture (PDA), the Agricultural Research Council (ARC), the Landbank and various private companies. *AGIS* includes a Crop Suitability and Adaptability Decision Support System, which is a complex DSS that provides answers to questions such as:

- What crops are suitable for a given area? (crop suitability).
- Where can a specific crop be grown? (crop adaptability) (*AGIS*, 2002).

Wildfire, Standard Prescribed Burning and Security Burning, are three different expert systems that were developed to form part of an expert system shell. These systems were developed to assist in the fire management of the Pilanesberg National Park in South Africa. They are valuable to the practising fire manager, in order to ensure consistency in the implementation of fire policy and to facilitate adaptive management in the park (*Bailey et al.*, 1993).

The *Agro-Ecological Zoning Programme* (AEZ) of Namibia under the Division Plant Production Research, Directorate of Agriculture and Training, Ministry of Agriculture, Water and Rural Development has captured all the generally available Namibian farm data. This will assist the research team in projects and enable them to supply cadastral as well as topographical information, which is necessary for sustainable agriculture development of the entire country. This database comprises of two linked tables: *Farminfo.dbf* and *Farmown.dbf*. the *Farminfo* table consists of fields such as farm number, farm size, GIS area and magisterial district. *Farmown* consists of fields such as surname of farmer, nationality, and birth date and farm number. The database query tool makes faster access to farm information possible (*Beukes*, 2003).

*SHRUBKILL*, is a microcomputer-based advisory programme, that has been developed to provide advice on the use of prescribed fire to control dense shrubs (*Ludwig*, 1991). This programme is a fully operational decision support system designed to help managers resolve difficult management decisions e.g. to decide whether and how to use management burns on pastoral properties in the semi-arid savanna rangelands of northwestern New South Wales and southwestern Queensland, Australia. This main-

programme provides a series of screens explaining the use and purpose of the programme, as well as how the user should respond to certain commands. Furthermore the user is asked a set of questions in order to obtain general information, which will later be needed by the following three modules that the main-programme consists of. These three modules include BURNTIME, BURNWAYS and BURNECON. BURNTIME is an expert system that provides advice on whether a burn is needed and the most effective time to do so. BURNWAYS is an information database on how to plan and safely conduct a prescribed fire and retrieves case studies most applicable to that of the problem experienced by the user (e.g. specific shrub problem). And finally, BURNECON is a numerical simulation model, which computes a cost-benefit analysis for the prescribed fire. It considers direct (cost of blading firebreaks), as well as indirect costs (loss of income from removing livestock) (Ludwig, 1991). The philosophy behind the development of a DSS (as used in SHRUBKILL), is currently a major goal of the CSIRO Division of Wildlife and Ecology in Australia, which involves the increasing development of such microcomputer-based advisory programmes, to be directly used in the on-farm situation in Australia. Another similar system developed for pastoral land management, is CSIRO RANGEPACK (Stafford Smith & Foran, 1991).

Concerning the basic components, this DSS closely resembles the one developed for the study discussed in this dissertation (*EcoRestore*) and it also involves the control of problem woody species. A DSS similar to the SHRUBKILL one could be a valuable addition to available systems concerning burning-programmes in southern Africa.

*Watershedss* (WATER, Soil, and Hydro-Environmental Decision Support System) was developed to adequately control non-point source pollution of a water resource. The strategic placement of Best Management Practices (BMPs) in the watersheds can successfully reduce the input of individual pollutants and may improve water quality. This DSS was designed to help watershed managers and land treatment personnel identify their water quality problems and select appropriate best management practices. *Watershedss* is comprised of three main components: 1.) Watershed assessment and evaluation: including pollutant budget spreadsheet and agricultural BMP database; 2.) An educational component: detailed information and references on Non-point Source (NPS) pollutants; and 3.) An annotated bibliography of NPS literature (*Watershedss*, 2003).

*Colorado's Decision Support Systems* (CDSS) is a water management system being developed by the Colorado Water Conservation Board and the Colorado Division of Water Resources. The main goal of this DSS is to assist in making informed decisions regarding historic and future use of water. Currently the DSS consists of three sub-DSS, one for the Colorado River (CRDSS), Rio Grande (RGDSS) and South Platte (SPDSS), with the possibility of future extension for the Arkansas River DSS (ARDSS) (Colorado's Decision Support Systems, 2003).

The *Environmental Potential Atlas* (ENPAT) is a Geographical Information System (GIS) decision support tool for environmental management, including the scoping phase of environmental impact assessments (EIAs). In an ENPAT, the environment is firstly evaluated for its inherent sensitivity for development using various available data categories of environmental information (digital maps). All the data categories are overlaid to compile a graded general sensitivity map, representing the total number of reasons for sensitivity. Secondly, environmental management parameters for various development categories are provided to ensure the protection and sustainable management of sensitive environments. ENPATs also indicate the environment's potential for development. A national ENPAT has been developed as well as an ENPAT for each province, with the exception of Gauteng (DEAT, 2003).

The Department of Agricultural Resources & Economics (AREC) of the University of Arizona, has developed a *Cow Culling Decision Support System*. This is an interactive DSS which will provide farmers with educational information and recommendations concerning cow culling decisions, generated by the current version of the model (AREC, 2003).

The *Environmental Decision Support System* (EDSS) is a problem-solving environment that provides an advanced modeling and analysis system for environmental scientists, engineers, policy makers and educators. EDSS's design goals include allowing modelers to incorporate new science with minimal effort, providing flexibility to model diverse issues and scales, helping decision makers reliably generate and understand more information with less effort and contribution to a community modeling and analysis system. EDSS is a project of the Environmental Programmes group at the North Carolina Supercomputing Center (Environmental Monitoring Group, 2003).

### 2.3. WORK DONE PRIOR TO THE DEVELOPMENT OF THE *ECORESTORE* DECISION SUPPORT SYSTEM

Existing data obtained from a thorough study conducted within the Savanna and Grassland biomes of South Africa, were incorporated into a computerized restoration database, which formed part of a Decision Support System (DSS) designed by Mr. J.P.A. van der Merwe (Van der Merwe, 1997). The case studies mainly comprised the evaluation of different technologies applied to restore bare and denuded areas. The database included a total of 171 case studies carried out within five provinces, ten different land types and varying climatic conditions in annual rainfall areas ranging from 120mm-634 mm (Van der Merwe, 1997). These case studies served as a possible reference to farmers experiencing similar degradation problems.

CBR-Express technologies were used, which are based on the principle of solving problems by calling up previous solutions. It consists of a maintenance- and search-mode (Inference Corporation, 1990). The maintenance mode is used to construct the database, also known as the *author mode*. The search mode is used to conduct searches in order to find the best possible answer, also referred to as the *consulting mode*. As mentioned, the case studies used in this earlier DSS developed by Mr. B. van der Merwe, focused more on the problem of degraded, denuded areas and the restoration thereof.

Due to problems encountered with the Information Technology (IT)-company that was responsible for installation, servicing and maintenance of the existing CBR-computer programme, it was decided to assign the latest development task to another company. Seeing that this is quite a new line of research application in South Africa, especially the construction of a DSS within the natural sciences, finding a new IT-company that could serve the specific needs of such a DSS, ended up as a big challenge. The IT-company, Environmental Management Services (EMS)<sup>3</sup> in South Africa, was contracted to handle the development of the new DSS forming part of this study.

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<sup>3</sup> Environmental Management Services cc. (EMS) / Redlog Data Solutions. Contact details: P.O. Box 5260, Halfway House, 1685, South Africa. Tel: +27-(0)11-254-4929; Fax: +27-(0)11-805-7010.

## 2.4.THE DEVELOPMENT OF THE *ECORESTORE* DECISION SUPPORT SYSTEM

### 2.4.1. Background

Similar to the restoration of bare and denuded areas, land users have also applied a variety of bush control technologies in the short- or long-term. These technologies are based on indigenous and scientific knowledge and mostly include conventional methods, such as chemical, manual, mechanical or biological control technologies, as advised by scientists, agricultural extension workers and consultants.

A wealth of knowledge on technologies to control bush encroachment already exists in southern Africa. Data of long-term research studies by experts in the field of bush encroachment and control thereof exist and is mostly readily available within different literature sources and unpublished documents, have been presented at workshops and conferences and can be obtained by means of personal communication. Literature concerning this subject includes the following:

- Research done on *Colophospermum mopane*: Scholes, 1990; Smit, 1994; Dekker & Smit, 1996; O'Connor, 1998; Smit & Rethman, 1998a; Smit & Rethman, 1998b; Smit & Rethman, 1999; Smit & Rethman, 2000; Smit, 2001a, Smit, 2001b; Brönn *et al.*, 2002; Smit, 2003b.
- Tree-grass interactions: Bosch & Van Wyk, 1970; Smit & Rethman, 1989; Richter, 1991; Teague & Smit, 1992; Brönn, 1993; Romburgh & Smit, 1993; Smit & Swart, 1994; Meyer, 1997b; Mapuma, 1998; Smit *et al.*, 1999; Richter *et al.*, 2001; Lloyd, 2003; Rothauge *et al.*, 2003.
- General rangeland issues concerning the bush component and encroachment thereof: Donaldson, 1967; Smit, 1989a; Smit, 1989b; Smit, 1990; Smit & Rethman, 1992; Reed, 1996; Meyer, 1997a; Smit, 1998; Smit, 1999b; Meyer, 2000; Meyer *et al.*, 2001; Kraaij, 2002; Smit, 2002; Kraaij & Ward, 2003; Smit, 2003a; Ward, 2003a; Ward, 2003b.

The challenge is however is to bring both local and scientific knowledge together in a single, computerized database and expert system, forming the basic components of a DSS. Such a system is based on already existing technologies to control natural degradation processes such as encroachment of woody and/ or alien species, as well as the occurrence of open and denuded patches. The DSS is directly accessible by the land users

and assists them in their decision-making process by providing recommendations on how to restore degraded land. The results obtained from the system also encourages the awareness, training and capacity building of all parties, such as conservationists and land users.

#### **2.4.2. Origin of the current version of the *EcoRestore* Decision Support System**

A presentation of the previous CBR-system, made to the NAU (Namibian Agricultural Union)<sup>4</sup>, by Prof. K. Kellner (personal communication<sup>5</sup>), at a farmer's day in Namibia, sparked the idea of capturing data of already existing restoration technologies, especially bush control technologies in a similar way. The approach of data capturing of case studies conducted by land users with regard to bush control technologies, is very applicable in Namibia. Seeing that this country is experiencing a major problem concerning bush encroachment. The problem mainly occurs in the arid and semi-arid environments situated in the central and northern regions of the country.

Various estimates of the extent to which bush encroachment has taken place in Namibia, have been made. The generally accepted figure is in the order of 8-12 million hectares. However, all the savanna veld types north of the 23 degrees latitude line are subjected to one or other form of bush encroachment or thickening. It comprises an area of approximately 17 million hectares (Bester & Reed, 1997a) of the total 82.31 million hectares covered in Namibia. According to Ward & Ngairorue (2000), approximately 60% of the farms and rangelands in the northern regions of Namibia suffer from problems with bush encroachment. More details on the extent and effects of bush encroachment will be discussed in Chapter 3 (Study Area) of this dissertation.

As mentioned, for the purpose of this study, it was necessary to develop a new approach to capture data on indigenous and other knowledge obtained from researchers, land users and other specialists in rangeland conservation, with regard to bush control technologies. This need led to the development of a system that could act as a Decision Support System, containing case studies involving indigenous knowledge inputs as well as

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<sup>5</sup> **Prof. Klaus Kellner**: Developer: *EcoRestore* DSS and Supervisor of this MSc.study. Contact details: School of Environmental Sciences and Development: Botany, Potchefstroom University for Christian Higher Education, Potchefstroom, 2520, South Africa. Tel: +27-(0)18-299-2510; Fax: +27-(0)18-299-2503, Mobile: +27-(0)82-569-6145. E-mail: [plbkk@puknet.puk.ac.za](mailto:plbkk@puknet.puk.ac.za)

information about the applied restoration technologies (Kellner & Van der Merwe, 2000). It was decided to also incorporate the data of the previously designed CBR-system, regarding restoration of bare and denuded areas, which formed part of a M.Sc. study by Mr. B. van der Merwe (Van der Merwe, 1997), into the new DSS.

These two databases (restoration of bare areas, as well as the control of bush encroachment), would then be combined into a new computerized DSS, named *EcoRestore*. The main focus of this study was therefore to develop a DSS, which included a database and expert system focusing on bush control technologies. The same approach that was used to develop the database and expert system for the reclamation of degraded and denuded rangelands was therefore to be used to develop a DSS and consulting tool for the control of bush encroachment. The reason for concentrating on bush control technologies as a division of rangeland restoration, rather than on restoration of bare and denuded areas, is to avoid duplication of research done by Mr. B. v.d. Merwe on a similar subject.

The DSS (*EcoRestore*) constructed for this study, consists of the two databases *Grass Expert* and *Bush Expert* (Figure 2.1). As mentioned above, the *Grass Expert* database mostly contains case studies focused on restoration of bare and denuded areas, taken from the 'old' CBR-programme used by Mr. B. van der Merwe. *Bush Expert* on the other hand focuses on technologies applied to control bush encroachment (subject to this study). The structure and consultation of the *Grass Expert* and *Bush Expert* databases within the *EcoRestore* DSS will be discussed in Chapter 6 (Decision Support System Structure and Consultation).

Namibia and South Africa are currently experiencing the same problems regarding bush encroachment, as well as the occurrence of bare and denuded areas, thus the development of such a combined DSS would be beneficial to both these countries. In future other southern African countries experiencing similar problems might benefit from such a DSS as well. Due to the problems encountered with the IT-company and updating the CBR-programme, a new computerized approach was followed. The expert system shell is therefore based on the Microsoft Windows admittance database (ACCESS). This software is easily accessible and updateable, should it be necessary to incorporate additional data, edit existing data or construct extra databases within *EcoRestore* DSS.

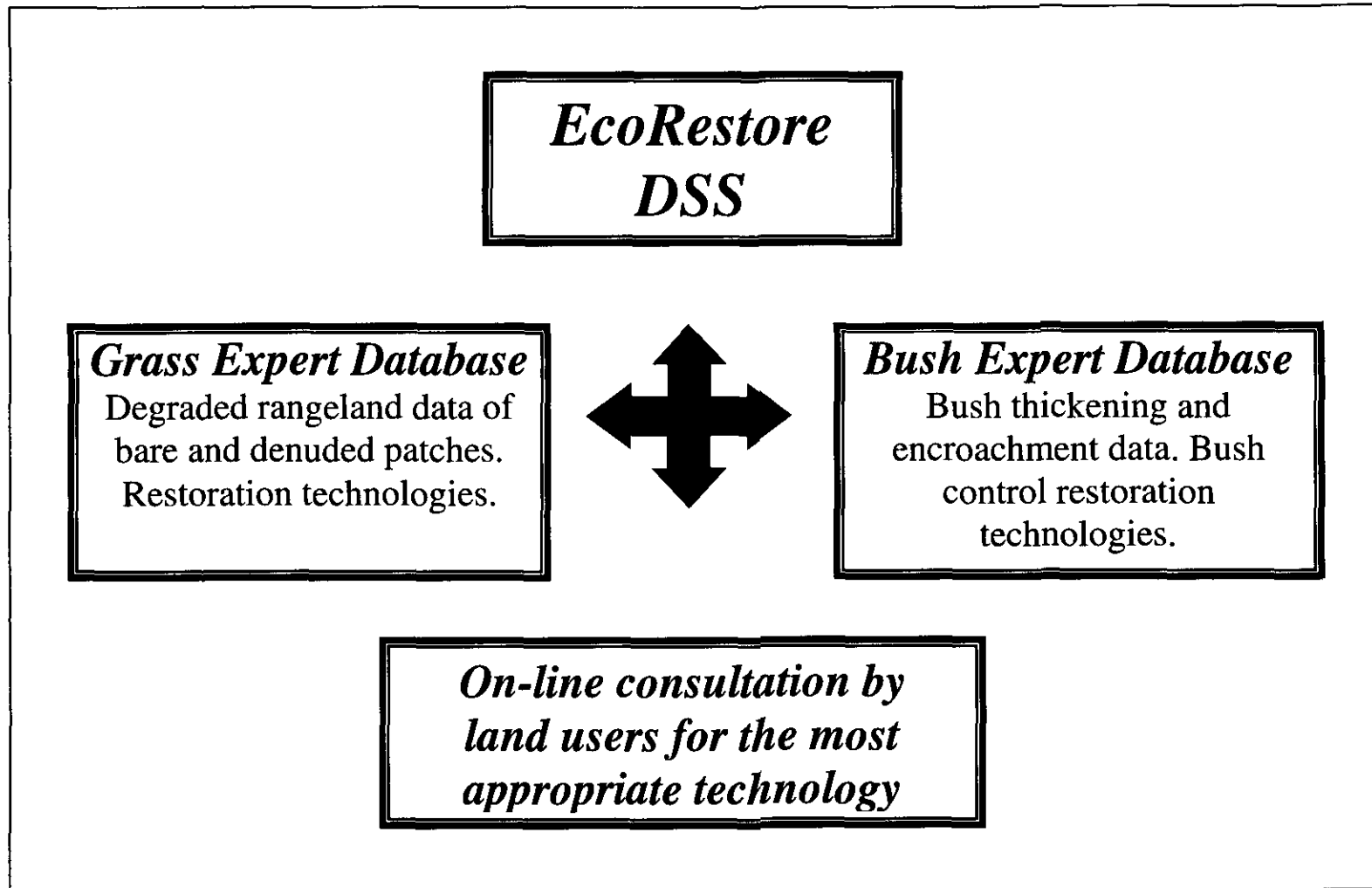
The DSS is still based on artificial intelligence methodologies by which a number of case studies, that have been stored in the databases, can be searched by means of an expert system approach to advise the most appropriate solution (action) to land users regarding similar bush encroachment or degradation problems. In using Microsoft Access, one can manage all the relevant information from a single database file. Within the file, data is divided into separate storage containers called tables, view, add, and update table data using online forms; find and retrieve just the data one needs by using queries; and analyze or print data in a specific layout using reports (Willits, 1992).

#### **2.4.3. Final remarks regarding the development of a DSS such as *EcoRestore***

As mentioned, the task of knowledge maximization should be seen as a co-operative venture between research scientists and land users. This also implies the need for more participatory research, whereby land users are encouraged to become directly involved as 'researchers', through implementing management strategies and monitoring outcomes (Bosch *et al.*, 1997).

The computerized Decision Support System (DSS) consisting of a database and expert system, must be a user-friendly tool which can be consulted for future combating of degradation and desertification problems. The system should lead the user to make the most applicable (right) decision regarding his or her specific problem. Problems that cannot be solved or that are not addressed by the existing database as is, will lead to new knowledge and challenges. In updating the DSS on an ongoing basis, the substance and context of the required information flow is updated as more knowledge becomes available. The build-up and improvement of this DSS is therefore a never-ending and ongoing process and will involve further studies and surveys in future.

The databases containing case studies of successfully applied restoration technologies or practices (restoration of bare and denuded areas or bush control), together with results of statistical analyses done on data obtained at these sites, will serve as reference to the expert system (where matches can be made to similar case studies to those experienced by



**Figure 2.1:** Schematic diagram to explain the structure of the *EcoRestore* Decision Support System.  
[DSS = Expert System + Databases]

Land managers (farmers, conservationists, land users etc.) are continually implementing management actions. By measuring these outcomes, new information is gained, which can be used to update the knowledge-based framework (DSS). This approach also defines future research priorities at research institutions and emphasizes the maximization of both local and scientific knowledge (Bosch *et al.*, 1997).

Monitoring (e.g. of bush control practices in natural rangelands) is an essential component of any management system. The results of a monitoring programme provide a basis for the sound management decisions to be made over the long-term. The decisions that are made need to be based on a sound knowledge and understanding of what the magnitude of the measured indicators indicates. With monitoring, a system is included that facilitates the process of decision-making (Zimmerman, 2002).

According to Klein and Methlie (1995), a sound knowledge base and understanding of the dynamics of a situation are required, before a DSS is developed.

The development of an effective DSS enables, that the most effective restoration that has been tested previously by land users, be implemented for a specific problem in a certain area. It can now serve as a directive to identify future priorities and possibilities. The effectiveness of the DSS will greatly depend on the quantity and quality of the data sampled and incorporated into the database.

This study will however only focus on the incorporation of the data that has been collected by agricultural extension officers and farmers in Namibia into the prototype of the *EcoRestore* DSS and more specifically the *Bush Expert* database. Thus the existing case studies in the database currently only apply to Namibian data on bush control technologies.

In order for the development of such a DSS and the bush control study as a whole, to be successful, certain objectives and planned outcomes need to be stipulated prior to the start of the project. When the project is completed, the success can be estimated according to the number of objectives met and the various outcomes that were established during the course of the project.

## 2.5. OBJECTIVES OF THE STUDY

The objectives that have been set for this study include the following, namely to:

- 1) Gather as much quantitative data of existing rangeland restoration and control of bush encroachment technologies as possible, in order to develop the *Bush Expert* database.
- 2) Evaluate the different rangeland restoration and bush control technologies used by farmers, rangeland managers, scientists and extension workers.
- 3) Identify the most applicable 'best bet' bush control technologies (practices) for a certain problem under specific environmental conditions.
- 4) Evaluate the economic viability of the bush control technologies.
- 5) Construct a user-friendly DSS which rangeland managers, farmers, scientists and extension workers could use as a consulting tool.
- 6) Create a web page to make the data available to as many users as possible.
- 7) Link the *EcoRestore* web page to other web pages and databases, especially those of other Agricultural and Conservation institutions.
- 8) Create networks and participation between farmers or rangeland managers, scientists and extension workers.

The objective was further, to incorporate *EcoRestore* as a part of the Namibian Action Plan towards mitigating the effect of rangeland degradation. A detailed structure and information on the Namibian Bush Encroachment, Monitoring and Management Project (De Klerk, 2000) as administrated by Mr. Nico de Klerk<sup>6</sup> from the Namibian Ministry of Environment and Tourism, is given in Box 1.

An aspect that should be stressed concerning this entire study on bush control and the development of a DSS, is that the main aim was to gather as much data and information concerning 'best bet' restoration (bush control) practices and to set up a basic inventory.

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**Box 1: Namibian Bush Encroachment, Monitoring and Management Project :**

- *Implementing organisation:* Directorate of Environmental Affairs, Ministry of Environment and Tourism and National Programme to Combat Desertification.
- *Overall objective:* Promotion and establishment of appropriate systems for diverse and sustainable land management in encroached areas in Namibia.
- *Project purpose:* Obtain a common information-base and understanding on the issues related to bush encroachment, as well as to prepare a *monitoring* and *integrated management* programme.

❖ The project consists of two main phases of implementation:

**Phase 1:** Will focus on establishing a common information base and participatory preparation of an integrated research, monitoring and management programme and action plans.

**Phase 2:** Will then implement the action plans and monitor the progress and impacts on the bio-physical and socio- economic environments.

❖ In the short-term the expected results of the project include the following outputs:

*Result 1:* Improved understanding of the causes and impacts of the species-specific bush encroachment process.

*Result 2:* Impact of bush encroachment on land capability as well as the socio-economic situation of farmers.

*Result 3:* Updated and time-sequenced, historical information in map- and GIS-database form available for e.g. researchers, planners and general public.

*Result 4:* Improved monitoring systems and methodologies for land capability assessments purposes.

*Result 5:* Sustained and functional mechanism and capacity to operate and manage the bush. Monitoring and Management Project is being developed and operational for Phase 2.

*Result 6:* Compiled policy analysis of bush encroachment related issues for policy reforms.

*Result 7:* Increased awareness of bush encroachment dynamics and operational networks for information and experience sharing.

❖ *Remarks: The implementation period of project: September 2000-2003.*

Although the information and data is not always obtained by means of scientifically sound methodologies, but rather based on the incorporation and use of indigenous knowledge, this DSS could prove to serve as an important reference source. The information obtained during this study is however scientifically evaluated, and compared to the current literature and scientific findings concerning the control of bush encroachment in southern Africa. This basic inventory could serve as a basis for future development and research in the field of rangeland restoration.

## 2.6. EXPECTED OUTPUTS OF THE DECISION SUPPORT SYSTEM AND STUDY

The *EcoRestore* DSS does not only offer a consulting tool for extension workers and technicians, but also creates networking and participation between other land users, researchers and conservationists. Indigenous knowledge therefore plays a very important part in the construction of the database for the restoration of bare and denuded, as well as bush control in rangelands in southern Africa.

By consulting the database, the best action will be proposed to the land user for future combating of degradation in southern Africa. Since the case studies are based on past and existing experiences and research, the land user will have an indication of the result that can be expected should the same advised technology be applied.

By developing the *EcoRestore* DSS, the following additional issues will be addressed:

- Instigation of better awareness amongst land users within farming communities (Ludwig *et al.*, 1990);
- Linking the DSS to other national and international web sites and databases; and
- Initiation of collaboration and communication between stakeholders both nationally and internationally, especially between countries that are experiencing the same problems and are opting to achieve the same goal concerning bush control (De Groot *et al.*, 1992).

The *EcoRestore* DSS is also an example of the many information hubs that the international Desert Margins Programme (DMP)<sup>7</sup> is aiming at developing in future. The main purpose of the Information and Communication Technologies (ICT) information hub-system of the DMP is to look at ways of transferring the different technologies and alternative livelihood activities, to the land user at grassroots level, as well as to scientists and extension officers. In other words, knowledge sharing that will take place by means of information hubs, which are run through the internet or within computer systems.

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<sup>7</sup> **Desert Margins Program (DMP):** Towards sustainable management of the desert margins of sub-Saharan Africa. Contact person: Saidou Koala, Desert Margins Program Coordinator ICRISAT, BP 12404, Niamey, Niger. Tel: +227 7225 29; Fax +227 734329 or E-mail: [ICRISAT@CGIAR.ORG](mailto:ICRISAT@CGIAR.ORG)

## CHAPTER 3

### STUDY AREAS

This chapter will mainly focus on the choice of study areas in Namibia and South Africa, as well as the reasons for choosing these specific areas concerning bush control technologies applied as a form of rangeland restoration. Detailed descriptions of the main study areas as well as general information such as climate, vegetation and geology of more specified sites, will be discussed in more detail in the form of text as well as maps.

The documentation of bush control technologies was conducted in both Namibia and South Africa. The reason for this is that both countries are experiencing the same problem concerning bush encroachment. The construction of the *Bush Expert* database thus involves trans-boundary collaboration when it comes to sharing knowledge and solutions for problems such as these. The surveys conducted in Namibia were carried out by a number of different stakeholders, which included agricultural extension officers and farmers. The case studies conducted in South Africa were carried out by myself with the help of fellow students.

#### 3.1. NAMIBIA

Agricultural extension officers initially conducted the majority of the *Bush Expert* surveys in Namibia. In time however, a number of farmers within the different regions were identified as surveyors. Extension officers and farmers were trained in the survey procedures used for this study. Training workshops were facilitated by other extension officers and scientific personnel from the Namibian Department of Agriculture. As mentioned in Chapter 1, surveys were focussed in the central and northern regions of Namibia, due to the fact that bush encroachment mostly occurs in these savanna areas (Bester & Reed, 1997a).

The rainfall and vegetation factors, characterizing the savanna regions of Namibia, will be discussed in broad outlines for each of the study areas where most of the bush control study sites were situated.

### 3.1.1. Biomes

Most of the study sites in Namibia were situated in the Savanna biome, one of the four major general terrestrial biomes in Namibia (Barnard, 1998; Namibian Nature Foundation, 2002). The other biomes include Desert, Karoo and Woodland areas. According to Trollope *et al.* (1990), the Savanna biome can be defined as a physiognomic type of vegetation comprising of a tree or shrub overstory (upper stratum) and an herbaceous understory (lower stratum).

The Savanna-biome can be sub-divided into smaller units describing the type of savanna. Case studies were carried out within the following sub-biomes:

- Mountain Savanna and Karstveld, Thornbush and Highland Savannas (dominating the central highlands of the country);
- Camelthorn Savanna (mostly confined to the Kalahari Sandveld);
- Mopane Savanna (northwestern parts of Namibia); and
- Semi-desert & Savanna transition (southeast of the escarpment).

According to Mendelsohn *et al.* (2002), the Savanna-biome is the largest of all the biomes and the most important factors affecting both the *Acacia* and Broad-leaved Tree-and-shrub Savanna sub-biomes are the summer rainfall, frequent and widespread fires and grazing pressures from wildlife and livestock.

### 3.1.2. Vegetation

Namibia's steep northeast-to-west climatic gradient, plus its varied soil types and landforms, largely determine the distribution of its characteristic vegetation zones. Annual rainfall determines the three main vegetation zones of Namibia: deserts, savannas and woodlands. Temperature and seasonality of rainfall, plus topography and soil, influence the 14 major subdivisions of these vegetation zones (Barnard, 1998).

Extensive grasslands dominate the endless expanse of central Namibia. Thorny woody tree species (*Acacia* species) dot the landscape, known as the Thorn savanna or Thornveld (Barnard, 1998).

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<sup>1</sup> Mr. F.V. Bester: Namibian Ministry of Agriculture, Water and Rural Development, Sub-division: Pasture Research. Contact details: Private Bag 13184, Windhoek, Namibia. Tel: +264-(0)61-2022005.

The woody species that are characterized as the problem species, with regard to the ability to cause encroachment or thickening of bush, include both thorny and non-thorny species. Among the thorny species the most important problem species are: *Acacia mellifera*, *Acacia reficiens*, *Acacia erubescens*, *Acacia fleckii* and *Dichrostachys cinerea*, while most of the non-thorny species include: *Colophospermum mopane*, *Terminalia sericea* and *Terminalia prunioides* (De Klerk, 2004; FAO, 2003).

According to De Klerk (2004), experts in Namibia agreed on the following classification in terms of bush encroachment, which is expressed as total number of trees per hectare (ha) and includes all woody species (bushes and trees), problem as well as non-problem species:

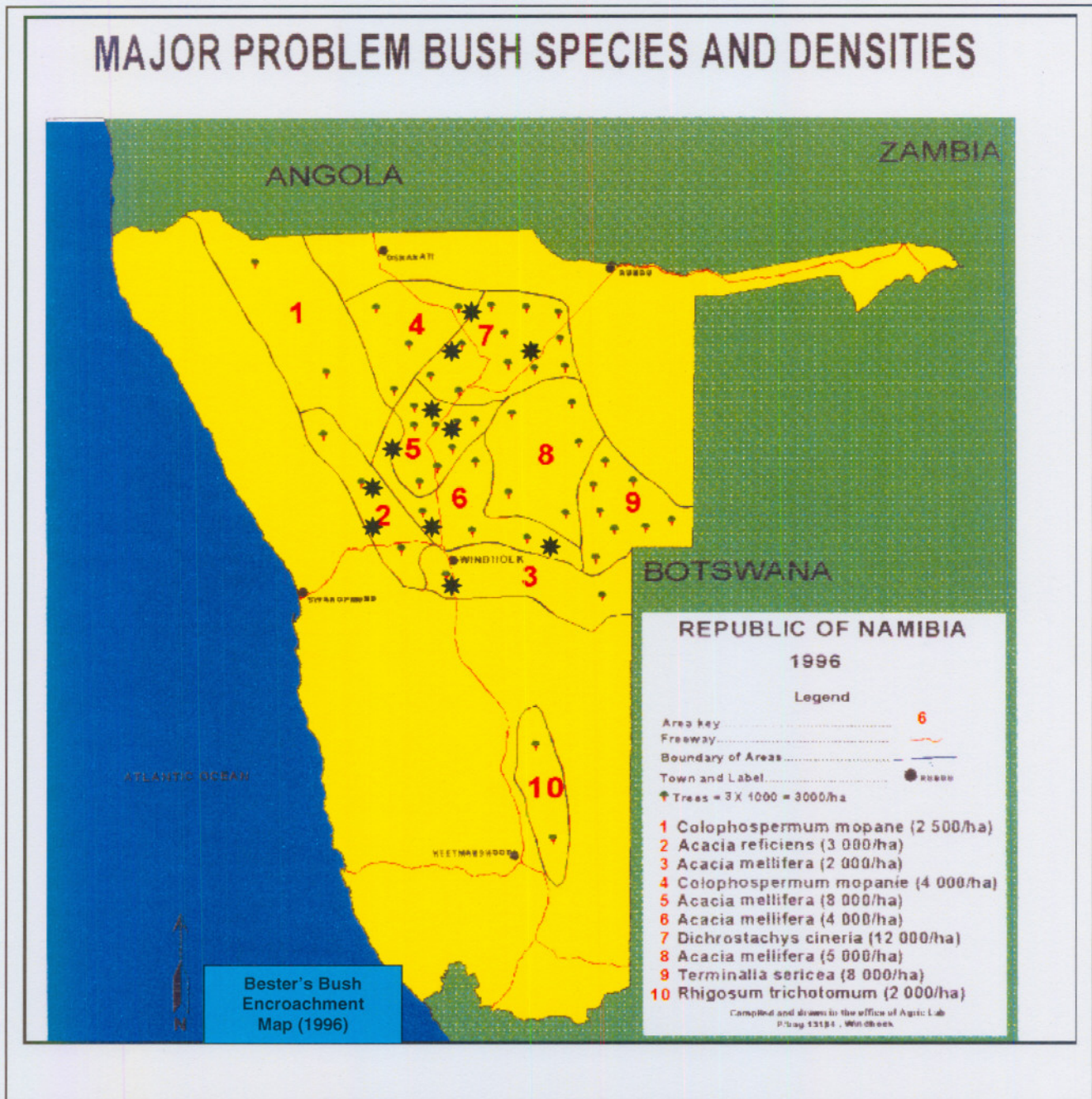
- < 1 000 trees/ha = Low density
- 1 000 - 2 000 trees/ha = Medium density
- 2 001 - 3 000 trees/ha = High density
- > 3 001 trees/ha = Very high density (serious bush encroachment or thickening problem).

To be scientifically correct, once all the height classes of all the different species are known, these numbers can be expressed as tree equivalents (TE) per hectare, (De Klerk, 2004). The term tree equivalent (TE) is used to express the tree populations of different sites in a common currency. One TE is normally defined as a 1.5m tall tree or shrub. Tree equivalent values are usually expressed as TE/ha and are widely used throughout southern Africa (Teague *et al.*, 1981 and Tainton, 1999).

A map has been constructed indicating the current status of bush encroachment in Namibia (Figure 3.1). The data and bush density values used for this map were obtained from bush sampling surveys carried out by Mr. F. V. (Bessie) Bester<sup>1</sup> and fellow agricultural extension officers in Namibia.

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**Figure 3.1:** Bush encroachment map of Namibia indicating species-specific bush densities/ha (De Klerk, 2004). \* = Approximate location of the main regions where surveys for this study were carried out.

### 3.1.3. Soil and Geology

The *geology* of Namibia is complex and fascinating and it is known for its rich ore deposits over large parts of the country.

Although the country is divided into numerous minor landforms or geophysical zones, four major categories can be distinguished: coastal plain and Namib Desert; the broken and rugged Namib escarpment; the rocky central plateau; and the Kalahari Sandveld.

Only the Sandveld is geologically fairly simple, while the other zones conceal a combination of intrusions, ridges, dykes, sills and outcrops. The country owes its name to the Namib Desert and coastal plain (Barnard, 1998).

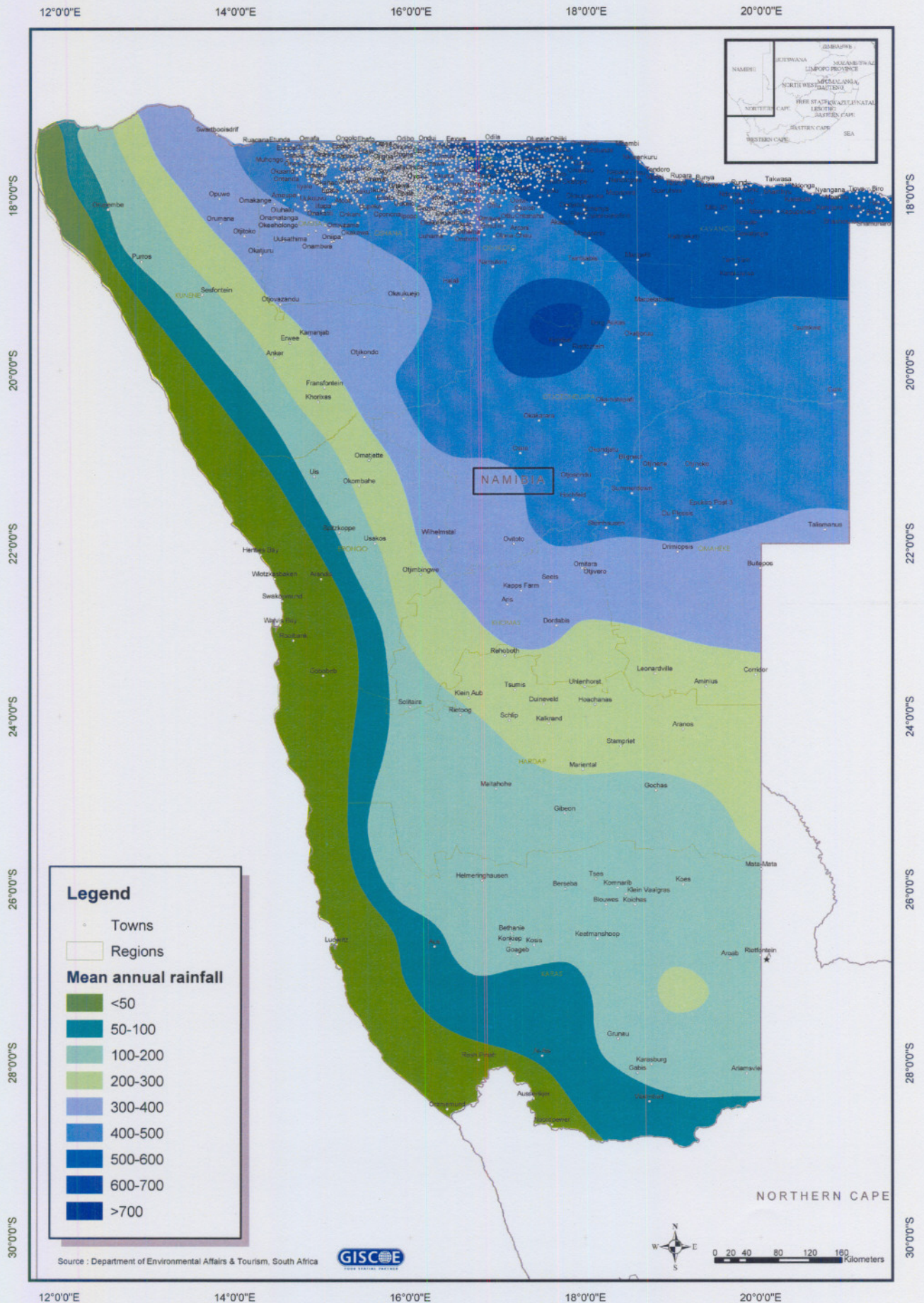
The *soil* types in the different sites where bush encroachment surveys for this study were conducted, differ from one area to the other. The same applies for the clay percentage of the soil. In the study areas a generalization can thus not be made concerning soil types and clay percentages of the survey sites on the farms or rangelands that serve as case studies. It can however be said, that the soil characteristics play an important role in determining the vegetation types in an area, e.g. *Acacia erioloba* trees are usually found in deep sandy soils (Barnard, 1998; Smit, 1999a).

### 3.1.4. Climate

The overwhelming two features of Namibia's climate are the scarcity and unpredictability of *rainfall*. Within the whole of Africa, Namibia's climate is second in aridity only to the Sahara (De Klerk, 2004). The countrywide average rainfall (Figure 3.2) of under 250 mm per annum is coupled with the annual mean evaporation of up to 3 700 mm. Overall, 69% of the country is regarded as semi-arid, with the remaining 16% as arid. The little rain that reaches the dry, crusted soil, is mostly lost again through evapotranspiration. It is estimated that approximately 83% of rainfall evaporates and a further 14% is transpired by plants. The other 3% is retained in dams and filters through to the groundwater table (Barnard, 1998).

Most of Namibia's rain falls during the summer months, from November to April and can usually be expected as thunderstorms (Barnard, 1998; Namibia Online Travel Guide, 2003). There is extraordinary variation between years concerning rainfall, with the driest areas having the least predictable rainfall.

### Chapter 3 - Study Areas



**Figure 3.2:** Rainfall map of Namibia indicating the different mean annual rainfall zones and main towns (Source: Department of Environmental Affairs and Tourism, South Africa).

*Temperatures* in Namibia can be extremely variable and challenging to plant and animal life. Daily fluctuations are greatest in the hyper-arid zones, where there is very little vegetation cover. Namibia is characterized by a semi-desert climate, with hot days and cool nights. Temperatures can rise above 40° C during daytime and drop beneath -10° C at night (Barnard, 1998). As temperatures are high and precipitation is very low, the country often appears dry and arid (Namibia Online Travel Guide, 2003).

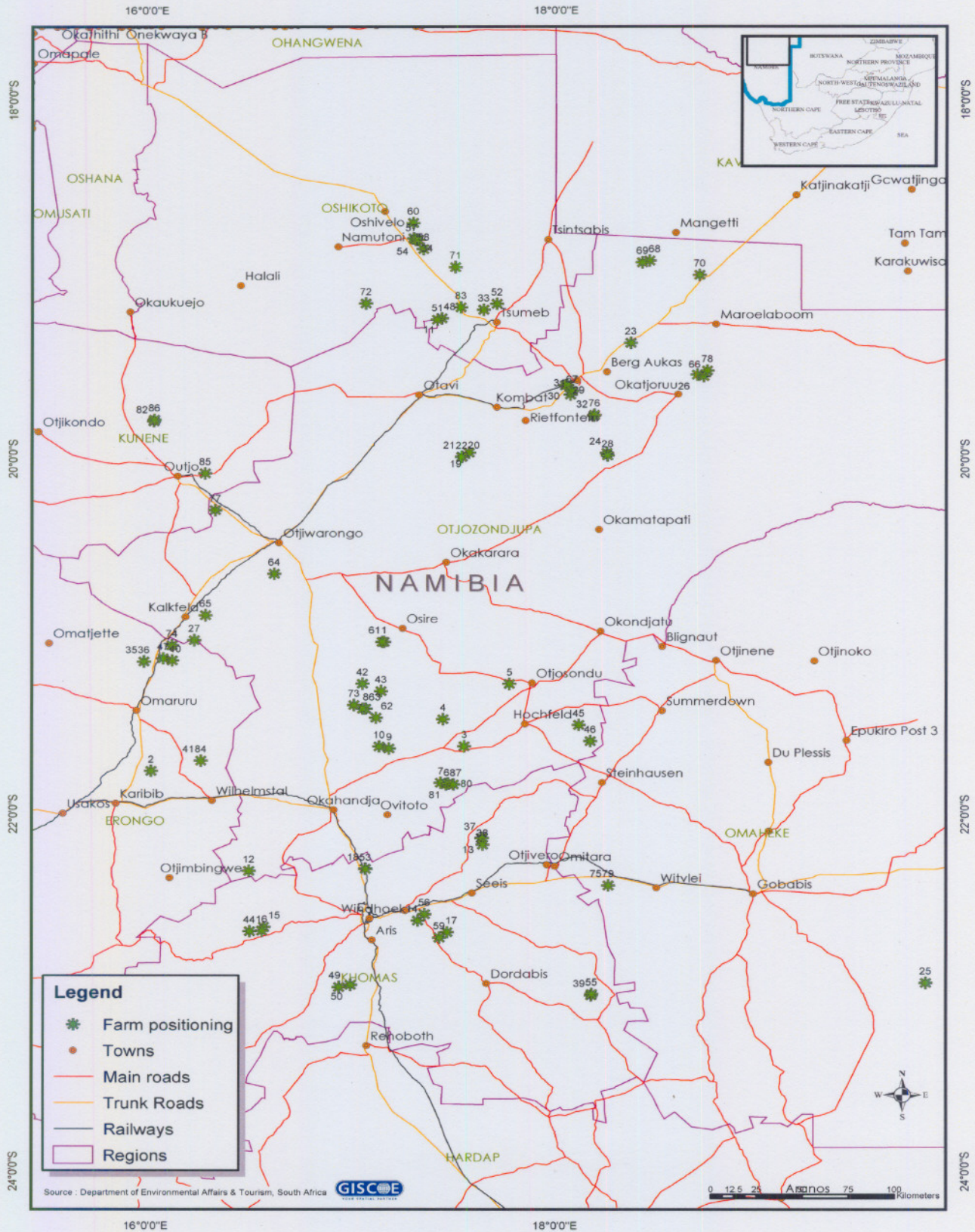
### **3.1.5. Location of the study sites within the regions of Namibia**

#### *Regions*

The surveys conducted in the central and northern regions of the country are mostly situated in the Savanna biome (which is prone to bush encroachment). The main *regions* included: Kunene, Oshikoto, Otjozondjupa, Omaheke, Erongo and Khomas.

A total of 175 Namibian study sites were selected as case studies in bush encroached areas and where bush control technologies have been applied in the past. The locations of the sites were determined by the vegetation type, which is prone to bush encroachment (usually savanna) and the degree of bush encroachment, together with the availability of information on bush control practices applied by land users in these areas. Of these 175 case studies, only 100 of the best cases were selected for the prototype development of the *Bush Expert* database. Only these 100 cases will be discussed and taken into consideration during statistical analyses for the purpose of this dissertation Figure 3.3 indicates the location of the 100 Namibian study sites according to GPS readings.

Chapter 3 - Study Areas



**Figure 3.3:** General map of the central and northern regions of Namibia, indicating the different farm positions where surveys for case studies were carried out (GPS readings). The number at each position, indicates the site number of the survey. (Source: Department of Environmental Affairs and Tourism, South Africa).

*Agro-Ecological Zones (AEZ)*

De Pauw *et al.* (1998), describes AEZs as being based on landforms and vegetative growing periods. De Pauw and Coetzee (1998) further describes AEZs to be considered as land entities that are uniform in terms of climate, landforms and soil features and are unique by the specific combinations of these features. Eight major Agro-Ecological Zones have been differentiated in Namibia:

- Central plateau
- Damaraland landscapes
- Ekuma plains and Etosha pan
- Escarpment
- Kalahari sands plateau
- Kalkveld
- Kaokoland landscapes
- Namib sand seas and desert plains.

According to De Klerk (2004), each of these above-mentioned major AEZs, are subdivided into smaller components (Figure 3.4) e.g.:

- Cpl 1 - Central plateau, southern Omatako plain;
- Kao 2 - Kaokoland, pediment plains; or
- Kal 3-2 - Kalahari sands plateau, stabilized sand drift with few pans, average growing period 91-120 days.

In addition, important river canyons (Gor) and undifferentiated rocky hills (R) are also indicated as smaller components on the Namibian AEZs-map.

*Fairly Homogenous Farming Areas (FHFAs)*

According to the Department of Agriculture: Technical Services (1979), optimum agricultural production is dependent on optimum utilization and expansion of natural resources. In order to optimize production, the problems concerning the lack of sufficient information within certain domains, need to be determined.

Seeing that the total production potential is dependent on natural resources, the farming areas are divided into sub-regions with regard to differences in terrain morphology, soil

patterns and macroclimate. Each one of these sub-regions are seen as a Fairly Homogenous Farming Area (FHFA), within which (if at all) only slight differences should exist concerning production techniques and yield norms. These FHFAs are divided into high, medium and low production potential areas for cattle and sheep farming. Further refining or division of such areas, is only necessary in regions with an agricultural potential where the slope and soil characteristics are used as criterion for demarcation. Extensive sheep and cattle farming are the main forms of production and income generating venture in agriculture in Namibia. Dairy farming and crop production plays a lesser role. Further refining or division of FHFAs is therefore only necessary in regions with an agricultural potential where the slope and soil characteristics are used as criterion for demarcation (Department of Agriculture: Technical Services, 1979).

# AGRO-ECOLOGICAL ZONES OF NAMIBIA

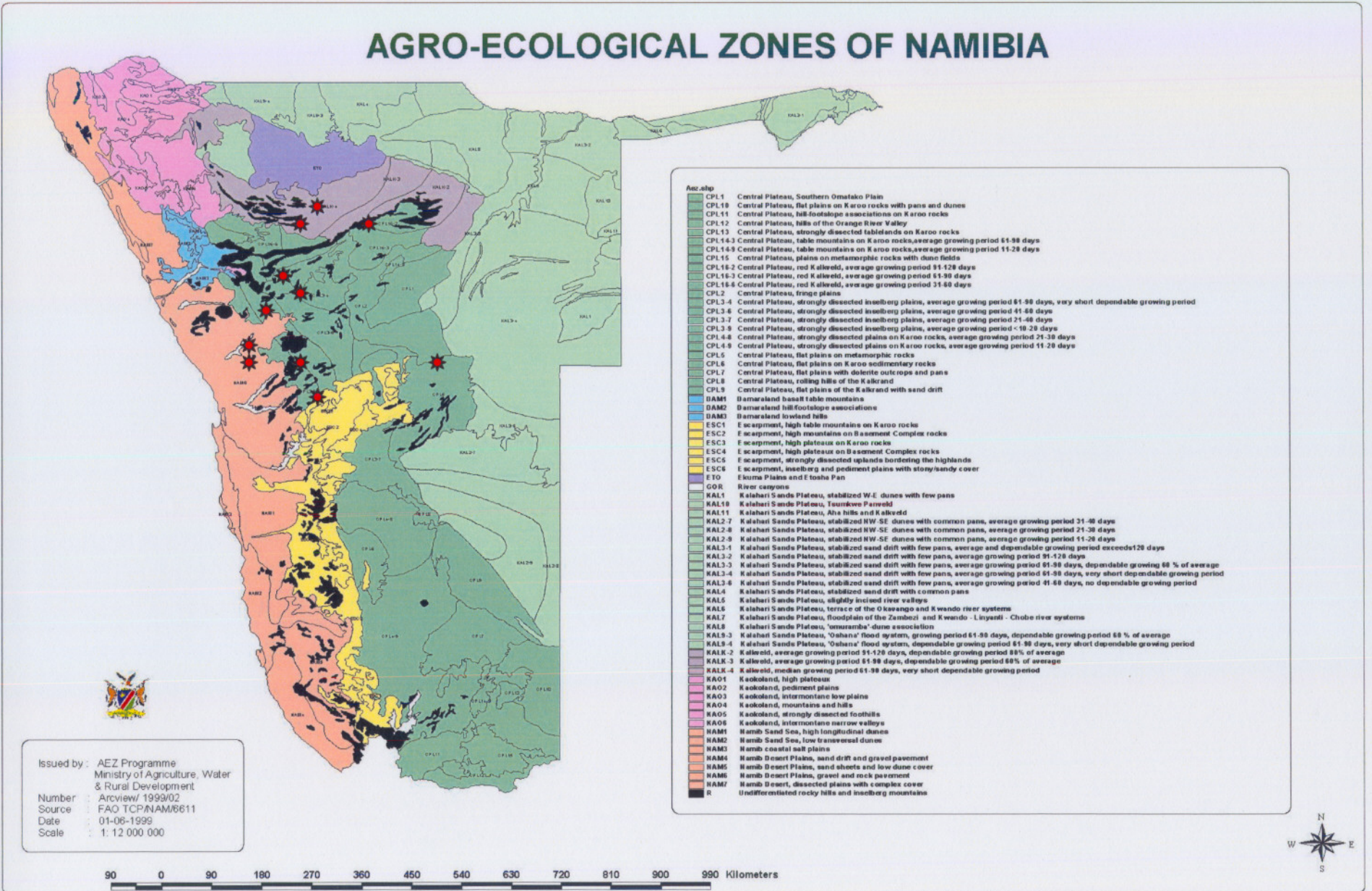


Figure 3.4: Agro-Ecological Zones (AEZs) map of Namibia (De Klerk, 2004). \* = Approximate location of main regions in which surveys were carried out.

## **3.2. SOUTH AFRICA**

Bush control studies in South Africa were conducted in two main provinces, i.e. the Limpopo and Northern Cape Provinces. These provinces were chosen for the purpose of this study, due to the fact that they both fall within the savanna biome, as well as being areas prone to bush encroachment (Rutherford & Westfall, 1994). For the purpose of this study and dissertation, references will however only be made to surveys conducted in the Limpopo Province.

A total of nine case studies were carried out within the Limpopo Province during March 2003. The Limpopo Province is the most northern province of South Africa, bordering Botswana, Zimbabwe and Mozambique (Department of Environmental Affairs and Tourism, 2003).

### **3.2.1. Biomes**

A biome is commonly referred to as a large, natural, reasonably representative homogeneous area consisting of biotic and abiotic factors (Rutherford & Westfall, 1994). Smith (1974), as in Rutherford & Westfall (1994), also refers to a biome as a broad ecological unit.

The Limpopo Province comprises mostly of the Savanna Biome and a very small portion is made up of the Grassland biome (Low & Rebelo, 1996). The study areas fall within parts characterized by the Savanna biome (Figure 3.5).

The Savanna biome is the largest biome in southern Africa, occupying more than 46% of its area and over one-third the area of South Africa. The Savanna biome is characterized by a grassy ground layer and a distinct upper layer of woody plants. Almost every major geological and soil type occurs within this biome and the most limiting factor in this biome, is the lack of sufficient rainfall which prevents the upper layer from dominating, coupled with fires and grazing, which keep the grass layer dominant. The shrub-tree element (woody species) in the savanna vegetation regime may dominate the areas, which are being overgrazed (Trollope, 1980; Rutherford & Westfall, 1994; Low & Rebelo, 1996; Fuhlendorf, 1999; O'Connor & Crow, 1999).

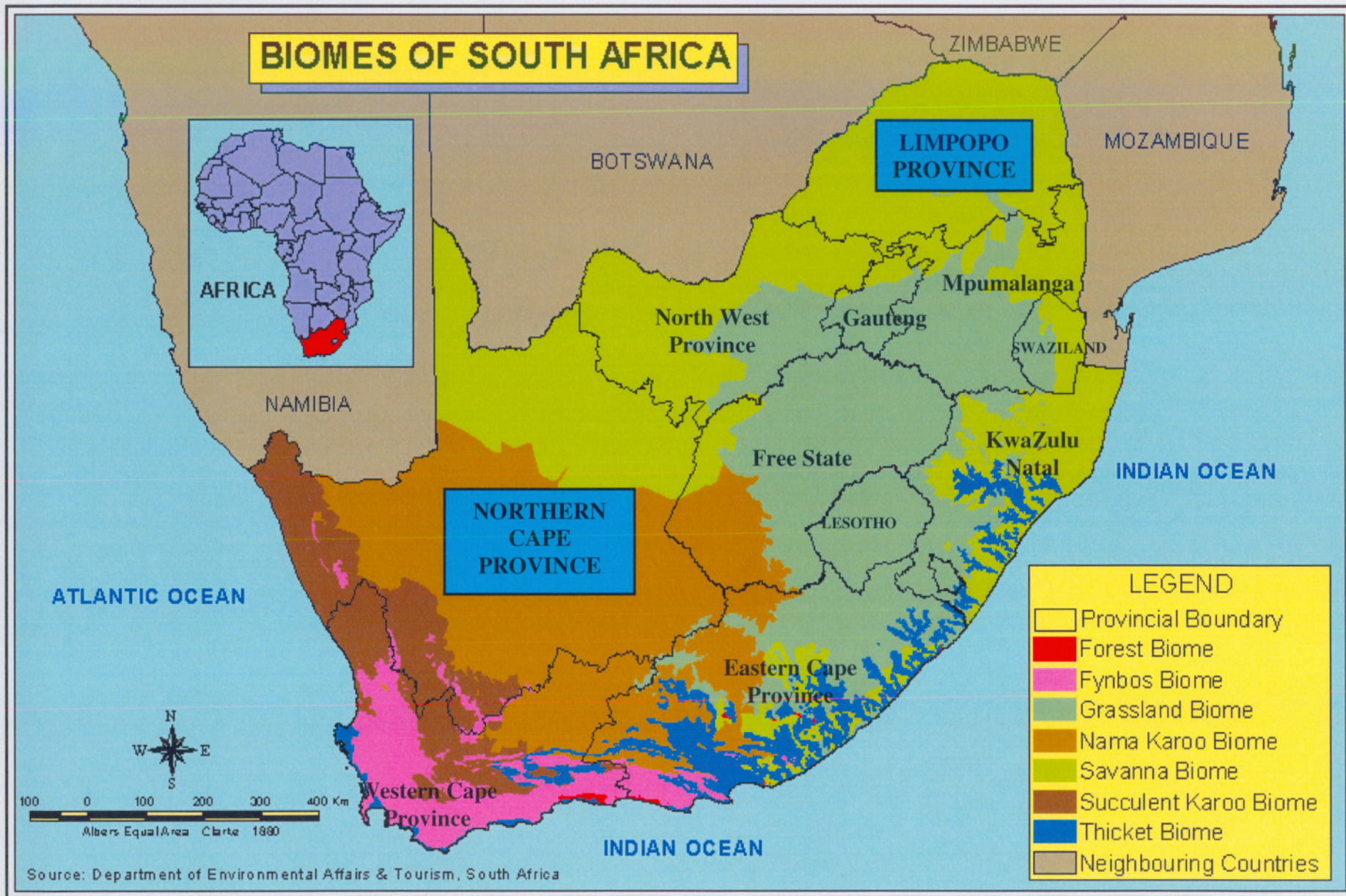


Figure 3.5: Map indicating the 7 biomes of South Africa, where surveys were carried out within the Northern Cape and Limpopo Provinces. (Source: Department of Environmental Affairs and Tourism, South Africa).

### 3.2.2. Vegetation

The nine sites sampled for the purposes of this study, fall within the Mixed Bushveld vegetation type (A18) of South African (Low & Rebelo, 1996). Other synonyms for this vegetation type are the Sourish Mixed Bushveld (A19) and Broad-orthophyll Plains Bushveld (Acocks, 1988). This vegetation type comprises 642 600 km<sup>2</sup> of the land in South Africa. This type of bushveld represents a great variety of plant communities, with numerable variations and transitions. The vegetation varies from dense, short bushveld to a rather open tree savanna, covering the greater part of the Limpopo Province and northern parts of the North-West Province (Acocks, 1988).

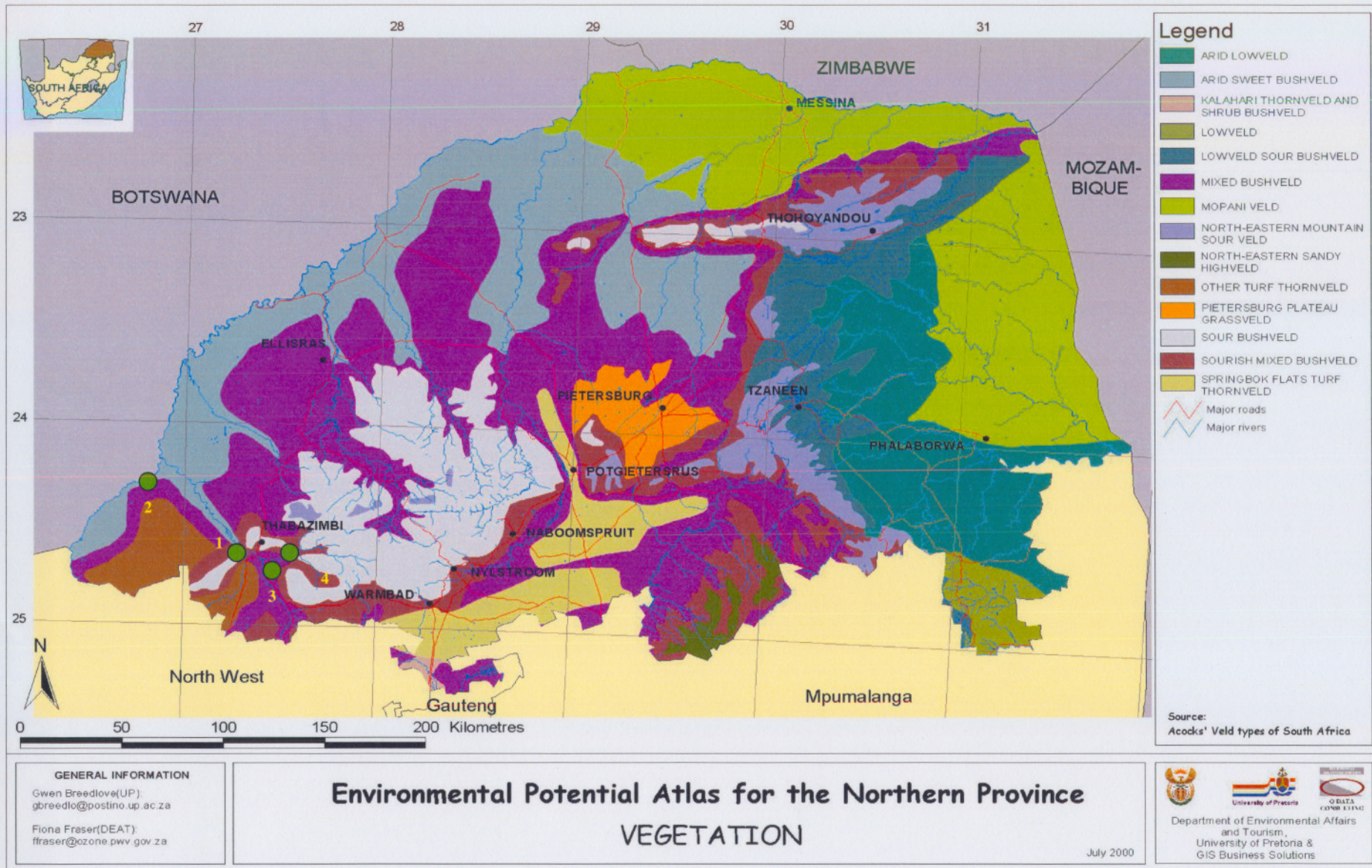
*Combretum apiculatum* dominates on shallow soils, commonly found in this vegetation type. Other trees and shrubs that also occur here are: a number of *Acacia* spp., such as *Acacia caffra* and *Acacia erubescens* (Carr, 1976) and other species such as *Dichrostachys cinerea*, *Sclerocarya birrea* and *Grewia* spp., such as *Grewia flava* and *Grewia bicolor*. This area consists of sweet grassveld and the herbaceous layer is dominated by grasses such as *Digitaria eriantha*, *Schmidtia pappophoroides*, *Antheophora pubescens* and various *Aristida* and *Eragrostis* spp. (Low & Rebelo, 1996).

The vegetation types and location of the four main study sites, in which the nine sample plots are situated within the Limpopo Province, are indicated in Figure 3.6. Especially important are the vegetation types in the southwestern part of the province surrounding the Thabazimbi-area, as they are often prone to a high bush encroachment rate. This is usually caused by a combination of factors favouring the specific rangeland condition (Arnaud le Roux, personal communication <sup>2</sup>).

The most commonly occurring problem woody species acting as encroachers in the Limpopo Province, include thorny species such as: *Acacia karroo*, *Acacia nilotica*, *Acacia erubescens*, *Acacia mellifera*, *Acacia tortilis* and *Dichrostachys cinerea* and non-

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<sup>2</sup> **Mr. Arnaud le Roux:** EcoGuard Project Manager: Selective bush control - southern Africa. Contact details: Mobile: +27-(0)83-679-7775 or E-mail: [lepetit5@lantic.net](mailto:lepetit5@lantic.net). EcoGuard website: [www.ecoguard.co.za](http://www.ecoguard.co.za)



**Figure 3.6:** Vegetation map of the Limpopo Province, South Africa ( ● = Approximate location of the four main study areas: (1) Mount Joy (1 site), (2) Twee (2 sites), (3) Leadwood Lodge (3 sites) and (4) Ben Alberts Nature Reserve (3 sites). (Source: Department of Environmental Affairs and Tourism, South Africa).

thorny species include *Grewia* spp. (e.g. *Grewia flava* and *Grewia bicolor*) (CARA<sup>3</sup>, Smit & Rethman, 1992; Smit & Van Romburgh, 1993; Smit, 1999b).

### 3.2.3. Soil and Geology

The soil found in the Mixed Bushveld of the Limpopo Province, especially where the surveys were conducted, has a coarse texture. It is sandy and usually quite shallow with overlying granite, quartzite, sandstone and shale. The percentage clay and depth of the soil differ between the different survey sites within this province (Low & Rebelo, 1996).

The clay percentage of the soil is of great importance regarding the type of woody species or problem woody species found in an area, as certain species prefer deep, sandy soils with a low clay percentage i.e. *Terminalia sericea* (Schmidt *et al.*, 2002).

### 3.2.4. Climate

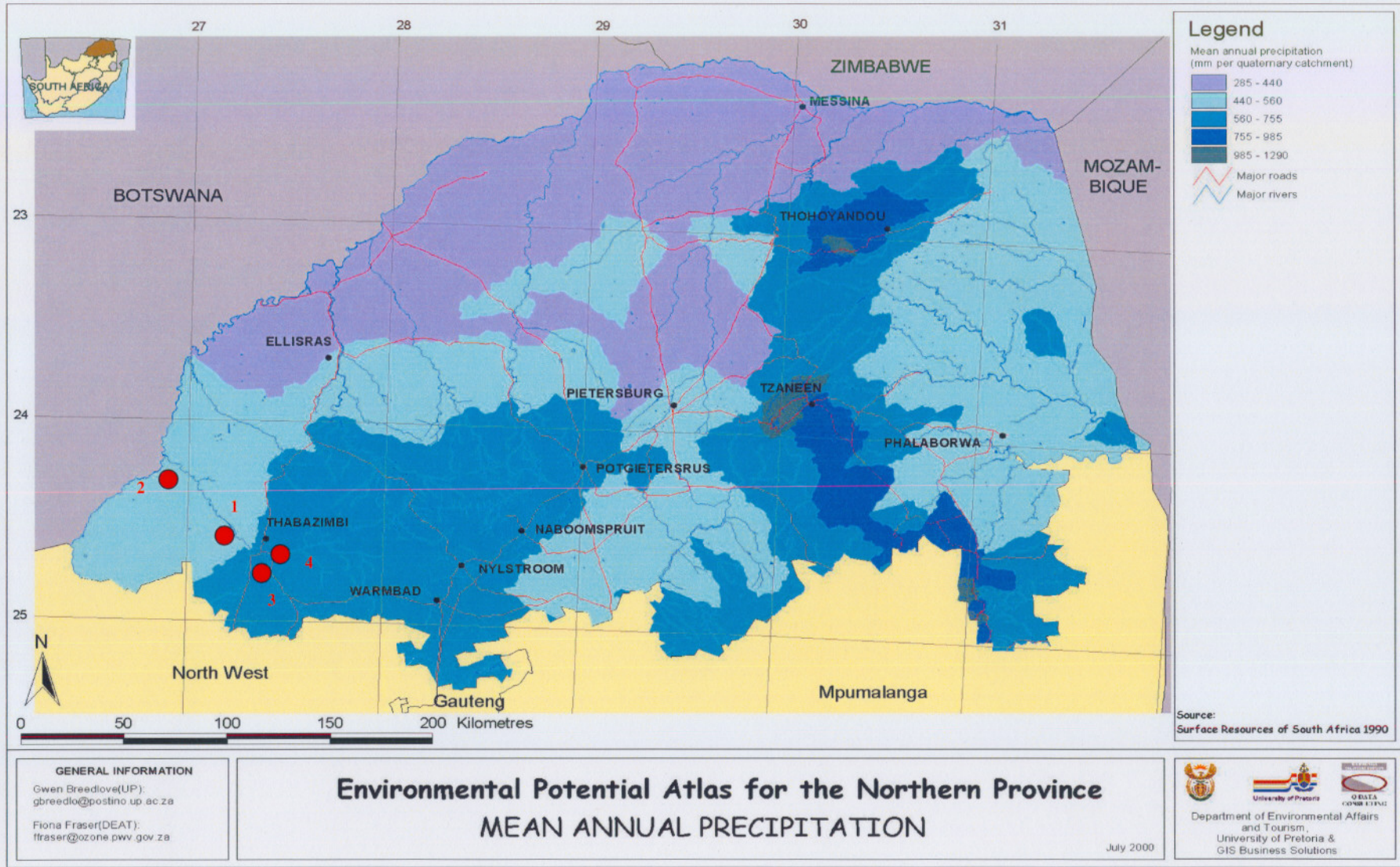
According to Low & Rebelo (1996) and DEAT (2003), the general rainfall for this vegetation type (Mixed Bushveld) varies between 350-650 mm and occurs during the summer months. Schulze (1997) estimates the rainfall to be between 400-600 mm annually and mentions that most of the summer rainfall occurs during mid summer (January). Figure 3.7 indicates the mean annual precipitation map for the Limpopo Province.

The general minimum and maximum temperatures range between -8 °C during the winter months and 40 °C in the summer. According to Low & Rebelo (1996) and Schulze (1997), the average mean temperature for this specific area within the Limpopo Province is 21 °C.

The average number of days with severe frost per annum for the Limpopo Province, especially the Thabazimbi or Dwaalboom area, adds up to a total of between 1-30 days (Schulze, 1997).

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<sup>3</sup> CARA Legislation Made Easy. Undated document. Basic contents, explanations and guidelines concerning the amended Regulations 15 and 16 of the Conservation of Agricultural Resources Act. Published and distributed by the National Department of Agriculture, Pretoria, South Africa.



**Figure 3.7:** Map indicating the mean annual precipitation for the Limpopo Province, South Africa ( ● = Approximate location of the four main study areas: (1) Mount Joy (1 site), (2) Twee (2 sites), (3) Leadwood Lodge (3 sites) and (4) Ben Alberts Nature Reserve (3 sites). (Source: Department of Environmental Affairs and Tourism, South Africa).

The short- and long-term rainfall averages differ between the nine sites where surveys were carried out within the Limpopo Province. This aspect will be discussed and elaborated on in Chapter 5.

### 3.2.5. Location of the study sites within the Limpopo Province

As previously mentioned, a total of nine study sites were chosen within the Limpopo Province in the vicinity of Thabazimbi and Rooibokkraal/ Dwaalboom areas (Figure 3.8). The sites were recommended as good case studies due to the availability of information concerning the bush control technologies that were applied in the Thabazimbi area. These sites were recommended by consultants of chemical (herbicide) distributing companies<sup>2</sup> as well as bush control contractors<sup>4</sup>.

*Mount Joy* and *Twee* (Diamond Hill), are two privately owned farms, belonging to Mr. Tony Morton (personal communication)<sup>5</sup>. *Mount Joy* (2 000 ha) is located on the Dwaalboom road between Thabazimbi and Dwaalboom (24° 34' 80.4" S; 27° 09' 38.8"). The farm *Twee* (1 500 ha) is located on the road between Rooibokkraal and Derdepoort, close to the Botswana border (24° 19' 40.8" S; 26° 44' 07.0" E). Two surveys were carried out within the same Geographical Positioning System (GPS)- location on the farm *Twee*, but the effect of different bush control technologies were sampled and documented as case studies. Both the farms are divided into breeding camps for the breeding purposes of rare antelope species (Sable, Roan and Nyala). The main objective for applying bush control technologies on these two farms, were to open up the area for it to be suitable for breeding purposes. One survey was carried out on *Mount Joy* and two surveys on the farm *Twee*.

*Leadwood Lodge*<sup>6</sup> (previously known as Rhino Eco-Park) is situated approximately 30 kilometres from Thabazimbi in the direction of Northam. This is a private game reserve (12 500 ha) previously owned by one of the iron ore mines in the area. Prior to that, it was a privately owned cattle farm. Currently this area is only accessible to tourists from

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<sup>4</sup> **Mr. Pieter Eloff:** Managing Director: Wes Enterprises. Contact details: Mobile: +27-(0)83-441-7585 or Tel: +27-(0)14-777-1330, P.O.Box 340, Thabazimbi, 0380, South Africa. E-mail: [boskos@intekom.co.za](mailto:boskos@intekom.co.za)

<sup>5</sup> **Mr. Tony Morton:** Owner of the two farms *Mount Joy* and *Twee* (Diamond Hill). Contact details: +27-(0)83-442-7334 or Tel: +27-(0)14-778-0628, P.O. Box 65, Dwaalboom, 0319, South Africa.

<sup>6</sup> **Leadwood Lodge.** Contact person: Mr. Wikus Stemmet (Head Game Ranger). Contact details: P.O. Box 454, Thabazimbi, 0380, South Africa. Tel +27-(0)14-772-1658. E-mail: [leadbush@lantic.net](mailto:leadbush@lantic.net)

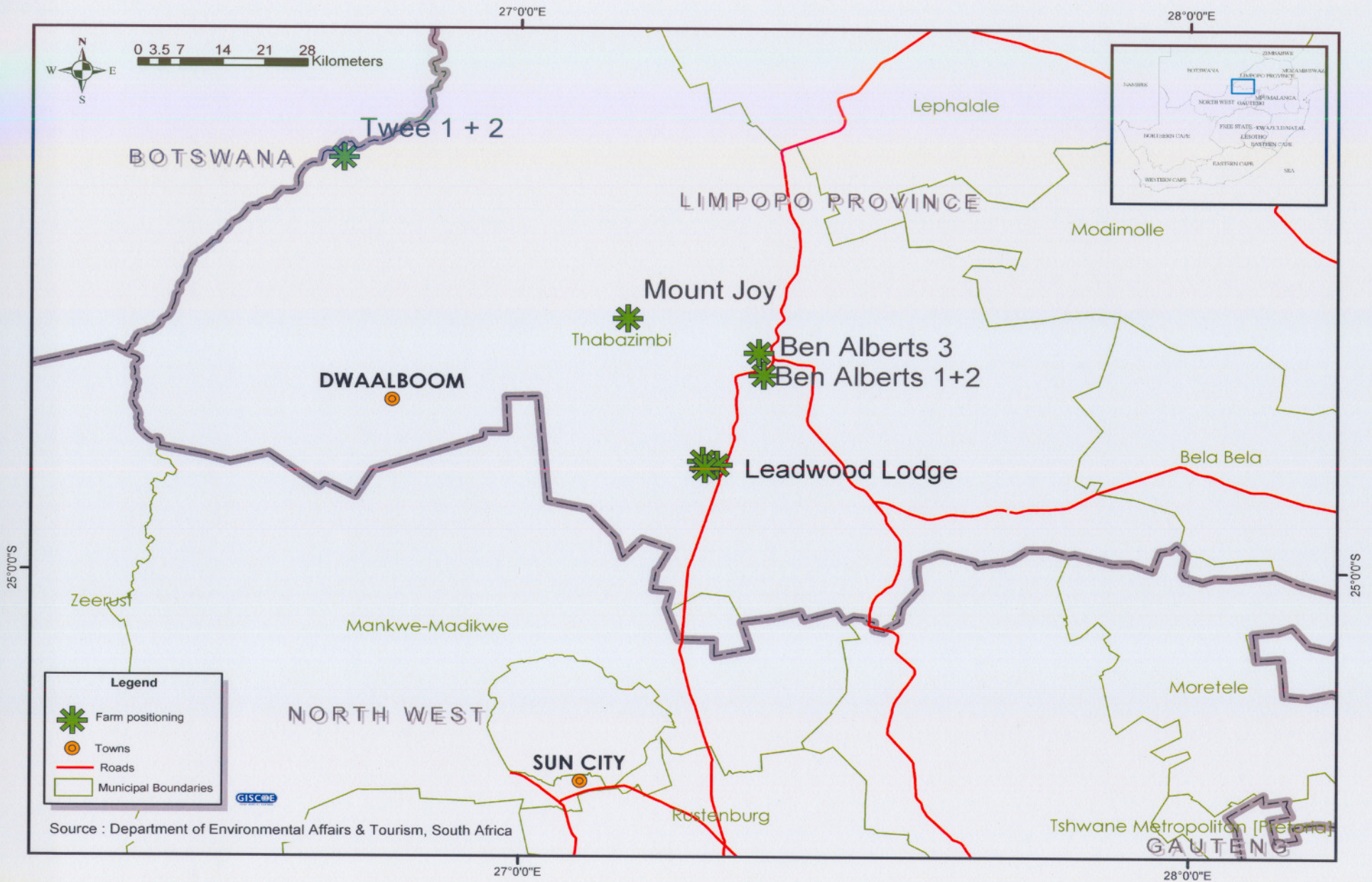
overseas, mainly for bow-hunting and local or foreign conference purposes. The main objective for bush control within the reserve was to make it more accessible and improve visibility of game to the bow hunters. Three sites were surveyed within the reserve at the following locations:

- LW1 = 24° 74' 10.3" S; 27° 21' 79.8" E
- LW2 = 24° 73' 21.4" S; 27° 22' 88.4" E
- LW3 = 24° 73' 55.8" S; 27° 26' 00.8" E

The *Ben Alberts Nature Reserve*<sup>7</sup> (currently known as Ferroland, but will be referred to as Ben Alberts for the purpose of this study) is situated approximately five kilometres from Thabazimbi in the direction of Northam. This is a privately owned game reserve, open to overseas hunters for bow-hunting purposes alone. The main objective for bush control was also to open up the area in order to improve visibility for hunting purposes. The total size of the game reserve comprises 12 500 ha and it is situated against the mountainside. Two surveys were carried out within the reserve itself, BA1 and BA2 both within the same GPS-location, on opposite sides of the road (24° 38' 39.6" S; 27° 21' 27.2" E). The third site (BA3) (24° 40' 50.3" S; 27° 21' 54.7" E), was located outside the main reserve, approximately two kilometres further up the Northam main road, but also on property owned by Ben Alberts Nature Reserve.

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<sup>7</sup> **Ben Alberts Nature Reserve (Ferroland)**. Contact person: Mr. Andries Schutte (Manager). Contact details: Tel: +27-(0)14- 777-1670, P.O. Box 1, Thabazimbi, 0380, South Africa. E-mail: [ferrobow@mweb.co.za](mailto:ferrobow@mweb.co.za)



**Figure 3.8:** General map of a part of the Limpopo Province in South Africa, indicating the different farm positions where surveys for case studies were carried out (GPS readings). The named sites (Mt. Joy, Twee, Ben Alberts and Leadwood Lodge) indicate the game farms and reserves (Source: Department of Environmental Affairs and Tourism, South Africa).

## CHAPTER 4

### PROCEDURES

As mentioned, this dissertation will only include information on the *Bush Expert* database and surveys concerning bush control of problem woody species in Namibia and South Africa.

#### 4.1. INTRODUCTION

Data was collected by means of both quantitative and qualitative sampling techniques. The qualitative data for the case studies was mainly obtained from a questionnaire, whereas vegetation-sampling procedures were carried out for quantitative data assessment.

In order to obtain high quality results for better statistical analyses and to exclude variability of edaphic, climatological and vegetation factors, survey sites were chosen to be mainly concentrated in one area (district). Approximately the same environmental conditions prevail in such districts concerning factors such as the climate, soil type and vegetation.

#### 4.2. THE *BUSH EXPERT* QUESTIONNAIRE

The *Bush Expert* questionnaire was compiled during the year 2000 at a workshop held at the Namibian Agricultural Union-building in Windhoek, Namibia. The development of the questionnaire took place in close co-operation between the different stakeholders who are experts on the control of bush encroachment and have long-term experience concerning this problem. The group of stakeholders, included scientists, land users, farmers, rangeland managers, consultants and other experts in the field of bush control. The final version of the questionnaire was tested and evaluated, in practice and in close collaboration with a land user on a farm near the town of Otjiwarongo in Namibia.

After in-depth discussions and verifications with the farmers, a final version of the *Bush Expert* questionnaire was composed (Annexure 2). The final version of the *Bush Expert* questionnaire comprises a total of 18 pages containing 24 main questions with some sub-

divisions. A total of 112 questions are contained in the questionnaire. This bulky questionnaire, took approximately one hour to complete.

The questionnaire is divided into three main sections. The first section comprises of questions about the personal information of the land user, the questions in the second section concerns the situation on the farm before bush control was applied, while the third section focuses on the type of control and the situation of the rangeland after bush control.

The questions contained in the *Bush Expert* questionnaire include the important aspects that have to be considered when effective bush control technologies have to be applied. The type of questions as divided into the three main sections of the questionnaire are as follows:

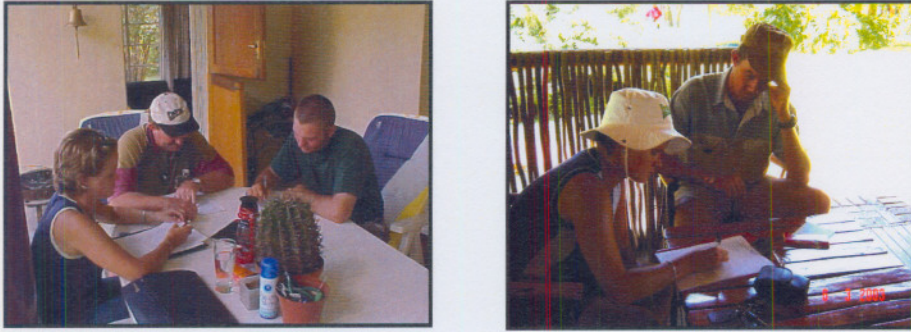
- *Personal information* concerning the farmer or land user e.g. name, contact details, farm name, farm size, farming region, number of years of experience in bush control;
- *General information* mostly including the environmental conditions in the region and questions related to the problem species (e.g. list of problem species, height classes, distribution of problem species and number of problem species per hectare); climatic conditions (rainfall, occurrence of frost and temperatures); edaphic related questions (clay percentage, general condition of topsoil, soil depth and soil type); questions on land use (e.g. grazing system applied on farm, farming enterprise, carrying capacity (kg/ha) and whether the site is near an old watering point); aim of bush control; size of controlled area; time of control; period since control and type of control technology applied. Most of the answers to these questions were provided by the land user according to his or her estimations.
- *Specified questions concerning the type of control technology* was asked in separate divisions under the heading of each control type: chemical, mechanical, manual or biological control. The information needed concerning the control methods includes aspects such as: type of control, application method, time of control, Geographical Positioning System (GPS)-reading of the bush control site, size of site, duration of control and costs involved concerning bush control.

A very important aspect of the questionnaire was the questions asked about the possible application of after-care (follow-up) technologies. This involved the re-application of a control method, a certain time after the initial control procedure (e.g. the burning of the veld, a second herbicide application or 'forced' browsing by animals). This is an important aspect seeing that it greatly determines the success of bush control on a rangeland in the long-term.

At the end of the questionnaire, a section is included in which the farmers' own opinion is asked concerning the success of the control method applied. This includes aspects such as: general improvement of the environment after the control of bush encroachment (e.g. soil erosion, increase in biodiversity of animals such as invertebrates); economical viability of control methods applied; and general findings and recommendations to other land users experiencing similar problems.

The questionnaire was completed by the person who carried out the survey (e.g. extension worker or trained farmer) in collaboration with the land user who applied the bush control technology (see Figure 4.1). Some problems arose during the completion of the questionnaire. These problems included that, due to a lack in sufficient data, often, very important questions could not be answered, which was then left out and thus caused 'gaps' in the data obtained. These problems created some difficulties in the analysis of bush control data. Although 175 questionnaires were completed, the data of only 100 case studies were used in the construction of the *Bush Expert* database.

The same questionnaire was used to obtain qualitative information in both Namibia and South Africa. Only slight changes were made in the question section on *general information*. This included questions applicable to the Namibian regions only, such as to specify the Fairly Homogeneous Farming Areas (FHFA) and the Agro-Ecological Zones (AEZ), which are not characterized in South Africa. The Namibians also refer to stocking rates of animals in the unit of kilogram per hectare (kg/ha) (De Klerk, 2004), whilst South Africans refer to it as Large Stock Unit per hectare (LSU/ha) (Milton & Dean, 1996).



**Figure 4.1:** "On-site" or "on-farm" completion of *Bush Expert* questionnaires, in collaboration with land users as done in the Limpopo Province, South Africa.

A separate questionnaire was completed for each case study. Where an after-care treatment (follow-up treatment) was applied within a study site, it was regarded as a new case study and a separate questionnaire was completed for that specific site.

### 4.3. VEGETATION SAMPLING

The agricultural extension officers from the Department of Agriculture in Windhoek initially conducted all the vegetation sampling surveys for the bush encroachment project in Namibia, but as the project progressed, a number of farmers were trained to carry out the surveys in the study areas.

Where possible, vegetation sampling was conducted by the same person/s (e.g. agricultural extension officers) that completed the questionnaire.

The time of year (seasonality) when vegetation surveys are carried out is an important aspect to be considered. The herbaceous and woody species are more easily identified during the active growing season. This is especially true when determining the success of chemical (herbicidal) bush control technologies. The results of such an application is better visible after the first rainfall. During this period, it is easier to determine whether the problem woody species has re-sprouted. The degree of recovery of the herbaceous component is also better estimated during the active growing period or rainy season. This includes the re-establishment of grasses from the natural soil seed bank.

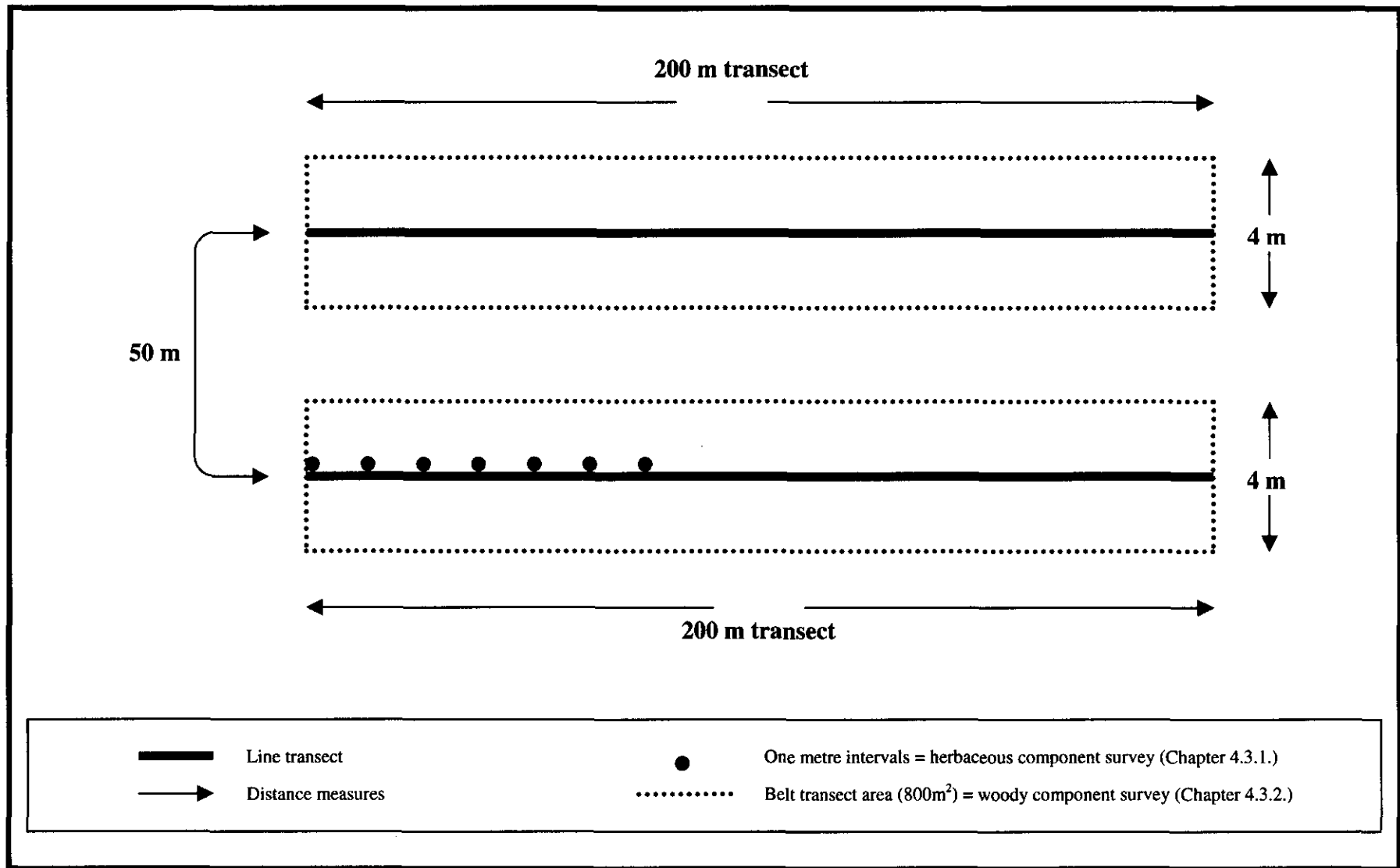
The vegetation sampling site layout (Figure 4.2) for both Namibia and South Africa were the same. Vegetation sampling was carried out in a representative, homogeneous area of the study site on each farm where the bush control technology was applied. The site layout involved a *line-transect* of 200 metres in a straight line. A belt-transect method, combined with a descending point method along the transect, was used to sample the woody and herbaceous components in each sample site (Whittaker, 1982; Sutherland, 1996; Kent & Coker, 1997; Kellner & Cilliers, 1998; Hardy *et al.*, 1999; Offwell Woodland and Wildlife Trust, 2003). A measuring tape or rope, marked at one metre (1m) intervals, was used to demarcate the extent of the transect. To form the belts for the woody component sampling, two line-transects were laid out parallel to one another, approximately 50 metres apart (line-transect 1 and line-transect 2). The total sampling area of each belt-transect comprised approximately 800m<sup>2</sup> (200m x 4m).

Two vegetation components were monitored. The woody component (problem and non-problem trees or shrubs) and the herbaceous component (grasses and forbs). A detailed description of the survey methods used for each of the two components are discussed below.

#### **4.3.1. Herbaceous component**

The abundance or frequency (expressed as a %) of the grass and forbs species within the survey sites along the two 200m transects, was determined by means of the descending point method (Mueller- Dombois & Ellenberg, 1974; Bosch *et al.*, 1989; Sutherland, 1996; Kent & Coker, 1997). According to the Offwell Woodland and Wildlife Trust (2003), this vegetation surveying method is seen as systematic sampling, where the presence of a species at each marked point is recorded.

The method involved walking along the line-transect (Whittaker, 1982) with a walking stick. The stick is lowered into the vegetation at one-metre intervals, as marked on the transect-line. The grass or forb species rooted nearest to the descended point within a radius of 30 centimetres (cm), was recorded (Figure 4.3). Grasses were recorded per species name and all forbs were combined in one group and characterized as '*forbs*'. Should the nearest rooted individual grass be an annual species, the nearest perennial was also noted. This was done in order to determine the true representation of both annual and perennial species within the study site.



**Figure 4.2:** Line diagram indicating the layout of the vegetation sampling sites for each qualitative *Bush Expert* survey. (Diagram not to scale).

If no grass or forbs species occurred with the radius of 30 centimetres of the descending point, the point was recorded as 'bare ground'.

Two 200 metre line-transects were laid out within each site. A total of 400 points were therefore recorded per site. An example of the herbaceous component survey form is included in Annexure 3.

The herbaceous component was classified into five main categories, these included:

- 1.) **Perennial grass species** (each species noted separately);
- 2.) **Annual grass species** (all the species were collectively referred to as **annuals** in the Namibian case studies. In the South African case studies, annual species were identified per species);
- 3.) ***Aristida species*** (all the *Aristida species* were collectively referred to as *Aristidas* in both Namibian and South African case studies);
- 4.) **Bare ground** and
- 5.) **Forbs.**

Problems in surveying and data capturing occur very easily when different surveyors are involved e.g. annual species being noted under one main heading for the Namibian case studies, but not for South African case studies. Variables like these also affect the reliability and analysis of the data.



**Figure 4.3:**  
Sampling of the herbaceous component in the Limpopo Province, South Africa, during the year 2002.

### 4.3.2. Woody component

Sampling of the woody component at each survey site, comprised the determining of the 1.) *Type* of problem and non-problem woody species; 2.) *Height classes* of individual plants; 3.) Growth form (*single- or multi-stemmed*); 4.) *Density* of the problem woody species per hectare and 5.) *Crown cover* of each woody plant at the height classes of:

- 0.5m
- 1m
- 2m
- 3m
- 4m
- and >4m

The woody component was sampled along the same line-transects as the herbaceous component survey, by means of the belt-transect method (Kent & Coker, 1997; Offwell Woodland and Wildlife Trust, 2003). With this method, the relative density of individual species per area can be determined. The method comprised of walking along the 200 metres line transect with a rod of two metres held perpendicular to the rope, at each side of the transect (De Beer & Jordaan, 2001). As previously mentioned, the total sampling area of each transect comprised 800 m<sup>2</sup> (4m x 200m) (Figure 4.2). All the rooted woody species within the four-metre wide belt-transect were identified and the above-mentioned parameters monitored (Figure 4.4). An example of the *Bush Expert* woody component survey form used in the South African surveys is included in Annexure 4.

The density of problem woody species was calculated per hectare (10 000 m<sup>2</sup>) by extrapolating the belt-transect data values (800m<sup>2</sup>). Should the land user not have done a bush count prior to bush control, an area similar to 'pre-control' conditions was selected, where a bush count was carried out. These sites were chosen according to characteristics such as similarities in the soil, topography and homogenous vegetation types. The bush count was carried out in order to estimate the density of problem bushes prior to the application of bush control technologies. These estimates served as the control data (see 4.3.3.).



**Figure 4.4:** Sampling of the woody component within the 800m<sup>2</sup> belt-transect area.

#### 4.3.3. Control sites

As mentioned, an area similar to the bush controlled sampling site described above, where no control technologies were applied, was chosen as the control site. A quantitative vegetation survey of the woody species was carried out within this control site, to determine the possible density of the problem woody species as it occurred before bush control.

In areas where no control site could be identified representing the vegetation condition similar to that of the area prior to bush control, an estimate of the density of the woody component during that time was made by the farmer or extension worker. This aspect was also included as a question in the qualitative *Bush Expert* questionnaire that was completed by the farmer (Annexure 2).

#### 4.3.4. Photographs

A photo was taken of the surveyed area at each sampling site (Esler *et al.*, 2002). For standardization and possible future monitoring, photographs were all taken in a northerly direction where possible. Where a control site was present, a 'before' bush control photograph was taken to get a representation of the possible condition of the rangeland prior to bush control. An 'after' bush control photograph was taken in the area where a bush control technology was applied and the vegetation survey carried out (e.g. sampling area of a specific study site). Although there is a time difference between the date of

sampling of a study site and the time of actual bush control, in comparing these two photographs the user of the *EcoRestore* DSS could still get a visual reference of the effectivity of a certain bush control technology (Figure 4.5). The photographs thus give an indication of what the density of the bush could have been, if no control technology was applied.



**Figure 4.5:** Two examples of photographs taken at a study site, 'before' (left) and 'after' (right) bush control technologies were applied.

#### 4.4. DATA ANALYSIS

As mentioned, a total of 175 Namibian bush control case studies were received of which only 100 cases were selected and incorporated into the *Bush Expert* database and first version of the *EcoRestore* DSS. As mentioned, the reason for selecting only 100 case studies, was due to the fact that many of the questionnaires received were incomplete and many data 'gaps' existed. This is a definite shortcoming in using questionnaires to gather data and when sites are sampled by different people (farmers or agricultural extension officers). Of all the study sites sampled within South Africa, only the Limpopo Province case studies (total of 9 cases) were analysed and incorporated for statistical data analyses purposes.

Both quantitative and qualitative data analysis methods (Causton, 1988) were completed for the data of each study area (questionnaires and vegetation surveys). The data was consolidated and statistically analysed.

The raw datasets received for Namibia and South African case studies, were summarised in a *spreadsheet format* (Annexure 5). The programme software used was that of the Microsoft Windows Excel programme. The reason for choosing this programme is that

the data is in a very universal format and the data could be easily updated and incorporated into the multivariate analysis programme as well as the Microsoft ACCESS database programme used for the *Bush Expert* Database in the *EcoRestore* DSS.

Most of the questions in the *Bush Expert* questionnaire were answered by ticking of the appropriate answer given by the land user in a multiple answer line (blocks as seen on the *Bush Expert* questionnaire). The given answers that the land user could choose from to suite his specific situation, were often in the form of classes, e.g. Figure 4.6 explaining the possible rainfall classes.

<b>1.) RAINFALL</b>							
(a) Long-term average (mm)							
0-100	100-250	250-300	300-350	350-400	400-450	450-500	500-550
550-600	>600		X				
			↩	325 mm			

**Figure 4.6:** Example of the different 'answer classes' for questions in the *Bush Expert* questionnaire.

For the purpose of *multivariate* data analysis techniques, the classes were simplified by calculating the average value within each class (Figure 4.6). See Annexure 6 for an extended version of simplified question classes in the *Bush Expert* questionnaire. Not all the questions asked involved classes. Some answers were indicated by choosing the appropriate action indicated or by answering the question in writing.

Other adjustments that were made to simplify the data for processing purposes, involved combining of species of the same genus name. This change only applied to certain species of the woody component having the same palatability and browsing value e.g. *Grewia flava* and *Grewia flavescens*, were indicated as *Grewia* species in the analyses. The values of occurrence for each genus were added together and then indicated as a total for the *Grewia* species. The same was done by separately grouping all the species of *Aristida* and *Asparagus*, as well as the different annual grass species (only Namibian data) grouped under the name 'Annuals'.

All the data from the questionnaires and vegetation survey forms were consolidated and analyzed accordingly.

#### 4.4.1. Statistical analysis

*Country specific statistical data analyses* were done separately for the 100 selected case studies from Namibia and the nine South African case studies for the Limpopo Province. The results obtained from the data were presented in histogramme format and will be discussed in detail in section 5.4 of Chapter 5 (Results and Discussion).

*Multivariate analysis techniques (MVA)* were used to analyse the data for the combined study areas, consisting of both Namibian and South African case studies. The reason for combining the case studies for the purpose of multivariate analysis is, that only nine of the South African case studies were included in this dissertation and thus one would not be able to define definite conclusions from the data, as it would be insufficient in terms of number of case studies.

This type of analysis (MVA) is the branch of mathematics that deals with the examination of numerous variables simultaneously: the need for multivariate analysis arises whenever more than one characteristic is measured on a number of individuals, and relationships among them to be studied simultaneously. As in this case, when there are several environmental variables to be taken into consideration, the appropriate approach is multivariate and a possible method is *Canonical Analysis* (Orlòci, 1978). Multivariate analysis provides a relatively objective, easy summarization of the data, which both facilitates the ecologist's comprehension of the data and provides a means for effective communication of results (Gauch, 1982).

Combined statistical analyses were carried out with the computer software programme Canonical Correspondence Analysis (CANOCO) (Ter Braak, 1987; Ter Braak, 1988; Ter Braak & Verdonschod, 1995), STATISTICA for Windows (1995) and the statistical package, GenStat for Windows (2000). These analyses included several multivariate analysis techniques as well as the determination of multiple regressions and Analysis of Variance (ANOVA), concerning the environmental variables and problem woody species and herbaceous species.

Multivariate data analysis techniques were used to determine the most important factors influencing the success rate of bush control technologies. Another aspect that was determined was that of the positive and negative correlations between factors such as vegetation species and environmental variables.

All the multivariate analysis ordinations were completed either by means of direct gradient analysis (Redundancy Analysis ordination - RDA) or indirect gradient analysis techniques, such as Detrended Correspondence Analysis (DCA) and Principal Components Analysis (PCA) (Kent & Coker, 1997; Kellner & Cilliers, 1998; Lěps & Šmilauer, 2003).

Computed PCA scores indicate, in decreasing order of importance, the distribution of case studies and give a graphical representation of the first few given variables, that might indicate a pattern in the data (Rayner, 1969).

*Manipulation of species data for combined statistical analysis purposes*

For the purpose of Redundancy Analyses (RDA), Principal Component Analysis (PCA), Analysis of Variance (ANOVA) and multiple regression techniques, separate lists for all of the woody species and herbaceous species were used. The species were combined to a certain extent to decrease the amount of variation in the data (e.g. *Terminalia sericea* and *Terminalia prunioides* were grouped under the name *Terminalias*). See Annexure 7 for a complete list of combined species names for the woody and herbaceous components. Species or groups represented by very low frequency/ abundance or density percentages (lower than 10% representation) were excluded from the datasheets, as well as those species represented in only a few case studies (e.g. *Acacia fleckii*, *A.hereroense*, *A.luederitzii*, *A.tortilis*, *Asparagus spp.*, *Catophractes alexandri* and *Colophospermum mopane*).

## CHAPTER 5

### RESULTS AND DISCUSSION

The results presented and discussed in this chapter are based on information obtained from the *Bush Expert* questionnaires and vegetation sampling surveys for the 100 case studies carried out in Namibia and nine in South Africa. Only these nine South African case studies sampled within the Limpopo Province will be discussed. An introduction will be given to describe the different control technologies used for bush control purposes; whereafter country-specific results will be given separately for both *Namibia* and *South Africa*. The result of the statistical evaluations will be combined for both countries. The final part of the Results and Discussion chapter will include the economical implications that need to be taken into consideration, during the control of bush encroachment.

#### 5.1. INTRODUCTION

The control of bush encroachment (and alien invasives) can be divided into four main technologies. Each technology involves different methods of application. These four technologies include chemical, mechanical, manual or biological control. It is important to note that these four control technologies are not only applied individually as a bush control treatment (isolated control technology), but can also be applied as a combination of technologies e.g. mechanical or manual control in conjunction with chemical control. This involves the mechanical or manual control (cut-stumps) of the problem species, whereafter the cut-stumps are chemically treated with herbicides and thus an integrated approach is followed (De Beer & Jordaan, 2001). Bush control technologies can either be of a selective or non-selective nature (Bromilow, 1995). Selective control usually involves the thinning of a stand of bush to a certain pre-determined percentage, while non-selective control involves the total clearing of bush in a specific area (Meyer, 1997b; Smit & Rethman, 1998b; Smit *et al.*, 1999; Smit & Rethman, 2000; Smit, 2001b).

According to De Beer & Jordaan (2001) and Meyer (2000), the choice of control technology is mainly determined by the following factors:

1. **Bush density:** At low densities, problem bushes can be manually controlled. However at higher densities, more rapid methods such as chemical control technologies by means of aerial application of herbicides are recommended.

2. **Effect of the problem bushes on the herbaceous production:** When grass production is severely reduced, intensive control measures are needed.
3. **Growth form of the dominant species that cause encroachment:** Single-stemmed trees can easily be cut down and chemically treated, whereas for control of multi-stemmed trees more intensive methods are needed.
4. **Size (age) of the majority of plants:** Seedlings and young trees can easily be hacked out, while bigger trees should rather be cut down manually or treated chemically, depending on the growth form.
5. **Size of the affected area:** For the control of small areas, manual control is an option, but if larger areas have to be treated, more rapid and extensive measures are needed e.g. aerial spraying with chemical herbicides.
6. **Production potential of the region:** Large sums of money should not be unnecessarily spent in areas with low production potentials, seeing that the control effort will not be cost effective.
7. **Financial position of farmer and economic viability of the specific control technologies:** The costs of control technologies should be in accordance with the financial position of the farmer. Where possible, a land user should always opt for the most affordable technology.

The potential consequences of improper bush control practices are severe. Bush clearing should thus not be commenced without *careful consideration* (De Klerk, 2004).

A detailed discussion on the four (4) different bush control technologies and influence of each on the environment will be given in the following paragraphs.

#### **5.1.1. Chemical control**

The majority of problem woody species in southern Africa coppice vigorously if not chemically controlled with herbicides after cutting down the trees or shrubs (Teague & Killilea, 1990).

When choosing a chemical control technology, it always involves the use of herbicides as a substance. This substance can either be naturally occurring (plant hormones) or man-made (artificial products). These substances alter the metabolic processes of a plant so that the plant is suppressed, killed or its growth is altered in such a way that it becomes

less of a problem. Some growth hormones cause the plant to grow continuously (non-stop), thus causing it to grow itself to death (e.g. the herbicide/hormone Grazer 20P). Two important aspects to take into consideration when opting for chemical bush control, is the botanical composition of the area to be controlled, as well as the selectivity of the herbicide to be used (Richter, 1991).

Herbicides can be divided into *selective* and *non-selective* products. Selective herbicides are intended to affect only a target group of plants and have a reduced effect on the surrounding vegetation e.g. substances for bush control are aimed at affecting the problem woody species with no major effect on the surrounding grass, forbs and other tree species. The degree of selectivity of herbicides is however greatly influenced by the method of application, activation and effect thereof in the soil as well as the physical characteristics of the vegetation (e.g. distribution of roots). Where soil-applied herbicides are concerned, non-problem woody species also tend to be affected by the herbicide due to the extended root distribution of the plants, thus these species also come into contact with herbicides applied some distance from the stem of the problem species. Non-selective herbicides are developed to affect any plant with which they come into contact. These herbicides are targeted to destroy the plant-chlorophyll (Bromilow, 1995).

Herbicides can either work *on contact* or *systemically*. Contact herbicides affect only the plant tissue with which it comes into direct contact e.g. wetting of the plants' leaves. This is however not always an effective method, seeing that some plants are likely to recover via the remaining root systems. Systemic control involves the translocation of the herbicide throughout the whole plant from the initial site of application, e.g. soil applied herbicide taken up by the root system (Bromilow, 1995).

The herbicides used during chemical bush control can be divided into three main groups, *soil-applied*, *foliar-applied* and *cut-stump-applied* substances. Soil-applied substances (e.g. bromacil, tebuthiuron and ethidimuron as active ingredients) are applied to the soil surface and are taken up by the roots of the plant. Foliar application of substances involves the spraying of a herbicide onto the leaves of the plant, which is then taken up directly by the aboveground parts of the plant. Foliar application can be done by means of knapsack, high-pressure pump or aeroplane spraying methods. These applications should preferably be made during the active growing season of the plants that need to be

controlled (e.g. herbicides with picloram as active ingredient) (Smit, 1998; De Beer & Jordaan, 2001). Cut-stump application of herbicides involves the mechanical or manual cutting of the bush beforehand (to a height of approximately 15 cm above ground level), after which the herbicide is directly applied to the cut-stump area and bark with a knapsack sprayer or brush (Arnaud le Roux, personal communication<sup>1</sup>). Bush control technologies are thus not always applied as an individual technology, but usually as a combination of technologies as mentioned above. Favoured combined technologies include e.g., the use of chemical herbicides together with manual control. For the purpose of this dissertation, case studies where mechanical or manual removal of the problem woody plant species or parts thereof was involved prior to the application of herbicides, will only be referred to as *chemical bush control* case studies, but will not necessarily indicate a single technology application.

A number of factors that influence effective soil-applied and foliar-applied herbicides are known and will be discussed in the following paragraphs.

According to Bromilow (1995) and De Beer & Jordaan (2001), factors influencing soil-applied herbicides include:

1. **Soil moisture or rainfall:** These herbicides usually need a certain level of moisture or need to be washed into the soil by rain, before they become active and can be taken up by the plant.
2. **Clay percentage:** Most soil-applied herbicides are chemically adsorbed by clay particles, thereby rendering them inactive. Usually, the higher the clay content, the more herbicide should be applied to compensate for this loss.
3. **Soil pH:** The pH can affect the rate of herbicide breakdown and thus cause a residual effect of some chemicals.
4. **Humus or organic material content of the soil:** The organic fraction of the soil acts in a similar way than clay. Organic material is an even stronger adsorber of chemical ions than clay particles.
5. **Application method:** The type and accuracy of application equipment is of the utmost importance for successful bush control.

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According to Grobler *et al.* (2000) and Bromilow (1995), factors that affect foliar-applied herbicides, include:

1. **Climate or season:** This factor affects the plant vitality, e.g. rain can wash a chemical off before the plant has taken it up. The atmospheric humidity and temperature should be suitable (as prescribed) in order for a chemical to be effective, e.g. during dry and very hot periods, trees such as *Acacia* species, tend to 'close' their leave-pinnae in order to avoid excessive transpiration, thus causing chemicals not to be applied sufficiently over the whole leave-surface (Arnaud le Roux, personal communication).
2. **Vitality of the plant:** Plants under stress cannot efficiently absorb or translocate an herbicide.
3. **Application method and degree of wetting:** Suitable equipment and sufficient water (if necessary) should always be used for sufficient coverage of the contact surface of the plant.

Certain *advantages* and *disadvantages* exist concerning the use of soil-applied and foliar-applied herbicides (Table 5.1).

**Table 5.1:** Advantages and disadvantages of soil-applied and foliar-applied herbicides.

<b><u>SOIL-APPLIED HERBICIDES</u></b>	
<p style="text-align: center;"><b>ADVANTAGES:</b></p> <p>1.) Treatment is rapid and requires no prior mechanical actions (e.g. cut-stump treatment).</p> <p>2.) The residual effect can suppress seedling regeneration for up to 5 years.</p> <p>3.) Least expensive of all chemical methods due to small quantities of herbicide needed.</p>	<p style="text-align: center;"><b>DISADVANTAGES:</b></p> <p>1.) The substance is slow to become active. Only starts once it has rained and the substances are drained into the soil.</p> <p>2.) Required dosages are greatly influenced by soil clay and organic material content.</p> <p>3.) Sensitivity towards the product differs between tree species and the dosage needs to be adjusted as such. This complicates the treatment.</p> <p>4.) Not always very selective due to possible spreading of herbicides to other favourable tree species by means of the root system.</p>
<b><u>FOLIAR-APPLIED HERBICIDES</u></b>	
<p style="text-align: center;"><b>ADVANTAGES:</b></p> <p>1.) Application can be selective, especially when applied by hand rather than aeroplane.</p> <p>2.) Results of application can be seen rather quickly and can determine whether or not an appropriate number of trees have been affected/killed.</p> <p>3.) The result is aesthetically pleasing.</p>	<p style="text-align: center;"><b>DISADVANTAGES:</b></p> <p>1.) The procedure is very time-consuming.</p> <p>2.) Hand application of these substances is labour intensive and this procedure is more expensive.</p> <p>3.) Hazardous to apply when a strong wind is blowing.</p>

(Smit, 1998; Smit *et al.*, 1999)

According to De Klerk (2004), complete mortality of problem woody species can be achieved by applying recommended dosages of granular herbicides, such as those containing the active ingredient tebuthiuron or ethidimuron.

For the purpose of this study a number of possible herbicides were listed in the *Bush Expert* questionnaire (Annexure 2), as well as different application methods. Since the database includes some case studies of control technologies that have been applied a long time ago, herbicides that are not available on the market anymore were also listed.

Herbicides that were listed, include products such as:

- Molopo SC and Molopo GG,
- Tordon 155/225 and Tordon Super,
- Savana,
- Grazer,
- Graslan,
- Bromacil
- Bushwacker,
- Access,
- Ustilan,
- Reclaim and several others that are not mentioned here.

(Also see Annexure 8 for more details on the herbicides commonly used for bush control in southern Africa and the active ingredients thereof).

Methods of herbicide application according to Moore (2003), include:

- Aerial spraying (foliar application) or spreading of granular herbicides by means of a positive metering device (soil application) (Figure 5.1a).
- Spoon application of granular herbicides (applied to the soil surface around the stems of trees).
- Soil application of soluble herbicides by means of knapsack spraying.
- Basal stem application, involves the application of herbicide to the stems of standing trees by means of a brush or knapsack spraying (Figure 5.1b).
- Cut-stump treatment, where a brush or knapsack is used to apply soluble herbicides to the stem (cut-stump) (Figure 5.1c).

It is very important to take the rate of chemical (herbicide) application, as prescribed by manufacturers, into consideration when bush control practices are carried out, seeing that application of herbicides at a lower than prescribed rate, might cause ineffective control. Land users often tend to apply a lower rate of herbicides in order to save money and avoid the high costs. On the contrary, herbicides applied at rates higher than prescribed, can lead to a damaging effect on the whole ecosystem, rather than only the problem species. The application rate might possibly be adjusted (as recommended by agents) in order to suit a specific situation or species. This usually involves higher, rather than lower application rates of herbicides.

According to Trollope *et al.* (1989), Reed (1996) and Smit *et al.* (1999), chemical control technologies are mostly applied when:

1. The stand of problem bush is so dense that animal access is severely restricted and manual control is unsuitable due to the high tree density.
2. Where the woody component is largely unpalatable.
3. Where a majority of the trees have grown out, beyond the reach of browsers.
4. Where selective herbicides are available to affect only certain target species.

### **5.1.2. Mechanical control**

Mechanical bush control involves using a heavy implement or machinery in order to remove trees from an area, usually root-and-all, depending on the size of the tree (Figure 5.1.d & e). Heavy disturbance of the soil component is known to accompany this process, causing severe degradation of the existing grass layer and compacting the soil surface to such an extent that re-growth of grass and ephemeral species are restricted (De Klerk, 2004). Highly palatable, big tufted and perennial grasses often need to be re-established, seeing that the first species to occur after bush control are usually annual pioneer species, with low grazing values.

The disturbance of the soil surface may also lead to the stimulation of the soil seed bank or young emerging tree saplings (gullivers according to Midgley *et al.*, 2000) of the problem woody species, resulting in an aggressive re-establishment of seedlings of the problem species (e.g. *Dichrostachys cinerea*). This may lead to the occurrence of a far denser stand of problem species, than was present before the initial bush control technology was applied (Zapke, 1986; Reed, 1996; Smit *et al.*, 1999).

Should the controlled area be suitable for crop or cultivated pasture production, a mechanical control technology that involves successful removal of all trees need to be applied. The soil can then be cultivated for the establishment of crops and/or pastures. Mechanical control technologies are not recommended in areas not suitable for cultivation, seeing that it is very expensive and an environmentally destructive technology (Meyer, 2000; De Beer & Jordaan, 2001). This type of control technology is not economically viable in the sense that the costs involved in hiring or buying a mechanical implement (e.g. bulldozer) and the additional costs of fuel are very high (Scott, 1967).

For the purpose of this study, mechanical control technologies listed in the *Bush Expert* questionnaire included: The use of bulldozers, rollers, bush-eaters, bush cutters, bush harvesters or a combination of these technologies e.g. bulldozer and roller. The availability of these mechanical implements however often proved to be a problem to the land users, as well as the high maintenance costs of the machinery.

### 5.1.3. Manual control

Due to the time consuming and labour intensive nature of these technologies, this control technology is only viable if the area to be treated is small (De Beer & Jordaan, 2001). Although time consuming, manual control is a very selective bush control technology. De Klerk (2004) suggests that manual clearing (e.g. by means of bow-saws, axes and chainsaws) is one of the least ecologically disruptive technologies.

According to Meyer (2000) the different manual control methods include:

1. **Hacking or digging out the trees (uprooting):** Suitable at low bush densities where only individual trees need to be eradicated (Figure 5.1f). The root bases of woody species can be dug open and hacked out below the growing point. This method would however be unsuccessful where plants have an underground rootstock.
2. **Felling of trees:** This involves the felling of the above ground parts of individual trees by means of an axe, panga, handsaw or chainsaw. It is especially suitable for removing single stemmed plants. This method should preferably be followed-up by the application of chemical herbicides to the stump, in order to ensure successful control (cut-stump treatment) and avoid possible coppicing from the stumps or roots.

3. **Stemburning or fire-girdling:** This technique involves the smouldering and glowing (not flaming) of fire, which is ignited around the base of the tree. Cattle or sheep dung or peanut shells are mostly used as burning material. The material is packed around the base of the plant, ensuring that the entire area of the stem is encircled up to a height of about 15-20 cm. In order for this method to be successful, the fire must be hot, produce no flames and burn for a period of approximately 4-8 hours. The dormant bark and coppice buds of the trees are killed in this way. This bush control method is unpractical in controlling multi-stemmed or very small trees. It however proves to be a very affordable and cheap, although it takes very long when carried out over large areas. In comparing the effect of felling of trees with that of fire-girdling, Strohbach (1998c) found the latter control manual method to be more successful in bush control of *Acacia* species.
4. **Ring-barking or strip-barking:** Ring barking involves the removal of all the bark and cambium of a tree in a 30cm wide band around the stem at a height of about 50 cm above ground. Strip-barking on the other hand involves the stripping of the bark of the tree from approximately waist height to below the surface of the soil (Macanda & Scogings, 2003; Moore, 2003).

The manual bush control methods listed in the questionnaire for this study included the use of: axes, hand or chain saws, bushcutters, mattocks ('bospik'), stemburning or a combination of these methods. The working depth concerning this control method was also asked. It tended to be either under ground, above ground at 0-0.5 m or > 0.5 m. The working depth influenced the amount of time spent and severity of an application of a specific manual control method.

#### **5.1.4. Biological control**

Biological bush control involves the application or manipulation of natural factors that control the composition of savannas. These methods can also be used to prevent or slow down bush encroachment. The two main biological control methods used, included fire and the incorporation of browsers.

**a.) Fire**

Fire is generally accepted as a natural management component of savanna ecosystems (Trollope, 1974). The use, control and exclusion thereof, is however a contentious issue to most land users. Many farmers are afraid of burning their veld, due to the possibility of incorrect application and management thereof, as it accidentally can cause runaway fires that destroy large portions of suitable grazing. In most arid and semi-arid areas, the rainfall is very erratic and unpredictable; thus recovery of vegetation after the application of fire as a bush control method is therefore not guaranteed. Sufficient precaution measures need to be taken and implemented when fire is used as a management tool in controlling bush encroachment (De Beer & Jordaan, 2001). Fire usually does not cause total kill-off of problem trees, shrubs and other woody plants, but only causes top-kill of aboveground plant parts up to a height of 2-3 metres (Trollope & Tainton, 1986). If trees are not totally killed-off, coppicing and re-growth may occur. Such re-growth can cause a much larger bush encroachment problem in future, than initially experienced (Figure 5.1g). The extent of control of trees by means of fire will depend on the intensity of the fire and the size and growth form of the trees and shrubs (Meyer, 2000).

Fire intensity refers to the rate at which the heat energy per unit length of the fire front is released and is measured in kilojoule per second per metre (kJ/sec/m). In order to control problem woody species, a high intensity fire of more than 2 000 kJ/sec/m is needed. This is only possible if the grass fuel load is more than 4 000 kg/ha, atmospheric temperature is higher than 25°C, relative humidity is less than 30%, and wind speed does not exceed 20 km/h. In order to assure a suitable grass fuel load for this purpose, the veld needs to be rested or lightly grazed in the years preceding fire application. Burning of veld with the aim to control bush encroachment needs to take place just prior to the first spring rains and it should involve a hot head-fire (Trollope, 1999; Trollope as quoted by Botha, 2003b).

**b.) Browsers**

According to Trollope & Aucamp (1981), the most economically and ecologically acceptable way of bush utilization in an encroached ecosystem is the use of browsers. The main type of animals suitable for control of bush encroachment is boer goats, Angora goats and a number of wild game species (Botha, 2003b). Boer goats, being mainly browsers, are well suited to keep bush encroachment under control, especially as a form

of after-care following the burning of a bush control area (Zimmerman *et al*, 2003). These goats do not only utilize a wide spectrum of woody plants, but also over a wide stratum and can greatly reduce the canopy and density of the majority of problem woody species (Sweet & Mphinyane, 1986; Bester & Reed, 1998). They must be kept at high numbers in a confined area and forced to browse the area intensively for a short period of time. Goats are also relatively insensitive to chemical deterrents, such as high tannin levels present in most woody species (Botha, 2003b). Boer goats and wild game species can however not be used as control measure in very dense stands of bush, seeing that it is inaccessible to them. These animals are mainly only able to browse up to a height of approximately 1.5 m, with the exception of game farms and other conservation areas, where elephants, giraffe and black rhino are present (Botha, 2003b).

In a study conducted in Omatjenne in Namibia, where boer goats were used as biological control method, it was found that *Acacia mellifera* and *Acacia reficiens* shrubs were utilized at a much lower rate than *Dichrostachys cinerea*, which indicated the higher palatability and feeding value of the latter species (Bell & Van Staden, 1993). The goats effectively stunted the re-growth of problem species and a total increase in meat production/ha was also observed. Both these observations can be seen as positive effects of bush control and it could contribute to an increase in the financial state of the land user (Zapke, 1986).

### *c.) Natural die-back*

Natural die-back is another form of biological bush control, which only occurs in certain areas in Namibia (De Klerk, 2004). It is a totally natural process and not a well-known phenomenon in areas outside Namibia, except for the western regions of the Northern Cape in South Africa, where it occurs in isolated areas (Holz, 1986).

The natural die-back of the blackthorn species (*Acacia mellifera* subsp. *detinens*) was first observed by farmers during the mid-1970's in the northern regions of Namibia. At first, little attention was given to the disease, until around 1983 when it reached epidemic proportions (Holz & Shreuder, 1989a and Holz & Shreuder, 1989e).

*Acacia mellifera*, which has invaded about 10 million hectares of rangelands in the northern parts of Namibia, is subject to natural die-back. This disease has already killed

thousands of hectares of shrubs and trees. This form of biological bush control is of great concern to the land users, as it has opened up large areas infested by blackthorn and thereby enhanced the economic value of farms (Vermeulen, 1997).

Symptoms of this phenomenon include leaf chlorosis, defoliation, twig and branch die-back and canker formation (Holz, 1986). Internal decay of the sapwood and heartwood is evident at the base of the trunk and upper taproot. Shoot die-back and decline was positively correlated with decay at the base of the trunk (Holz *et al.*, 1989b). Blackthorn die-back is a disease of complex abiotic and biotic origin, possibly enhanced by drought stress (Vermeulen, 1997).

The main fungal species responsible for this disease are *Phoma glomerata*, *Phoma cava*, *Phoma eupyrena* and *Cutospora chrysosperma*. *P. glomerata* is the most common species. It is thought that this fungal-disease responsible for natural die-back, is biotically or abiotically stress-initiated (Holz & Schreuder, 1989a; Vermeulen, 1997).

*Acacia mellifera* seeds from different regions of Namibia (Okahandja, Neudamm and Windhoek) and the northwestern Cape Province in South Africa (Bray, Kimberley and Vryburg) were collected and examined for seedborne fungi. *P. glomerata* occurred on seeds from all regions, while the other two *Phoma* species were only found on seeds from a farm near Okahandja in Namibia. The fungi tend to colonize the hypocotyl and radicle and only *P. glomerata* grew systematically in the hypocotyl and radicle, which caused distinct lesions on the seedlings. It was concluded that seed transmission plays an important role in transferring inoculum to the appropriate tissue for successful infections (Holz & Schreuder, 1989c).

*Acacia mellifera* shrubs of all sizes and ages, growing in single or thicket stands in different habitat and soil types, are all infected by these fungal species (Vermeulen, 1997). By exposing young *A. mellifera*-plants to controlled water stress during a 65-week period, it was noted that stems were more prone to be attacked by the four pathogens. All four fungi caused significantly more discolourations than wounding alone on plants subjected to water stress and defoliation prior to inoculation and normal irrigation. However only plants inoculated with *P. cava* were severely stunted and showed typical die-back symptoms. It thus indicates that this species is considered to be the more

aggressive type and should be able to infect *A. mellifera* under normal field conditions (Holz & Schreuder, 1989d).

The *Phoma* species are most commonly found to influence die-back of *A. mellifera* trees (Figures 5.1. h & i), but the fungi has also been detected on other species such as *Acacia hebeclada*, *Acacia karroo*, *Acacia reficiens* and a number of *Grewia* species (Vermeulen, 1997). This could pose a problem in future, seeing that the extent of die-back has dramatically increased among more palatable and also non-thorny species. It is a seed-transmitted fungus, which infects seedlings at a young stage and could thus lead to unnecessary die-back of more favourable species (Holz, 1986). According to a personal communication (Marianne Strohbach<sup>2</sup>), the order of infection by *Phoma* fungi in *Acacia spp.* is usually as follows (in the order of species firstly infected to those last infected): *Acacia mellifera*, *A. reficiens*, *A. hebeclada*, *A. erioloba* and *A. tortilis*. The fungi will 'attack' *A. mellifera* rather than any other *Acacia spp.*, but should all the *A. mellifera* trees have died off in an area over a period of time, the fungi will focus on any of the other species. According to Ms. Strohbach, *Acacia tortilis* is least likely to be infected, due to its extreme hardiness.

For the purpose of this study, the options of biological control in the questionnaire included the following: The use of goats, fire (originating due to natural causes such as lightning), as well as controlled fire (human induced and planned fire control programme). The occurrence of natural die-back is not included here but asked as a separate question later on in the *Bush Expert* questionnaire (Annexure 2).

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## 5.2. AFTER-CARE

The maintenance following bush control technologies in rangelands is a very important aspect of the restoration process. When it follows an action of bush control and is directed at ensuring that the restored ecosystem fully recovers. This form of maintenance is termed *after-care* (Bradshaw, 1997).

A comprehensive follow-up or after-care programme should follow initial bush control application (De Klerk, 2004). The aims of such a programme are to prevent or stunt the re-growth and coppicing of the problem plants and promote the recovery of the herbaceous layer (Figure 5.1j). Poor veld management can neutralise the effect of bush control and lead to 're-encroachment'. Good veld management on the other hand is aimed at preventing over-utilization of the herbaceous (grass) layer in order to ensure a vigorous and highly competitive grass layer (Meyer, 2000; De Beer & Jordaan, 2001).

In order to improve the growth and production of perennial grass species, appropriate veld management procedures need to be followed. These procedures involve realistic stocking rates and adequate resting periods. However, even if good management practices are in place, the coppicing and re-growth or sprouting of problem woody species from stumps or root systems usually still occurs after a few years (Smit *et al.*, 1999).

Single-stemmed trees that were initially treated by means of a certain bush control technology tend to become multi-stemmed (numerous stems are visible from the ground level) when re-growth or coppicing of the bush occurs. If the coppicing of problem species is not prevented and controlled in time, the re-encroachment that usually occurs seems to be worse than the initial bush encroachment problem. Therefore, after-care is an essential part of any bush control management programme. Milton (1987) has found that repeated damage caused to the coppice shoots of most *Acacia* species, tend to reduce regrowth of the plant in the following season.

Many land users have neglected the condition of their rangelands after the initial control of bush encroachment and never bothered to apply after-care measures within the controlled areas. This is mostly due to the high costs involved in bush control and the intensive management of an after-care programme. This kind of negligence resulted in

many land users being furious with themselves for not applying any after-care technology, as the initial control method is of no use now and great amounts of money were wasted in the process. Consequently farmers are often forced to sell their farms, since their enterprises are running at a loss due to debts, caused by the unsustainability of their land.

Three quarters of the 100 land users that formed part of this case study and of which case studies have been incorporated into the *Bush Expert* database, indicated that an after-care programme is a very important aspect of any bush control programme. To a certain extent, it is even more important than the initial control treatment. The initial treatment usually invigorates the problem species and leads to aggressive re-growth in the future (especially *Dichrostachys cinerea*). The moral of the story is, as one of the farmers (Mr. J. A. Grové)<sup>3</sup> stated in his completed *Bush Expert* questionnaire: "If you want to farm you need to 'struggle' with the bush."

According to Trollope (as quoted by Botha, 2003b), studies were carried out where boer goats, instead of sheep or cattle, were used as management tool in an after-care programme. It was found that one goat can successfully stunt re-growth of 2 000 trees per year. This is calculated for a carrying capacity of 1-1.5 ha/SSU (Small Stock Unit) per year. During this time, the goats browse approximately 70% shrubs and graze only 30% of the grass layer. Trollope (as quoted by Botha, 2003b) also states that in a cattle-farming system, problem bushes can only be successfully controlled when the veld is burnt more frequently. For high rainfall areas, this implies burning every 4-5 years.

The most commonly used after-care technologies include:

1. **Fire:** Applied to kill re-growth and young emerging seedlings (Trollope, 1974; Trollope, 1980; Teague *et al.*, 2003).
2. **Browsers:** Used to slow down the rate of recovery. Care should be taken that enough browsing material is available; otherwise browsers will result in grazing the newly established grass layer that needs to recover sufficiently (Sweet & Mphinyane, 1986).

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3. **Chemical follow-up:** Selective use of herbicides will often be necessary to stunt re-growth (Smit *et al.*, 1999). According to Reed (1996), the advantages of chemical control as an after-care measure makes this technology the most satisfactory option for after-care, should the necessary funds be available.
4. **Manual control:** the manual control of re-growth of problem woody species is usually carried out by hacking out or pruning back the coppicing plant parts at the base of the stem (De Beer & Jordaan, 2001).

(a.)



(b.)



(c.)



(d.)

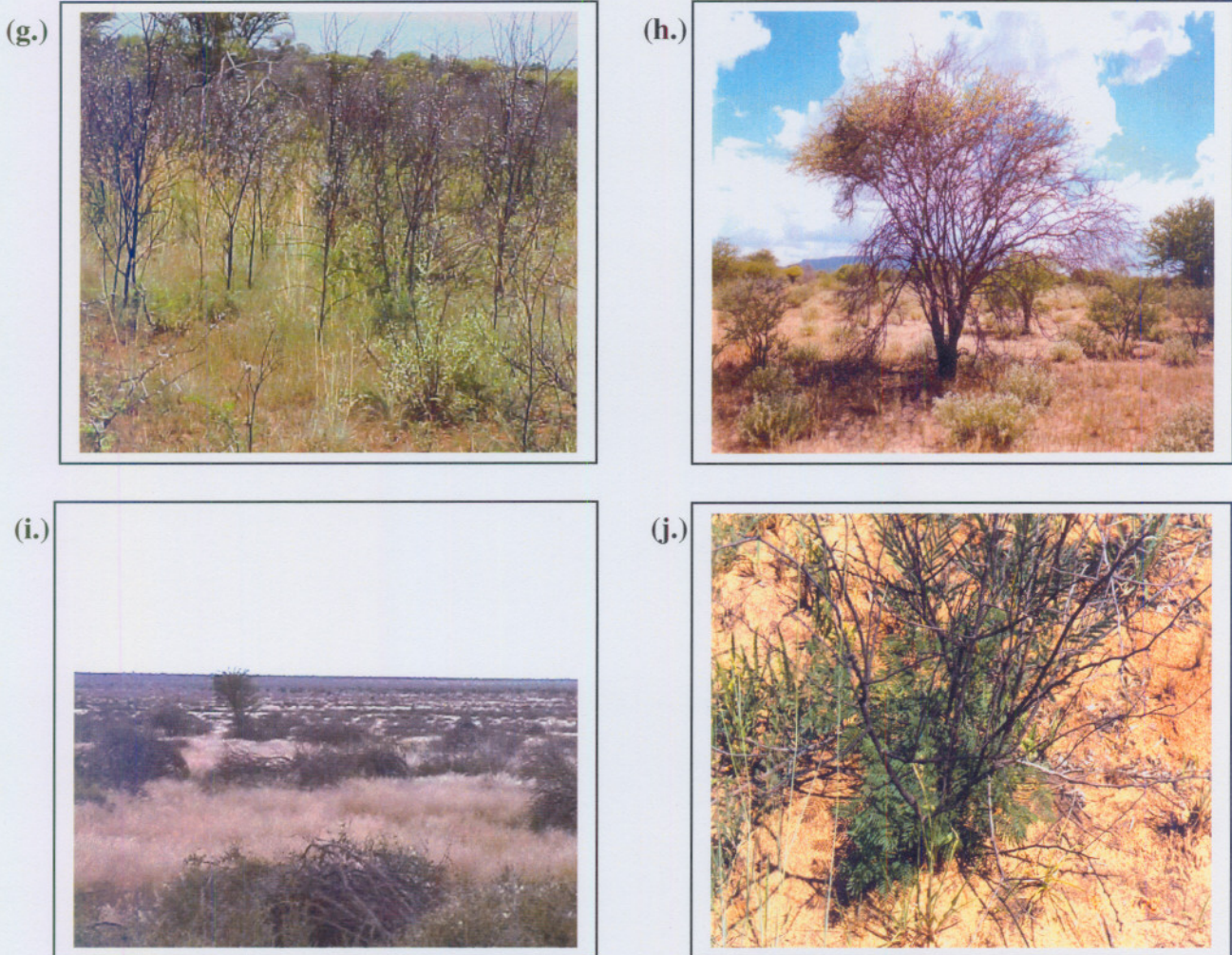


(e.)



(f.)





**Figures 5.1 a-j:** Examples of different bush control technologies as applied in Namibia and South Africa. **(a.)** Microlite aircraft used for aerial application of herbicides. **(b.)** Knapsack spraying for application of herbicides to cut-stumps or foliar surfaces of the problem woody species. **(c.)** Cut-stump treatment where herbicide (e.g. Access) is applied to cut-stumps with a brush. Note the colouring agent (Ecoblue), which helps to identify stumps that are already treated with herbicides. **(d.)** Bulldozer-type machinery used for mechanical bush control. **(e.)** Bush cutter used which is used as a mechanical implement. **(f.)** Manual bush control involving chopping problem species down with a panga. **(g.)** Area where controlled fire was implemented to control *Acacia karroo*, notice the coppicing trees. **(h.)** Natural die-back, an individual tree showing signs of defoliation and leaf chlorosis. **(i.)** Area where die-back occurred in a stand of *Acacia mellifera*, notice the grass re-establishment. **(j.)** Coppicing or re-growth of controlled problem woody species.

### 5.3. THE IMPORTANCE OF THE SEASON REGARDING BUSH CONTROL

Season of control is important, seeing that it could have a lasting effect on the population dynamics of trees and especially on the dependant browsing animals. The physiology and phenology of the plant species being controlled plays an important role concerning the season of bush control, seeing that it influences the effectiveness of the herbicides. Generally controlling bush during winter months would be advantageous, as the palatability of most mature leaves of deciduous tree species declines during the winter months. The situation may however differ from one case to another concerning the specific requirements and suggestions applying to a control technology e.g. soil applied herbicides should preferably be applied during late winter in order to ensure maximum utilization of the first rainfall occurrence during spring, which will ultimately activate the herbicide and increase its effectiveness (Prof. G.N. Smit, personal communication)<sup>4</sup>.

Other advantages of control during the winter months are mild mean temperatures, which are more suitable for the labourers applying technologies, in comparison with the extremely hot summer months. One of the disadvantages of a winter control, however, is that it could interfere with other activities, such as hunting on a game farm (De Klerk, 2004).

Bush control should be avoided during spring, as it is the time when the palatable new flush of leaves are prominent and a great source of food for animals is made available. The only form of control recommended for application during the active growing season (rainy season), is fire-girdling (stemburning), for it is during this time that the re-growth proves to be the lowest and mortality rates the highest (Strohbach, 1998b).

### 5.4. COUNTRY SPECIFIC RESULTS

The following two sections will concentrate on the different aspects that are important in the evaluation of the different bush control technologies. The first section will contain results of case studies carried out in Namibia and the second, case studies of South Africa (Limpopo Province).

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Important aspects that will be discussed are concluded from the case data and include the following information: areas in which surveys were carried out, rainfall data, different bush control technologies applied, the main aims of bush control, the representation of species causing bush encroachment within the different height classes, clay percentage of the soil, use of problem species after bush control, degree of problem woody species encroachment before and after control, herbaceous component as noted after control, as well as the period since the control of the problem bush.

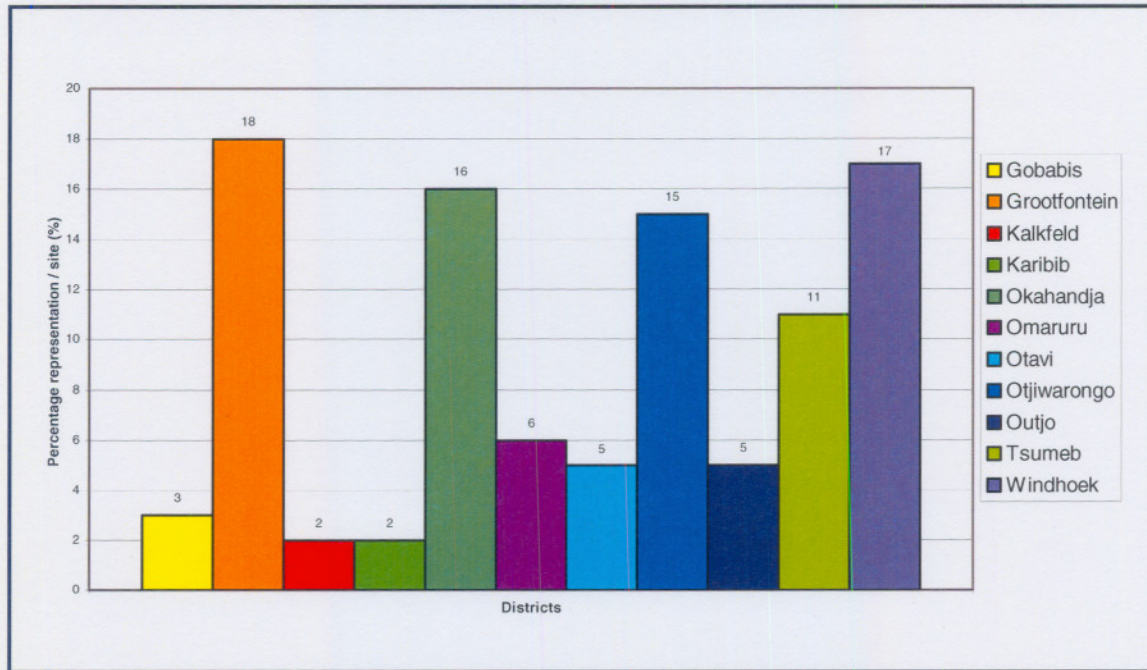
#### **5.4.1. Results from the Namibian case studies**

All of the results that will follow concerning bush control technologies in Namibia are concluded from data obtained by means of the *Bush Expert* questionnaires, as well as on-site quantitative vegetation surveys.

##### **5.4.1.1. Location of the study sites**

The 100 case studies were carried out throughout the central and northern parts of Namibia, within the following regions: Kunene, Oshikoto, Otjozondjupa, Omaheke, Erongo and Khomas. Figure 5.2 indicates the more specific location of the representative sites, occurring within the vicinity of the major districts in Namibia.

Case studies sampled were mainly found in the Grootfontein (18), Okahandja (16), Otjiwarongo (15), Tsumeb (11) and Windhoek (17) districts (See Chapter 3, Figures 3.2 and 3.3, for maps indicating the location of these districts). Table 5.2 indicates the type and number of control technologies for each district. It is important to note once again that the bush control technologies were not necessarily applied as individual treatments, but could have been applied as part of a combination of technologies. The combined technologies are however referred to as one of the individual technologies (main technologies) for the purpose of this dissertation e.g. the mechanical removal of problem species and the application of herbicides thereafter are often referred to as a chemical control technology in general.



**Figure 5.2:** The distribution of the 100 case studies in the 11 major districts of Namibia.

**Table 5.2:** The type and number of different bush control technologies, applied within the major districts of Namibia.

District (cases per district)	Control technology used (% representation of cases / technology)			
	Chemical	Mechanical	Manual	Biological
Gobabis (3)	2	0	1	0
Grootfontein (18)	11	0	7	0
Kalkfeld (2)	0	0	1	1
Karibib (2)	0	0	2	0
Okahandja (16)	14	0	1	1
Omaruru (6)	3	1	0	2
Otavi (5)	5	0	0	0
Otjiwarongo (15)	8	4	3	0
Outjo (5)	4	0	1	0
Tsumeb (11)	2	3	6	0
Windhoek (17)	10	3	4	0
<b>Total (100)</b>	<b>59</b>	<b>11</b>	<b>26</b>	<b>4</b>

The study sites were representative of a total of 14 Agro-Ecological Zones (AEZs) (Chapter 3, Figure 3.4 - AEZ map). Unfortunately many of the land users or extension officers were not sure in which AEZ the farms were situated and thus a lack of information concerning this aspect exists in this study. The main AEZs represented in this study are those on the Central Plateau, Escarpment, Kalahari Sands Plateau and Kalkveld, as indicated in Table 5.3.

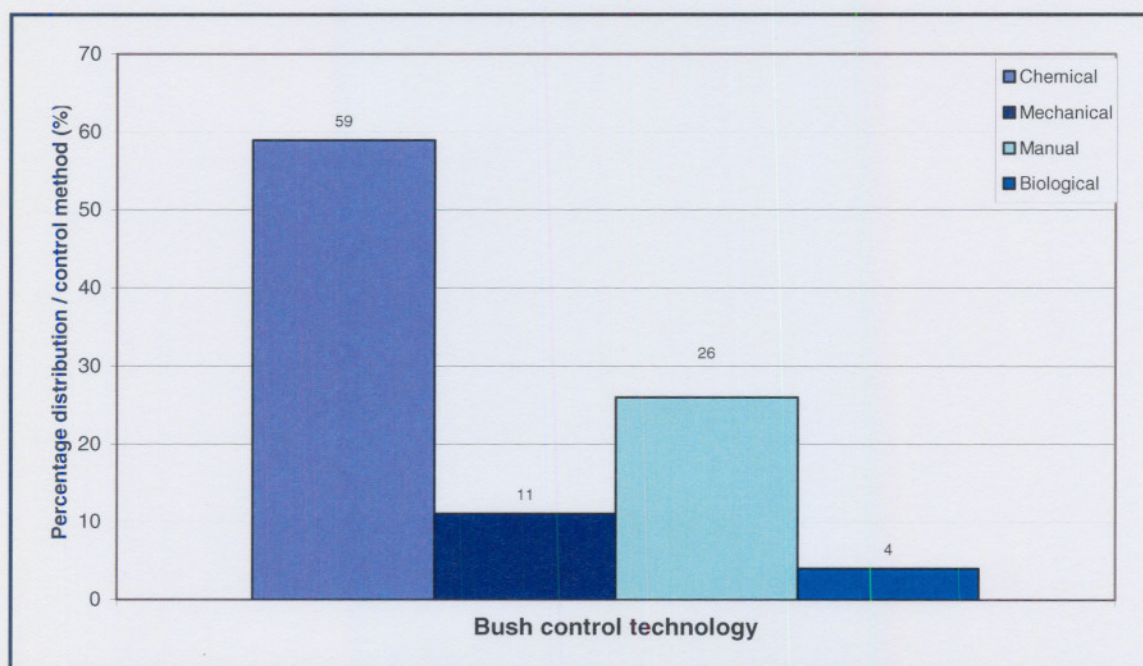
**Table 5.3:** List of the 14 Agro-Ecological Zones that are represented by the 100 Namibian case studies on bush control.

<b>Agro-Ecological Zone (AEZ)</b>	<b>Description of the AEZ</b>
CPL 1	Central Plateau, Southern Omatoko Plain
CPL 2	Central Plateau, fringe plains
CPL 3 - 4	Central Plateau, strongly dissected inselberg plains, average growing period 61-90 days, very short dependable growing period
CPL 3 - 6	Central Plateau, strongly dissected inselberg plains, average growing period 41-60 days
CPL 3 - 7	Central Plateau, strongly dissected inselberg plains, average growing period 21-40 days
CPL 5	Central Plateau, flat plains on metamorphic rocks
CPL 14 - 3	Central Plateau, table mountains on karoo rocks, average growing period 61-90 days
CPL 16 - 2	Central Plateau, red Kalkveld, average growing period 91-120 days
CPL 16 - 3	Central Plateau, red Kalkveld, average growing period 61-90 days
ESC 2	Escarpment, high mountains on Basement Complex rocks
ESC 4	Escarpment, high plateaux on Basement Complex rocks
KAL 3 - 6	Kalahari Sands Plateau, stabilized sand drift with few pans, average growing period 41-60 days, no dependable growing period
KALK 2	Kalkveld, average growing period 91-120 days, dependable growing period 80% of average
KALK 3	Kalkveld, average growing period 61-90 days, dependable growing period 60% of average

(See Figure 3.4 as displayed in Chapter 3 of this dissertation for additional information on the distribution of the Agro-Ecological Zones).

#### 5.4.1.2. Bush control technologies applied

Four different control technologies were applied by land users in Namibia. These included chemical (Ch), mechanical (Mc), manual (Mn) or biological (Bio) control and sometimes a combination of technologies. Figure 5.3 clearly indicates that the most commonly applied technology was chemical control (59%), followed by manual control (26%), mechanical (11%) and biological control (4%).



**Figure 5.3:** Distribution of the number of case studies per control technology in Namibia.

Each of the four control technologies is further divided into sub-categories. These include the type of application method for each of the four control technologies.

According to Figure 5.4a, the most commonly used herbicides within the 59 chemical bush control case studies included Grazer (20%), Savana (15%), Ustilan 10GG and Molopo GG (13.5% each), and Graslan 20P and Reclaim (12% each). According to Reed (1996), from a study carried out in Namibia where the problem woody species *Acacia mellifera* was controlled, it was observed that this species tends to be quite sensitive to the active ingredient tebuthiuron. This ingredient is present in most of the above-mentioned herbicides. Annexure 8 contains a detailed list of herbicides used, as well as the active

ingredient and type of formulation of the product. A list of the problem woody species that occurred in Namibia (and South Africa) and that were sampled during this study, together with recommended herbicides that can be used to control these species, is given in Annexure 9.

Figure 5.4b indicates the different possible methods of herbicide application. The most common application method according to answers obtained from the *Bush Expert* questionnaires and as indicated by the land users, proved to be aerial application (46% of the chemical control case studies), followed by soil-application by means of spraying (29%), soil application by means of the spoon method (22%) and stem-spraying (3%).

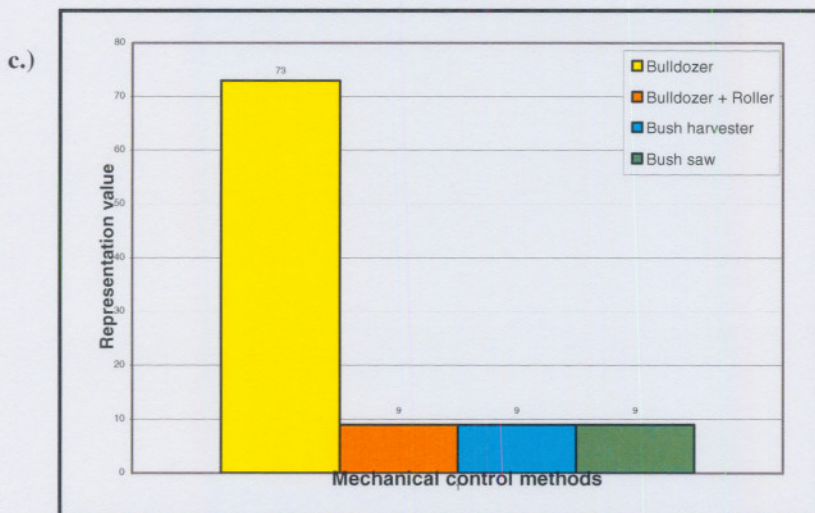
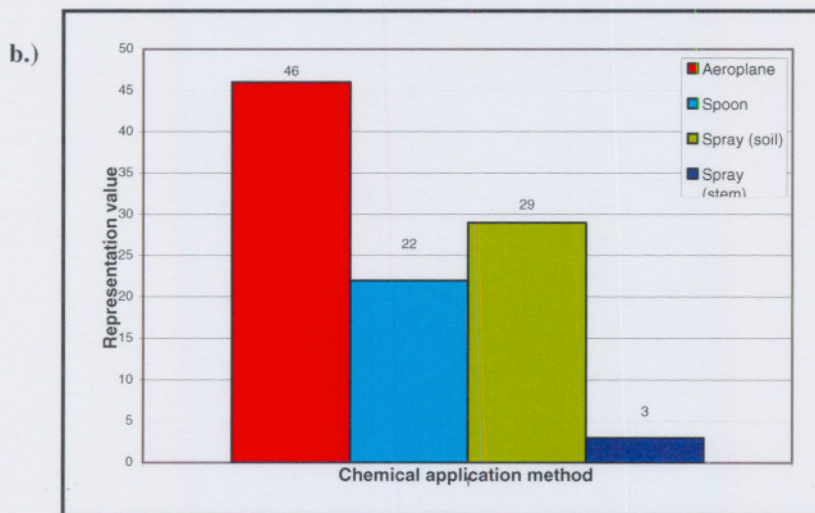
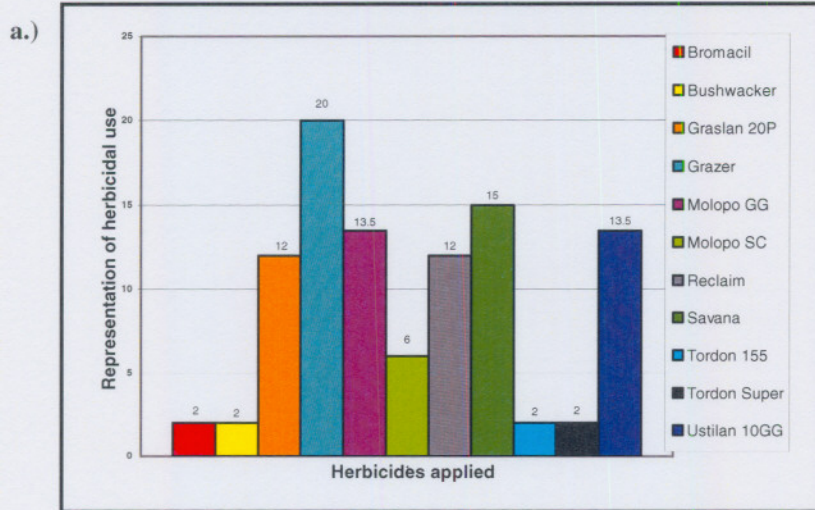
Although aerial application proved to be the most favoured herbicide application method used in Namibia in the past, it should however be stressed that this result does not necessarily reflect the most effective or ecologically sound method of application concerning bush control in general. The reason for this is that aerial application is not a very selective method of bush control, seeing that favourable (non-problem) woody and also herbaceous species might also be affected by the applied herbicides. This is especially true in cases where herbicides are applied by means of a fixed-wing aircraft rather than a helicopter. More recent case studies indicate the tendency to rather use more selective chemical application methods.

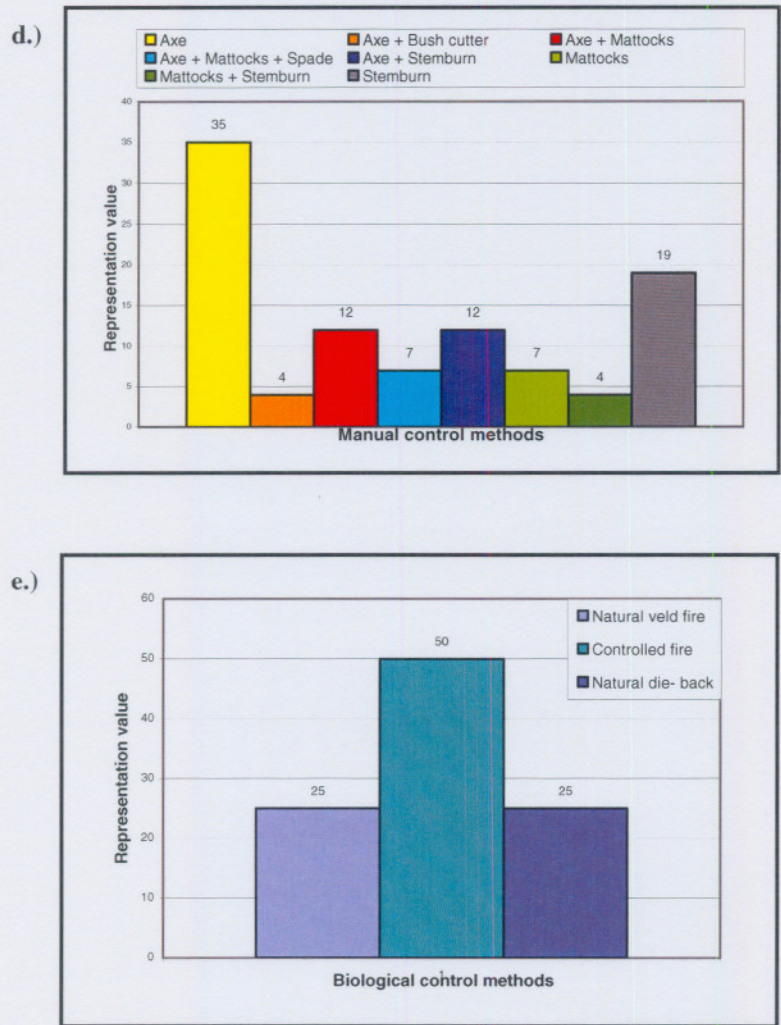
Of the four different mechanical control methods that were applied, the use of bulldozers proved to be the most commonly used method. A total of 73% of the case studies indicated the use of a bulldozer, followed by evenly distributed use (9% each) of a bush saw, bush harvester and a combination of bulldozer and roller (Figure 5.4c).

The use of axes proved to be the most commonly applied manual control method in Namibia (35% of the case studies). Stemburning was also regularly applied (19%), followed by other methods, such as axe and stemburning in combination (12%) and axe and mattocks use in combination (12%). A total number of eight different manual control methods were used throughout Namibia (Figure 5.4d).

Although many more case studies of biological bush control exist in Namibia, only three methods were surveyed during this study (Figure 5.4 e). This included controlled fire

(50% of the case studies), the occurrence of natural veld fires (25%), as well as natural die-back caused by the fungi *Phoma glomerata* (25%).





**Figures 5.4 a-e:** Indication of the different methods used for each of the bush control technologies applied: (a.) Type of herbicides applied, (b.) chemical application methods, (c.) mechanical, (d.) manual and (e.) biological application methods.

### 5.4.1.3. Rainfall areas

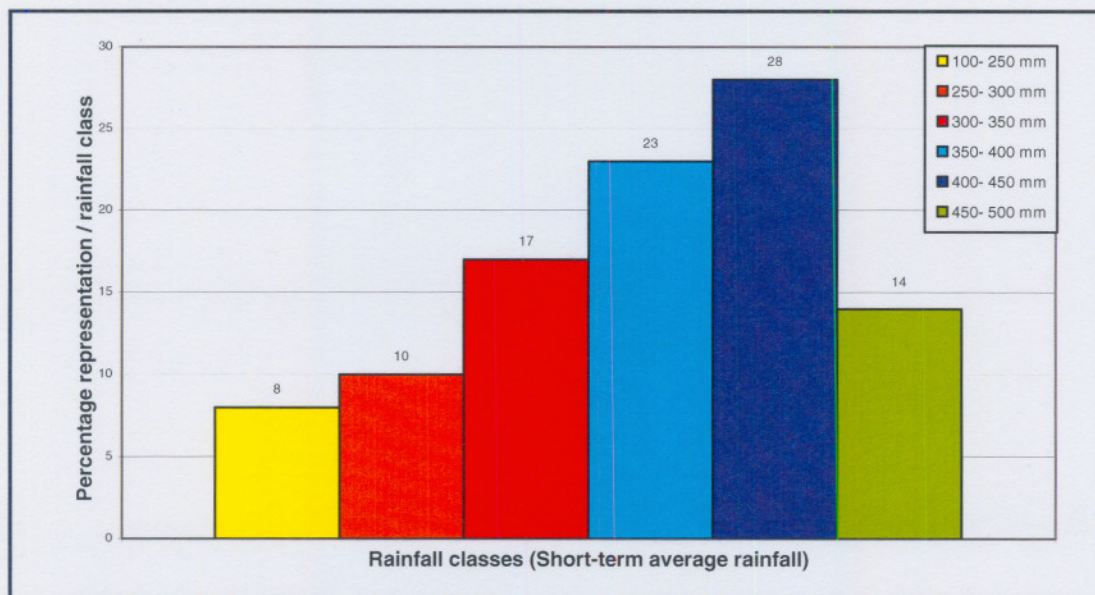
Long-term (> 30 years) and short-term (last 5 years) rainfall values were obtained from the *Bush Expert* questionnaires that were completed by the agricultural extension workers in collaboration with the land user. The values are indicated within certain rainfall classes e.g. 100-250 mm and 250-300 mm.

Short- and long-term rainfall data is important to evaluate the effectivity of a certain control technology at a specific study site. The re-growth of the woody and herbaceous

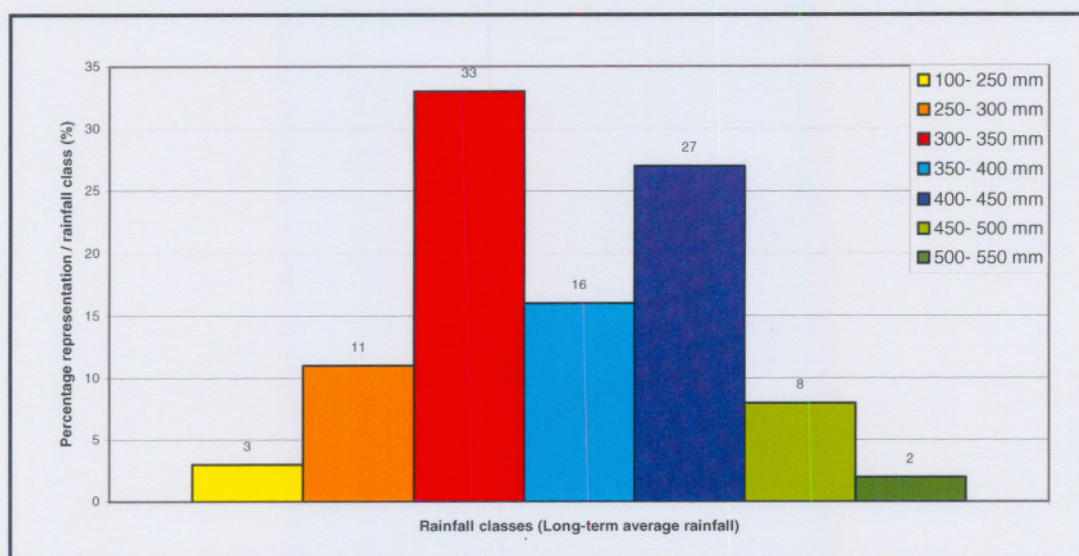
components is affected by especially the short-term rainfall. The arid and semi-arid regions are mainly rainfall-driven systems, which have an important effect on the bush encroachment problem.

Figures 5.5 a & b represent the number of case studies that are characterized by the short- and long-term rainfall classes. Regarding the short-term rainfall data, most of the case studies (28%) fall within the 400-450 mm rainfall class. As for the long-term rainfall, most case studies (33%) were represented within the 300-350 mm class. This included data of study areas mostly situated in the Okahandja (16%), Otjiwarongo (13%) and Grootfontein (135) districts of Namibia. (Figure 3.2 in Chapter 3, refers to the mean annual rainfall for all the above-mentioned districts and Figure 3.3 indicates the specific location of these districts).

Concerning the short-term rainfall, 68% of the case studies were sampled within the 300-450 mm rainfall range and 76% in the same long-term rainfall class. It therefore seems that the problem of bush encroachment as surveyed during this study, is more severe in these areas (Figure 3.1. in Chapter 3 clearly indicates the districts where the highest bush densities occur).



**Figure 5.5 a:** Number of case studies (of the 100) within the short-term average rainfall classes for Namibia.



**Figure 5.5 b:** Number of case studies (of the 100) within the long-term average rainfall classes for Namibia.

#### 5.4.1.4. Soil clay percentage (%)

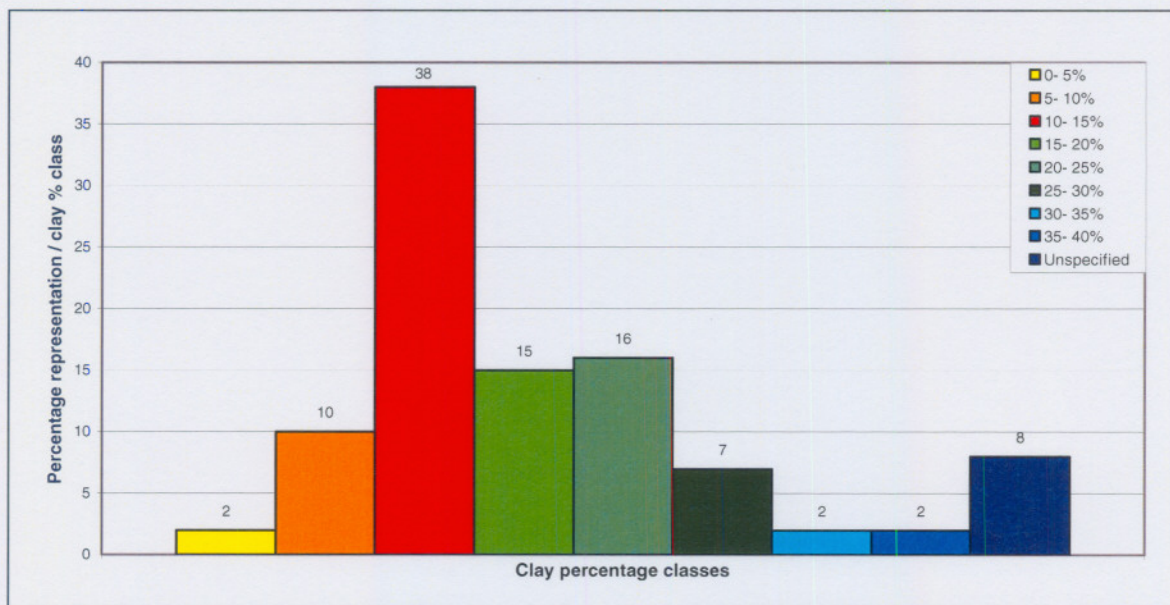
According to the results obtained from the *Bush Expert* questionnaire (indicated as answers given by the land users or extension officers) represented in Figure 5.6., the clay percentage of the soil in the majority of case studies in Namibia are within the class of 10-15% (38%), followed by 15-20% (15%) and 20-25% clay (16%). The 10-15% and 15-20% clay classes are characterized by a sandy loam type of soil and the 20-25% class by a sandy-clay-loam soil texture.

The soil clay percentage is important in the application of certain control technologies. These include soil-applied herbicides used in chemical bush control, as well as mechanical control technologies. Also see 5.1.1 and 5.1.2.

As mentioned previously, heavy mechanical implements cause widespread compaction and disturbances of the grass-stands. It negatively impacts on the soil condition, which leads to the dominance of less productive and less palatable grass species. Sandy soils tend to be poor in nutrients because of the leaching effect that occurs when water infiltrates the soil. More fertile soils are often indicated by a higher clay percentage. The bush control management seems to be more effective in these soils, seeing that grass production tends to be higher and re-growth of trees easier to control. Sites to avoid when opting for

mechanical control technologies are those on sandy, sodic or duplex soils with a high erosion risk (De Klerk, 2004).

According to the results obtained from the *Bush Expert* questionnaires, it is clear from Figure 5.6, that 38% of the study sites occurred in areas with a sandy-loam complex (10-15% clay). It seems that this soil texture class occurred in most soil applied chemical bush control technologies. These soils may however tend to lack sufficient soil nutrients, except for areas where leguminous tree species, such as *Acacia spp.* occur. These species greatly contribute to the nitrogen in the soil substrate (Smit & Swart, 1994).



**Figure 5.6:** The number of case studies (of the 100) in the different soil clay percentage classes for Namibia.

#### 5.4.1.5. Density of the problem woody species

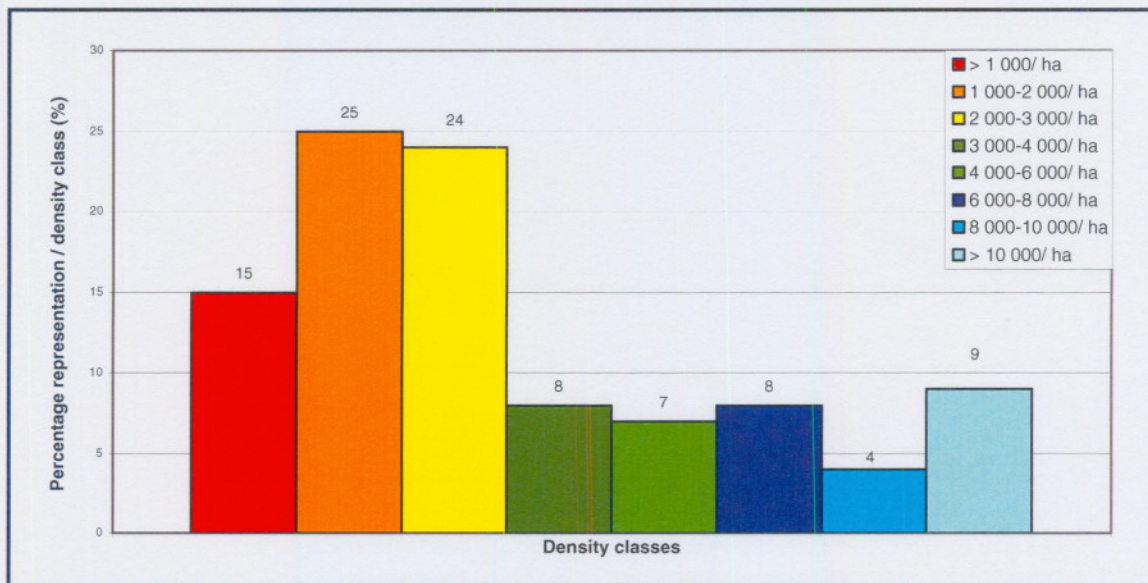
Data obtained from the questionnaires concerning the density of woody species within the chosen study sites, is of value when comparing the densities of problem bush, before and after control. By doing this, the success of the applied technology over time can be estimated. It is important to note that tree densities were measured as trees per ha (trees/ha) and not as Evapotranspiration Tree Equivalents per hectare (ETTE/ha). The trees/ha unit is more commonly used by land users.

Most of the case studies indicated a slight to dramatic decrease in bush densities after control (Annexure 10). However a number of land users complained about only a fatuous

decrease in numbers or even an increase thereof, which clearly indicates an unsuccessful application of the control technology, or a lack in after-care, including proper management strategies following the initial control. Nine percent (9%) of the Namibian case studies indicated an increase in bush density after control for the periods ranging between 7-13 years since control. The increase in bush densities in these case studies can readily be explained by the fact that no after-care was applied in any of the cases, except in one, where *Cenchrus ciliaris* was established as a cultivated pasture.

The bush densities before control are indicated in Figure 5.7. The majority of case studies comprised of bush densities of between 1 000-2 000 (25%) and 2 000-3 000 (24%) trees/ha. A total of sixty-four (64%) of the case studies were characterized by tree densities varying between >1 000-3 000 trees/ha, which indicates that most of the stands had lower densities. A number of cases did however indicate very high densities before bush control. In eight case studies the tree density was 6 000-8 000 trees/ha and in nine (9), the density was > 10 000 trees/ha. These areas where the highest densities were observed, were mostly in the Windhoek and Tsumeb districts (these densities are in accordance with the bush species and densities map of Bester as seen in Chapter 3, Figure 3.1).

Most of the case studies indicated a decrease in bush density after control, which indicates successful control of the encroachment problem in these areas (Annexure 10 indicates the bush density values for the before and after bush control situation in the case studies). A few case studies (9 case studies) however indicated an increase in bush density after control. These nine case studies and the possible cause of increase in bush densities will be discussed in section 5.4.1.12.



**Figure 5.7:** Number of case studies (of the 100) within different bush density classes, before control in Namibia.

#### 5.4.1.6. Aims of bush control

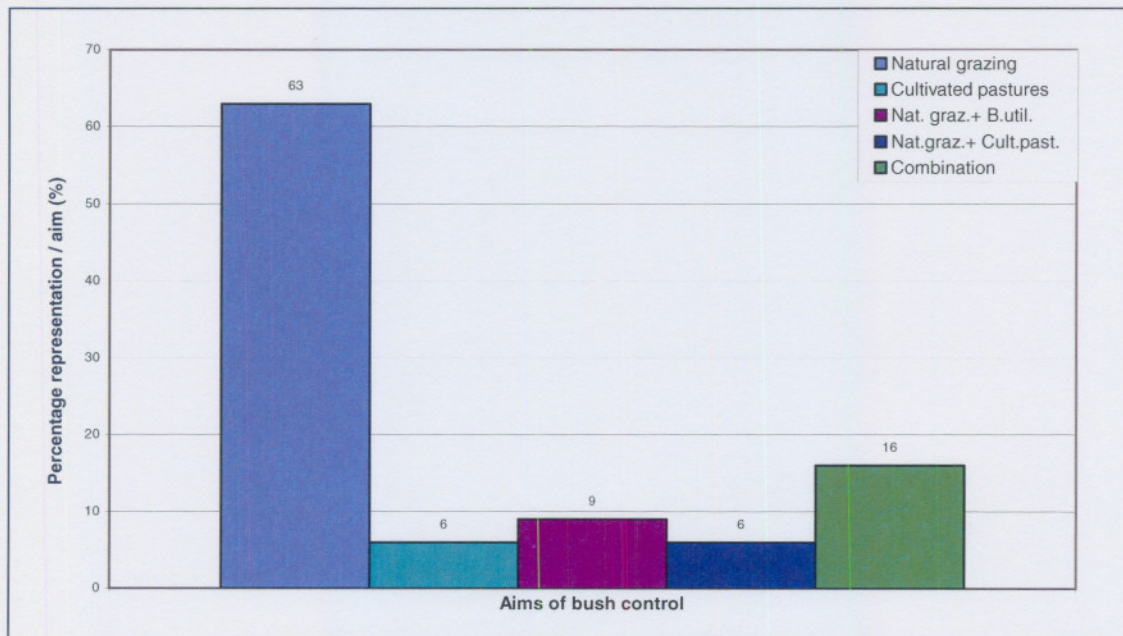
The results obtained from the *Bush Expert* questionnaire indicated that land users in both Namibia and South Africa most commonly applied bush control technologies for the following reasons:

1. *Natural grazing* to increase grazing and carrying capacity of the land.
2. *Cultivated pastures* to increase grazing capacity by producing extra fodder for livestock in the dry seasons. Figure 5.8 indicates an example of a *Cenchrus ciliaris* cultivated pasture.
3. *Bush utilization* in the form of charcoal or firewood, which illustrates that bush encroachment can be positively utilized (Reed, 1996).



**Figure 5.8:** *Cenchrus ciliaris* cultivated pasture.

From Figure 5.9, it is evident that the most common aim of bush control in Namibia is to improve the natural grazing (63%). This is mostly for cattle and sheep farming or game ranching. Bush encroachment limits the availability of grazing and movement of such animals and by the implementation of bush control practices, the grazing capacity and optimum production of the land can be increased. Another aim of bush control is that of a combination of aims (16%) (Figure 5.9), which includes the improvement of natural grazing, the production of charcoal as by-product after bush control, as well as the establishment of cultivated pastures.



**Figure 5.9:** Main aims of bush control in Namibia, as preferred by land users.

#### 5.4.1.7. Use of the problem woody species after bush control

The use of problem species after bush control in both Namibia and South Africa varied according to the type of farming enterprise and financial inputs of the land user. Some of the uses include activities that generate additional income to the land user, e.g. production of charcoal, manufacturing of fence poles or 'droppers' and the production of fuel- or firewood (Figure. 5.10). Figure 5.11 indicates the type and percentage representation of the different uses of problem bush in Namibia.



Figures 5.10: Production of fuel or firewood.

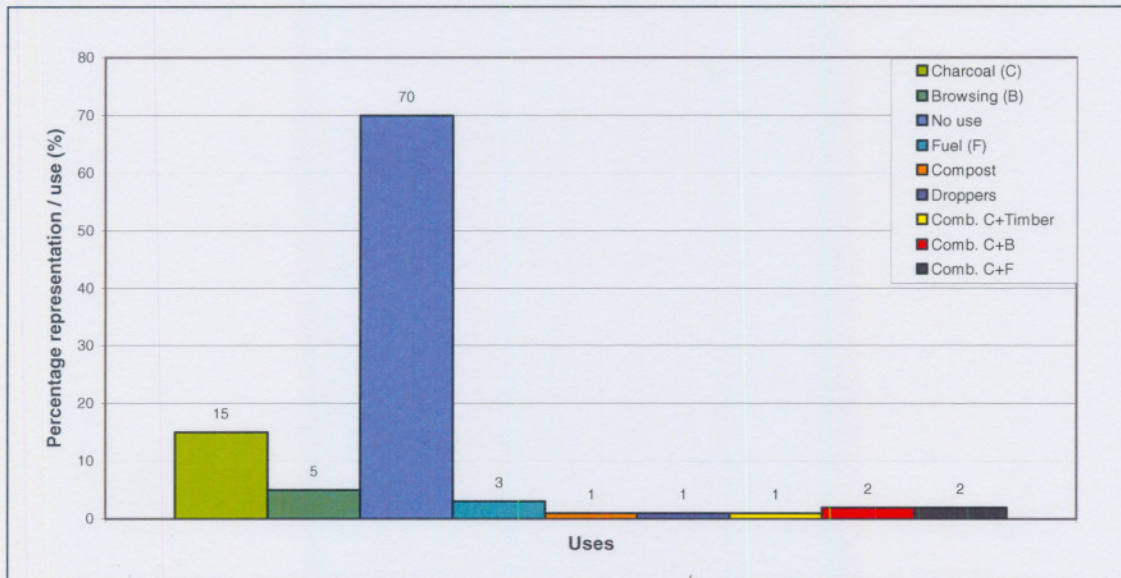


Figure 5.11: The different uses of problem woody species after control in Namibia.

The different types of uses include:

- 1.) *No use* (70%): This does not necessarily indicate that the problem species is not utilized at all. It rather refers to farmers opting to leave the branches and dead woody material on the land after the control practices, in order for it to disintegrate and contribute to organic material, serving as additional nutrients in the degraded soil. The branches can also be used for brushpacking purposes (Van Oudtshoorn, 1999; Boateng, 2002). Brushpacking forms an ideal micro-climate for the germination and establishment of grass seeds and seedlings from the soil seed bank. It also helps in the prevention of soil erosion in bare areas.

- 2.) **Browsing** (5%): This refers to the utilization of the shrubs and trees that are chemically, mechanically or manually controlled. Removed or standing (remaining) plant material is suitable for consumption by animals such as boer goats and game, while the plant is still green or alive. The cutting or removal of trees brings the leaf-bearing branches within better reach for these browsing animals. This form of plant material serves as an additional form of fodder for animals, especially during the dry seasons. Re-growth or coppicing occurring in the already treated sites can also be utilized by the browsers, which can serve as a form of after-care.
- 3.) **Charcoal production** (15%): Charcoal is mainly produced to generate an additional form of income, that may compensate for the initial financial inputs made by the land user for a specific control technology (Nico de Klerk, personal communication<sup>5</sup>). This is a common practice especially in Namibia. The detailed process of charcoal production in Namibia was studied during another project carried out by E. Reed (1996) and information was mainly obtained by means of the completion of questionnaires concerning the matter of bush utilization.

De Klerk (2004) mentions that the Charcoal Producers Association of Namibia in 1993 already estimated there to be approximately 30 producers of charcoal in Namibia, producing 28 000 tons of charcoal per annum. The following information concerning charcoal production and economic benefits thereof are based on information from the 1993 study (De Klerk, 2004).

De Klerk (2004) also mentioned that the cycle of charcoal production and marketing thereof in Namibia, is from the small entrepreneur, to the producer and finally to the marketer. It is estimated that five tons of wood produces one ton of charcoal. The average production of one small entrepreneur (Figure 5.12) is 3.6 tons of charcoal per month from approximately 18 tons of usable wood. The average price paid to the entrepreneur for this production lot is N\$120/ton. The producer receives an amount of N\$ 417/ton from the marketer for the charcoal. The marketer in turn receives an amount of N\$ 1 700/ton of charcoal on the international market in Europe (Namibian

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Ministry of Trade and Industry as cited by De Klerk, 2004). This data gives an indication of the economic viability and potential employment opportunities that can be achieved by becoming a charcoal producer in Namibia.

According to the International Development Consultancy (2003), the production of charcoal in Namibia has increased to roughly 30 000 tons per year.

Trees or shrubs with stem diameters (mm) of approximately 20-150 mm are suitable for charcoal production. The bush species that produce the best quality charcoal seems to be *Acacia mellifera*, *Dichrostachys cinerea* and *Terminalia prunioides*. Factors to take into consideration in determining the economic viability of charcoal production are: bush densities, composition of the woody component, height classes (age) and stem diameters of the species to be used (Bester & Reed, 1997b). Stems and leaves that are not suitable for charcoal production are left on the soil in controlled areas. This could act as protection against soil erosion and serve as grass seed traps (micro-climate), as well as contribute to the re-cycling of nutrients in the soil (De Klerk, 2004).

According to De Klerk (2004), the wood for charcoal production is harvestable on a sustainable basis over a 15-year cycle. The charcoal production industry in Namibia is reflected by the growing need to utilize problem bush species.

Charcoal is however not the only product obtained from the wood of problem woody species. Other products include chemical by-products (in the production of charcoal), as well as wood fibre briquettes and logs, fuelwood (Figure 5.10), and building material (De Klerk, 2004).



**Figure 5.12:** Example of the charcoal production process in Namibia.

#### 4.) *Production of organic feed for animals*

In South Africa, the wood of the problem species is also used to produce *organic feed* for game species and horses in the form of pellets. The company responsible for the production of these pellets (also called 'boskos') is Wes Enterprises<sup>6</sup>. This company also does contracting work, which includes mechanical removal of the problem shrubs from a desired area, collection of all cut material (stems/branches/leaves), shredding it to a finer texture, and then mulching it by forcing it through a hammermill. By adding necessary nutrients to the mulch, organic feed in the form of pellets is then produced (Figures 5.13a-f). 'Boskos' is registered with the South African Department of Agriculture as it meets the requirements for a supplementary animal feed. It contains up to 65% of the natural diet of game.

According to Kubirske (1989), several attempts have been made in Namibia in the past to incorporate palatable bush and trees as a form of additional fodder during times of drought. Results varied, but *Acacia mellifera* proved to be a possible fodder resource. Although further tests are necessary, it seems as if *A. mellifera* consists of sufficient nutrients to serve as an additional fodder source for animals.

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<sup>6</sup> **Wes Enterprises (Pty.) Ltd.** Contact details: P.O. Box 340, Thabazimbi, 0380, South Africa. Tel: +27-(0)14-777-1330, Fax: +27-(0)14-777-1334. E-mail: [boskos@intekom.co.za](mailto:boskos@intekom.co.za)



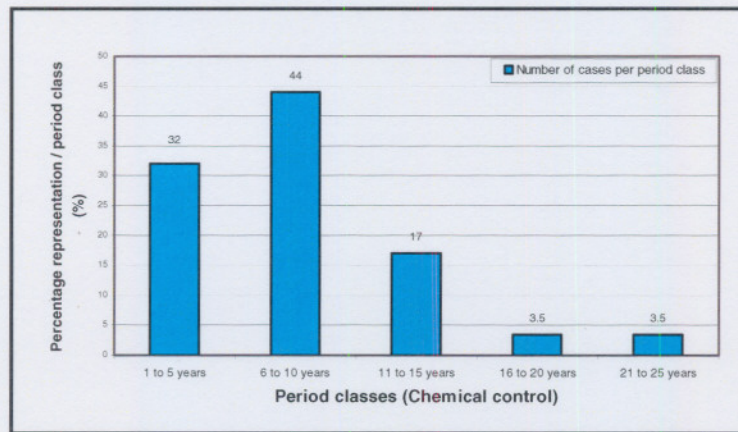
**Figure 5.13 a-f:** Wes Voere manufacturers of organic feed produced from wood of problem woody species in South Africa.  
**(a.)** Mechanical removal (cutting) of bushes;  
**(b. - c.)** Collection of all cut material (stems/ branches/ leaves) and shredding it to a finer texture and then;  
**(d.)** Mulching material by forcing it through a hammermill; **(e.)** and adding necessary nutrients and finally compressing it into pellets that can be  
**(f.)** fed to game.

**5.4.1.8. Period since bush control**

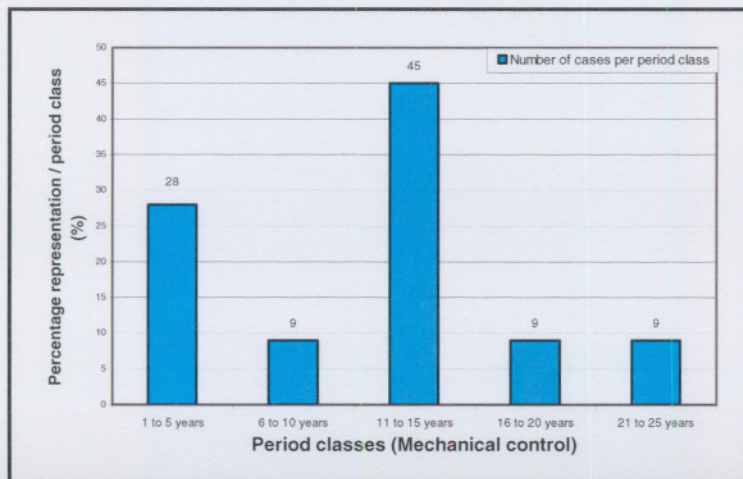
'Period since control' refers to the time that has elapsed since the initial implementation of bush control practices up to the time that the survey was carried out for this study. This period is considered important in the evaluation of the success of a specific control technology. It also indicates to what extent an after-care programme should be implemented.

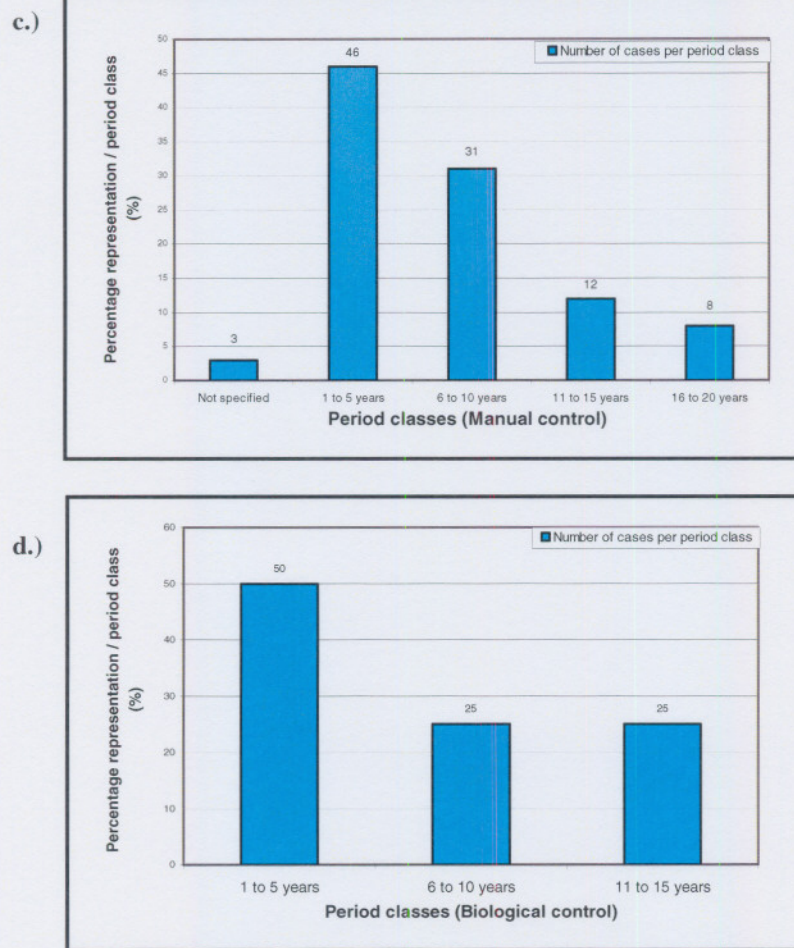
The information for the data on period since bush control was obtained from the *Bush Expert* questionnaires. The data was classified into one of eight different period classes (years) for each of the four main control technologies applied (Figures 5.14 a-d). From the results, it is evident that the majority of the chemical control technologies have been applied within a 6-10 year period (44% of the case studies), while the dominant period since control for mechanical technologies was 11-15 years (45%). Both manual (46%) and biological control (50%) technologies were mainly applied 1-5 years ago.

a.)



b.)





**Figures 5.14 a-d:** Representation of case studies within the different period classes for the four control technologies. a.) Chemical; b.) Mechanical; c.) Manual; and d.) Biological control.

#### 5.4.1.9. Problem woody species occurring in the study sites

The different woody species that mostly contributed to the problem of bush encroachment were noted in the before- and after-bush control surveys. In comparing these occurrences, one can conclude whether a specific control technology proved to be successful in the control of a certain problem species. The data shows that some species have increased rather than decreased in density after the initial control technology was applied. An example of such an indicator species is *Dichrostachys cinerea*. The density of this species will increase when controlled with fire (biological) or mechanical implements, and should

thus rather be controlled by means of chemical technologies (Danie Swanepoel, personal communication<sup>7</sup>).

From data obtained from the *Bush Expert* questionnaires as well as on-site surveys, the major problem species, causing bush encroachment, include *Acacia mellifera* (present in 90% of the case studies), *Dichrostachys cinerea* (57% of the case studies) and *Acacia reficiens* (36%). The problem caused by these species tends to differ between the different regions of Namibia. The occurrences of these problem woody species are mostly in accordance with Bester's map of the major problem bush species and densities in Namibia (Chapter 3, Figure 3.1.). *A. mellifera* however seems to occur as a problem species in most of the study sites throughout the central and northern regions, where severe bush encroachment occurs (Figure 3.1). All three these thorny species, together with the non-thorny species *Terminalia prunioides* (present in 18% of the 100 case studies), occurred in higher densities both before and after bush control, in comparison with other problem species present in the same sites. Annexure 11 contains a list of all the problem woody species that occurred in the survey sites in Namibia (and South Africa).

#### **5.4.1.10. Height classes of the problem woody species**

Although small and low growing trees and shrubs limit the movement and visibility of livestock and game, they contribute to the fodder source of the browsers. If maximisation of grass biomass is the main objective of bush control, most of the trees, including the small ones, should be removed in order to improve natural grazing.

As mentioned, bush control should be a selective thinning process. Larger trees left standing could serve as shade for the animals, or contribute to the aesthetic value of the environment for eco-tourism purposes (Smit & Swart, 1991).

Problem woody species that are classified and fall within the lower height classes (lower stratum), are often not visually prominent, but may however be dominant when compared to larger trees and shrubs. These smaller shrubs contribute significantly, yet 'unnoticed', to the total density of problem species in an area. According to Bester & Reed (1997b),

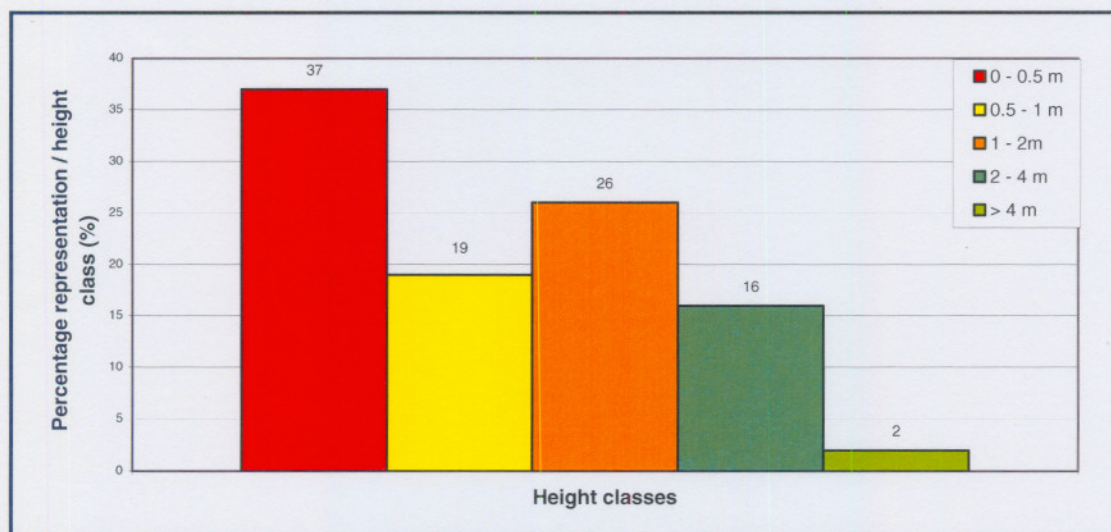
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<sup>7</sup> **Mr. D. Swanepoel:** Distributing agent of bush control herbicides, manufactured by Dow AgroSciences. (Odussa Trading, Okahandja, Namibia). Contact details: Tel: +264-(0)62-501-321/ 564; Mobile: +264-(0)81-243-2578; E-mail: [extokaha@iway.na](mailto:extokaha@iway.na)

studies carried out within areas prone to bush encroachment in Namibia, e.g. Karstveld, indicated that the small *Acacia mellifera* shrubs in the less than 50 cm height class, contributed up to 23% of the total population of problem species. Together with the contribution (density) from two other problem species (*Terminalia prunioides* and *Dichrostachys cinerea*), the percentage contribution of trees or shrubs within this height class (0-0.5 m) added up to 39%.

These figures strongly correlate with results obtained in this study. Figure 5.15 clearly indicates that the 0-0.5 m height class is the dominant height of most woody species causing bush encroachment in Namibia.

If a proper control and after-care programme is not in place, the lower height classes could cause the most problems with regarding coppicing and re-growth, thereby aggravating the bush encroachment problem. Often, the smaller, less obvious shrubs and trees tend to be the most vigorous concerning the problem at hand, as the land users tend to overlook these species in the application of a control technology. The focus is mostly on the bigger shrubs and trees that do not necessarily occur in very dense stands (Bester, 1998).



**Figure 5.15:** The dominant height classes of the problem woody species, as represented in the 100 case studies in Namibia.

As mentioned, Figure 5.15 clearly indicates that most of the case studies surveyed in Namibia had higher densities of trees and shrubs within the lower height classes, ranging between 0-2m in height.

With regard to the four control technologies surveyed, height class representation for each technology (according to the data directly obtained from the Bush Expert questionnaires) is as follows:

- Chemical control: Highest bush densities occur within the height class range of 0-2m (83%).
- Mechanical control: The height class indicating the highest density proves to be 0-0.5m (50%).
- Manual control: The height class 0-0.5m represents a percentage of 34% and the following three height classes (0-0.5m, 0.5-1m and 1-2m) represent densities of 21%, 22% and 21% respectively.
- Biological control: A total representative value of 48% of the bush/trees occurred within the 1-2m height class range.

#### **5.4.1.11. Herbaceous component occurring after bush control**

The herbaceous component represents grass and forb species. During the vegetation sampling procedures, the occurrence of bare ground was also noted and classified within this specific category (herbaceous component). The grasses were respectively split into perennials, annuals and *Aristida spp* (collectively referred to as *Aristidas*) (Annexure 7).

Proper rangeland management after the initial control of the problem woody species plays an important role in the success of an applied technology, due to the fact that a poor veld condition and low herbaceous cover could reflect on poor rangeland management strategies implemented by the land user and vice versa. The intensity, season and frequency of grazing by livestock and game after bush control thus influence the success of control technologies. Only after excluding grazing impacts from a bush controlled area for a full growing season, will one be able to accurately determine the potential improvement of the rangeland condition and herbaceous production (grasses) due to lowered tree-grass competition. Then the occurrence of grass species and the type of species can serve as indicator for the success rate of a certain control technology, seeing

that an abundance of perennials indicate a secondary stage of succession after a certain control technology was applied. The occurrence of higher annual grass species densities, can be due to the fact that the time after the initial application of the control technology was still very short, which does not necessarily indicate that the success rate of the control technology is low.

The grass species most commonly found to occur in high densities after control in a majority of the Namibian case studies, is *Stipagrostis uniplumis* (33% of the cases), which is a perennial sub-climax species, with an average grazing value. Forbs, which usually serve as pioneer species, occurred in 22% of the study sites. Annual grass species (68%) (e.g. *Eragrostis porosa*, *Stipagrostis hirtigluma*, *Enneapogon cenchroides* and *Enneapogon desvauxii*) with average to low grazing value, also occurred in high frequencies in most of the study sites. Annexure 12 provides a list of the dominant grass species represented in the Namibian case studies, as sampled during the quantitative surveys.

The two most dominant herbaceous (perennial or annual grass species, *Aristida* species, bare ground or forbs) found at each of the 100 case study sites (per farm name) is presented in Annexure 13. This data could be very useful and important in long-term monitoring plans for each of the farming areas. The change in the herbaceous component could be used to evaluate the effectivity of the control technologies, as well as the change in the state of range conditions over time.

#### **5.4.1.12. After-care**

Only 11% of the total of 100 case studies surveyed in Namibia, indicated the implementation of an after-care programme. These findings are in accordance with that of Reed (1996), who also found that very few farmers implement after-care programmes. After-care is either applied constantly or after a certain period of time since the initial application of the control technology. Table 5.4 gives a detailed summary of the period and type of control technologies used in the initial and after-care programme of the 11 case studies in Namibia.

**Table 5.4:** Summary of the 11 Namibian case studies where after-care technologies was applied (period and control technologies).

Case number	Initial control technology	Method of initial application	Period since initial control (after-care application)	After-care method applied
Case 8	Manual	Mattocks	2 years	Fire
Case 17	Chemical	Tordon 155 (aeroplane)	Constant	Rotational grazing + Browse: goats
Case 38	Mechanical	Bulldozer	Constant	Browse: goats
Case 39	Manual	Axe	Constant	Browse: goats
Case 41	Mechanical	Bulldozers	Constant	Chemical + Cultivated pasture ( <i>C.cil.</i> )
Case 44	Chemical	Grazer (aeroplane)	Unknown	Chemical: Molopo SC
Case 59	Manual	Axe + Mattocks	1 year	Fire
Case 62	Mechanical	Bulldozer	9 years	Chemical + Manual
Case 65	Chemical	Molopo SC (soil spray)	2 years	Cultivated pasture ( <i>C.cil.</i> )
Case 68	Mechanical	Bulldozer + Roller	Unknown	Fire
Case 90	Chemical	Bromacil (soil spray)	Constant	Browse: goats

According to the information in Table 5.4, ten of the eleven case studies indicated a different form of after-care technology, than that of the initial control technology. Only one case study (Case 44) indicated the same initial and after-care technology. The *initial control process* in four of the cases consisted of chemical control, and in four cases mechanical control technologies were applied, while manual control was applied in only three of the cases. In comparing this to the *after-care applications*, it is clear that in seven of the 11 cases biological control was used as an after-care technology, while only three used a chemical control technology (of which two cases involved chemical control in conjunction with another control technology). In only one case study a manual after-care technology was applied (cultivated pastures). The main biological control method used was browsing by boer goats (4 cases) and natural veld fires (3 cases).

The reason for the change in technology from the initial to the after-care technologies could be due to a lack of funds for chemical (herbicides), mechanical (implements) or

manual control (labour) technologies. Biological control technologies were thus mostly used, as it seems to be more cost effective and the least labour intensive. Very often farmers also realized how destructive the use of large implements such as bulldozers are, and therefore reverted to other technologies in the application of after-care.

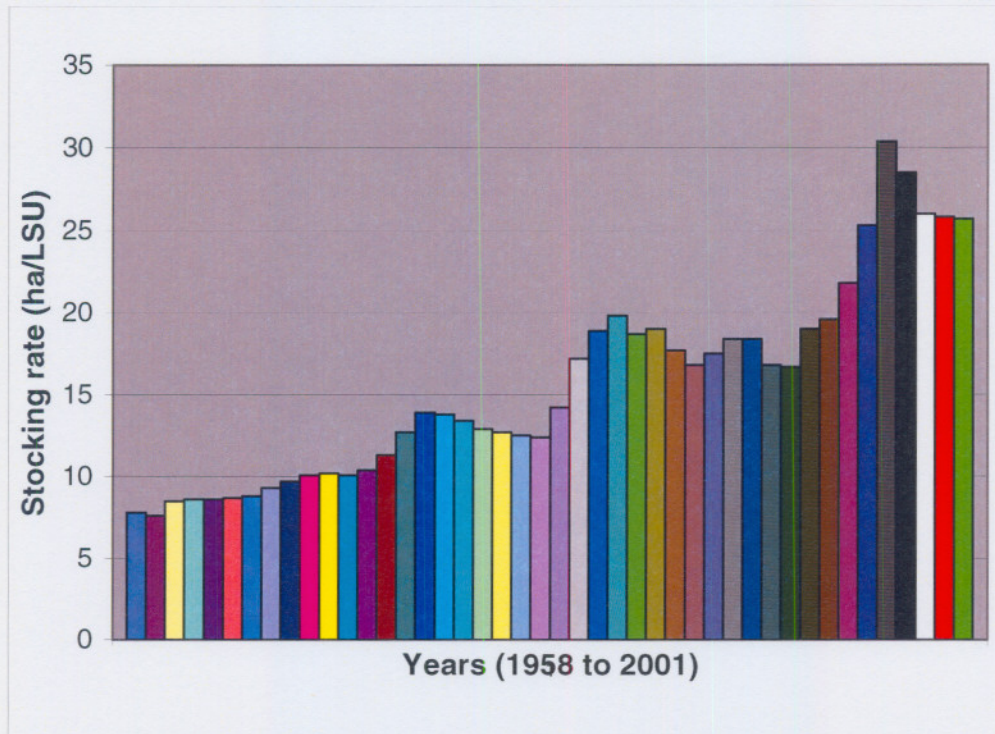
A total of nine percent (9%) of the case study surveys of the 100 carried out in Namibia indicated a higher density of problem woody species *after* the initial control. Of the nine cases, four comprised chemical control, three manual control and two case studies involved the use of mechanical bush control. In eight of the cases the period since control was longer than seven years. None of these nine case studies indicated the implementation of an after-care programme in the initially controlled sites, except for one, where in some areas planted pastures were established. The absence of a proper after-care programme could thus be the reason for an increase in bush densities after the first control application.

#### 5.4.1.13. General stocking rates

In the arid regions of central Namibia, farming is essentially limited to extensive pastoral agriculture (Mouat *et al.*, 2003). Sheep and goats are predominant in the southern parts of Namibia, whereas the northern parts are mostly cattle farming areas.

Stocking rate is the variable input directly controlled by the land user or land manager and has a tremendous influence on the limitation of environmental risks, the long-term vegetation composition, animal performance as well as economical advantages for the land user (Snyman & Fouché, 1991; Snyman & Fouché, 1993; Snyman, 1998).

Overstocking and overgrazing is generally seen as major factors causing or leading to general land degradation, more specifically bush encroachment. Cattle tend to easily overgraze an area where proper management systems are not in place. Game ranching involves the 'free roaming' of game within an area, allowing animals to move around, often resulting in bigger animals, such as kudu, to cross over to other farming areas. The free movement of these animals, together with proper management of watering holes (alteration thereof) and animal numbers (sustainable stocking rates), commonly leads to a smaller chance of overgrazing (Lange *et al.*, 1997).



**Figure 5.16:** Change in stocking rates in Namibia from 1958 - 2001 (De Klerk, 2004).

These stocking rate estimations shown in Figure 5.16 indicate a definite fluctuation over the years. The increase in ha/LSU, especially during the last six years, is alarming. This increase indirectly indicates a decrease in rangeland condition and carrying capacity of the natural rangelands in Namibia. Bush encroachment has also contributed greatly to the decrease in the rangeland condition. The year of 1997 is indicated as the year with the highest stocking ratio of approximately 30 ha/LSU. Since then the stocking rate values have dropped slightly, but remains constant at the moment at a rate of 26 ha/LSU, which is still very high. Fluctuations in stocking rates over the years could be due to many factors, of which below average rainfall and periods of drought, as well as rangeland degradation in the form of bush encroachment and loss in herbaceous cover, are the most important.

The application of the most effective bush control technology, which forms part of this study, can therefore not be underestimated.

#### **5.4.2. Results from the South African case studies: Limpopo Province**

All of the following results concerning bush control technologies in the Limpopo Province in South Africa are concluded from data obtained by means of the *Bush Expert* questionnaires, as well as quantitative vegetation surveys carried out on-site.

##### **5.4.2.1. Location of the study sites**

As mentioned in Chapter 3, the four main study areas where the nine case study surveys were carried form part of the savanna biome (see Figure 3.5 in Chapter 3). Two of the study areas were situated on privately owned commercial farms in the Dwaalboom district (Mount Joy and Twee) and the other two were game farms, near the town of Thabazimbi (Leadwood Lodge and Ben Alberts Nature Reserve).

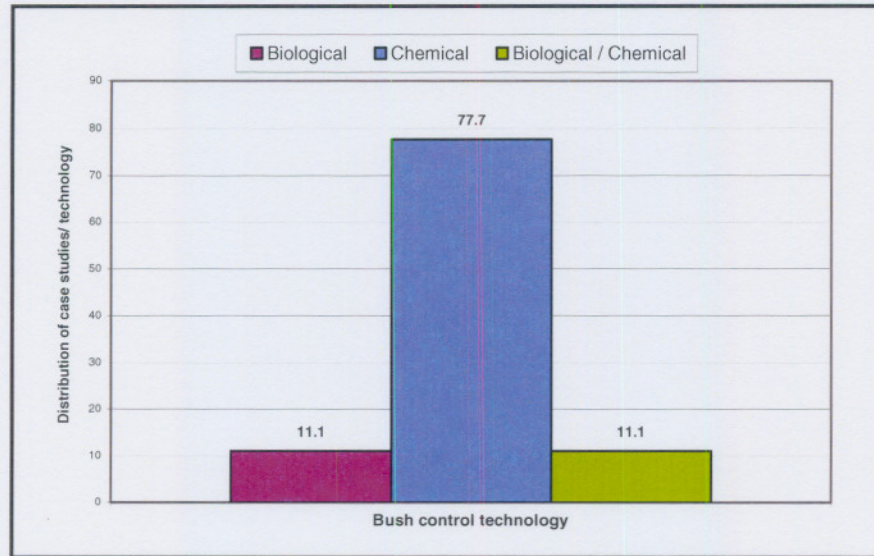
Abbreviations that will be used throughout the following section for the names of the study sites are as follow:

- Mt J = Mount Joy (Site 1)
- T1 & T2 = Twee (Site 2-3)
- LW1, LW2 & LW3 = Leadwood Lodge (Site 4-6)
- BA1, BA2 & BA3 = Ben Alberts Nature Reserve (Site 7-9)

(Figure 3.8 of Chapter 3 indicates the precise locations of the nine case study sites).

##### **5.4.2.2. Bush control technologies applied**

Only three different control technologies were applied in the Limpopo Province case study sites surveyed in South Africa. These include the application of chemical, biological as well as a combination of biological and chemical control technologies. The latter control technology was applied in only one of the nine case studies (11.1%). This technology was seen as one single application, as it was carried out within the same time frame, one technology directly following the other (Leadwood Lodge, LW 1). A natural veld fire occurred which burnt down the whole site and directly after that the farm manager decided to hire contractors to apply a chemical bush control technology as well. Figure 5.17 gives an indication of the representation of use of the different technologies at the nine study sites in the Limpopo Province.



**Figure 5.17:** Representation of the case studies for each of the control technologies applied.

As for the majority of case studies surveyed in Namibia, the control technology most often applied was chemical control. Seven of the nine case studies (77.7%) were chemically controlled, while one case study (11.1%) represented each of the other two technologies respectively (e.g. combination of biological & chemical control or biological control).

Table 5.5 provides a more detailed description of the specific technologies and methods used in the case studies surveyed in the four main study areas in the Limpopo Province in South Africa. It is clear that mainly chemical control technologies were applied at these sites, using a more expensive type of herbicide (e.g. Access). In general chemical control is much more expensive and often applied by large-stock owned enterprises or game farms and reserves. The economic implications of the control technologies will be elaborated on in section 5.6 of this chapter, as well as Chapter 7.

**Table 5.5:** Detailed description of the bush control technologies applied within the nine study sites in the Limpopo Province, South Africa.

Site name	Control technology	Method of application
Mt J	Chemical	<i>Access</i> applied to cut-stumps (spray)
T1	Chemical	<i>Access</i> applied to cut-stumps (spray) + After-care
T2	Chemical	<i>Access</i> applied to cut-stumps (spray)
LW1	Biological + Chemical	Natural veld fire + <i>Tordon Super</i> applied to cut-stumps (brush)
LW2	Chemical	<i>Tordon Super</i> applied to cut-stumps (brush)
LW3	Biological	Controlled fire
BA1	Chemical	<i>Tordon Super</i> applied to cut-stumps (brush)
BA2	Chemical	<i>Buschwacker</i> sprayed onto the soil
BA3	Chemical	<i>Buschwacker</i> sprayed onto the soil

As mentioned, in seven of the nine case studies, chemical control in the form of herbicides was applied. *Access*, a herbicide in the form of a soluble concentrate, with picloram as active ingredient, was applied in the first three case studies (Mt J, T1 and T2), by means of cut-stump treatment. This herbicide can either be applied to the cut-stump or by means of aeroplane or helicopter, depending on the bush density or accessibility of the area. *Tordon Super* was applied in three of the case studies (LW1, LW2 and BA1). It is an oil miscible liquid, which in these case studies was usually mixed with old oil obtained from the surrounding mines in the Thabazimbi district. The active ingredient of *Tordon Super* is a combination of picloram and triclopyr and the herbicide was applied as a cut-stump treatment. This product is however not available on the market anymore, although it is regarded as one of the best herbicides for bush control purposes. The demand for this herbicide was not high enough and thus it was taken from the market.

*Buschwacker* was applied in two of the case studies (BA2 and BA3). This herbicide is still available on the market in a wettable powder form. The active ingredient of the product is bromacil, which is not preferred for bush control, seeing that bromacil has a long-lasting negative effect on the natural environment. This herbicide was applied to the soil surface surrounding the problem trees and shrubs (see Annexure 8 for a list of the

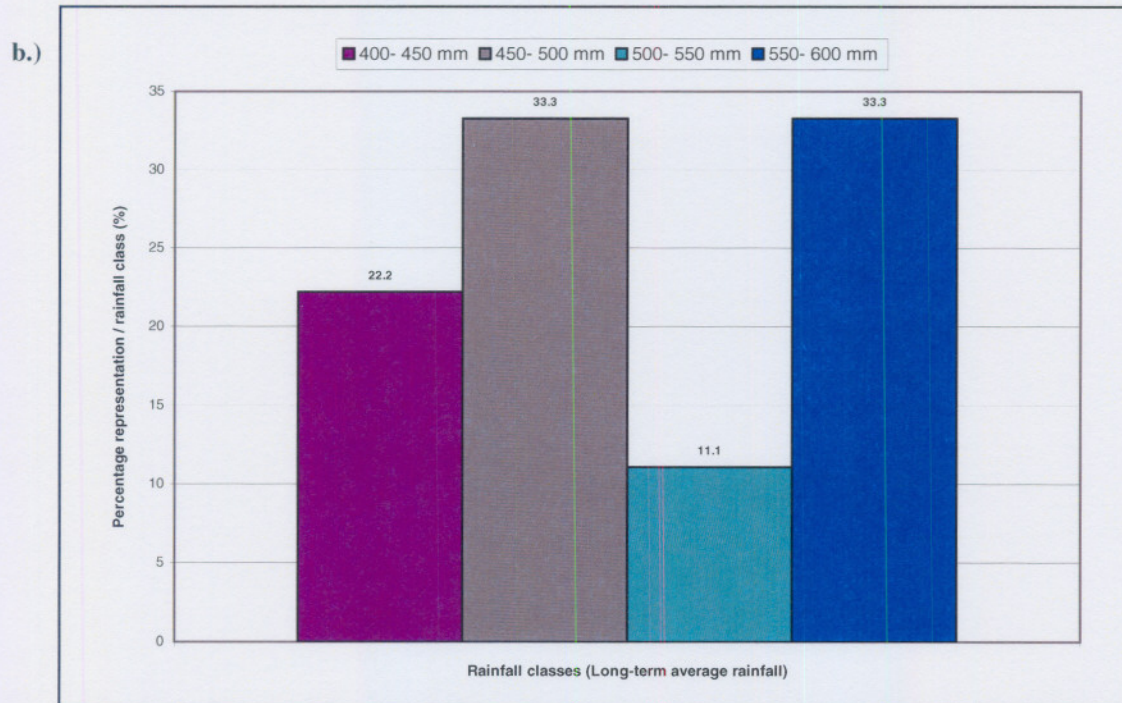
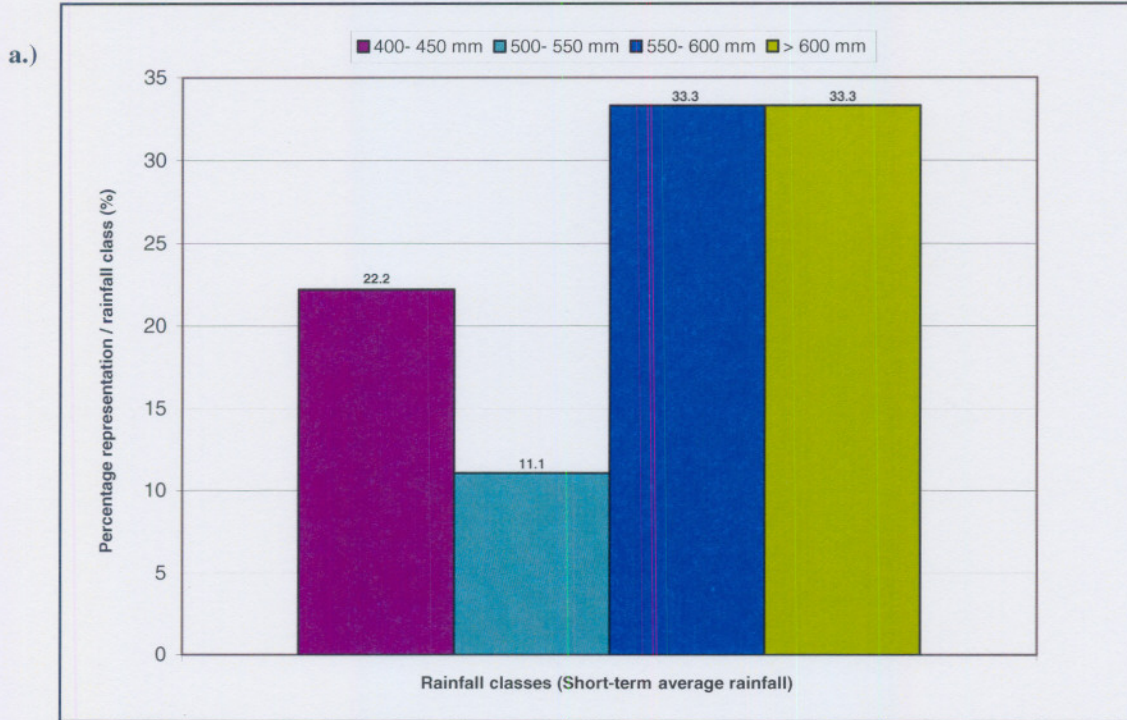
herbicides most commonly used in chemical bush control, according to the answers given in the *Bush Expert* questionnaire). Annexure 9 contains a list of all the problem woody species found in South Africa (and Namibia), together with the recommended herbicide for chemical control.

#### **5.4.2.3. Rainfall areas**

The short- and long-term rainfall averages for the nine study sites in the Limpopo Province were obtained from the *Bush Expert* questionnaires. Concerning the short-term rainfall, most of the case studies fell within the 550-600 mm and > 600 mm class range, while the long-term rainfall was best represented within the ranges of 450-500 mm and 550-600 mm of rainfall per annum. Figure 3.7 of Chapter 3 indicates the rainfall zones in which the case study areas in the Limpopo Province are situated. Figures 5.18 a & b indicate the representation of the rainfall classes, as was listed on the questionnaire. Table 5.6 gives a more detailed description of the rainfall at each of the study sites.

Regarding the short-term rainfall, 66.6% of the case studies were sampled within the 550->600 mm rainfall range. A total of 55.5% of the case studies were surveyed in the 400-500 mm long-term rainfall range and 33.3% in the 550-600 mm range. It therefore seems that the majority (of the nine cases) of bush encroachment case studies occurred in these rainfall ranges and that the problem of bush encroachment is indicative for these areas in this part of South Africa.

In comparing the occurrence of the majority of case studies surveyed in Namibia and South Africa concerning the short- and long-term rainfall classes, it is evident that in Namibia the majority of study sites occurred in the drier parts of the country, with lower rainfall (300-400 mm class range). The majority of South African case studies on the other hand, occurred in areas characterized by higher rainfall (400-500 mm and 550-600 mm class range). It is thus evident that bush encroachment does occur in both low and high rainfall regions throughout southern Africa



Figures 5.18 a & b: (a.) Short-term, and (b.) Long-term average rainfall classes, representative of the South African case studies.

**Table 5.6:** Summary of the average short-term and long-term rainfall for the nine study sites within the Limpopo Province, South Africa.

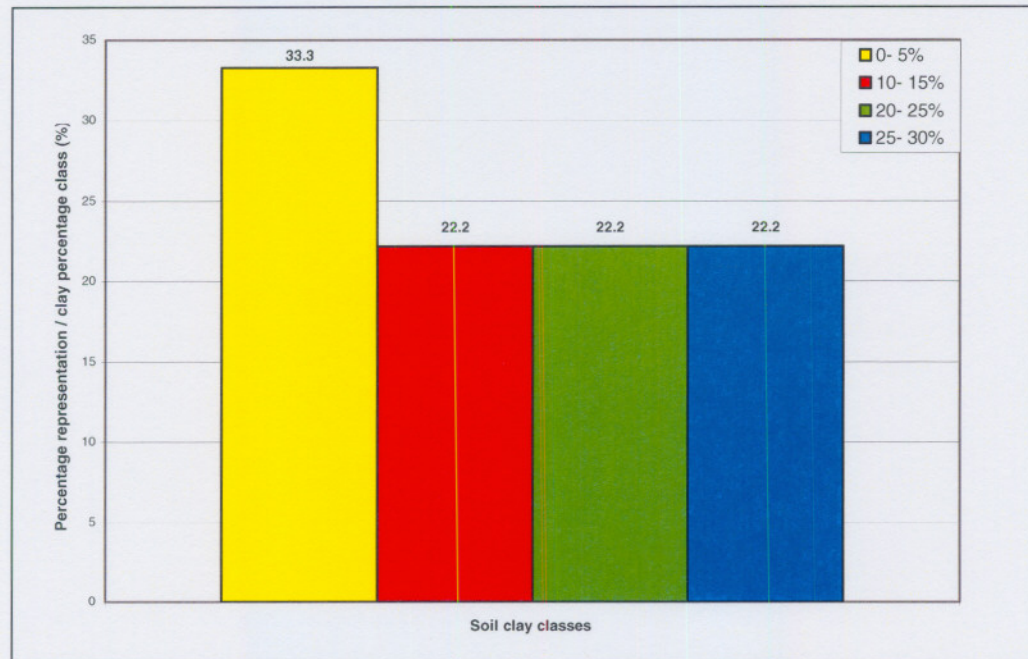
District	Farm Name	Short-term rainfall (mm)	Long-term rainfall (mm)
Thabazimbi	Mt. J	500-550	500-550
Rooibokkraal/Dwaalboom	T 1	400-450	400-450
Rooibokkraal/Dwaalboom	T 2	400-450	400-450
Thabazimbi/Amandelbult	LW 1	> 600	550-600
Thabazimbi/Amandelbult	LW 2	> 600	550-600
Thabazimbi/Amandelbult	LW 3	> 600	550-600
Thabazimbi	BA1	550-600	450-500
Thabazimbi	BA2	550-600	450-500
Thabazimbi	BA3	550-600	450-500

(Rainfall values are indicated in 'rainfall-classes' as indicated on the *Bush Expert* questionnaire, see Annexure 6 for the different classes used).

From Table 5.6 it can be concluded that the rainfall at each of these study sites is rather high, in comparison with that of the Namibian case studies. The highest average rainfall is observed at the Leadwood Lodge sites, followed by the Ben Alberts study sites together with the Mount Joy site. This variation in rainfall, however did not contribute to the differences in bush densities in these study sites.

#### 5.4.2.4. Soil clay percentage (%)

According to the results obtained from answers given in the *Bush Expert* questionnaires, it is clear that 33.3% of the study sites occurred in areas with a sandy soil texture (0-5% clay). The remaining 66.6% was represented within the classes 10-15%, 20-25% and 25-30% clay classes (Figure 5.19). As mentioned previously for the Namibian case studies, soils with a high clay content are more suitable for soil applied chemical bush control technologies, should the rainfall be sufficient. The above mentioned soils consisting of a higher sand content, may however tend to lack sufficient soil nutrients, except for areas where leguminous species (e.g. *Acacia* spp.) occur, seeing that these increase the soil nitrogen content (Smit & Swart, 1994).



**Figure 5.19:** The soil clay percentage classes as it occurred in the nine study sites surveyed in South Africa.

#### 5.4.2.5. *Density of the problem woody species*

The total bush densities of all the woody species (problem and non-problem) as it occurred before control in the nine case studies sampled in the Limpopo Province, are indicated in Figure 5.20. Annexure 10 contains a list of the total problem woody species bush densities, before and after control. The majority of case studies (66.6%) comprised bush densities of between 6 000 – 8 000 and 8 000 – 10 000 trees/ha. In comparing these figures with the after-control densities, one can estimate the success rate of the applied control technology. All nine of the case studies indicated a definite decrease in bush densities after bush control.

In comparing the bush densities before control in South Africa with that of Namibia, it is evident that 64% of the Namibian case studies surveyed consisted of densities between 1 000- 3 000 trees/ha. Only 17 case studies indicated bush densities higher than 6 000 trees/ha, whereas in the South African case studies surveyed, the majority of cases indicated densities of higher than 6 000 trees/ha (66.6%). Representative case studies in South Africa thus indicated a generally higher bush density occurrence than Namibia..



**Figure 5.20:** The respective density classes (as a %), for all the woody species in the nine case study sites in South Africa (before control).

#### 5.4.2.6. Aims of bush control

According to information gained from the *Bush Expert* questionnaires, the main aim of bush control in all the case studies proved to be to improve the natural grazing, mainly for game species. All nine case studies were surveyed on game farms and nature reserves.

A total of 63% of the Namibian case study surveys also indicated natural grazing to be the most common aim of bush control. Although not clearly stated by the land users in the questionnaires, another aim for the control of problem bush in the South African case studies would include the improvement of the aesthetic value of the ecosystems, as well as the visibility for hunting and eco-tourism purposes.

#### 5.4.2.7. Use of the problem woody species after bush control

While 70% of the case study surveys in Namibia indicated the main use of the problem woody species to be *no use*, all nine of the South African surveys indicated *browsing* of the woody species as additional fodder source, to be the preferred use. An additional use was to leave some of the dead material on the land as a form of brushpacking, in order to decrease the possibility of soil erosion and increase the soil nutrient sources. The problem woody species that were removed at the Leadwood Lodge sites 4 and 5 were however removed by the contractor, in order to produce organic feed for game in the form of pellets (see 5.3.1.7. – *Production of organic feed for animals*).

#### **5.4.2.8. Period since bush control**

The period since control for the case studies in South African, indicated that most of the control technologies were applied rather recently, namely in the 1-5 (66.6%) and 6-10 (33.3%) year periods. This might influence the evaluation of the success rate of an applied bush control technology, seeing that the recovery process of a natural rangeland system is usually a long-term process (Kellner & Bosch, 1992). The period since control for the South African case studies are mostly in accordance with the periods representative for the chemical (6-10 years), manual and biological (1-5 years) control technologies in Namibia.

#### **5.4.2.9. Problem woody species occurring in the study sites**

The problem woody species occurring in each study site before and after bush control technologies were applied, have been monitored during vegetation sampling surveys. According to the information obtained from the *Bush Expert* questionnaire, the main problem species that occurred in the nine case studies before bush control took place, included *Dichrostachys cinerea* (66.6% of the cases), *Acacia erubescens* (22.2%), *Acacia karroo* (22.2%), *Acacia tortilis* (11.1%) and the combined *Grewia* species (11.1%). Annexure 11 contains a list of all the problem woody species that occurred in the survey sites in the Limpopo Province in South Africa (and Namibia).

The results from the vegetation surveys after bush control, indicates that the main problem species that remained, were *Grewia* species (88% of the nine case studies), *Dichrostachys cinerea* (77.7%), *Acacia karroo* (66.6%) and an approximate equal representation of *A. erubescens*, *A. tortilis*, *A. mellifera* and *Asparagus* species (3-4% each). The latter species (*Asparagus* spp.) did not occur as a problem species before control and were thus not seen as a threat to the natural vegetation. This species however mostly established after bush control due to the changed environment. Although *Grewia* species are found to be a problem woody species, many land owners consider these shrubs as an additional form of fodder for browsing animals during times of drought (Watson & Brown, 2000). Land users therefore often do not attempt to remove all of these additional fodder plants, by applying selective bush control.

The increase of *Asparagus* species and *Grewia* species could be as a result of more favourable conditions that were created for these species, as well as a reduction in the competition by species such as *D. cinerea* and *Acacia* species. It is a well-known fact that once one problem species is removed, it might lead to the establishment of another species in its place that did not seem to be a dominant species previously (Meyer, 1997a; Mouat *et al.*, 2003).

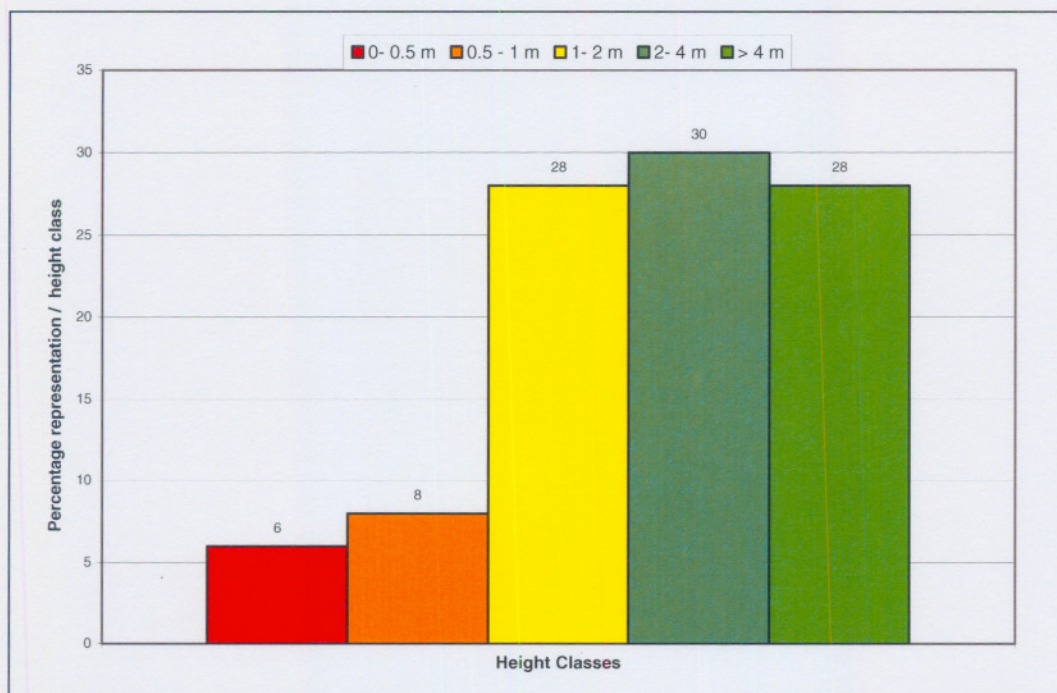
The only two problem woody species that were present in both the Namibian and South African case study sites were *A. erubescens* and *D. cinerea*. The latter species proved to be a dominant species concerning bush encroachment in both countries, but *A. erubescens* were only noted as a dominant problem species in the South African case studies.

#### **5.4.2.12. Height classes of the problem woody species**

In comparison to the dominant height classes observed in Namibia, it is clear that the lower height classes (0-0.5 m) were not as dominant in the South African case studies. The dominant heights were the 1-2 m (28%), 2-4 m (30%) and > 4 m (28%) height classes, with the total representation for the three dominant height classes being 86% (Figure 5.21).

The reason for this difference in height class representation might be that the case study sites in South Africa were situated in a higher rainfall zone (long-term average of between 450-600 mm), in comparison to Namibia (long-term average of between 300-450 mm), as higher rainfall usually has a positive effect on the growth and establishment of trees.

Another reason could also be that the species causing the bush encroachment problem differed between the two countries, as was the case in this study. In Namibia the problem species were *Acacia mellifera*, *A. reficiens* and *Dichrostachys cinerea*, while in South Africa problem species were represented by *A. erubescens* and *D. cinerea*.



**Figure 5.21:** The distribution of the problem woody species of the total nine case studies in South Africa, within the five different height classes as it occurred before bush control.

With regard to the three different control technologies applied, the height class representation for the technologies were as follows:

- Chemical control: Highest bush densities occurred within the height class range of 2-4 m and >4 m (60%).
- Biological-Chemical control: The height class indicating the highest density proved to be 2-4 m and >4 m (totalling 100%).
- Biological control: A total representative value of 100% of the bush/trees occurred within the 1-2 m height class range.

#### **5.4.2.11. Herbaceous component occurring after bush control**

The herbaceous component for each of the nine case studies represents both grass and forbs species, as well as bare ground. Annuals and perennial grasses are clearly distinguished. As for Namibia, the abundance and the type of grass species can serve as an indicator for the success of a certain control technology. From results obtained by

means of the *Bush Expert* questionnaire and vegetation surveys, it is evident that the most dominant herbaceous component consists of perennial grass species. The two grass species most commonly found to occur after the application of bush control technologies at each of the study sites, are indicated in Table 5.7.

**Table 5.7:** The two most dominant herbaceous species occurring at each of the nine study sites after bush control in the Limpopo Province, South Africa.

SITE NAME + CONTROL METHOD	GRASS SPECIES
Mt. J (Ch)	<i>Cenchrus ciliaris</i> , <i>Bothriochloa insculpta</i>
T 1 (Ch) & T 2 (Ch)	<i>Panicum maximum</i> , <i>Eragrostis rigidior</i>
LW 1 (Bio + Ch)	<i>Eragrostis lehmanniana</i> , <i>Heteropogon contortus</i>
LW 2 (Ch)	<i>Enneapogon cenchroides</i> , <i>Digitaria eriantha</i>
LW 3 (Bio)	<i>Heteropogon contortus</i> , <i>Fingerhuthia africana</i>
BA 1 (Ch) & BA 2 (Ch)	<i>Urochloa panicoides</i> , <i>Cynodon dactylon</i>
BA 3 (Ch)	<i>Panicum coloratum</i> , <i>Urochloa panicoides</i> , Bare ground

According to the results indicated in Table 5.7. it is evident that none of the grass species were dominant in all of the study sites. Each area was characterized by its own composition, mainly due to the environmental variability between all the sites. This is also true when comparing the occurrence of the dominant grass species of Namibia with those of South Africa. Annexure 14 contains a complete list of the grass species that occurred in the study sites.

#### 5.4.2.12. After-care

At only one study site, Twee (T2), a form of after-care was applied one year after the initial bush control technology was applied. This after-care application involved a controlled fire, which was used to open up the veld by burning moribund grass biomass, decrease dead woody plant material and control the tick problem in this particular camp of the game farm.

into consideration had the main influence on the success rate; they all just partly contributed to the total variance.

A possible explanation for the low percentage of variance could be the tremendous variation within the raw data (as obtained from vegetation surveys and the *Bush Expert* questionnaire), as well as the fact that many similarities are found within the data concerning environmental factors within the different study sites. These shortcomings, together with additional recommendations will be elaborated upon in Chapter 7 (Conclusion).

As mentioned in the previous section, proper rangeland management following initial drastic bush control measures, is an essential factor in determining the success rate of such control technologies. Although the influence of management strategies is not evident in the supplied data and results for this study, it should definitely be considered as an indicator of the success rate in future studies, seeing that this factor influences the recovery of the herbaceous layer and also the degree of re-encroachment. Success rate of bush control cannot be determined if the indirect cause of the problem (e.g. overgrazing) is not addressed.

#### **5.5.4. Correlations between the environmental factors, plant species and the control technology applied at all the study sites in Namibia and South Africa**

Redundancy analysis (RDA) ordinations were carried out in order to determine the possible correlations or trends between the different environmental factors, plant species and control technologies. As indicated by the values in Table 5.8, the two most successfully applied bush control technologies were chemical and manual control. For the purpose of the RDA ordinations, only the data of the case studies where these two specific control technologies were applied, were used (technologies separated). The results for each technology are presented in four different graphs (Figures 5.24, 5.25, 5.26 and 5.27). All of the abbreviations that are used in this section, regarding tree and grass species as well as environmental factors, are listed in Annexure 15.

The period since the application of the after-care technology (one year) was however too short in order for this case study to be included as a new case study. The very short period of time since the after-care application also explains why there is no distinguished difference or result to be seen in the herbaceous layer composition yet.

Figures 5.22 a-c give a final visual representation of the possible outcome to be expected, should selectively applied control technologies be used to control bush encroachment.

(a.)



(b.)



(c.)



**Figure 5.22 a-c:** Representation of the possible outcome to be expected, should selectively applied control technologies be used to control bush encroachment. **(a.)** Encroached area with 8 000 trees/ha = 45 ha/LSU. **(b.)** Directly after selective bush control = 700 trees/ha. **(c.)** 5 years after selective bush control = 9 ha/LSU.

## 5.5. STATISTICAL ANALYSES FOR COMBINED STUDY AREAS IN NAMIBIA AND SOUTH AFRICA

The data obtained during the vegetation surveys and completion of the *Bush Expert* questionnaire for both Namibia and South Africa, were combined for the purpose of further statistical analyses. In doing so, the combined case study data could indicate clearer trends or results as well as a better representation of any possible correlations that could exist in bush control technologies. Seeing that only nine of the South African case studies were included in this dissertation, one would not be able to formulate definite conclusions from the data, due to the limited number of South African case studies carried out in the Limpopo Province. Combined statistical analyses were carried out with the computer software programme, Canonical Correspondence Analysis (CANOCO) (Ter Braak, 1987; Ter Braak, 1988; Ter Braak & Verdonschod, 1995) and the statistical packages, STATISTICA for Windows (1995) and GenStat for Windows (2000). These analyses included several multivariate analysis techniques (Stols, 1991), as well as the determination of multiple regressions, analysis of variance (ANOVA) and Principal Component Analysis (PCA) techniques, concerning the environmental variables and plant species.

### *Manipulation of species data for statistical analysis purposes*

As mentioned in Chapter 4 (Procedures), the species were combined to a certain extent to decrease the amount of variation in the data (e.g. *Terminalia sericea* and *Terminalia prunioides* were grouped under the name *Terminalias*). Species or groups represented by very low frequency or density percentages (lower than 10% representation) were excluded from the datasets, as well as those species represented in only a few case studies (See Annexure 7 for a detailed list of the combined species groupings).

The South African case study, LW1 case 104 BioCh was, for statistical analysis purposes noted as a case study where biological control was applied, seeing that there was only one case study of the total 109 that involved a combination of control technologies such as Biological-Chemical control (see 5.5.2.2. - *Bush control technologies applied in South Africa*). The biological control was applied before the chemical control. Thus for the purpose of statistical analysis, this case study was noted as one of the biological control technology case studies, in order to simplify the data.

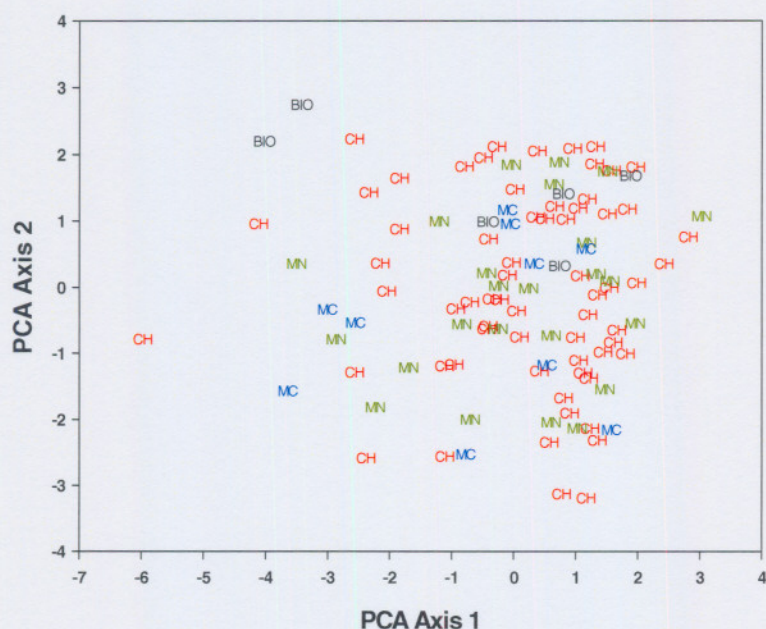
In a similar way, the Namibian case study, N69 ND case number 14ND, was noted as 14Bio (Biological) for combined statistical analysis purposes. The abbreviation ND refers to natural die-back, a disease caused by the fungi *Phoma glomerata*. This case study was thus grouped under biological control technologies (Bio) as well.

***Multivariate Principal Component Analysis (PCA)***

Multivariate analysis techniques were used to determine possible correlations between the technologies applied, such as the occurrence of grass and tree species after control, as well as a number of environmental variables, such as rainfall (mm), success rate (%) of bush control or soil clay percentage (%). These correlations were determined by using the CANOCO computer programme as well as with Principal Component Analysis techniques (GenStat, 2000).

### 5.5.1. Type of bush control technology vs. specific location of study sites

A Principal Component Analysis (PCA) (Rayner, 1969), was used to determine whether the four control technologies could be separated into definite groupings, according to the different sampling areas and the location of the case study sites.



**Figure 5.23:** Principal Component Analysis (PCA) indicating the four different bush control technologies and distribution of each of the combined case studies for Namibia and South Africa. PCA Axis 1 scores = X-axis coordinates of case studies and PCA Axis 2 scores = Y-axis coordinates of case studies. CH = chemical control, MC = mechanical control, MN = manual control and BIO = biological control.

The PCA axes 1 and 2 indicate the distribution of all the case studies (105), according to the applied bush control technologies. Only four of the 109 sites are not represented in the graph, seeing that the data for these sites lacked important information. The first PCA (X-axis) accounted for 40% and the second (Y-axis) for a further 28.3% of the total variation in the data. Thus this two-dimensional representation of control technologies within the case studies (Figure 5.23) accounted for approximately 68% of the total variation in the data obtained from the *Bush Expert* questionnaires and quantitative vegetation surveys.

From Figure 5.23 it can be concluded that no definite trend could be observed in the ordination graph, regarding the control technologies and locality of the sampled case studies within the different study sites. This means that a particular control technology was not independently applied, regarding a specific area or problem woody species in Namibia or South Africa, but that all four technologies were randomly applied in all the regions. Thus no definite groupings regarding the four technologies applied, were observed. This could be ascribed to the tremendous variation found in the data within the particular control technology groupings (e.g. chemical control) as well as between groupings.

### **5.5.2. Success rate of applied bush control technologies**

The success rate of the applied bush control technologies was mainly determined according to the subjective evaluation of the land users or extension officers as indicated in the *Bush Expert* questionnaires and from the quantitative vegetation surveys. The density of the problem woody species were determined by the before and after control situations within the treated area of a rangeland. Thus the expectations of the land users concerning the applied control technology, target problem species, desired problem bush density and recovery of the herbaceous layer greatly influenced the evaluation of success rate. A high mortality rate of favorable woody species can also be seen as an indicator of a low success rate. Aspects such as grazing management after control should definitely also be considered as an indicator of success rate in rangeland restoration by means of bush control. Although factors such as economic implications and an increase in esthetic value should also be considered, these factors were not taken into account during the evaluation of the success rate of the control technologies in this study.

*A one-way analysis of variance (ANOVA)* (Snedecor & Cochran, 1980) was carried out to test for differences between the four control technologies concerning the success rate of each.

**Table 5.8 :** Mean percentage success rate and standard deviation for each of the four main bush control technologies. The number of case studies representative of a control technology is indicated by n. Ch = chemical control, Mn = manual control, Mc = mechanical control and Bio = biological control.

Technology	Mean success rate value (% and SD)	n
Ch	81.7 a ± √229.5	66
Mn	75.2 a ± √651.0	25
Mc	72.0 ab ± √306.7	10
Bio	56.7 b ± √426.7	6
<hr/>		
F-prob.	P = 0.009	
CV%	23.8	
Means per control technology were separated using Fisher's protected t-test. Least Significant Difference (LSD) was determined at the 5% - level. Means followed by the same letter (a or b) did not differ significantly. F-prob. = F-probability value and CV% = Coefficient of Variation of the data.		

According to the estimated mean values given in Table 5.8, it is clear that of the four control technologies, chemical control (81.7%) proved to be the most successful technology used to control bush encroachment, followed by manual (75.2%), mechanical (72%) and biological control (56.7%).

No significant difference was noted between the chemical and manual control technologies, however these two technologies did differ significantly ( $P < 0.05$ ) from biological control. Mechanical and biological control did not differ significantly from one another (Table 5.8).

From the  $R^2$ -value, it is evident that the effect of the control technologies that were applied, accounted for only 10.5% of the total variation in the success rate. Factors (or terms) other than the control technology used, were also evaluated in order to determine the possibility of additional factors influencing the success rate, as indicated by the land

users (e.g. environmental factors and tree or grass species). Additional factors that mainly contributed to the success rate are listed in Table 5.9 below.

### 5.5.3. Factors affecting the success rate of the applied bush control technologies

Through a multiple regression, the factors (or terms) other than the control technology used, were also evaluated in order to determine the possibility of additional factors influencing the success rate as indicated by the land users (e.g. environmental factors and occurrence of tree or grass species after bush control). This was done by using Forward selection stepwise regression analysis techniques (Draper & Smith, 1981).

**Table 5.9:** Forward selection stepwise regression analysis used to determine the effect of additional factors (fitted terms - environmental variables or species) on the possible success rate of applied bush control technologies (as indicated by land owners). D after control = bush density of problem species after control. Method = bush control technologies (Ch, Mc, Mn or Bio). (See Table 5.8 for the explanation of abbreviations).

Fitted Term	Adjusted R <sup>2</sup> (% increase)	Standard Error of regression	Probability
D after control	17.9	16.9	P < 0.001
<i>Terminalia spp.</i>	29.5 (11.6)	15.7	P < 0.001
Technology	35.2 (5.7)	15.0	P = 0.011
Forbs	36.1 (0.9)	13.5	P = 0.109

Values in the adjusted R<sup>2</sup>-column as indicated in brackets, account for the increase in percentage of variance of the success rate, by adding that specific fitted term to the model. The other values (not in brackets) indicate the total percentage of variance of the full model for every fitted term added at each step. The percentage of variance indicates the degree of influence, that a specific factor (fitted term) had on the total success rate of the applied bush control technologies. The higher the percentage of variance per factor, the greater the influence of that factor on the final success rate, be it positive or negative.

According to the values given in Table 5.9 it can be concluded that variation concerning the success rate of the bush control technologies, is not only explained by the influence of the specific control technology that was applied (Table 5.8). It could also be ascribed to the influence of other factors such as the density of the problem species after bush control. This factor (density after control) had a significant influence ( $p < 0.001$ ) on the success rate of the applied technologies. The influence of density after bush control, can be explained as follows: the lower the bush density after control, the higher the success rate of the applied technology (positive influence). Should the density after control, however, be higher than before control, a definite decrease in the success rate would be seen.

The occurrence of the woody *Terminalia* spp. (*T. prunioides* and *T. sericea*), could possibly be explained by the fact that these species sometimes establish in an area when other problem woody trees or shrubs, such as the thorny *Acacia* species have been removed. The high establishment rate of *Terminalia* spp. directly after bush control in certain soils (sandy), had a significant influence (negative) on the success rate ( $p < 0.001$ ). The seed of the *Terminalia* spp. could have been dormant in the soil seed bank for some time, or seedlings could have been present in the study site and by removing the other problem woody species, this species could benefit and establish successfully. This mostly occurs due to a driven-event factor, such as high rainfall occurrence or suitable temperatures. In short it can be concluded that the higher the establishment rate of another problem woody species (re-encroachment) after the initial bush control, the lower the success rate of such a control technology.

In a similar way, but not statistically significant ( $p = 0.109$ ), is the occurrence of forbs after the application of a control technology. A high abundance of forbs usually indicates a lower success rate, seeing that the forbs compete with the grass species (especially desirable grass species) within the herbaceous layer. Forbs are generally also the first pioneer species that establish after bush control.

Table 5.9 reflects to a certain extent the influence of different factors on the total success rate. The total percentage of variance accounted for concerning all the listed factors, only adds up to 36.1% of variance. No definite relationship could be established between these factors and the success rate of bush control. In other words, none of these factors taken

into consideration had the main influence on the success rate; they all just partly contributed to the total variance.

A possible explanation for the low percentage of variance could be the tremendous variation within the raw data (as obtained from vegetation surveys and the *Bush Expert* questionnaire), as well as the fact that many similarities are found within the data concerning environmental factors within the different study sites. These shortcomings, together with additional recommendations will be elaborated upon in Chapter 7 (Conclusion).

As mentioned in the previous section, proper rangeland management following initial drastic bush control measures, is an essential factor in determining the success rate of such control technologies. Although the influence of management strategies is not evident in the supplied data and results for this study, it should definitely be considered as an indicator of the success rate in future studies, seeing that this factor influences the recovery of the herbaceous layer and also the degree of re-encroachment. Success rate of bush control cannot be determined if the indirect cause of the problem (e.g. overgrazing) is not addressed.

#### **5.5.4. Correlations between the environmental factors, plant species and the control technology applied at all the study sites in Namibia and South Africa**

Redundancy analysis (RDA) ordinations were carried out in order to determine the possible correlations or trends between the different environmental factors, plant species and control technologies. As indicated by the values in Table 5.8, the two most successfully applied bush control technologies were chemical and manual control. For the purpose of the RDA ordinations, only the data of the case studies where these two specific control technologies were applied, were used (technologies separated). The results for each technology are presented in four different graphs (Figures 5.24, 5.25, 5.26 and 5.27). All of the abbreviations that are used in this section, regarding tree and grass species as well as environmental factors, are listed in Annexure 15.

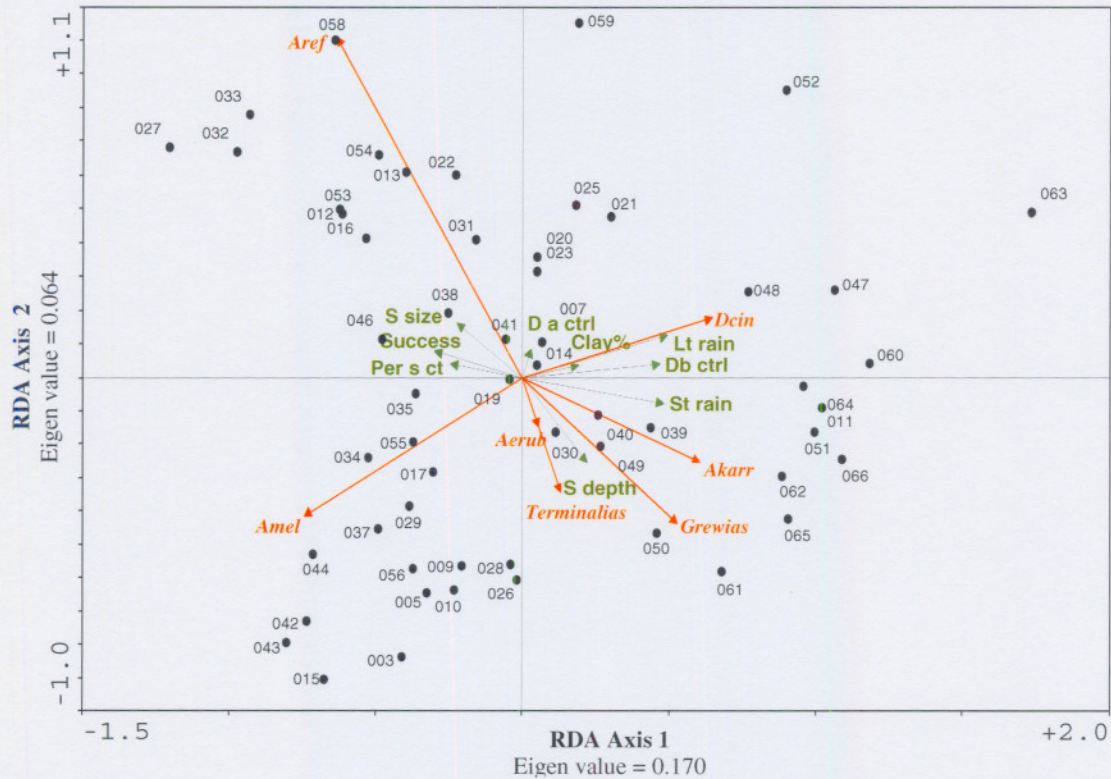
**5.5.4.1. Chemical bush control: Environmental factors and problem woody species**

From the results of the RDA tri-plot ordination, it is evident that according to both axes, the problem species, such as *Acacia reficiens*, *A. mellifera* and *D. cinerea* are not positively correlated with each other (Figure 5.24). This indicates that each of these species formed dominant stands in certain case studies and seldom occurs together in one study site. On the other hand, the species *A. erubescens* and *Terminalia* species, as well as *A. karroo* and *Grewia* species occurred in the same study sites, thus indicating that they are positively correlated with each other. The latter group is negatively correlated with *A. reficiens* stands, meaning that in study sites where *Terminalia* species, *A. erubescens* and *Grewia* species were found, none or very few trees of the species *A. reficiens* occurred.

From the ordination it is evident that the *Terminalia* species are more positively correlated with soil depth (deep sandy soils). The affinity of these species for deep sandy soils with a low clay percentage is also clearly stated in the literature (Van Wyk & Van Wyk, 1997; Schmidt *et al.*, 2002).

Although clay percentage does not indicate a clear positive correlation with any of the case study sites, it seems as if a higher soil clay percentage is found in areas where the species *D. cinerea* dominates. The poor correlation of clay percentage can be ascribed to varying clay percentage values indicated for each case study and the fact that many land users and extension workers who were responsible for the data collection provided poor datasets in this regard.

The species *D. cinerea* is further strongly positively correlated with certain environmental factors such as density of trees before control and long-term rainfall. It can thus be concluded that this species might have occurred in very high densities in the associated cases before chemical bush control and long-term rainfall might have aggravated the encroachment process.



**Figure 5.24:** A RDA triplot-ordination, taking into account the environmental and problem woody species data, together with the distribution of the chemical control case studies (66 cases) for Namibia and South Africa (see Annexure 15 for abbreviations).  
(● = case study with number).

Another trend that can be observed is that a negative correlation exists between the *Terminalia* species and the success rate. As mentioned previously, this could be due to the fact that high densities of *Terminalia* species occurred in areas that have been controlled (see 5.6.4.).

The eigen-values on both the first (0.170) and second (0.064) ordination axes are very low, indicating that the correlations between different factors are not very strong.

#### 5.5.4.2. Chemical bush control: Environmental factors and the herbaceous component

The results from the RDA tri-plot ordination (Figure 5.25), indicates that strong negative correlations exist between annual and desirable perennial grass species. The annual grass species are negatively correlated with desirable perennial grass species, seeing that both these species seldom occurred in high frequencies within the same study sites. Annual

grass species are usually pioneer species in comparison to perennial grass species that are more likely to be sub-climax or climax species, thus these two different herbaceous components are not often found in the same successional state.

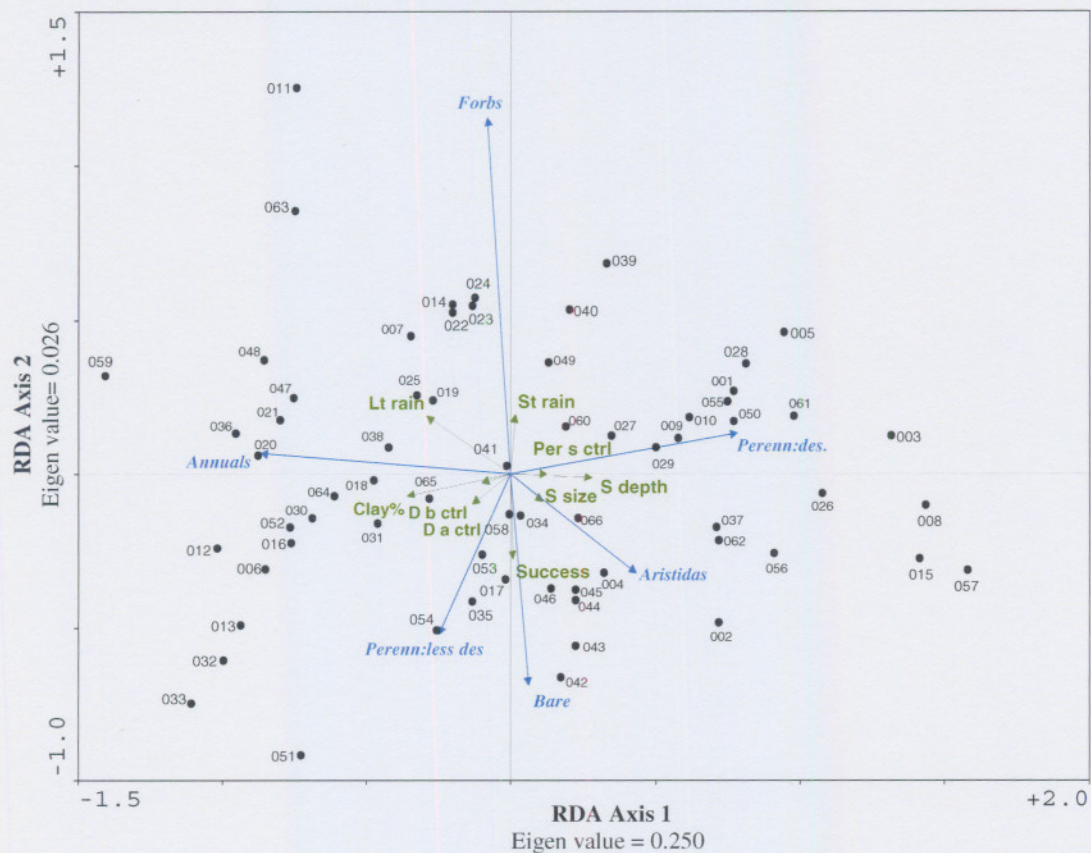
A strong negative correlation is also indicated between the forbs species and bare ground, which can be ascribed to the fact that case studies in which bare areas are evident after bush control, no forbs species were noted and the opposite is also true, seeing that no or very few bare areas were visible in sites where forbs species occurred in high abundance.

According to axis 2, *Aristida* species and less desirable perennial grass species are more closely associated with areas where bare ground occurs. As for the previous ordination, no strong positive correlation could be observed between environmental factors and the herbaceous species. Some of the deductions that can however be made, is that deeper soils (S. depth) and longer periods after control (Per s ctrl) are more positively correlated with the desirable perennial grass species, whereas both short- and long-term rainfall favours forbs and annual grass species establishment.

It is also interesting to note that the success rate is positively correlated with bare ground. This could be due to the fact that either dense stands of *Terminalia* species now occur in the associated sites, or some of the controlled and thinned areas have not been populated by herbaceous species.

The eigen-values on the first (0.250) and second (0.026) ordination axes are very low and thus explains the poor correlation between environmental factors, herbaceous species and chemical control study sites in the ordination.

The correlations between the environmental variables and herbaceous species components could have better been, if grazing pressure after bush control would have been included as a determinant in the dataset. A particular grazing pressure could have influenced abundances of certain annual and perennial grass species, which would in turn influence the results of the dataset.



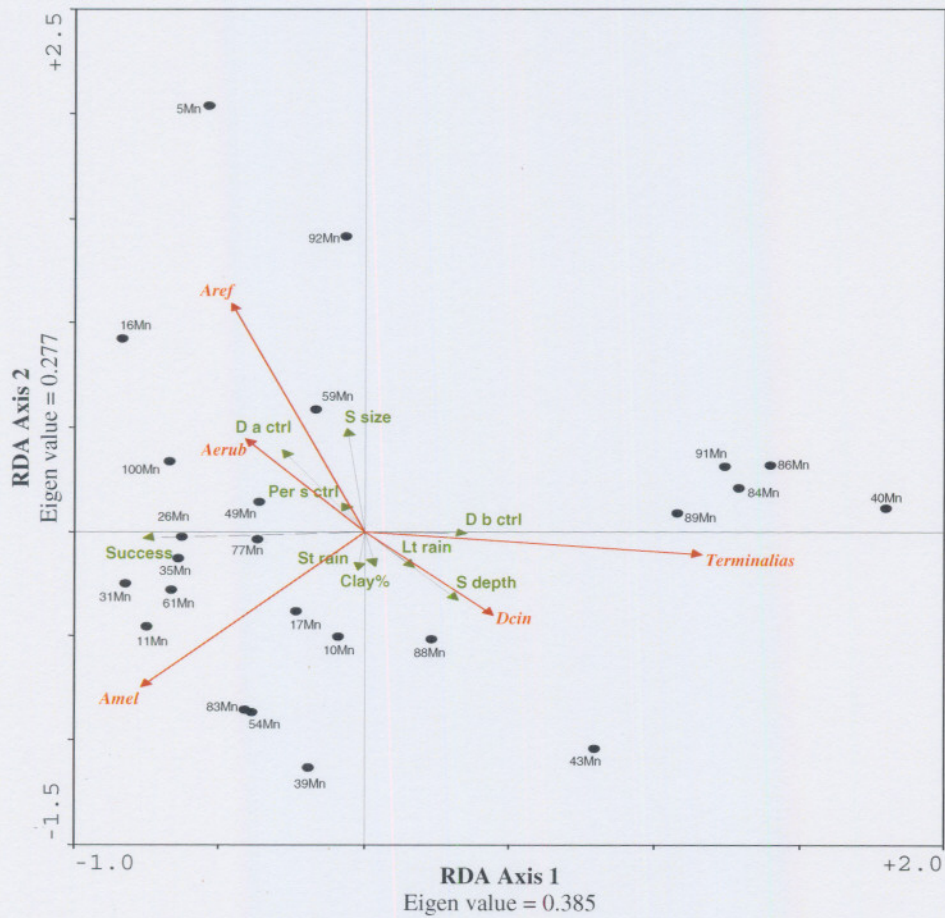
**Figure 5.25:** A RDA triplot-ordination, taking into account the environmental and herbaceous component data, together with the distribution of the chemical control case studies (66 cases) for Namibia and South Africa (see Annexure 15 for abbreviations).  
(● = case study with number).

#### 5.5.4.3. Manual bush control: Environmental factors and problem woody species

Manual bush control technologies proved to be the second most successful control technology and is represented by 26 case studies in the following ordination graphs. No manual control case studies were surveyed in South Africa. Only Namibian case studies are therefore used in these ordinations.

As for the chemical control technologies, this RDA triplot-ordination clearly indicates strong negative correlations between the three most important problem woody species, e.g. *Acacia mellifera*, *A.reficiens* and *Terminalia* species, seeing that they seldom dominate in the same study sites (Figure 5.26).

The problem woody species, *Terminalias* are also strongly negatively correlated with the thorny *Acacia* species e.g. *A. reficiens.*, *A. mellifera.* and *A. erubescens.* This could indicate that *Terminalia* spp. are often not associated with the other species mentioned in the study sites, or that the *Terminalia* species occurred in lower densities than the other species.



**Figure 5.26:** A RDA triplot-ordination, taking into account the environmental and problem woody species data, together with the distribution of the manual control case studies (26 cases) for Namibia (see Annexure 15 for abbreviations). (● = case study with number).

Very few of the environmental factors are positively correlated with the different species in the manually controlled study sites. The only factor that can be mentioned is soil depth that is associated with *D. cinerea* and to a lesser extent with the *Terminalia* species, and bush density after control that is positively correlated with *A. erubescens*, therefore possibly indicating that this species occurred in high densities after manual bush control.

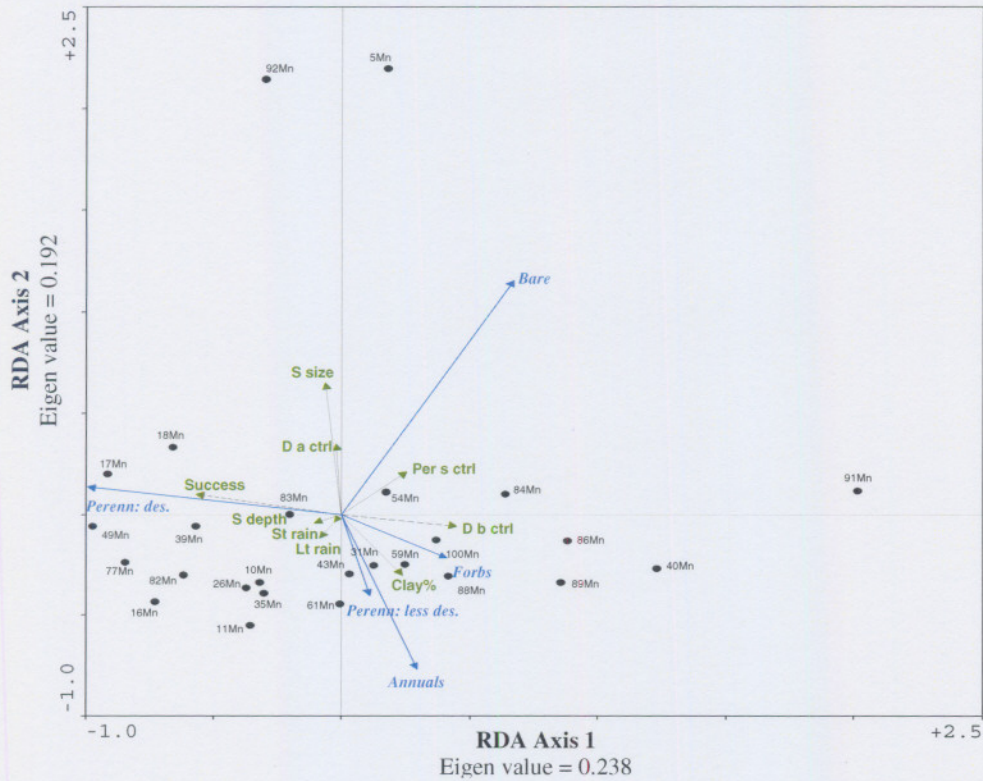
Another obvious trend that can be observed is that of the negative correlation between the *Terminalia* species and a high success rate. This could be due to the fact that high densities of *Terminalias* have a negative influence on the success rate of bush control (see 5.6.4.).

The eigen-values on the first (0.385) and second (0.277) RDA-axes are not as low as for the previous two RDA ordinations, but are still fairly low, thus indicating that no strong correlations exist between the different environmental factors, woody species and study sites.

#### **5.5.4.4. Manual bush control: Environmental factors and the herbaceous component**

The results of this RDA ordination graph (Figure 5.27) clearly indicate three outliers (case study 5Mn, 91Mn and 92Mn). These outliers were not removed from the data set, but rather used to indicate that bare ground occurs in high abundance in these three sites. In the case of site 91Mn, manual control was applied in the form of cutting down the trees with axes, no after-care programme was implemented, and the density of the trees did not decrease but remained the same, with the only change being that trees turned into bushes due to the cutting of branches.

Case study 5Mn and 92Mn are sites situated on the same farm and the same manual bush control methods were applied (cutting with axes and stemburning). No after-care was applied in any of the cases and the stemburning process resulted in bare areas occurring around the trees. The bush densities in case study 5Mn increased from 550 trees/ha before control to 2 250 trees/ha after bush control, and in case study 92Mn only a slight decrease in density is observed (550 trees/ha to 400 trees/ha). As mentioned, no definite decrease in bush densities can be observed and consequently there was no significant establishment rate of the herbaceous component, thus explaining the high occurrence of bare ground in these three sites.



**Figure 5.27:** A RDA triplot-ordination, taking into account the environmental and herbaceous component data, together with the distribution of the manual control case studies (26 cases) for Namibia (see Annexure 15 for abbreviations). (● = case study with number).

The desirable perennial grass species are negatively correlated with bare ground, annual grass species, less desirable grass species and forbs, seeing that most of the latter herbaceous components are associated with the early successional stages in a natural environment. Strong positive correlations also exist between desirable perennial grass species and a high success rate.

The only positive correlations concerning environmental factors are that of the fairly strong correlation between density of problem woody species before control and forbs. This could possibly be explained by the fact that at sites in which the density before bush control was fairly high, forbs occurred in high frequency after bush control.

Another positive correlation can be seen between the high clay percentage and less desirable perennial, as well as annual grass species.

It should be mentioned that no *Aristida* species were represented in this RDA-ordination concerning the herbaceous component of manual control case studies. The reason being that the *Aristida* species did not occur in high enough frequencies in any of these case studies.

The eigen-values for the first and second RDA-ordination axes are 0.238 and 0.192 respectively. These values are quite low, indicating that no strong correlations exist within the data for manual bush control, regarding the herbaceous component.

In conclusion it can be said that the only environmental factors that influenced the occurrence of woody and herbaceous species, as well as the distribution of case studies in the ordination graphs, were density of problem woody species before control, soil depth, long-term rainfall, density of problem woody species after control, clay percentage and success rate. The other factors did not contribute significantly to the explanation of the occurrence of species and site distribution, in either the chemically or manually controlled study sites.

The low eigen-values in all of the ordinations prove that the environmental data used in the analysis is either very diverse, or that the amount of data was insufficient. More case studies have to be surveyed in order to obtain better correlations and trends between problem woody species, herbaceous species and the environmental factors.

#### **5.5.5. Problem woody species and herbaceous species distribution within the Namibian and South African case studies**

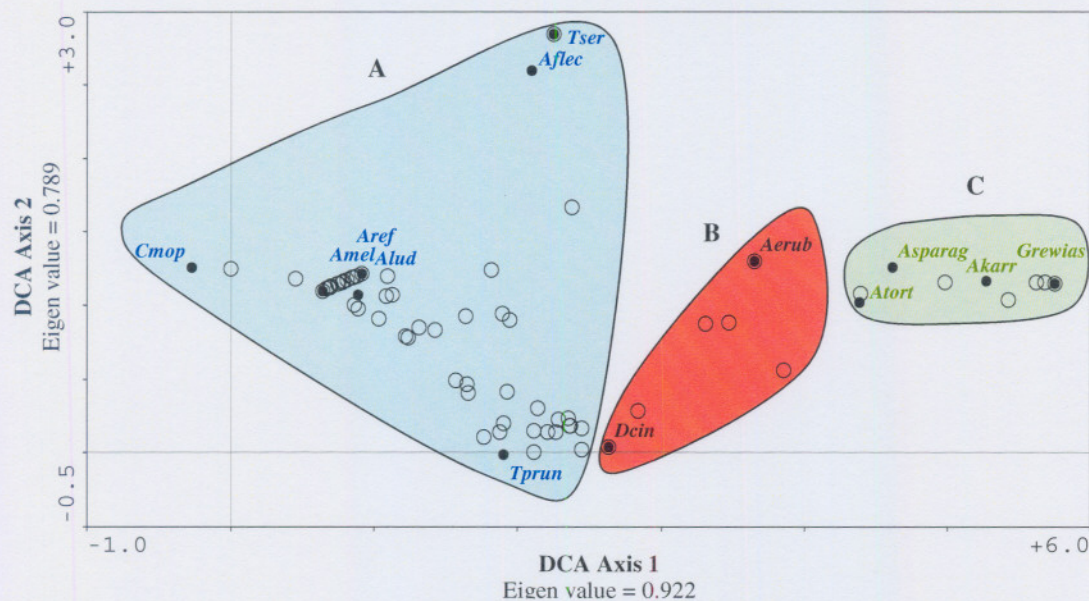
Detrended Correspondence Analysis (DCA) ordinations were carried out in order to determine the possible correlations or trends between the different tree and herbaceous species for both Namibian and South African case studies respectively. Two graphs are included and discussed in the following section. The first graph indicates the distribution of problem woody species, and the second graph the distribution of herbaceous species. Concerning the use of species names, the original species names for grasses and trees are used as indicated on the *Bush Expert* questionnaires and vegetation survey forms and species will thus not be combined as in the case of all the RDA-ordination graphs indicated in the previous section.

### 5.5.5.1. DCA ordination for problem woody species occurrence in Namibia and South Africa

Three very distinctive groups of tree species can be observed in the DCA-ordination graph (Figure 5.28). Group A, on the left hand side of the graph, indicates the problem woody species that dominated in case studies surveyed in Namibia, e.g. *Terminalia prunioides*, *T. sericea*, *Colophospermum mopane*, *Acacia mellifera*, *A. reficiens*, *A. luderitzii* and *A. fleckii*.

Group C, on the right hand side of the ordination graph, represents the dominant problem woody species that occurred in the case studies surveyed in South African after bush control, e.g. *Grewia* spp., *Asparagus* spp., *Acacia tortilis* and *A. karroo*.

Group B, in the middle of the ordination graph, represents the 'overlapping' (mutual) species, which occurred in both Namibian and South African surveyed case studies.



**Figure 5.28:** DCA-ordination taking into account the different problem woody species (13 species) which occurred in Namibia (A), South Africa (C) and in both countries (B) after the application of bush control technologies.

(See Annexure 15 for abbreviations).

(● = problem woody species; ○ = case studies).

The 'overlapping' species include *Dichrostachys cinerea* and *Acacia erubescens*, indicating that these two species occurred in high densities in all of the case studies, in both countries.

The two problem woody species *Acacia hereroensis* and *Catophractes alexandri*, which occurred only in the Namibian case studies, were excluded from the ordination. It must however be emphasized that these two species, although poorly represented in low densities in the 100 Namibian case studies, are also regarded as important problem species concerning bush encroachment in Namibia.

The species *Colophospermum mopane* almost seems to be an outlier on the ordination graph. This can be ascribed to the fact that this species was only represented in three case studies in Namibia. The species however occurred in very high densities and could therefore not be left out of the data set for analysis purposes.

The eigen-values on the first (0.922) and second (0.789) ordination axes are very high, which indicates that the three groups (A, B and C) are very distinct and account for the clear distributions of case studies along these axes for each of the two countries.

#### **5.5.5.2. DCA ordination for herbaceous species occurrence in Namibia and South**

##### ***Africa***

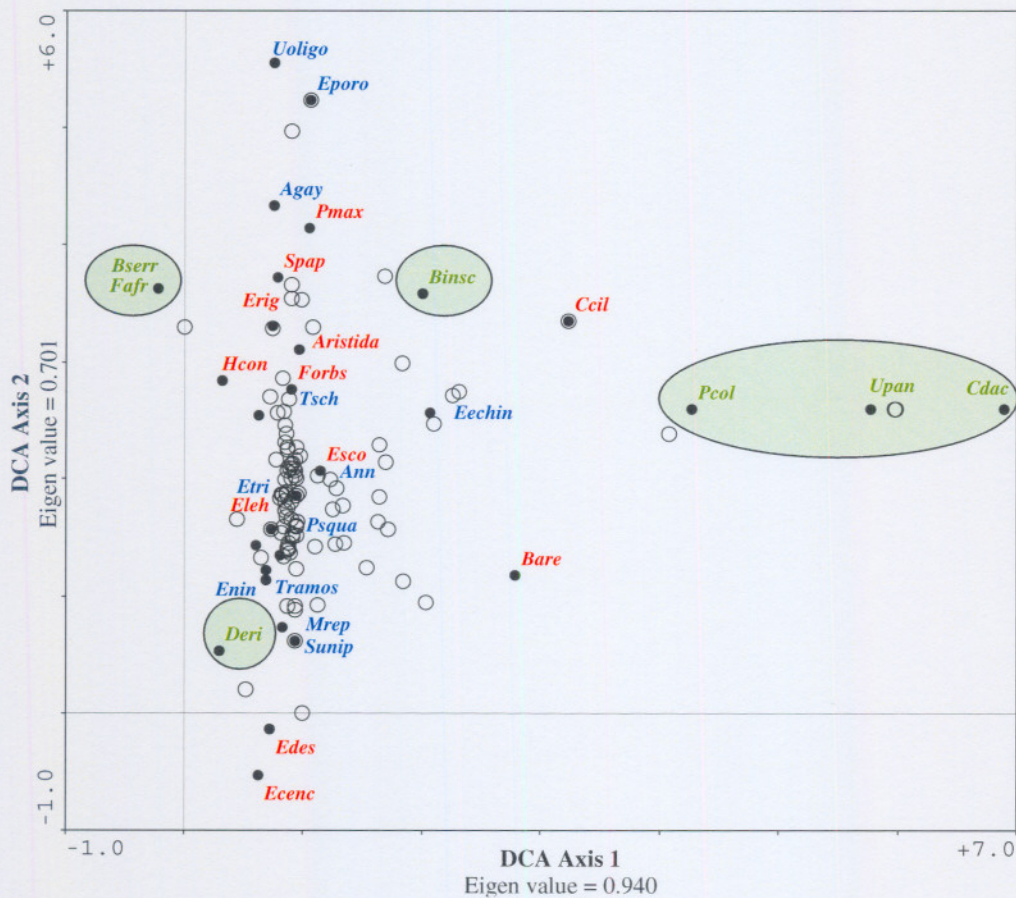
This ordination-graph (Figure 5.29), does not indicate the different groupings of species for each country as distinctly as the problem woody species (Figure 5.28). A collective total of 31 herbaceous species are represented in this ordination for the Namibian and South African case studies.

A total number of seven herbaceous species are indicated in the ordination graph, as representative species for South African case studies. These species include: *Panicum coloratum*, *Urochloa panicoides*, *Cynodon dactylon*, *Digitaria eriantha*, *Brachiaria serrata*, *Fingerhuthia africana* and *Bothriochloa insculpta*.

Twelve of the total 31 herbaceous species in the graph are representative of the Namibian case studies. Some of the dominant Namibian grass species include *Stipagrostis uniplumis*, forb species and annual grass species such as *Eragrostis porosa*. The latter

species (*E. porosa*) is indicated separately in the ordination graph and not as part of the annual grass species, due to the fact that this species was indicated individually in the questionnaires and occurred in higher densities than the other annual grass species in the study sites.

Twelve species are 'overlapping' (mutual) herbaceous component species, which occurred in both Namibian and South African case studies. These include species such as *Enneapogon cenchroides*, *Heteropogon contortus*, *Eragrostis lehmanniana* as well as bare ground and forbs.



**Figure 5.29:** A DCA-ordination, taking into account the different herbaceous species (31 species) which occurred in Namibia and South Africa after the application of bush control technologies (see Annexure 15 for abbreviations) (● = problem woody species; ○ = case studies).

A clear wedge effect from the right hand side to the left hand side can be seen on axes 1 and 2 of this ordination graph. Normally this effect requires extensive analysis manipulation, e.g. by removing the three species *Panicum coloratum*, *Urochloa panicoides* and *Cynodon dactylon* on the right hand side of axis 1. This was however not done, seeing that this three-species group on the right hand side occurred in high abundances in the case studies surveyed in South Africa, which characterizes the sites in the Limpopo Province. These three species can therefore be regarded as key-species for these distinctive environments.

No specific reasons can be given for the further distribution of all species within the ordination, except differences in frequency and number of case studies in which species occurred.

The eigen-values for the first and second ordination axes are high, with values of 0.940 and 0.701 respectively. This indicates a distinct grouping of species on the right and left hand side of axis 1. The distinct groupings along axis 2, at the top (characterized by species such as *U. oligotricha* and *E. porosa*) and bottom (represented by species such as *E. cenchroides* and *E. desvauxii*) of the ordination graph, could be ascribed to the high variability concerning the different species that are expressed on this axis. No clear differences are apparent regarding the abundances of these species within the various study sites and thus the distinct groupings (at the top and bottom of axis 2) cannot be ascribed to differences in abundance. It is possible that the variability in the herbaceous species data (as seen in Figure 5.29), will decrease when additional data from the same study sites is added to the original dataset.

The aim of this ordination was to indicate distinct herbaceous species groupings and that is the reason why no refinement took place in the dataset, as would usually be done in order to exclude 'noise' from the ordination.

In comparing the tendencies and correlations observed in these two DCA-ordination graphs, with results as indicated in the section on country specific results for Namibia (5.4.1.) and South Africa (5.4.2.), it is clear that the results coincide regarding the occurrence of problem woody species and herbaceous component species as it occurred in the study sites after bush control.

In conclusion it can be said that, although certain bush control technologies have the same effectivity or success rate, whether applied in Namibia or South Africa, the problem woody and herbaceous species occurring after bush control may differ dramatically, depending on the location of the study sites. The same rule applies to the specific environmental variables that differ between the two countries, especially long-term and short-term rainfall (higher in South Africa than in Namibia). All these factors, together with the available resources concerning the control technology to be applied, may cause a difference in the results and success rates for case studies sampled in the two countries.

The following section will now elaborate on the general economic implications and different aspects concerning affordability of bush control technology application, as a means of mitigating the process of degradation in the natural rangelands of southern Africa.

## **5.6. ECONOMICAL VIABILITY OF THE APPLIED BUSH CONTROL TECHNOLOGIES**

The economical viability of bush control is often the main reason influencing the land users' choice of a specific control technology. Seeing that most of the technologies involve a large capital investment, care should be taken that the costs of implementing such a technology do not exceed the financial position of the land user in the long-term.

In effect, only land users that are financially strong, or have the ability to expect positive returns over the long-term, should implement bush control technologies on their land. Land users often acquire large loans from financial institutions in order to control bush encroachment. The returns (from the restored land) after bush control application are often very slow and exceed the interest rates of such loans, leaving land users in great debt for long periods of time. This also leads to insufficient implementation of after-care programmes and consequently the re-encroachment of problem woody species after some time.

Although certain technologies are more expensive to apply initially, the long-term benefits and economic gains from these applications are often higher and more cost effective. Less after-care programmes are needed if better initial bush control is carried out. Chemical control technologies are for example more expensive, but most farmers

tend to apply this technology due to its effectivity and better income returns, in the form of increased meat production and utilization of the controlled species in the long-term.

To calculate the costs for control technologies per hectare, in Rands or Namibian dollars (R or N\$ /ha), the formulae in Box 2 can be used.

<p style="text-align: center;"><b>BOX 2</b> <b><math>(R/ hr) / (ha/ hr) = R/ ha</math></b></p> <p style="text-align: center;">Example: Bush control at 4 ha/10 hrs e.g. 0.4 ha/hr Cost per hour = R8</p> <p style="text-align: center;">Therefore rand per hectare = <math>R8 \div 0.4 = R20</math></p>
---

( Müller & Archer, 2001).

The economical implications and costs involved in the control of bush encroachment will briefly be discussed within the following section under the headings: wages, implements and herbicides.

### 5.6.1. Wages

According to the Minister of Labour, the honourable Mr. Membathisi Mdladlana (2002) speaking at Elsenburg Agricultural College near Stellenbosch, the updated version of the South African Basic Conditions of Employment Act (75/1997) indicates that the new minimum wages legislation set for farm workers in South Africa, should be as follows:

- Wages for workers in high-income areas had been set at R800/month and in lower-income areas at R 650/month.
- Those labourers working 27 hours or less a week, would be entitled to R4.10 an hour in high-income areas and R3.33 per hour in lower-income areas.

These wage guidelines serve as a good indication of the labour costs involved in bush control technologies. These wages can however be adapted (and usually are) by the land user, according to the specific situation on the farm and agreement with the labourers. In calculating the minimum wage for a worker per day, the working hours usually come to

eight-hours/day. Thus a worker in a low-income area would be paid R26.64 for an eight hour working day. The working hours may however also differ according to the land user. According to personal communications (Lehman Lindeque<sup>8</sup> and Chris Richter<sup>9</sup>) the commonly accepted daily wage for farm workers within the LandCare-programme (LandCare, 1998) in South Africa and workers in general, varies between R30 - R40/day, and that of a foreman or supervisor, between R 50 - R60/day.

Concerning the minimum wages legislation set for farm workers in Namibia, no definite law has yet been stipulated by the government concerning this matter (Labour Act, 6/1992; International Development Consultancy, 2003). The Namibia Agricultural Union (NAU) however, has set up a document indicating the date of promulgation for the payment of wages to farm workers, to be 5 November 2002. The document stipulates minimum wages payable for work done, as N\$ 2.20/hour (irrespective of the total number of working hours per week) or N\$ 17.60/eight-hour working day (Namibia Agricultural Union, undated).

Contractors can also be hired to conduct the bush control, but the costs involved concerning this matter will not be discussed in this dissertation. No legislation currently exists concerning the payment of contractors in either South Africa or Namibia. The best option would be for a farmer to contact such contractors directly or obtain information from their local agricultural co-operation.

### 5.6.2. Implements

Costs involved when using implements for bush control are not standardized and may vary with regard to the availability of the correct equipment. Many farmers use their own mechanical or manual control equipment. Implements and equipment need to be hired and should a contractor be hired to perform the bush control procedure, costs could greatly increase. Implements that are normally used include bulldozers, rollers and other mechanical equipment. Purchasing of manual control equipment such as axes, spades and pangas should also be taken into consideration. See Annexure 16 for a pricelist containing

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<sup>8</sup> **Mr. Lehman Lindeque:** National LandCare Secretariat, National Department of Agriculture of South Africa. Contact details: P.O. Box X120, Pretoria, 0001, South Africa. E-mail: [LehmanL@nda.agric.za](mailto:LehmanL@nda.agric.za). Tel: +27-(0)12-319-7546.

<sup>9</sup> **Mr. Chris Richter:** Terra Care Vegetation Consultants (Pty.) Ltd. Contact details: P.O. Box 17323, 13 Orange Road, Bainsvlei, 9338, South Africa. Mobile: + 27-(0)82 458 4558; Fax: +27-(0)51 445 2602.

estimated prices of the basic equipment or implements needed for different bush control technologies.

A list of price estimations for bush control machinery according to Müller & Archer (2001), is also included in Annexure 17. These estimations include aspects such as purchasing prices, depreciation values, repair and maintenance costs of machinery such as tractors. The prices indicated in Annexure 17, are estimations for the year 2001, but seeing that the prices don't vary considerably from one year to another these can be seen as quite accurate and applicable guidelines for the present circumstances. The engineers and agricultural officers at the Provincial Department of Agriculture, Conservation and Environment in Potchefstroom still use the prices listed in Annexure 17. The factors that vary considerably from one year to the next, which should be taken into consideration, are fuel prices and insurance costs.

Prices concerning the equipment needed for chemical control technologies will be discussed in the following section 5.7.3 - *Herbicides* (also see Annexure 16).

### **5.6.3. Herbicides**

The costs of herbicides used for bush control in southern Africa vary according to the different manufacturers and suppliers and the active ingredients of the chemical substances. Chemical control was regarded to be one of the cheapest and most effective technologies suitable for eradicating problem woody species in Namibia, as estimated during trials in the 1950's (Bester, 1996). Presently the situation is slightly different. Though chemical control is still regarded to be one of the most effective bush control technologies, it is also currently one of the most expensive technologies, due to the high cost of herbicides.

Herbicides can be manually applied by means of a brush, knapsack spraying, high-pressure sprayers or aerial application with a fixed-wing aircraft, helicopter or microlite. It usually involves the hiring of a contractor to carry out these bush control practices (Annexure 16 includes a list of the most needed equipment for bush control). Annexure 18 however gives an indication of the costs involved in the aerial application of a specific herbicide (Access), by means of a helicopter.

The costs of the equipment needed for chemical bush control may vary and will depend on the prices of purchasing or hiring of suitable apparatus and whether the land user or manager carries out the application himself.

In Annexure 19, a list of some chemical control product suppliers or agents is included. A detailed and updated pricelist can be obtained from these suppliers. A list containing the herbicides most commonly used for chemical bush control technologies is given in Annexure 8.

## CHAPTER 6

# DECISION SUPPORT SYSTEM STRUCTURE AND CONSULTATION

The following chapter will include descriptive information on the structure of the *EcoRestore* Decision Support System and a manual that comprise detailed instructions on how to access the *Grass Expert* and *Bush Expert* databases. The *EcoRestore* Decision Support System in the CD-ROM-version is included at the back of this dissertation, which can be consulted by using the manual supplied in this chapter. This DSS is also available on the internet in the web-version and can be consulted at the following web-address: [www.puk.ac.za/EcoRestore](http://www.puk.ac.za/EcoRestore) . The only difference between the two DSS versions, lies in the help function component, which is only included in the web-version, seeing that this version has no accompanying manual to assist the user.

### 6.1. INTRODUCTION

The construction and development of the *EcoRestore* DSS, is an attempt by scientists and land users to combine, share and store indigenous and other knowledge concerning restoration technologies which are applied to reclaim degraded rangelands. By consulting this DSS, the land user could find a possible solution to his or her specific problem regarding the degradation on their land. The databases in the *EcoRestore* DSS are by no means complete and still need further updating and expansion in future. The first version of the DSS presented, is only the first attempt to document restoration practices, which focuses on the reclamation of degraded and denuded land and the control of bush encroachment. The aim is to expand the databases to other countries and services, which are faced with similar problems and challenges.

As previously mentioned in Chapter 2, the *EcoRestore* DSS, (Decision Support System Development), consists of two databases, *Grass Expert* (database containing information on restoration technologies applied to recover bare and denuded areas) and *Bush Expert* (database containing information on bush control technologies).

By combining these two databases, they will complement each other and benefit from the existing case studies. For example, after the control of bush encroachment, bare and

denuded areas often occur which need to be restored, by means of effective reclamation technologies. Thus after consulting the *Bush Expert* database for guidelines and best practices involving bush control, the *Grass Expert* database can be consulted in order to obtain relevant information on the restoration of bare and denuded patches in that specific area.

The following section will elaborate on the final structure of the two databases contained in the DSS as it appears in the present web- and CD-ROM -versions of *EcoRestore*.

## **6.2. STRUCTURE OF THE *ECORESTORE* DECISION SUPPORT SYSTEM DATABASES**

In this section the structural appearance of the *EcoRestore* DSS databases, *Grass Expert* and *Bush Expert* will briefly be discussed.

### **6.2.1. *Grass Expert* database**

The *Grass Expert* database in itself entails 14 questions. The answers that the land user needs to choose from appear on the computer screen in the form of droplists. One has to keep in mind not to present the on-line land user with too many questions, as that would discourage completion of the questionnaire. The list of questions that form part of the on-line *Grass Expert* database consultation phase is included in Annexure 20.

The appearance of the *Grass Expert* database as seen on the computer screen by the online-user, can be seen on pages 11 and 12 of the *EcoRestore* User's Manual included at the end of this chapter (screen captures).

### **6.2.2. *Bush Expert* database**

The 100 case studies that were incorporated into the database, were chosen out of a total of 175 cases on terms of completeness, methods applied as well as to try and include a couple of case studies from each of the Namibian regions.

It should be emphasized that not all the questions from the initial *Bush Expert* questionnaire, that was used to obtain information for data analysis purposes, were included in construction of the consultation-panel for *Bush Expert* within the computerized DSS. Questions incorporated into the on-line consultation-panel only

included the most important questions, which are directed at the problem of bush encroachment and possible control technologies that can be applied. These questions are indicated in Annexure 21 and Annexure 22, contains a list of the problem woody species listed within this panel.

The appearance of the *Bush Expert* database as seen by the online-user on the computer screen, can be viewed on pages 14, 17, 18 and 19 of the *EcoRestore* User's Manual included at the end of this chapter (screen captures).

The questionnaire as it is at present, makes provision for incorporation of case studies from other southern African countries in future, and question one (1) already gives the on-line user the option to choose between the following countries: Namibia, South Africa, Botswana, Zimbabwe, Kenya and others. The next *Bush Expert* database version will contain specifications for all the above-mentioned countries.

Bush encroachment specific problem solutions are explained by means of the acquired quantitative data sampled at each of the experimental sites (case studies) as well as the statistical analysis carried out.

In conclusion it can be said that, since the databases (*Grass Expert* and *Bush Expert*) and expert system are based on questions, answers and possible actions based on previous case studies, it is important that the most effective and correct parameters are incorporated into the DSS. Following a question-and-answer procedure the user will be led to the best possible solution to his or her specific problem. The effectivity of a certain suggested solution, given to the land user by the DSS, can be evaluated if the same technology is applied and similar results as given in the case study in the database, is obtained.

The following section will include the *EcoRestore* Decision Support System User's Manual (Version 1). This is an exact representation of the manual, which forms part of the CD-ROM-version packages (CD-ROM and A5-size manual). The two databases can be activated and consulted by following the instructions on pages 5, 6 and 11-21.

### **6.3. ECORESTORE DECISION SUPPORT SYSTEM CD-ROM VERSION USER'S MANUAL**

A 24-page document consisting A5-size pages (excluding cover-page). Annexure 23 contains the *EcoRestore* DSS CD-ROM, Version 1.0.

# **EcoRestore**

**A Decision Support System  
for the Restoration of Degraded  
Rangelands**



**User's Manual**

**CD - Version**

**Version 1.0**



**EcoRestore**  
**A Decision Support System for the Restoration of Degraded Rangelands**

Version 1.0

© August 2003

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**Funded by:**

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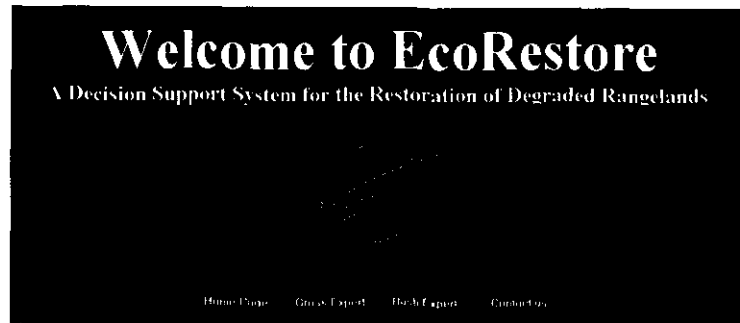
**Disclaimer:**

The Potchefstroom University for CHE accepts no responsibility if the use and application of any procedures expressed by this system does not satisfy the needs or expectations of the user.

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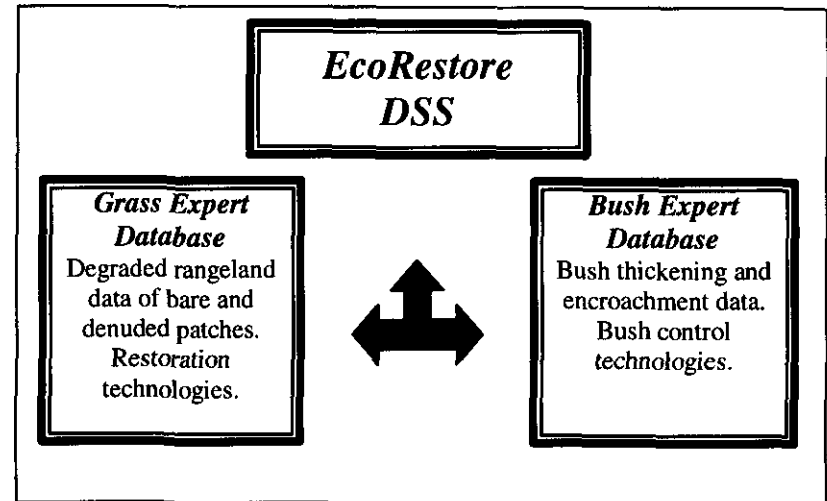
## Introduction



The **EcoRestore Decision Support System (EcoRestore DSS)** is based on case studies of technologies and approaches that have been researched and applied by rangeland managers, scientists and farmers over the short- and long-term in order to restore degraded rangelands or combat problem woody species (bush) and alien species encroachment and thickening. The DSS consists of two databases, i.e. **Grass Expert** - which includes mechanical and/or biological technologies to restore or re-vegetate bare and denuded areas, as well as unproductive rangelands, and **Bush Expert** - which includes case studies of technologies to control or combat bush encroachment and thickening (chemical, manual, mechanical and biological).

The challenge of this DSS is to optimize the exchange of knowledge concerning these practices that have been applied previously and disseminate it to as many users as possible for future rangeland management applications.

## Structure of the EcoRestore DSS



The restoration technologies that have been applied previously, mostly on a trial-and-error basis, over the short- and long-term in different habitats and environmental conditions are quantitatively assessed and the data is incorporated into the databases. The databases can now be consulted. By means of an expert system approach, certain results (solutions/actions) are given that can help the user to address the problem of degraded rangelands or bush encroachment. The results will indicate what the user can expect if the same technology is applied over a similar time frame and under the same environmental conditions, as indicated by the case studies in the databases.

The case studies currently incorporated into the *Grass Expert* database, includes technologies, which have mainly been assessed in South Africa. The *Bush Expert* database mainly includes technologies of case studies sampled in Namibia.

The two databases that are presently incorporated in the *EcoRestore* DSS can be used in conjunction with one another. Areas that have been cleared by means of bush control technologies are often bare and denuded. The *Grass Expert* database can then be consulted to gain knowledge on how these areas can be restored by different methods of re-vegetation or reclamation.

The *EcoRestore* DSS is, however, a dynamic system and as new data from other case studies in southern Africa or other parts of the world become available, they will be incorporated into the databases of the DSS. Please consult the developers for updated *EcoRestore* versions in future.

## EcoRestore DSS versions

Two versions of the *EcoRestore* DSS are available.

1. The on-line, web-version. This version can be extracted and consulted via the following internet address: [www.puk.ac.za/EcoRestore](http://www.puk.ac.za/EcoRestore).
2. The CD-ROM version. This version needs to be updated regularly, either by means of an updated CD of the *EcoRestore* DSS, or from the on-line web-version. Please contact the developers of the *EcoRestore* DSS as indicated in this manual for further information.

This user's manual concentrates on the use and operation of the *EcoRestore* DSS CD-ROM version.

## Hardware specifications

- Internet Explorer 5 (or better) (NB!)
- Windows 98 (or better)
- Office 2000 (or better)
- 68 MB RAM
- Pentium I
- 10 MB Hard-drive Space

## Installation

Follow these procedures for installation:

1. Go to “**Windows Explorer**” of your computer and make sure that you are in the C: drive.
2. Insert the *EcoRestore* CD-ROM in the **CD-drive** of your computer.
3. The *EcoRestore* CD will install **automatically**. A small black screen will appear. **Wait!** Please do not close the application. It will take 3-5 minutes to install, depending on the speed of your computer.
4. Depending on the settings of your computer, one of the following may happen:
  - The black screen will disappear automatically.
  - In the title bar of the black box a command will appear that installation is “finished”. Close the box by clicking on the “” in the right hand corner.
  - If nothing happened after 5 minutes check in Windows Explorer if *EcoRestore* has installed.
5. Go to “**View**” on your Windows Explorer toolbar. Click on “**Refresh**”.
6. An “***EcoRestore***” folder has now been created in the C: drive of your computer.
7. You can now **remove** the CD-ROM and store it in a safe place.

8. Double-click on the “***EcoRestore***” folder.
9. Search for the “**setup.exe**” application by scrolling down.
10. Double-click on “**setup.exe**”.
11. Choose “**OK**” on the next screen.
12. Click on the “**computer button**”-icon.
13. The name “***EcoRestore***” should appear in the “**Program Group**” box.
14. The name “***EcoRestore***” should be highlighted in the “**Existing group**” box.
15. Click on “**Continue**”.
16. Wait until the *EcoRestore* setup is completed successfully (a window will now appear).
17. Click on “**OK**”. The files in the *EcoRestore* folder will appear again. **NB:** The system is now installed successfully on your computer.

To activate the *EcoRestore* DSS, follow this procedure:

- Click on “**Start**” on your Windows tool bar in the bottom left hand corner.
- Go to “**Programs**”.
- Go to “***EcoRestore***”.
- Go to “***EcoRestore Index***”.
- The *EcoRestore* homepage will appear and the DSS can now be consulted.

## Components of the *EcoRestore* DSS

The *EcoRestore* DSS consists of the following components:

1. **Main Page** with links to the funding agencies and important role players.
  2. **Introduction** with a brief explanation of the structure of the DSS.
  3. **Information** which includes the aims of the DSS.
  4. **Grass Expert** introduction, questionnaire and the procedure for the consultation of the database.
  5. **Bush Expert** introduction, questionnaire and the procedure for the consultation of the database.
  6. **Profiles** of the developers of the *EcoRestore* DSS.
  7. **Web Links** to web pages of other important institutions and interrelated service providers.
- The information contained in all of the components of the *EcoRestore* DSS can be printed by clicking on “**File**” in the toolbar at the top of the screen and choosing the “**Print**” option in the drop list.

## Principle on which the *EcoRestore* DSS operates

The *EcoRestore* DSS operates on the principle of questions and answers (Figure 1). Depending on the problem the user experiences (bare/denuded areas and unproductive rangeland, or bush encroachment and thickening), either the *Grass Expert* or *Bush Expert* database can be consulted.

1. Choose the appropriate database on the *EcoRestore* Home Page.
2. The chosen database (*Grass Expert* or *Bush Expert*) will be activated.
3. A short introduction of the specific database will be given.
4. When consulting the chosen database, a number of questions will be asked by the *EcoRestore* expert system.
5. The type and extent of the problem is described by the land user by answering a number of questions. These questions can be answered by choosing the best possible option from the list provided by the database in the DSS. (Drop lists in *Bush Expert*).
6. Using expert system approaches, the system will now search through the database and try to match the answer given by the user to similar case studies already incorporated into the database.

7. Answer as many questions as possible. If the answer to a question is not known, choose the "other" option on the list of answers. It is not compulsory to answer all the questions.
8. Some questions and answers provide hyperlinks to additional information, e.g. maps, diagrams or images. These will assist you with the interpretation of the question and in choosing the most appropriate answer. In the *Grass Expert* database, the "Display help" function can also be consulted.
9. The best possible solution to a specific problem is obtained through the matching process as previously described.
10. The best possible solution (answer) to a specific problem is given as an "action" or "result". The solution will depend on how close the answers given are matched to the data of previous case studies already incorporated in the specific database. The percentage match to the case studies in the database indicates the degree of the best possible solution to the user's problem. A selection of case studies, including different technologies and results, are given. From these the user can choose the most suitable option that will address his/her specific problem.

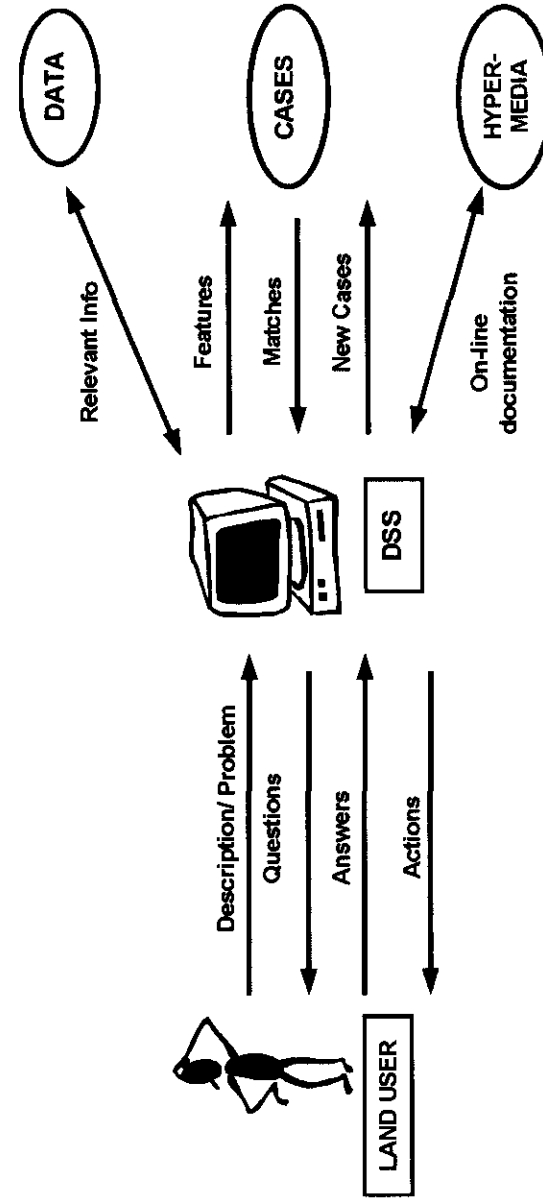


Figure 1. Principle on which the EcoRestore DSS operates.

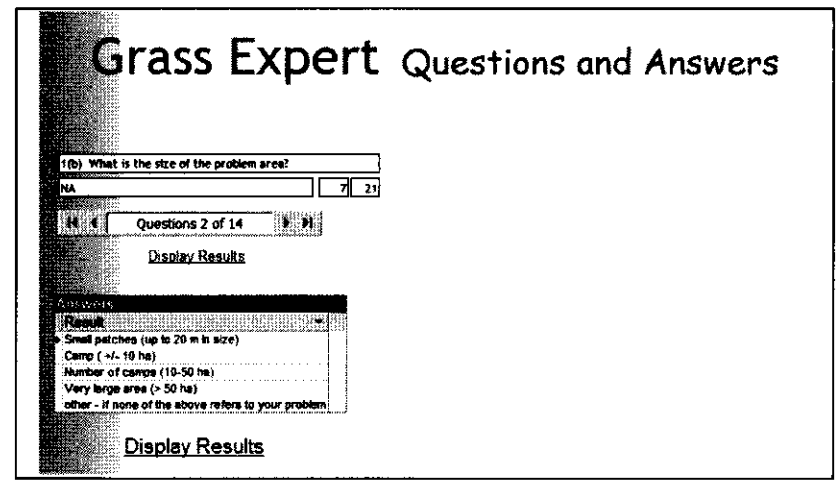
## Consultation of the *Grass Expert* database

This database is consulted when bare and denuded areas, as well as unproductive rangelands, have to be restored or re-vegetated.

Follow this procedure to consult the database:

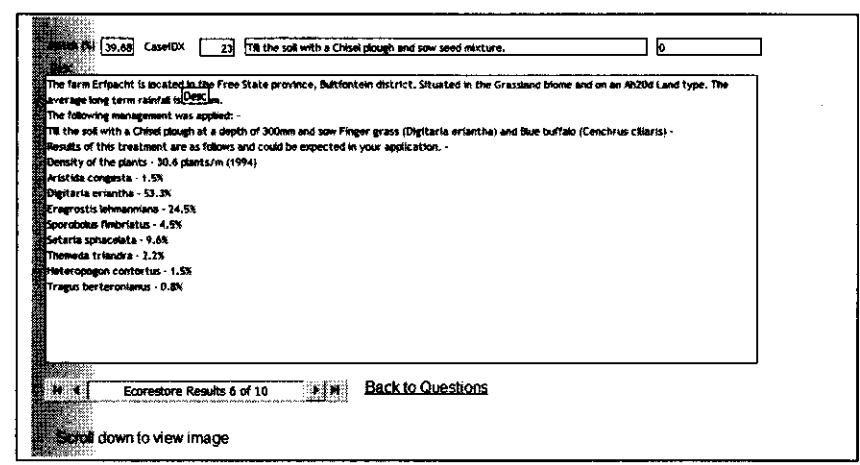
1. Double click on the “*Grass Expert*” database icon on the Home or Main page area.
2. Click on “Click here to consult the *Grass Expert* database”.
3. Fourteen questions will be asked, each with a list of answers to choose from.

### Grass Expert Questionnaire



4. Help to the questions can be obtained as follows:
  - (a) **Scrolling down** on the same page, e.g. average annual rainfall; terrain’s topographical unit; type of mechanical implement; or
  - (b) By clicking on “**Display help for this question**”, e.g. soil type. A whole book of all the soil types with names and photos will be displayed.
5. After most or all questions have been answered, click on the “**Display results**” option. A possible solution (action) to the particular problem, as identified by the user for a specific environment, will be displayed. The solution is based on data of previous knowledge and case studies similar to the problem identified.

### Grass Expert Results





## GENERAL QUESTIONS

4. The answers to the questions in this database consist of drop lists. Click on the arrow next to the answer to activate the drop list.
5. **Area, general vegetation and environment**  
The first set of questions focuses on the region, farming area and general description of the vegetation and environmental factors. Please **do not** fill in the space about comments regarding the soil type, if you are not sure of your answer.
6. **Problem species**
  - (a) The second set of questions focuses on the type, percentage of each type, height classes and density of the problem species that need to be controlled.
  - (b) Also indicate the following:
    - What the problem species will be used for after bush control.
    - Is the site that needs to be controlled near an old land?
    - Is there a watering point near the site that needs to be controlled?
    - What is the aim of bush control at the site?
7. **Type and number of animals**  
For this question, the type of animals (livestock and/or game), as well as the percentage of each that will utilize the rangeland needs to be indicated.

## CONTROL TECHNOLOGY QUESTIONS

8. Choose the type of bush control technology that you would like to use. Only choose **one** of the following treatments i.e. **Chemical, Mechanical, Manual or Biological Control**. If you would like to investigate another technology, please run the system again.
9. Answer the questions for the specific control technologies that you would be able to apply regarding the resources (financial, manpower, etc.) available.
10. After the questions have been answered, click on  
  
***“Run Bush Expert Analysis and Show Results”***

A search will now be carried out to find the best possible match between the answers given and data of the case studies already incorporated in the *Bush Expert* database.

The result of the analysis will follow.

## Bush Expert Results

11. The results of up to 15 case studies are shown. The results are based on previous knowledge and include possible actions and technologies that can be implemented to control bush encroachment in similar areas and environmental conditions. The value of the answer to the specific problem identified by the user will depend on the percentage (%) match as indicated.
12. Other **general information** of the technologies that were previously implemented by land users, includes:
  - The number of the case study in the database.
  - The area, location and main environmental factors.
  - The type, frequency (%), structure and density (trees/ha) of the problem species that were previously controlled.
  - The type of animals of the previous land user.

13. Details of the control technologies that were applied by the previous land user are given ("Control methods"). These include:
  - The type of herbicide, implement or management system.
  - The method of application.
  - Frequency of frost
  - Whether the application was part of an after-care treatment or not.

## Control methods

## After-care

After-care can be characterized by any maintenance strategy implemented after the first bush control treatment, or a follow-up treatment after the first application. After-care is aimed at preventing or stunting re-growth and coppicing of problem plants.

14. Images of the "before" and "after" situation in a previous application of a specific control method are supplied in some case studies. This gives a visual representation of the success of the applied technology and what can be expected should the

same technology be applied in a similar environment and over the same time frame.

15. A detailed description of all the qualitative and quantitative data that was surveyed for the case study is given as a result ("Survey Data Results"). Qualitative data includes all information given by the farmer in answering certain questions of a questionnaire. Quantitative data includes the results of the vegetation sampling that was carried out at the study site of the case study, to assess or estimate the success rate of the applied technology. This mainly includes the woody (bush) and herbaceous composition of the current sward.

### Survey Data Results

```

Case number: 52
Owner: Schullenbach
Name of sampler: H. Kölling
Site nr: Camp 2/ band
Date: 21/2/2001
Farm region/ name: Christiodore/ Gemabokvlei
Farm number: 104+ 214
Farm size (ha): 10 317 ha
Type of enterprise: Large stock
District: Gobeabis
Tel nr 1: (082) 570307
Experience in bush control (years): 15 years
Vegetation type: Camelthorn savanna
Estimated carrying capacity of treated area: 14 ha/LSU
Long-term rainfall (mm): 302 mm
Short-term rainfall (mm): 396 mm
Frequency of frost: frequent
Soil type: Mispah
Clay content (%): 12%
Soil colour: Red
Soil depth: 20- 50 cm
Slope of site where control has taken place: Mid- slope
Soil condition before control: 50% bare, bare+ annuals
Vegetation composition before control (grasses): Annuals > 50%
  
```

16. Other information displayed in the "Survey Data Results" includes:
  - The owner of the farm, including his/her contact details.
  - The name of the sampler that conducted the survey.
  - The region, location, vegetation type and some important environmental factors, especially long- and short term rainfall.
  - The experience of the farmer with regard to bush control.
  - The type, structure and density of the problem species that was controlled by the farmer.
  - The carrying capacity before and after the control technology was applied.
  - Current kg live animal biomass/ ha on the treated area and the percentage (%) increase in grazing capacity after the implementation of the control technology.
  - Details about the control technology, including the type of control, period since control, application and all the resources that were necessary for the application.
  - The composition and abundance (%) of the grass species that occurred at the study site at the time of the vegetation survey. This data indicates how the grass cover has improved after the specific control technology was applied.
  - Any negative and/or positive observations of the farmer regarding the control technology that he/she has implemented.

## Additional Information

The user can consult additional information in the *Bush Expert* database. This information can be accessed by clicking on the icons given at the end of the Result window. The information includes:

1. The **cost** of certain **bush control** methods.
2. Name, address and telephone list of chemical/**herbicide** suppliers and distributors in southern Africa. A list of the most commonly used herbicides.
3. Some **statistical analyses** of the control methods that are currently included in the database.
4. **Opinions** by **experts** with regard to bush encroachment and control thereof.
5. List of **literature** on bush control, land degradation and other relevant information.

The additional information given is by no means complete and will be improved with updated versions of the *EcoRestore* DSS.

## Troubleshooting

The following problems may occur while operating the *EcoRestore* Decision Support System:

1. **The *EcoRestore* Decision Support System does not respond.**
  - Firstly, make sure that your computer meets the hardware requirements that have been set (see section on 'Hardware specifications'). It is important that Internet Explorer 5 should be installed on your computer as well as Windows 98 (or better).
  - If the problem persists, repeat the *EcoRestore* installation procedure.
2. **An error is shown, indicating that *EcoRestore* cannot find the expert database or is unable to connect to the data.** ("Error on page" message will occur at the bottom of the page in *Bush Expert* Questionnaire.)

The above mentioned is caused by one of the following problems:

- (a) Your computer does not meet the hardware specifications. Usually you do not have Internet Explorer 5 or better installed on your computer.

(b) A problem may have occurred while installing the *EcoRestore* DSS. In order to correct the problem, you have to re-install *EcoRestore* by completing the following procedure:

- The CD-ROM must be **out** of the CD-drive.
- Double click on **“My Computer”**.
- Double click on the **C: drive**.
- Click once on the **“Ecorestore”** folder.
- Right click on the mouse button and select **“Delete”**.
- Click on the **“Yes”** button of the box to proceed.
- Now follow the normal installation procedures (see section on ‘Installation’ in this manual).

## Acknowledgements

The developers of the *EcoRestore* DSS would like to acknowledge the following institutions for their continued support:

Potchefstroom University for CHE  
(PU for CHE)  
[www.puk.ac.za](http://www.puk.ac.za)



Namibia Agricultural Union (NAU)  
[www.agrinamibia.com.na](http://www.agrinamibia.com.na)



Desert Research Foundation of  
Namibia (DRFN)  
[www.drfn.org](http://www.drfn.org)



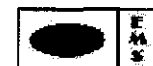
National Department of Agriculture in  
South Africa (NDA)  
[www.nda.agric.za](http://www.nda.agric.za)



Namibian Ministry of Environment  
and Tourism (MET)  
[www.met.gov.na](http://www.met.gov.na)



Environmental Management Services  
(EMS), Pretoria  
Miles Sowden: [miless@redlog.co.za](mailto:miless@redlog.co.za)



## CHAPTER 7

### CONCLUSION

This chapter of the dissertation will include the main concluding remarks and recommendations for further studies. A general conclusion will be given concerning the restoration of degraded rangelands, whereby subject-specific conclusions will follow, concerning the use of bush control technologies, as well as the development of the *EcoRestore* Decision Support System. Future extension possibilities of the DSS will also be discussed. The final part will entail shortcomings and recommendations identified during the course of this study.

#### 7.1. INTRODUCTION

General issues concerning rangeland degradation and possible restoration thereof throughout the world, with special reference to the situation in southern Africa, including Namibia and South Africa, were addressed during this study (Stocking and Murnaghan, 2001; FAO, 2003). Two main aspects formed the framework of this study. The first aspect included the monitoring and assessment of case studies where restoration technologies have been applied by land users in the past in order to control bush encroachment. The second aspect involved the development of a Decision Support System (*EcoRestore*), which can be used as a fully operational consulting tool that provides recommendations for future restoration applications.

The *EcoRestore* DSS that was developed consists of two databases: *Grass Expert* and *Bush Expert*. The focus of this study was the development of the *Bush Expert* database and to incorporate it with the previously developed *Grass Expert* database into one consulting tool system shell.

Close collaboration existed between Namibia and South Africa concerning the development of the *Bush Expert* database, as part of the *EcoRestore* DSS, seeing that the process of bush encroachment affects the rangeland potential of both countries.

The role of Indigenous Knowledge (IK) of the land users was a key-issue of this study, as it formed the basis on which the two databases were constructed. It thus proved to be an

essential aspect of any restoration programme that was implemented where local farming communities are involved (UNESCO, 2003).

The objectives that have been set for this study (as mentioned in Chapter 2) included the following, namely to:

- 1) Gather as much quantitative data of existing rangeland restoration and control of bush encroachment technologies as possible, in order to develop the *Bush Expert* database.
- 2) Evaluate the different rangeland restoration and bush control technologies used by farmers, rangeland managers, scientists and extension workers.
- 3) Identify the most applicable 'best bet' bush control technology for a certain problem under specific environmental conditions.
- 4) Evaluate the economic viability of the bush control technologies.
- 5) Construct a user-friendly DSS which rangeland managers, farmers, scientists and extension workers could use as a consulting tool.
- 6) Create a web page to make the data available to as many users as possible.
- 7) Link the *EcoRestore* web page to other web pages and databases, especially those of other Agricultural and Conservation institutions.
- 8) Create networks and participation between farmers or rangeland managers, scientists and extension workers.

In the following sections these objectives will be discussed and evaluated according to the degree of accomplishment thereof.

## **7.2. EFFICIENCY AND IMPORTANCE OF CERTAIN BUSH CONTROL TECHNOLOGIES**

In order to halt or combat the processes of rangeland degradation in southern Africa, especially concerning the large-scale encroachment of problem woody species in natural rangelands, one of four main bush control technologies were implemented by land users in Namibia and South Africa over time. These technologies included chemical, mechanical, manual, biological control and sometimes a combination of these bush control technologies. These were mostly carried out within the arid- and semi-arid savanna biome regions, which are more prone to bush encroachment.

The efficiency and success rate of such control technologies are however seldom assessed. The aim was therefore to identify as many farmers as possible, whom have applied a certain bush control technology, often at great costs, and to both quantitatively and qualitatively evaluate the efficiency of such applied technologies.

The qualitative evaluation included a questionnaire that was completed by the farmer together with the extension officer or researcher responsible for carrying out the survey. The quantitative evaluation included vegetation-sampling surveys, used to assess the woody and herbaceous component at the site where the bush control technology was applied. Each complete survey was identified as a case study.

Results have shown that not one of the four technologies was confined to a specific area (location) where bush control was carried out, or that one specific technology was applied to control a certain problem woody species.

Any control technology was applied, irrespective of the problem species, reflecting that land users tend to utilize whatever resource is readily available to them, or fits their financial position at the time of control. Should sufficient funds not be available to a land user to purchase herbicides for application of chemical bush control technologies, but they might own a mechanical implement, or have enough labourers that could implement a manual control technology, the obvious choice would be to utilize that specific resource at hand in order to control bush encroachment.

Some general conclusions concerning the four main control technologies are to follow in the next section.

### **7.2.1. Chemical control**

From the information obtained from the *Bush Expert* questionnaires and quantitative vegetation surveys, it was evident that this control technology was most commonly used in both Namibia and South Africa. Although it is quite an expensive control technology, it proves to be very effective, provided the correct method of application (aerial, spoon or knapsack) of the herbicides is used, as well as the prescribed dosage of the product.

Results proved that land users, due to the high success rate of bush control, mostly favoured this control technology. Although chemical control is probably the most expensive way of controlling bush, a study carried out by Zapke in a study site at the Omatjense Research Station in Namibia (Zapke, 1986), indicated a 110% increase in grass production after one year of chemical control with the herbicide Tordon 225 (active ingredient is picloram).

The high success rate can be ascribed to the effectivity of the active ingredients of the herbicides. Tebuthiuron is an active ingredient present in the herbicides Grazer, Molopo and Savana. According to a personal communication (Chris Richter<sup>1</sup>), very few problem species are not affected by the herbicide Molopo and it is especially sufficient in controlling *Acacia* species. One of the biggest problem species concerning bush encroachment (*Acacia mellifera*) is very sensitive to this specific active ingredient and thus a high mortality rate can be expected where herbicides containing this active ingredient, is applied. According to De Klerk (2004), herbicides containing tebuthiuron or ethidimuron as active ingredients usually cause a high mortality of problem species.

The herbicides Buschwacker, Bromacil G10 or Hyvar X were applied in a few of the case studies in Namibia and South Africa. Some of these herbicides are still available on the market in a wettable powder or granular form and are very successful concerning bush control. The active ingredient of the products however is bromacil, which is not preferred for chemical bush control, due to the long-lasting negative effect of the active ingredient on the natural environment (stays active for up to 6-9 months after application), seeing that it does not only kill problem woody species, but also grass and other non-problem woody species.

A total of 66 of the 109 case studies (61%) for both Namibia and South Africa involved chemical bush control. Only 100 Namibian case studies were however incorporated into the *Bush Expert* database thus far. Sixty of the 66 chemical control case studies (91%) indicated a slight or dramatic decrease in bush densities after the application of herbicides, thus reflecting on the high efficiency and success rate of this control technology.

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<sup>1</sup> Mr. Chris Richter: Terra Care Vegetation Consultants (Pty.) Ltd. Contact details: P.O. Box 17323, 13 Orange Road, Bainsvlei, 9338, South Africa. Mobile: + 27-(0)82 458 4558; Fax: +27-(0)51 445 2602.

### **7.2.2. Mechanical control**

This method of bush control was not applied as often, due to the unavailability of mechanical implements or machinery on the farms. Should a land user however own an implement or have regular access to one, such as a bulldozer or roller, this technology was generally applied. Mechanical control is usually not favoured by land users, due to the negative effect of disturbance caused by the heavy machinery on the environment. The use of this type of control technology often only increases the occurrence of certain problem woody species and can result in the re-establishment of a species (e.g. *Dichrostachys cinerea*) after the initial bush control. A total of 11 of the 109 case studies (10%) involved the application of mechanical control technologies, of which all 11 cases were surveyed in Namibia. Seven of the 11 case studies (64%) indicated a decrease in bush densities after control, of which the majority of control applications took place less than 15 years ago.

### **7.2.3. Manual control**

According to the results obtained from questionnaires and surveys, this type of bush control technology proved to be the second most successful, following chemical control. Manual control included the implementation of hand labour by using axes, handsaws or applying stem-burning methods to control problem bush or tree species causing bush encroachment. A total of 26 of the 109 case studies (24%) involved the application of manual control technologies, of which all 26 cases were surveyed in Namibia. Of the 26 case studies, a total of 21 cases (81%) indicated a decrease in bush density after control.

### **7.2.4. Biological control**

Of all the bush control technologies applied, biological control occurred the least. The main method of biological control seems to be the use of fire in the form of natural (caused by lightning) or controlled (human induced) veld fires, and one case study involved natural die-back caused by the fungi *Phoma glomerata* (Namibian case study). A total of six of the 109 case studies (5.5%) involved biological bush control, of which four cases were surveyed in Namibia and the other two in South Africa. Five of these six case studies (83%) indicated a definitive decrease in bush densities after control.

### 7.2.5. After-care

The importance of after-care as part of a follow-up programme after the initial bush control technology was applied, cannot be stressed enough. From the results of the case studies, it is evident that after-care is an essential part of effective bush control in the long-term, seeing that re-growth and coppicing of problem species is stunted in this way. The most common after-care measures implemented by land users, are browsing of new shoots by boer goats or wild ungulates (game), fire, establishment of cultivated pastures or chemical follow-up with herbicides.

Land users in general are well aware of the implications resulting from insufficient or a total lack in after-care. Only twelve of the 109 bush control case studies (11%) for Namibia and South Africa indicated the implementation of an after-care programme, following initial bush control. The majority of these twelve case studies involved biological control technologies as an after-care application, mostly in the form of browsing by boer goats and controlled or natural/accidental fire.

It can be concluded that a land user should not even consider implementing a bush control programme, if a proper after-care programme following initial bush control is not planned or budgeted for. Intervals of after-care application differ from one case study to the next and are mainly influenced by the environmental factors, type of problem species as well as the success rate of the initial control technology.

### 7.2.6. Economic implications

Whichever way one looks at bush control, it remains a costly operation and requires sufficient funding in the long-term. Some control technologies, such as chemical control, as mentioned in 7.2.1. are very expensive to implement, due to the high costs of herbicides. The most important aspects to take into consideration concerning the economic implications of bush control are wages and the prices of implements and herbicides. See Chapter 5, section 5.6 and accompanying annexures for more details concerning the economic implications of bush control.

Chemical bush control with herbicides requires high financial inputs and is mostly applied by farmers with highly profitable enterprises. These include stock or game farms that produce enough income through eco-tourism and sales of livestock or game. If the

land owners can afford the application of a chemical control technology, it should preferably be applied, as it is one of the most successful ways of controlling bush encroachment.

Land users often apply for a loan from the bank or other financial institutions, in order to finance the implementation of bush control. According to the answers given by some land users in the *Bush Expert* questionnaires, some control technologies seem to be cost effective over the long-term, if the applied technology was successful. This is due to the fact that the carrying capacity of the land increases as grasses and forbs re-establish and bush densities decrease. More livestock or game can be kept on the land, thus increasing the animal production in the long-term.

Another way of regaining money spent during the process of bush control is the manufacturing of charcoal or by selling the wood of the problem species as firewood (see Chapter 5, section 5.3.1.7). Fifteen of the total 100 Namibian case studies indicated the production of charcoal as an additional form of income. None of the South African case studies surveyed in the limited localities within the Limpopo Province indicated the production of charcoal. The production of charcoal and selling of problem species as firewood are however common practices in several areas of South Africa where bush encroachment occurs.

It can be concluded that bush control is a highly expensive process, but in the end the advantages exceed the disadvantages, provided the treated rangeland is managed correctly and sustainably.

### **7.3. CONCLUSIONS ON CASE STUDIES SURVEYED IN NAMIBIA**

A short summary of the most important conclusions concerning bush control in Namibia will be discussed in the following section.

A total of 175 case studies were surveyed in Namibia, of which only a 100 formed part of this study and were incorporated into the *Bush Expert* database. Four different bush control technologies were surveyed, which included chemical (59% of the cases), mechanical (11%), manual (26%) and biological control (4%) technologies.

Herbicides most commonly applied in Namibia included Grazer (20%), Savana (15%), Ustilan 10GG (13.5%), Molopo GG (13.5%), Graslan 20P (12%) and Reclaim (12%). These herbicides were most often applied by means of aerial application (46%), soil-application by means of spraying (29%) or the spoon method (22%), or by stem-spraying (3%) with the knapsack method.

Four different mechanical control methods were applied: bulldozers (73%), bush saw (9%), bush harvester (9%) or a combination of bulldozer and roller (9%). The main manual control methods used in Namibia included the use of axes (35%), stemburning (19%), a combination use of axes and stemburning (12%) or axes and mattocks (12%). Biological control in Namibia involved either controlled fire (50% of cases), natural veld fires (25%) or natural die-back caused by the fungi *Phoma glomerata* (25%). Section 7.2 contains more details concerning each of the control technologies.

The districts in Namibia with the highest bush densities, included: Grootfontein, Okahandja, Otjiwarongo, Tsumeb and Windhoek, in which 14 different Agro- Ecological Zones (AEZs) were represented. The majority of the case study sites (68%) occurred within the 300-450 mm short- and long-term rainfall zones. The dominant clay percentage for soils in the case studies (38%) occurring throughout the regions prone to bush encroachment is 10-15%.

A total of 64% of the Namibian case studies surveyed indicated problem bush densities of between >1 000 - 3 000 trees/ha before bush control. All except nine percent (9%) of the cases indicated a decrease in densities after control. The nine percent (9%) increase could be ascribed to insufficient or a total lack in application of after-care measures. The main aim of bush control for 63% of the case studies was that of providing natural grazing for livestock or game. Seventy percent (70%) of the cases indicated the use of problem species to be *no use*, which most probably refers to the brush being left on the land to serve as brushpacking and additional organic material source. The production of charcoal (15%) was also indicated as a possible use of problem species after control.

The dominant periods since control for each of the four control technologies were found to be as follows: Chemical control – 6-10 years (44%); Mechanical control – 11-15 years (45%); Manual control and Biological control – 1-5 years (46% and 50% respectively).

Statistical analyses carried out during this study, clearly indicated the following woody species to be the most dominant problem woody species: *Acacia mellifera*, *Dichrostachys cinerea*, *Acacia reficiens* and *Terminalia prunioides* throughout the central and northern regions of Namibia. The dominant height class represented by the problem woody species in all of the case studies, proved to be 0-0.5 m (37%). The dominant herbaceous species occurring after control included: Annual grass species in 68% of the case studies, *Stipagrostis uniplumis* (33%) and forbs (22%).

A total of 11% of the case studies surveyed indicated the implementation of an after-care programme (see section 7.2.5 for more details).

A detailed description of all the results obtained for the Namibian case studies is available in Chapter 5 (5.4.1.).

#### **7.4. CONCLUSIONS ON CASE STUDIES SURVEYED IN THE LIMPOPO PROVINCE, SOUTH AFRICA**

A short summary of the most important conclusions concerning the control of bush encroachment in the Limpopo Province in South Africa will be discussed in the following section.

Firstly it should be mentioned that the number of case studies surveyed within this province (nine cases), is not sufficient enough to make any definite conclusions concerning bush control in South Africa. The surveys were carried out in a limited location (survey area) in the Thabazimbi region on game farms and reserves. Recommendations and conclusions made concerning these case studies can thus not be seen as generalized perceptions regarding bush encroachment and the control thereof for the whole of South Africa, but only as limited perceptions for the situations in this confined area.

Within the nine case studies surveyed in the Limpopo Province, three main bush control technologies were applied, which included chemical (77.7%), biological (11.1%) and a combination of biological and chemical control (11.1%). The herbicides most often applied during chemical bush control included Access (33.3%), Tordon Super (33.3%) and Buschwacker (11.1%). Biological control involved the application of a controlled fire

and the one case study where a combination of technologies were applied, included a natural veld fire (accidental), cutting down the trees (bush cutter) and then the application of a herbicide.

The dominant short-term rainfall class for this region proved to be the 550-600 mm zone (66.6%) and that of the long-term rainfall the 400-500 mm rainfall zone (55.5%). The prevailing clay percentage of the majority of soils was that of 0-5%, indicating sandy soil textures in 33.3% of the nine case studies.

The dominant problem bush density before bush control, proved to be that of 6 000- 8 000 trees/ha and all of the case studies surveyed indicated a decrease in density after control. All nine cases indicated the main aim of bush control to be the improvement of natural grazing, and the use of problem species after bush control was mainly to serve as browsing (living plant parts) or additionally as brushpacking. The prevailing period since control for these cases were 1-5 years (66.6%) and 6-10 years (33.3%), indicating that most of the control technologies were applied fairly recently.

*Acacia karroo*, *Dichrostachys cinerea* and *Acacia erubescens* were indicated as the dominant problem woody species, causing bush encroachment in the confined localities in the Limpopo Province of South Africa. The dominant height classes represented by these problem woody species in all of the case studies, proved to be 1-2 m (28%), 2-4 m (30%) and > 4 m (28%). Not one herbaceous species was found to be highly dominant in any of the nine case study sites (see Table 5.7 in Chapter 5). One case study survey (11.1%) indicated the application of an after-care programme, involving the use of controlled fire.

A detailed description of all the results obtained for the Namibian case studies is available in Chapter 5, section 5.4.2.

## **7.5. CONCLUSIONS ON THE COMBINED CASE STUDIES SURVEYED IN NAMIBIA AND SOUTH AFRICA**

No definite trend could be determined regarding the control technologies applied and the locality of the case studies in these two countries. Control technologies were evenly spread amongst all of the case study sites.

Analysis of variance techniques indicated chemical control to be the most successfully applied control technology (81.7% successful), after which manual control (75.2%), mechanical (72%) and lastly biological control (56.7%) followed.

Multiple regression analysis techniques indicated the following additional factors to possibly have an influence on the final success rate of bush control technologies: the density of problem woody species after control, the occurrence of *Terminalia* species after control, the type of control technology applied and the occurrence of forbs after control.

Several multivariate analysis ordinations indicated other important results in the form of RDA and DCA graphs. Detailed conclusions concerning these ordinations can be seen in Chapter 5 (sections 5.5.4 and 5.5.5. respectively).

## **7.6. EFFICIENCY OF THE *ECORESTORE* DECISION SUPPORT SYSTEM AS A CONSULTING TOOL**

Data based on input or observations, usually made by managers, scientists and on-land users after monitoring of a problem, can be captured in databases, which form an integral part of a DSS, augmenting the knowledge base and efficiency of such a system (Zimmerman, 2002). DSSs like *EcoRestore* may therefore be a useful way to link monitoring results to management decisions.

*EcoRestore* was developed as a tool for documenting and evaluating restoration technologies, which in turn can be consulted in order to obtain the best possible recommendation considering rangeland restoration and more specifically the control of problem woody species causing bush encroachment. Collection of information and data involves personal contact and sharing of knowledge between land users and restoration specialists. This DSS essentially uses indigenous knowledge as basis for rangeland

improvement recommendations. It offers contacts and references as well as opportunities to share experiences worldwide, but especially in southern Africa.

Information obtained in every case study proved to be quite accurate, because the farmers and rangeland managers that took part in the study usually possessed long-term experience and knowledge concerning bush encroachment as well as the control thereof. This type of knowledge is usually passed on from one generation to the next in smaller circles. Access to this type of knowledge was however limited to other land users, especially upcoming and subsistence farmers in the formerly disadvantaged communities. This is where the aspect of the transfer of indigenous knowledge plays an important role.

Land users, scientists and conservationists are continually implementing new management actions. By measuring the outcomes of these studies, new information will be gathered, which can also be used to update the knowledge-based framework of the *EcoRestore* DSS. This approach also contributes to define new research priorities and emphasizes the maximization of both local and scientific knowledge (Bosch *et al.*, 1997).

The *EcoRestore* DSS will also enhance better awareness amongst land users in commercial as well as communal farming areas, with regard to the reporting of data and gathering of information of applied technologies. Subsequently the importance of monitoring of these practices is also emphasized.

The development of the *EcoRestore* DSS is therefore dynamic and the databases of the system will become more efficient as more information and data concerning other case studies are incorporated into the DSS in the long-term.

The scientifically developed *EcoRestore* DSS is linked to other national and international web-sites and databases, such as Agricultural Geo-referenced Information System (AGIS)<sup>2</sup>, World Overview of Conservation Approaches and Technologies (WOCAT)<sup>3</sup>, Namibian Agricultural Union (NAU)<sup>4</sup>, as well as the web-sites of programmes of the

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<sup>2</sup> Agricultural Geo-referenced Information System (AGIS): [www.agis.agric.za](http://www.agis.agric.za)

<sup>3</sup> World Overview of Conservation Approaches and Technologies (WOCAT): [www.wocat.net](http://www.wocat.net)

<sup>4</sup> Namibia Agricultural Union (NAU): [www.agrinamibia.com.na](http://www.agrinamibia.com.na)

Ministry of Environment and Tourism in Namibia (MET)<sup>5</sup> and National Department of Agriculture in South Africa (NDA)<sup>6</sup>. Through linkages like these, the on-line user is offered a wider range of information and technologies with regard to agricultural and conservation practices.

Collaboration and communication was formed both nationally and internationally, especially between countries that are experiencing the same problems and would like to achieve the same goal concerning bush control. At present, links only exist between South Africa and Namibia, but in future collaboration between other SADC countries, including Botswana, Zimbabwe and Kenya, will ensure more case studies to be incorporated into the *EcoRestore* DSS, which will lead to the expansion of the DSS and improve its effectivity.

It can thus be concluded that the main issues concerning the development of the *EcoRestore* DSS was successfully addressed and that some effective networking between land users, extension officers and researchers has been created. The consultation and development of the on-line (web) version and CD-ROM version of the *EcoRestore* DSS has been successfully communicated to land users, agricultural extension officers and scientists at workshops, farmers' days and conferences (Figure 7.1). Proper feedback to land users and extension officers is a high priority in such a study where many people and different parties are involved.

The *EcoRestore* DSS was developed in such a way for it to be as user-friendly as possible, in order to reach as many parties involved in current or future bush control programmes. This study involved the development of the first version of the DSS (Version 1.0), thus serving only as the prototype system that will be updated in future in order to increase its efficiency.

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<sup>5</sup> Ministry of Environment and Tourism of Namibia (MET): [www.met.gov.na](http://www.met.gov.na)

<sup>6</sup> National Department of Agriculture of South Africa (NDA): [www.nda.agric.za](http://www.nda.agric.za)



**Figure 7.1:** Example of collaboration and networking between scientists and land users, concerning the control of bush encroachment. A workshop held in Otavi, Namibia, to demonstrate the *EcoRestore* DSS to land users.

### 7.7. EXTENSION POSSIBILITIES OF THE *ECORESTORE* DECISION SUPPORT SYSTEM

As the monitoring of bush encroachment and the control thereof is an ongoing process, it is hoped that the database will constantly expand in future. The success and effectivity of the DSS will mainly depend on the number of high quality bush control case studies, containing detailed and complete questionnaire and vegetation survey information.

Expansion of this DSS (*EcoRestore*) in future is highly probable, which involves the addition of other databases (to the two existing ones) with relevance to the subject of restoration or rehabilitation of degraded land in southern Africa. An example of such a possible addition is that of a database concerning mine dump rehabilitation or erosion control in natural rangelands in southern Africa. Another extension possibility involves agricultural plant production processes and the subsequent determination of possible crop yields. The possibility of adding or linking another database and DSS, such as the one mentioned in Chapter 2 (2.2) on *SHRUBKILL*, which is used as a advisory burning programme in Australia, will broaden the use and consultation of *EcoRestore*. The need to link other databases is a high priority, especially the one where the use of fire in rangelands as a means to control invasive bush and problem woody species is explained. Land users are often reluctant to apply such measures due to the possibility of incorrect

application and management, but DSSs such as *EcoRestore* and *SHRUBKILL* provides them with a broader knowledge base to address a certain degradation problem.

## **7.8. SHORTCOMINGS AND RECOMMENDATIONS FOR FUTURE STUDIES**

General shortcomings experienced during this study, as well as possible recommendations that can be made to serve as guidelines for future studies of this nature, will be discussed below. Shortcomings and recommendations will be commented on concerning the collection of data and information needed for the *Bush Expert* database, as well as the development of the *EcoRestore* DSS.

### **7.8.1. Surveying of bush control technologies**

Relevant shortcomings and recommendations identified concerning the collection of data and restoration of degraded rangelands, include the following:

#### ***Shortcomings:***

- 1.) One of the main problems that arose during this study, was that the agricultural extension officers and land users responsible for completion of the questionnaires, did not always answer all the questions in detail. Often critical answers were left out, which subsequently decreases the effectivity of the database and DSS, thus causing problems during the completion of statistical analyses that are performed on the datasets.
  
- 2.) Although only land users and extension officers that were highly committed and disposed of good knowledge regarding bush control technologies were used to carry out the surveys, some mistakes still occurred. These are problems and shortcomings that need to be taken into account where several different individuals (surveyors) are employed as 'researchers' in a project such as this. A total of 175 case studies were surveyed (questionnaires and vegetation sampling) in Namibia, of which only 100 case studies could be used to develop the *Bush Expert* database, as the other 75 were not completed sufficiently.
  
- 3.) Concerning the case studies carried out in the Limpopo Province in South Africa, one can conclude that more case studies should have been carried out within that specific vegetation type, in order to assure more reliable data and better representation of the problem experienced. The reason for the limited number of case studies surveyed in this

province (limited locations), is that the recommendations concerning suitable study sites where bush control technologies were applied (nine sites), were made by only one person (Mr. A. le Roux).

4.) A wealth of knowledge concerning technologies to control bush encroachment already exists in South Africa, but due to several constraints the information is not always readily available for incorporation into the database. An example of such a constraint is that the data is often not published yet and can thus not be incorporated into a system such as *Bush Expert* without consent from the original surveyor or scientist.

5.) Determining the success rate of applied bush control technologies can be very subjective, especially if it is based on the evaluation and opinion of the land user. Land users expect immediate changes after the application of bush control technologies. These changes do however not occur over the short-term and land users might then regard the control technology as unsuccessful. On the contrary, should immediate changes be visible (e.g. after mechanical control) the land user might evaluate the technology as more successful, often disregarding long-term negative effects (Ludwig *et al.*, 1990). Land users often also expect an instant solution to the problem at hand after consulting the DSS and implementing the suggested technologies. They should however remember that these suggestions are mere guidelines aimed at improving the condition of their rangelands and factors such as the implementation of proper after-care and general management strategies (e.g. rotational grazing) will to a great extent influence the success of the applied technologies.

(A number of general aspects and problems that could lead to the possible failure of restoration projects and should be taken into consideration are discussed in Chapter 1, section 1.4.1.)

***Recommendations:***

1.) It was rather difficult to complete statistical analysis on the datasets obtained from the *Bush Expert* questionnaires, due to most of the answers being given as estimated figures or in answered question classes. Thus very few specified answers were provided in the questionnaires for this study. Should one thus aim to apply intricate and detailed

statistical analysis in future, questions should be asked in such a way that specific answers and values are provided.

2.) The parties involved in the setting-up of a questionnaire, should only consider questions that are clearly and easily understood. This could eliminate the problem of poor and insufficient completion of the questionnaires.

3.) In future it is advised that a team of surveyors should be appointed to do all of the surveys in a certain country. By doing this, one is assured that the questionnaires and vegetation surveys are completed in more detail, with limited variations in survey procedures. This will subsequently improve the quality of each survey of a case study.

4.) In future properly specified guidelines and requirements should be set to determine the success rate of bush control. These guidelines should be incorporated into the questionnaires to be completed by land users and extension officers and should be easily understood and completed in detail. Factors that should be included in the questionnaires concerning the evaluation of the control technologies include:

- degree to which the problem woody species were successfully controlled  
(desired number of dead plants)
- time frame (influence of the period since bush control on the long-term and short-term success of the applied technologies)
- recovery of the herbaceous component considering the grazing impact

5.) The choice of sites in a country or a specific vegetation type should always be taken into consideration, seeing that too much variation in the data can occur, concerning environmental aspects such as rainfall, soil clay percentage, problem tree species and herbaceous species. This causes extreme variation in the data, which results in insufficient datasets for statistical analysis purposes.

6.) The constant monitoring of the processes of either degradation or restoration needs to be emphasized, as it can give a clear indication of the succession of plant communities and changes in environmental parameters. Together with this aspect, fixed-point photography within a study site where bush control has been applied, should be promoted,

as '*a picture paints a thousand words*' and can give an indication of the success of an applied technology.

7.) In future emphasis should be laid on the surveying of more bush control study sites all over South Africa, as well as taking into account recommendations from several experts, researchers or control agents concerning study sites, thus increasing the possibilities and number of survey sites. By focusing on more representative case studies in areas prone to bush encroachment in South Africa, more reliable results, conclusions and recommendations can be made in future. The *Bush Expert* database can thus also be expanded regarding the South African case studies (e.g. surveying even more case studies in the Limpopo and Northern Cape Provinces, where several surveys have already been carried out in the past).

### **7.8.2. Decision Support System**

Shortcomings and subsequent recommendations concerning the development of the *EcoRestore* DSS can be listed as follows:

#### ***Shortcomings:***

1.) Very few IT-companies are known to specialize in the development and programming of Decision Support Systems consisting databases and expert systems concerning the natural sciences such as rangeland restoration. A lot of problems were experienced during the first stages of this study, as the IT-company initially chosen, did not meet its obligations regarding the development of the *EcoRestore* DSS. The company also demanded unnecessarily high development costs. A company meeting the expectations concerning the development of this DSS was however found one year later.

#### ***Recommendations:***

1.) The information contained in the *Bush Expert* database and resulting recommendations made by the DSS, could be refined during upgrading processes of the system in future. An example of such possible refinements is to consider the inclusion of the pros and cons regarding the application of specific herbicides as chemical bush control agents. Recommendations could thus be included in the system concerning the herbicides best suited for control of a certain problem species or in cautioning the land

user to avoid the use of particular herbicides containing substances that could be noxious to the environment in the long-term (e.g. herbicides containing bromacil).

2.) It should be mentioned that the IT-company one opts for in the end, should be reliable and keep to the target-dates and -goals set throughout the development process, in order to keep to the time schedule set for a study.

3.) A Decision Support System such as *EcoRestore* is a kinetic entity that needs to be updated and improved regularly, in order to assure its effectivity and success. It should be a user-friendly consulting tool and accessible to as many users as possible. This is especially true, seeing that this DSS is available on the internet, which is an ever-changing system in need of constant upgrading. The more case studies included from different southern African countries experiencing similar problems, the higher the effectivity of the system will be as a whole.

4.) The effectivity of the developed Decision Support System will depend on how frequently it is used and to what extent the decisions of the land user are affected by the system. To test the DSS, feedback by the land user concerning the application of control methods proposed by the DSS is very important for future improvements and needs to be taken into consideration.

5.) The necessary linkages should always be made to relevant and important web pages and databases of institutions and organizations which could benefit from information from this particular DSS (web-version) and vice versa.

6.) A system such as this should be expanded if possible, as it can greatly contribute to the success and application of scientifically sound practices and technologies concerning rangeland restoration.

7.) Sound international collaboration between the countries involved in a project like this need to be in place. All the involved parties should play a role in either the development, administration, distribution or financing of such a project, which results in a feeling of 'ownership' and responsibility. In the same sense, but on a smaller scale, networking between involved parties at ground level also need to be established, e.g. networking

between land users, scientists, funding parties and conservation or agricultural extension officers.

8.) Long-term funding mechanisms are of critical importance in order to ensure the maintenance and regular updating of the DSS.

It can finally be concluded that the objectives set for this study concerning the monitoring of bush control and development of a DSS, as listed under section 7.1. (Introduction), were all successfully met and evaluated at the end of this study.

***Acknowledgements concerning funding of the study***

The funds to complete the *EcoRestore* DSS, were mainly provided by the Finnish Government, which is the funding party of the *Namibian Bush Encroachment Research, Monitoring and Management Project* (Box 1 - Chapter 2). The Namibian programme is managed by Mr. Nico de Klerk<sup>7</sup> who is affiliated with the Namibian Ministry of Environment and Tourism (MET) based in Windhoek, Namibia. In South Africa the DSS-project is managed by the Potchefstroom University for Christian Higher Education (PU for CHE) and funded by the National Department of Agriculture (NDA): Agricultural Land and Resource Management<sup>8</sup>, as well as the PU for CHE.

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## CHAPTER 8

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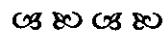
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Mr. P. (Pieter) Eloff	Wes Enterprises (Managing Director), Thabazimbi	3
Mr. T. (Tony) Morton	Farm owner of Mt. Joy and Twee, Thabazimbi-Dwaalboom district	3
Ms. M. (Marianne) Strohbach	BIOTA Group - Namibia	5
Mr. J. A. Grové	Owner of the Farm Kaitzaas in the Outjo-Okaukuejo district, Namibia	5
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Mr. G. H. L. (Lehman) Lindeque	National LandCare Secretariat, National Department of Agriculture - South Africa.	5
Mr. C.G.F.(Chris) Richter	Terra Care Vegetation Consultants - Free State Province, South Africa	5, 7

# **ANNEXURES 1-22**

## ANNEXURE 1

### List of declared indicator species of bush encroachment according to CARA Legislation

KIND OF PLANT		APPLICATION AREA
BOTANICAL NAME	GEWONE NAAM/ COMMON NAME	PROVINCE
<i>Acacia ataxacantha</i> DC.	Vlamdoring/ Flame thorn	Gauteng, KZN*, Mpumalanga, Eastern Cape, Northern Province**
<i>Acacia borleae</i> Burtt Davy	Kleefdoring/ Sticky thorn	KZN, Mpumalanga
<i>Acacia caffra</i> (Thunb.) Willd.	Haakdoring/ Common hooch- thorn	Gauteng, Mpumalanga, Northern Province, North- West
<i>Acacia erubescens</i> Welw. ex Oliv.	Blouhaak/ Blue thorn	Gauteng, Mpumalanga, Northern Province, North- West
<i>Acacia exuvialis</i> I. Verd.	Skilferdoring/ Flaky thorn	Mpumalanga, Northern Province
<i>Acacia fleckii</i> Schinz	Bladdoring, Geelhaak/ Plate thorn	Northern Province, North- West
<i>Acacia gerrardii</i> Benth. var. <i>gerrardii</i>	Rooidoring/ Red thorn	KZN, Mpumalanga, Northern Province
<i>Acacia grandicornuta</i> Gerstner	Horingdoring/ Horned thorn	KZN, Mpumalanga, Northern Province
<i>Acacia hebeclada</i> DC. subsp. <i>H. ebeclada</i>	Trassiedoring, Trassiebos/ Candle thorn	Gauteng, North- West, Northern Province, Free State
<i>Acacia karroo</i> Hayne	Soetdoring, Pendoring/ Sweet thorn, Karoo thorn	Whole of South Africa (all provinces)
<i>Acacia luederitzii</i> Engl. var. <i>luederitzii</i>	Baster haak -en- steek/ False umbrella thorn	Northern Cape, North- West
<i>Acacia luederitzii</i> Engl. var. <i>retinens</i> (Sim) J.H. Ross & Brenan	Buikdoring/ Belly thorn	KZN, Mpumalanga, Northern Province, North- West
<i>Acacia mellifera</i> (Vahl) Benth. subsp. <i>detinens</i> (Burch.) Brenan	Swarthaak/ Black thorn	Gauteng, Northern Cape, Northern Province, North- West
<i>Acacia nigrescens</i> Oliv.	Knoppiesdoring/ Knob- thorn	KZN, Mpumalanga, Northern Province, North- West
<i>Acacia nilotica</i> (L.) Willd. ex Delile subsp. <i>kraussiana</i> (Benth.) Brenan	Lekkerruikpeul, Stinkpeul/ Scented thorn, Redheart	Gauteng, KZN, Mpumalanga, Northern Province, North- West

KIND OF PLANT		APPLICATION AREA
BOTANICAL NAME	GEWONE NAAM/ COMMON NAME	PROVINCE
<i>Acacia permixta</i> Burt Davy	Slapdoring/ Slender thorn	Northern Province
<i>Acacia senegal</i> (L.) Will. var. <i>rostrata</i> Brenan	Driehaakdoring/ Three- hook thorn	KZN, Mpumalanga, Northern Province
<i>Acacia sieberiana</i> DC. var. <i>woodii</i> (Burt Davy) Keay & Brenan	Papierbasdoring/ Paperbark thorn	KZN, Mpumalanga, Northern Province
<i>Acacia tenuispina</i> l. Verd.	Fyndoring	Gauteng, Northern Province, North- West
<i>Acacia tortillis</i> (Forssk.) Hayne subsp. <i>heteracantha</i> (Burch.) Brenan	Haak- en- steek/ Umbrella thorn	Gauteng, KZN, Mpumalanga, Northern Province, Northern Cape, North- West, Free State
<i>Asparagus spp.</i>	Katbos/ Wild asparagus	North- West, Free State
<i>Azima tetraacantha</i> Lam.	Speldedoring/ Needle bush	KZN, Mpumalanga, Eastern Cape, Northern Province
<i>Colophospermum mopane</i> (Kirk ex Benth.) Kirk ex J. Léonard	Mopanie/ Mopane	Northern Province
<i>Combretum apiculatum</i> Sond. subsp. <i>apiculatum</i>	Rooibos/ Red bush willow	Gauteng, KZN, Mpumalanga, Northern Province, North- West
<i>Commiphora pyracanthoides</i> Engl.	Gewone kanniedood/ Common corkwood	Northern Cape
<i>Dichrostachys cinerea</i> (L.) Wight & Arn. subsp. <i>africana</i> Brenan & Brummit	Sekelbos/ Sickle bush	Gauteng, Mpumalanga, Northern Province, North- West
<i>Diospyros lycioides</i> Dest.	Bloubos/ Blue bush	KZN, Mpumalanga, Northern Province, North- West
<i>Dodonaea angustifolia</i> L.f. (= <i>Dodonaea viscosa</i> Jacq. var. <i>angustifolia</i> Benth.)	Sandolien/ Sand olive	Northern Province, North- West
<i>Euclea crispa</i> (Thunb.) Guerke subsp. <i>crispa</i>	Bloughwarrie/ Blue guarri	Whole of South Africa (all provinces)
<i>Euclea divinorum</i> Hiern	Tower- ghwarrie/ Magic guarri	KZN, Mpumalanga, Northern Province
<i>Euclea undulata</i> Thunb.	Gewone ghwarrie/ Common guarri	Whole of South Africa (all provinces)
<i>Grewia bicolor</i> Juss.	Basterrosyntjebos/ Bastard raisin bush	Mpumalanga, Northern Cape, North- West
<i>Grewia flava</i> DC.	Fluweelrosyntjie, Wilderosyntjebos/ Velvet raisin, Wild raisin bush	Gauteng, KZN, Mpumalanga, Northern Province, North- West, Northern Cape

KIND OF PLANT		APPLICATION AREA
BOTANICAL NAME	GEWONE NAAM/ COMMON NAME	PROVINCE
<i>Grewia flavescens</i> Juss.	Skurwerosyntjebos/ Rough leaved raisin, Sandpaper raisin	Mpumalanga, Northern Province, North- West
<i>Grewia monticola</i> Sond.	Vaalrosyntjebos/ Grey raisin, Silver raisin	Northern Province
<i>Leucosidea sericea</i> Eckl. & Zeyh.	Ouhout/ Old wood	Whole of South Africa (all provinces)
<i>Lopholaena coriifolia</i> (Sond.) E.Phillips & C.A.Sm.	Pluisbossie/ Lopholaena, Broad- leaved fluff bush	Gauteng, Mpumalanga, Northern Province, North- West
<i>Maytenus polyacantha</i> (Sond.) Marais	Kraalpendoring/ Kraal spike- thorn	Northern Province
<i>Maytenus senegalensis</i> (Lam.) Exell	Rooipendoring/ Red spike- thorn	KZN
<i>Rhigozum trichotomum</i> Burch.	Driedoring/ Three- thorn Rhigozum	Northern Cape
<i>Stoebe vulgaris</i> Levyns	Bakrotbossie, Slangbos/ Bankrupt bush	North- West, Free State
<i>Strychnos madagascariensis</i> Poir.	Swart klapper/ Black monkey orange	Gauteng, KZN, Mpumalanga, Northern Province, North- West
<i>Tarchonanthus camphoratus</i> L.	Kanferbos, Vaalbos/ Camphor bush, Sagewood	Northern Cape, North- West
<i>Terminalia sericea</i> Burch. ex. DC.	Sandvaalboom, Sandgeelhout/ Silver cluster leaf, Silver Terminalia	Gauteng, KZN, Mpumalanga, Northern Province, North- West, Northern Cape

(From: CARA Legislation Made Easy: The Conservation of Agricultural Resources Act 1983 (Act No. 43 of 1983) (CARA) - Regulation 16

\* KZN = KwaZulu-Natal

\*\* Northern Province = Limpopo Province

**Other references used to update common plant names in the table:**

(Van Wyk. & Van Wyk, 1997; Von Breitenbach *et al.*, 2001)

## ANNEXURE 2

**BUSH EXPERT QUESTIONNAIRE**  
**(DATABASE FOR BUSH CONTROL TECHNOLOGIES)**

**QUESTIONNAIRE**

NAME OF SAMPLER : \_\_\_\_\_ SITE No \_\_\_\_\_

DATE : \_\_\_\_\_

NAME OF FARMER/GROUP OF FARMERS:  
\_\_\_\_\_

NAME OF FARM/ REGION: \_\_\_\_\_

FARM NUMBER : \_\_\_\_\_

SIZE OF FARM/AREA : \_\_\_\_\_

TYPE OF ENTERPRISE, FARMING SYSTEM, MANAGEMENT AND OTHER INCOME :  
\_\_\_\_\_

DISTRICT/AREA : \_\_\_\_\_

TEL: \_\_\_\_\_ ADDRESS \_\_\_\_\_

FAX: \_\_\_\_\_

E-MAIL : \_\_\_\_\_

Cell : \_\_\_\_\_

**EXPERIENCE OF FARMER/S IN BUSH CONTROL :**

- a) Years since first treatment \_\_\_\_\_  
 b) Total Number of sites treated \_\_\_\_\_  
 c) Specific years in which treatment took place \_\_\_\_\_

**NAME OF FAIRLY HOMOGENOUS AREA**

A1	A2	A3	A4	A5	A6	A7	A9	A10	A11	B1	B2	B3	B4	B5	B6	C1	C2	D1	D2

D3	D4	D5	D6	D7	E1	E2	E3	E4	E5	E6	E7	E8	F1	F2	F3	F4	F5	F6	F7

F8	F9	G1	G2	G3	G4	G5	G6	H1	H2	H3	H4	H5							

**NAME OF AGRO-ECOLOGICAL ZONE (AEZ):**

(Include map of AEZ)

Cpl1	Cpl2	Cpl3-4	Cpl3-6	Cpl3-7	Etc														

**VEGETATION TYPE (List) :**

(Include map of vegetation types)

**ESTIMATED CARRYING CAPACITY OF TREATED AREA (Before clearing)**  
**(Include map of Carrying capacity)**

10ha/LSU	12ha/LSU	14ha/LSU	17ha/LSU	etc					
>45 Kg / Ha	36 – 45 Kg / Ha	31 - 35 Kg / Ha	26 – 30 Kg / Ha	21 – 25 Kg / Ha	16 – 20 Kg / Ha	11 – 15 Kg ? Ha	<10 Kg / Ha		

**1. RAINFALL (mm)**

Long-term average : (> 30 years)

0-100	100-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	>600
-------	---------	---------	---------	---------	---------	---------	---------	---------	------

Short term average : (last 5 years)

0-100	100-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	>600
-------	---------	---------	---------	---------	---------	---------	---------	---------	------

**2. TEMPERATURE (°C)**

Frequency of frost

Frequent	Infrequent
----------	------------

Average temperature :

Max average : \_\_\_\_\_

Min average : \_\_\_\_\_

**3. SOIL TYPE (Refer to book)**

(a) Type of soil : (List)

(i) \_\_\_\_\_

(ii) \_\_\_\_\_

(iii) \_\_\_\_\_

(iv) \_\_\_\_\_

(v) \_\_\_\_\_

(b) Clay content (%)

0-5 sand	5-10sand	10-15sa-lm	15-20sa-lm	20-25 sa-cl-lm	25-30 sa-cl-lm	30-35 cl-lm	35-40 cl-lm	>40 clay	Other
----------	----------	------------	------------	-------------------	-------------------	----------------	----------------	-------------	-------

(c) Soil colour

WHITE	RED	YELLOW	BLACK	RED-BROWN	GRAY	BROWN	OTHER
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## ANNEXURE 2

## (d) Soil depth (cm)

0-5cm	5-20cm	20-50cm	50-100cm	>100	Other

## (e) Topographical position/slope of site where bush control has been done

Crest (on top of hill)	Mid-slope	Foot-slope (flat)	Next to riverbed	Riverbed	Other

## 4. SOIL CONDITION - BEFORE CONTROL

> 50% bare	<50% bare	Litter	No litter	Capped	Other

## 5. VEGETATION CONDITION/ COMPOSITION: GRASS (BEFORE CONTROL)

Predominantly annual	Predominantly perennial	Annuals : Perennials 50:50	Other

6. VEGETATION (WOODY - PROBLEM SPECIES)- Before control  
 ( Complete Work sheet Annexes A and B and thereafter questionnaire)  
 (Use vegetation data adjacent to site as guideline)

(a) Type of problem species ( Indicate as % of Total PROBLEM species THORNY and NON THORNY)  
 (Surveyed)

<i>A.mel</i>	<i>D.cin</i>	<i>A.ref.</i>	<i>T.prun</i>	<i>C.mop</i>	<i>A.eru</i>	<i>A.fleck</i>	Other
<i>Rhigozum</i>	<i>A.mel</i> &	&	&	&	&		

## (b) Density of species - before control (All bush and trees - problem and non- problem )

Estimated / Surveyed

< 1000	1000-2000	2000-3000	3000-4000	4000-6000	6000-8000	8000-10000	> 10 000

## (c) Height classes - and % contribution ( All bushes and trees)

Estimated / Surveyed

0-0.5m	0.5-1.0	1.0-2m	2-3m	3-4m	>4m	Other
%	%	%	%	%	%	%

## (d) Growth form

Single stemmed	Multi stemmed

**ANNEXURE 2**

**(e) Distribution**

Single	Clumped	Rows	Random	Other

**(f) Use of problem species**

Charcoal	Timber	Fuel	Browsing	No use	Combination	Other

**7. LAND USE (Before clearing – historical background)**

**(a) Natural grazing/ management**

Rotational	Continuous	Holistic	No management	Other	

**(b) Animal type ( As % of Total Stocking Rate)**

Cattle	Goats	Sheep	Cattle & sheep	Cattle & goats	Game	Mixed	Other
%	%	%	%	%	%	%	%

**(c) Carrying capacity (kg/ha)**

< 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	45 - 50	> 50

**(d) Old land**

YES	NO

**(e) Old watering point**

YES	NO

**8. AIM OF BUSH CONTROL**

Natural grazing	Cultivated pastures	Crop production	Eco-tourism	Hunting	Job creation	Bush utilization	Combination	Other

**9. IF BUSH UTILIZATION under point 8 :**

Charcoal	Fuel	Timber		Other

**10. SIZE OF SITE (Ha)**

0-10	20-50	50-100	100-200	200-400	400-600	600-1000	> 1000

**11. SUCCESS RATE OF CONTROL (%)**

10-20%	20-40%	40-60%	60-80%	80-100%

## 12. TIME OF CONTROL (MONTH)

JAN	FEB	MRT	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DES

## 13. PERIOD SINCE CONTROL (YEARS)

1-2	2-4	4-6	6-8	8-10	10-12	12-15	>15

## 14. HEIGHT CLASS CONTROLLED

0-0.5 m	0.5-1 m	1-2 m	2-3 m	3-4 m	> 4 m	Other

## 15. TYPE OF CONTROL

Biological	Browsing	Natural (Fire)	Mechanical	Chemical	Resting	Controlled fire
Chemical & manual	Natural die-back	Other				

**NB: This case study is only one type of control, usually the first time/type of control. Any follow-up will be A NEW CASE STUDY and must be filled in on a separate form. This will then be regarded as a NEW CASE.**

**Only fill in ONE of the following i.e. Chemical, mechanical or manual in the next pages to follow.**

**IF TWO applications – combination has been used, e.g. Manual AND Chemical, fill in TWO/BOTH pages**

**16. CHEMICAL CONTROL**

YES	NO

GPS reading of treated area

\_\_\_\_\_

**(a) Period since control (years)**

1-2	2-4	4-6	6-8	8-10	10-12	12-15	>15

**(b) Target species**

1.Am	2.Ar	3.Ae	4.Dc	5.Tp	6.Ca	7.Rt	8.Gre
A.mel &	&	&	&	&	&	&	Other

**(c) Type of herbicide**

Molopo SC	Molopo GG	Savanna	Bromacil	Tordon Super	Access	Buschwacker	Ustilan
Grazer	Grasslan	Tordon 155	Tordon 225	Reclaim			Other

**(d) Method of Application**

Aeroplane	Spoon	Spray (Stem)	Spray (leaf)	Spray (soil)	Brush on stumps	Other

**(e) Application rate (kg or litre/ ha of original concentrate)**

0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	>5.0	Other

**(f) Area applied (ha)**

0-10	10-50	50-100	100-200	200-400	400-600	600-1000	> 1000

**(g) Duration of control (Man hours per ha)**

0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9	10	10-11	Other

**(h) Intensity of first rain/shower after application**

No run-off	Medium run-off	Heavy run-off

(i) Frequency of frost after control

Year 1	Year2

(j) Costs of control per ha

Give the separate costs for the chemical control per ha to the nearest Namibia Dollar if possible:

Herbicide : \_\_\_\_\_  
 Labour : \_\_\_\_\_  
 Other : \_\_\_\_\_

(k) Does the farmer/land user think that this type of chemical bush control was a success or not?  
 YES or NO

Please write down a short explanation of answer:

See Evaluation  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**NB: A complete “book” that can be “browsed” (consulted) of the latest prices and costs will be attached to the data base. The book will include the following**

- (i) Latest prices of all possible herbicides
- (ii) How to apply the different herbicides
- (iii) Costs of application

**A link to the financial system for bush control that has been developed by Mr Roelie Venter and Oliver Horsthemdke of the Namibia Agricultural Union will be created. This is a financial planner for bush control.**

## 17. MECHANICAL CONTROL

YES	NO

## GPS reading of controlled area

## (a) Period since control (Years)

1-2	2-4	4-6	6-8	8-10	10-12	12-15	> 15

## (b) Type of mechanical control

Bulldozer	Bulldozer & Roller	Bush-eater	Bush-cutter	Bush-harvester	Roller		Other

## (c) Area applied (ha)

0-10	20-50	50-100	100-200	200-400	400-600	600-1000	>1000

## (d) Target species

<i>1. Am</i>	<i>2. Ar</i>	<i>3. Ae</i>	<i>4. Dc</i>	<i>5. Tp</i>	<i>6. Ca</i>	<i>7. Rt</i>	<i>8. Grewia</i>
<i>A.mel &amp;</i>	<i>&amp;</i>	<i>&amp;</i>	<i>&amp;</i>	<i>&amp;</i>	<i>&amp;</i>	<i>&amp;</i>	<i>Other</i>

## (e) Working depth of control

Under ground	Above ground 0-0.5m	Above ground >0.5m		Other

## (f) Duration of control (Man hours per ha)

0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	Other

## (g) Frequency of frost after control

Year 1	Year2

## (h) Costs of machine used for control (Nam\$/hour)


**Give the separate costs (other than mentioned above) for the mechanical control per ha to the nearest Namibia Dollar if possible, e.g. :**

**Diesel**

**Labour :** \_\_\_\_\_

**Other :** \_\_\_\_\_

**(j) Does the farmer/land user think that this type of mechanical control was a success or not? YES or NO**

Please write down a short explanation of answer:

See evaluation

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**NB: A complete "book" that can be "browsed" (consulted) of the latest prices and costs will be attached to the data base. The book will include the following**

- (k) Latest prices of all possible machinery that can be used**
- (iv) How to handle the machinery**
- (v) Costs of each machinery**

**A link to the financial system for bush control that has been developed by Mr Roelie Venter and Oliver Horsthendke of the Namibia Agricultural Union will be created. This is a financial planner for bush control.**

**18. MANUAL CONTROL**

YES	NO

GPS reading of controlled area

---

**(a) Period since control (Years)**

1-2	2-4	4-6	6-8	8-10	10-12	12-15	> 15

**(b) Type of manual control**

Axe	Saw(hand)	Saw(chain)	Bushcutter	Mattocks "bospik"	Stemburning	combination	Other

**(c) Area applied (ha)**

0-10	20-50	50-100	100-200	200-400	400-600	600-1000	> 1000

**(d) Target species**

<i>1. Am</i>	<i>2. Ar</i>	<i>3. Ae</i>	<i>4. Dc</i>	<i>5. Tp</i>	<i>6. Ca</i>	<i>7. Rt</i>	<i>8. Gre</i>
&	&	&	&	&	&	&	Other

**(e) Height class of woody trees manually controlled**

0-0.5m	0.5-1.0m	1.0-1.5m	1.5-2.0m	2.0-2.5m	2.5-3.0m	3.0-4.0m	>4.0m	Other

**(f) Working depth / height of control**

Under ground	Above ground 0-0.5m	Above ground >0.5m		Other

**(g) Duration of control (Man hours per Ha)**

0-4	4-8	8-12	12-16	16-20	20-24	24-28	28-32	32-36	> 36

Give the separate costs (other than mentioned above) for the manual control per ha to the nearest Namibia Dollar if possible, e.g. :

Cost of implement used : \_\_\_\_\_

Labour : \_\_\_\_\_

Other : \_\_\_\_\_

- (h) Does the farmer/land user think that this type of manual control was a success or not? YES or NO  
Please write down a short explanation of answer:

See Evaluation

---

**NB: A complete “book” that can be “browsed” (consulted) of the latest prices and costs will be attached to the data base. The book will include the following**

- (b) Latest prices of all possible manual control that can be used
- (vi) How to handle the manual control
- (vii) Costs of each implement

**A link to the financial system for bush control that has been developed by Mr Roelie Venter and Oliver Horsthendke of the Namibia Agricultural Union will be created. This is a financial planner for bush control**

## 19 BIOLOGICAL CONTROL

YES	NO

GPS reading of controlled area

---

## (a) Period since control (Years)

1-2	2-4	4-6	6-8	8-10	10-12	12-15	> 15

## (b) Type of biological control

Goats	Fire	Controlled Fire	Other

## (c) Area applied (ha)

0-10	20-50	50-100	100-200	200-400	400-600	600-1000	> 1000

## (d) Target species

1.Am	2.Ar	3.Ae	4.Dc	5.Tp	6.Ca	7.Rt	8.Gre
&	&	&	&	&	&	&	Other

## (e) Height class of woody trees biologically controlled

0-0.5m	0.5-1.0m	1.0-1.5m	1.5-2.0m	2.0-2.5m	2.5-3.0m	3.0-4.0m	>4.0m	Other

## (f) Depth / Height of control

Under ground	Above ground 0-0.5m	Above ground >0.5m		Other

## (g) Does the farmer/land user think that this type of biological control was a success or not?

YES or NO

Please write down a short explanation of answer:

---



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**20 AFTER CARE (WILL BE REGARDED AS A NEW CASE STUDY)**

(ONLY FILL THIS PAGE IN FOR BRIEF COMMENTS)

**(a) Was after Care applied**

YES	NO

**GPS reading of controlled area**

\_\_\_\_\_

**(b) Why was the after care applied?**

\_\_\_\_\_

**(c) Type of after care?**

Biological	Browsing	Natural (Fire)	Mechanical	Chemical	Resting	Controlled fire
Chemical & manual	Natural die-back	Cultivated Land	Crops	Other		

**(d) Time and period after initial treatment (years) :**

**Mention date**

1	2	3	4	5	6	> 6	Other

**(e) Costs of after Care**

Give a brief outline of costs/ha for after treatment. Detailed costs will be discussed in the NEW CASE in ANOTHER FORM.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**(f) Vegetation and soil condition after the after-care has been applied. Fill in the Evaluation form of new Case study.**

**(g) Management after after-care?**

See recommendations of farmer under Evaluation

Give a short description of the management applied after after-care treatment:

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**NB : If an after care programme has been applied, please make reference to the previous/initial treatment described on this form. (Number and name of case study)**



## (d) Height class (all bushes and trees)

0-0.5m	0.5-1.0	1.0-2m	2-3m	3-4m	>4m	Other
%	%	%	%	%	%	%

## (e) Growth form (of problem spp)

Single stemmed	Multi stemmed

## (f) Distribution

Single	Clumped	Rows	Random	Other

**NATURAL DIE-BACK – INFESTATION BY *Phoma glomerata* (objective or subjective)**

Does natural die-back occur on your farm ?

None	Substantial	Extensive

**GRASS/HERBACEOUS COMPOSITION**(Objective vegetation sampling with point method on transect or step or walking stick method)(g) Grass/herbaceous composition (ONLY 5 key grasses per class or total composition)Dominant **Perennials** (5 key grasses) % :

1. \_\_\_\_\_

2. \_\_\_\_\_

3. \_\_\_\_\_

4. \_\_\_\_\_

5. \_\_\_\_\_

Dominant **Annuals** (3-5 key grasses) % :

1. Annuals \_\_\_\_\_

2. Forbcs \_\_\_\_\_

3. Bare areas \_\_\_\_\_

4. Aristidas \_\_\_\_\_

5. \_\_\_\_\_

**ANNEXURE 2**

**(h) Production of grass sward (kg/ha) – as calculated from 1 x 1m quadrat. Optional.**

0 - 300	301-600	601-900	901-1200	1201-1500	1501-1800	1801-2100	> 2100

**(i) Current kg live animal biomass/ ha on treated area.**

0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	> 45

10ha/LSU	12ha/LSU	14ha/LSU	17ha/LSU	etc					

**(j) Increase in grazing capacity (South African surveys only)**


**(k) Negative effect of bush control on environment:**

Name the three most important negative factors and give reasons that the bush control treatment that was applied had on the environment.

(1) \_\_\_\_\_

(2) \_\_\_\_\_

(3) \_\_\_\_\_

**22 GENERAL RESULTS FROM BUSH CONTROL TREATMENT**

Choose one or more of the factors listed, and indicate whether they were positively or negatively influencing the following conditions of the enterprise in general.

**ENVIRONMENTAL FACTORS**

TYPE	Pos	Neg	Neutr	Reason
Vegetation condition				
Soil organic material content				
Soil erosion (movement)				
Soil capping				
Biodiversity (Invertebrata)				
Biodiversity (small vertebrata)				
Biodiversity (large vertebrata)				
Other				

**OTHER FACTORS**

TYPE	Pos	Neg	Neutr	REASON
Charcoal/Fuel/Timber				
Cultivated pasture				
Rehabilitation (type)				
Crops				
Cost input (short term)				
Cost input (long term)				
Social impact e.g. job creation				
Hunting				
Eco-tourism				





## ANNEXURE 4

## ANNEXURE 4

<b>BUSH EXPERT - WOODY COMPONENT SURVEY FORM</b>
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Farm: OdussaDate: 2002/02/26Camp no: 14BMethod: Chemical / Molopo SCGPS: S 19 59 29 E 17 32 31

Species	0-0.5 m	0.5-1 m	1-2 m	2-3 m	3-4 m	> 4 m	Stems (ss/ms)
<i>Acacia mellifera</i>	0.5	0.7	2.0	4.0	4.2		SS
<i>Dichrostachys cinerea</i>	0.4	0.7	1.6	2.7			MS
<i>Acacia reficiens</i>	0.2	0.9	1.2	1.8			MS
<i>Acacia reficiens</i>	0.5	0.5	0.8	1.0	1.1		MS
<i>Acacia erubescens</i>	0.1	0.3	0.9	1.4	1.8	2.2	SS
<i>Colophospermum mopane</i>	0.3	0.9	0.9	1.2			MS
<i>Acacia mellifera</i>	0.6	0.9	1.1	1.5	1.5	2.0	SS
<i>Acacia mellifera</i>	0.2	0.5	0.7	1.0			MS
<i>Dichrostachys cinerea</i>	0.4	0.8	1.0				MS
<i>Dichrostachys cinerea</i>	0.3	1.2					MS
<i>Dichrostachys cinerea</i>	0.1	0.5	0.8				MS
<i>Dichrostachys cinerea</i>	0.1	0.8	0.8	1.2			MS
<i>Colophospermum mopane</i>	0.4	0.9	1.2	1.2	1.7		SS
<i>Colophospermum mopane</i>	0.5	0.7	0.7	1.8	2.3	2.4	SS
<i>Acacia erubescens</i>	0.6	0.7	1.0				SS
<i>Acacia reficiens</i>	0.5	0.9	1.0				SS
<i>Acacia mellifera</i>	0.4	0.7	0.9	1.3			SS
<i>Acacia reficiens</i>	0.1	0.4					SS
<i>Acacia reficiens</i>	0.1	0.6					SS
<i>Acacia mellifera</i>	0.3	0.9	1.2	1.5	2.0		MS
<i>Acacia mellifera</i>	0.6	0.9	1.5	2.0	2.3	3.5	MS
<i>Acacia mellifera</i>	0.4	0.8	1.3	1.8	2.4		SS
<i>Acacia mellifera</i>	0.2	0.5	0.9	1.6	2.2	2.4	SS

COMMENTS: \_\_\_\_\_

## ANNEXURE 5

### Example of the spreadsheet format used to summarize the data obtained from surveys at the case study sites

<b>BUSH EXPERT QUESTIONNAIRE</b>						
<b>GENERAL INFORMATION</b>		<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
	<b>Owner</b>	J. Waldschmidt	F. Krone	F. Krone	M. Koehler	W.O. Lepen
	<b>Case number</b>	59	61a	61b	62	63
	<b>Name of sampler</b>	E. Schwarting	F. Krone	F. Krone	F. Krone	F. Krone
	<b>Site nr.</b>	OM 9A	OT I (camp 16)	OT II (camp 11)	OT III	OT IV
	<b>Date</b>	5/4/2002	3/26/2002	4/3/2002	4/4/2002	4/13/2002
	<b>Farm region</b>	Wag-'n-Bietjie	Wesselton	Wesselton	Doornkom	Penwood
	<b>Farm number</b>	49	176	176	173	385
	<b>Farm size (ha)</b>	4 500 ha	4 260 ha	4 260 ha	4 952 ha	5 011 ha
	<b>Type of enterprise</b>	Cattle	Cattle	Cattle	-	Livestock
	<b>District</b>	Karibib	Otjiwarongo	Otjiwarongo	Otjiwarongo	Otjiwarongo
	<b>Tel.nr.</b>	064-570846	067-306522 (tel+fax)	067-306522 (tel+fax)	067- 306777	067-302603
	<b>Address</b>	Box 79 Omaruru <a href="mailto:metta@iway.na">metta@iway.na</a>	Box 301 Otjiwarongo	Box 301 Otjiwarongo	Box 613 Otjiwarongo	Box 946 Otjiwarongo
	<b>Experience in bush control (years)</b>	17 years	6 years	6 years	13 years	23 years
	<b>Total number of treated sites</b>	3 500 ha	5 camps (1 015 ha)	9 camps (1 621ha)	6 camps	5 camps
	<b>Specific years in which treatment took place</b>	1993	Nov. 1995	Sept. 1996	Aug-90	1980/ 81
	<b>Fairly homogenous farming area (FHFA)</b>	-	-	-	-	-
	<b>AEZ</b>	-	-	-	-	-
	<b>Vegetation type</b>	-	Thornveld savanna	Thornveld savanna	Thornveld savanna	Thornveld savanna
	<b>Estimated carrying capacity of treated area</b>	30 ha/LSU	12 ha/LSU 26-30 kg/ ha	12 ha/LSU 26-30 kg/ ha	12 ha/LSU	14 ha/LSU
<b>1</b>	<b>RAINFALL</b>					
a	<b>Long-term rainfall</b>	100-250 mm	400 mm	400 mm	300-350 mm	300-350 mm
b	<b>Short-term rainfall</b>	100- 250 mm	425 mm	425 mm	400-450 mm	300-350 mm
<b>2</b>	<b>TEMPERATURE</b>					
a	<b>Frequency of frost</b>	-	Infrequent	Infrequent	Infrequent	Frequent
b	<b>Max. temperature</b>	25 °C	-	-	36 °C	-
c	<b>Min. temperature</b>	8 °C	-	-	-4 °C	-
<b>3</b>	<b>SOIL</b>					

a	Soil type	Red sandy loam with lime	Sandy loam	Sandy loam	Sandy loam Loam	Sandy loam
b	Clay content (%)	25-30 %	-	-	-	15-20 %
c	Soil colour	Red	Red	Red	Red	Red
d	Soil depth	50-100 cm	50 - 100 cm	50-100 cm	50-100 cm	> 100 cm
f	Slope of site where control has taken place	Overall, except riverbed	Foot-slope	Foot-slope	Foot-slope	Next to riverbed
4	Soil condition before control	> 50% bare	Litter	Litter	< 50% bare	> 50 % bare
5	Vegetation composition before control (grasses)	Predom. Ann.	Ann: Perenn. 50:50	Ann: Perenn. 50:50	Predom. ann.	Ann: Perenn. 50:50
6	VEGETATION (WOODY-PROBLEM SPP.) (Before control)					
a	Type of problem species (surveyed)	<i>A.ref.</i> 14.29% <i>D.cin.</i> 77.14% <i>A.erub.</i> 8.57%	<i>A.mel.</i> 87.64% <i>A.fleck.</i> 12.36%	<i>A.mel.</i> 16.50% <i>A.erub.</i> 83.50%	<i>A.mel.</i> 95.9% <i>A.fleck.</i> 4.1%	<i>A.mel.</i> 96.7% <i>A.herero.</i> 3.3%
b	Spp. density of total bush + trees alive/ (before control)	2 250/ ha	366/ ha	267/ ha	1 667/ ha	1 632/ ha
c	Height class - and % contribution of total bush + trees alive	0-0.5m = 500/ 22.22% 0.5-1m = 1 000/ 44.44% 1-2m = 650/ 28.89% 2-4m = 100 / 4.44%	0-0.5m = 133/ 36.34% 0.5-1m = 66/ 18.03% 2-4m = 100/ 27.32% > 4m= 67/ 18.31%	0-0.5m = 67/ 25.09% 0.5-1m = 200/ 74.91%	0.5-1m = 67/ 4.02% 1-2m = 1 533/ 91.96% 2-4m= 67/ 4.02%	0-0.5m = 100/ 6.13% 0.5-1m = 299/ 18.32% 1-2m = 800/ 49.02% 2-4m = 400/ 24.51% > 4m= 33/ 2.02%
d	Growth form	Multi-stemmed	Multi-stemmed	Multi-stemmed	Single+multi-stemmed	Multi-stemmed
	Wood freight (tons/ ha) = Problem spp only:					
	Treated	-	-	-	-	-
	Control	-	-	-	-	-
e	Distribution	Random	Clumped	Clumped	Random	-
f	Use of problem species	No use	Charcoal	Charcoal + timber	No use	Browsing
7	LAND USE (Before clearing - historical background)					
a	Natural grazing/ management	Continuous	Rotational	Rotational	Rotational	Rotational
b	Animal type (as % of total stocking rate)	Cattle= 100%	Cattle= 100%	Cattle= 100%	Cattle= 95% Sheep= 5%	Cattle= 100%
c	Carrying capacity (kg/ha) or (ha/LSU)	-	25-30 kg/ ha	25-30 kg/ ha	10-15 kg/ ha	24 kg/ ha
d	Old land	-	No	No	No	No
e	Old watering point	-	No	No	No	No
8	AIM OF BUSH CONTROL	Natural grazing	Natural grazing	Natural grazing Bush utilization	Natural grazing	Natural grazing

9	IF BUSH UTILIZATION at point 8 = specify	-	Charcoal	Charcoal	-	-
10	SIZE OF TREATED SITE (ha)	3 500 ha	176 ha	244 ha	20-50 ha	100-200 ha
11	SUCCESS RATE OF CONTROL (%)	80-100%	80- 100%	80-100%	80-100%	80-100%
12	TIME OF CONTROL (month)	Jan-March 1993	Nov. 1995	Sept.1996	Aug. 1990	Feb. 1980
13	PERIOD SINCE CONTROL (years)	10 years	8 years	7 years	13 years	23 years
14	HEIGHT CLASS CONTROLLED	All	All	All	All	All
15	TYPE OF CONTROL	Chemical	Chemical	Chemical	Chemical	Chemical
16	CHEMICAL CONTROL					
	YES/ NO	Yes	Yes	Yes	Yes	Yes
	GPS reading of treated area	S 21 45' 30.6" E 16 01' 24.6"	S 21 01' 53.9" E 17 09' 45.2"	S 21 01' 53.9" E 17 08' 73.2"	S 20 97' 11.0" E 16 93' 19.5"	S 20 87' 62.3" E 17 27' 02.9"
a	Period since control (years)	9 years	8 years	7 years	13 years	23 years
b	Target species	<i>A.ref.</i> <i>D.cin.</i>	<i>A.mel.</i> <i>A.erub.</i>	<i>A.mel.</i> <i>A.erub.</i>	<i>A.mel.</i>	<i>A.mel.</i> <i>A.herer.</i>
c	Type of herbicide used	Ustilan	Reclaim	Reclaim	Reclaim	Tordon 155
d	Method of application	Spoon	Spray (soil)	Spray (soil)	Spray (soil)	Aeroplane
e	Application rate (kg or litre/ ha of original concentrate)	30 kg/ha	0.31 g/ ha	0.07 g/ ha	1.5 - 2 litre/ ha	Can't remember
f	Area applied (ha)	3 500 ha	176 ha	244 ha	20-50 ha	400-600 ha
g	Duration of control (man hours/ ha)	4-5 man hrs/ ha	19.69 man hrs/ ha	1.18 man hrs/ ha	8-9 man hrs/ ha	-
h	Intensity of first rain/ shower after application	-	Medium run-off	No run-off	No run-off	Medium run-off
i	Frequency of frost after control:					
	Year 1	-	Little	Little	10-20 times	3 times
	Year 2	-	Little	Little	10-20 times	4 times
j	Costs of control/ ha:					
	Herbicide	N\$ 75/ ha	N\$ 5 490/ 176 ha	N\$ 1 620	N\$ 60	N\$ 13.50/ ha
	Labour	N\$ 5/ ha	N\$ 574.70/ 176 ha	N\$213.50	-	-
	Other	Total incl. Transport etc. = N\$ 700/ 50 ha	N\$ 34.46/ ha	N\$ 65.78 Total= N\$ 1 899.28	-	Aeroplane= N\$1.50/ ha
k	Does land user think this type of chemical control was successful? Yes/No	Yes	Yes	Yes	Yes	Yes

	<b>Reason</b>	Carrying capacity went up to 12 ha/LSU in normal rainfall years	Total surface treated (5 camps) is 1 015 ha	<b>Duration of control:</b> Sept '96-Feb '98 (2 parts) <b>Surface treated =</b> 1 621 ha (9 camps) <b>Reclaim=</b> 20 700.00 <b>Workers =</b> 3 700.40 <b>Other =</b> 437.02 <b>Total =</b> 24 837.42 (N\$15.32/ ha) <b>Application:</b> 0.142 g/ ha 17.20 man hrs/ ha	Because of a success rate of more than 80%	95% + of the bush died
<b>17</b>	<b>MECHANICAL CONTROL</b>					
	<b>YES/ NO</b>	No	No	No	No	No
	GPS reading of treated area					
a	Period since control(years)					
b	Type of mechanical control					
c	Area applied (ha)					
d	Target species					
e	Working depth of control					
f	Duration of control (man hours/ ha)					
g	<b>Frequency of frost after control</b>					
	Year 1					
	Year 2					
h	Cost of machine used for control ( Rand or N\$/ hour)					
i	<b>Specify separate costs for control:</b>					
	Petrol/ diesel					
	Labour					
	Other					
j	Does land user think this type of mechanical control was successful? Yes/ No					
	Reason					
<b>18</b>	<b>MANUAL CONTROL</b>					
	<b>YES/ NO</b>	No	No	No	No	No
	GPS reading of treated area					
a	Period since control (years)					

b	Type of manual control					
c	Area applied (ha)					
d	Target species					
e	Height class of trees manually controlled					
f	Working depth/ height of control					
g	Duration of control (man hours/ ha)					
h	Specify separate costs for control:					
	Cost of implement					
	Labour					
	Other					
i	Does land user think this type of manual control was successful? Yes/No					
	Reason					
<b>19</b>	<b>BIOLOGICAL CONTROL</b>					
	YES/ NO	No	No	No	No	No
	GPS reading of treated area					
a	Period since control (years)					
b	Type of biological control					
c	Area applied (ha)					
d	Target species					
e	Height class of trees biologically controlled					
f	Depth/ Height of control					
h	Does land user think this type of biological control was successful? Yes/No					
	Reason					
<b>20</b>	<b>AFTER CARE (NEW CASE STUDY)</b>					
a	Was after-care applied?					
	YES/ NO	No	No	No	No	Yes
	GPS reading of controlled area					S 20 87' 62.3" E 17 27' 02.9"
b	Why was after care applied?					To restore veld
c	Type of after care?					Resting
d	Time and period after initial treatment (years)					23 years
e	Costs of after care/ ha					-
g	Management after after- care? Give a short description.					Rotational grazing and resting
<b>21</b>	<b>EVALUATION/ MONITORING</b>					

WOODY SPECIES						
a	Time and date of treatment (month + year)	Jan-March 1993	Nov. 1995	Sept. 1996	Aug/Sept. 1990	Feb-80
b	Type of species (remain/ increase/ encroached). Indicate % of <b>total problem bush</b>	No bush left, only fodder bush & shrubs	No bush left	<i>A.erub.</i> 100%	<i>A.mel.</i> 83.5% <i>D.cin.</i> 16.5%	<i>A.herero.</i> 100%
c	Density and contribution (%) of each problem spp. as a % of all bush and trees (remain/increase/encroached)/ ha	No bush left, only fodder bush & shrubs	No bush left	<i>A.erub.</i> 100/ 50.25%	<i>A.mel.</i> 167/ 50.15% <i>D.cin.</i> 33/ 9.91%	<i>A.herero.</i> 134/ 40.24%
d	Height class (all bushes and trees) as a %	No bush left, only fodder bush & shrubs	0-0.5 m = 33/ 100%	0.5-1m = 133/ 66. 83% 1-2m = 66/ 33.17%	0-0.5m = 167/ 50.15% 0.5-1m = 33/ 9.91% 1-2 m = 133/ 39.94%	0-0.5m = 67/ 20.12% 0.5-1m = 100/ 30.03% 1-2 m = 166/ 49.85%
e	Growth form of problem spp.	-	-	-	Multi-stemmed	Multi-stemmed
f	Distribution	-	-	-	Random	Clumped
<b>NATURAL DIE-BACK - Infestation by <i>Phoma glomerata</i> (objective or subjective)</b>						
	Does natural die-back occur on your farm?	-	Extensive (75+)	Extensive (75+)	Extensive	Extensive
<b>GRASS/ HERBACEOUS COMPOSITION (Objective vegetation sampling with point method on transect or step/ walking stick method)</b>						
g	<u>Grass/ herbaceous composition</u>					
	<b>Dominant Perennials (5-6 key grasses) as a %:</b>					
	1	<i>S.unipl.</i> 67%	<i>S.unipl.</i> 53%	<i>S.unipl.</i> 31%	<i>S.unipl.</i> 64%	<i>E.rig.</i> 30%
	2	<i>S.hochstetterana</i> 3%	<i>E.rig.</i> 22%	<i>E.rig.</i> 16%	<i>S.pap.</i> 8%	<i>S.pap.</i> 21%
	3	-	<i>S.pap.</i> 10%	<i>S.pap.</i> 13%	<i>E.rig.</i> 2%	<i>S.unipl.</i> 15%
	4	-	-	<i>M.rep.</i> 1%	<i>C.cil.</i> 1%	<i>P.max.</i> 3%
	5	-	-	-	<i>M.rep.</i> 1%	<i>M.rep.</i> 2%
	6	-	-	-	-	<i>C.cil.</i> 1%
	7	-	-	-	-	<i>S.fimb.</i> 1%
	<b>Dominant Annuals (3-5 key grasses) as %:</b>					
	1. Annuals	20%	6%	28%	20%	23%
	2. Forbcs	-	-	-	-	-
	3. Bare areas	10%	-	-	-	-
	4. <i>Aristidas</i>	-	9%	11%	4%	4%

h	Production of grass sward (kg/ha)- as calculated from 1x1m quadrat. (Optional).	-	-	-	-	-
i	Current kg live animal biomass/ ha on the treated area	12 ha/ Lsu in normal rainfall years	45.5 kg/ ha	35.5 kg/ ha	6-10 kg/ ha	21-25 kg/ ha 10 ha/LSU
j	Increase in grazing capacity (SA surveys)	-	60-70%	60-70%	-	70%
k	<u>Negative effect</u> of bush control on the environment:	None	-	-	-	-
<b>22</b>	<b>GENERAL RESULTS FROM BUSH CONTROL TREATMENT</b>					
	Choose 1or more of the listed factors and, indicate whether they had a positive, neutral or negative influence on the following conditions of the enterprise in general and give a reason.					
	<b>ENVIRONMENTAL FACTORS</b>					
	Vegetation condition	Positive	Positive	-	Positive	Positive
	Soil organic material content	Positive	Positive	-	-	Positive
	Soil erosion (movement)	-	Positive	-	-	Negative
	Soil capping	-	Positive	-	-	Negative
	Biodiversity (invertebrata)	-	Positive	-	-	-
	Biodiversity (small vertebrata)	-	Positive	-	-	-
	Biodiversity (large invertebrata)	-	Positive	-	Positive	Positive
	Other	-	Positive	-	-	-
	<b>OTHER FACTORS</b>					
	Charcoal/ fuel/ timber	Positive	-	-	-	-
	Cultivated pasture	-	-	-	-	-
	Rehabilitation (type)	-	-	-	-	-
	Crops	-	-	-	-	-
	Cost input (short term)	-	-	-	-	-
	Cost input (long term)	-	-	-	-	-
	Social impact e.g. job creation	-	-	-	-	-
	Hunting	-	-	-	-	Positive
	Eco-tourism	-	-	-	-	Positive
<b>23</b>	<b>GENERAL MANAGEMENT AFTER BUSH CONTROL</b>					

	<b>Give short general description of the impact that the control treatment had on the enterprise, farming system and management as a whole:</b>	<ul style="list-style-type: none"> <li>* Farming with cattle was only really possible after bush control</li> <li>* The grass cover multiplied after bush control</li> <li>* Now economical carrying capacity and cattle management was possible</li> </ul>	<ul style="list-style-type: none"> <li>* Water evaporation due to bush was reduced</li> <li>* More ground water available to grasses</li> <li>* Even with less rain, a good grass production can be expected</li> <li>* Drought will have a smaller impact on environment and grasses</li> <li>* Increased profitability of farm               <ul style="list-style-type: none"> <li>* Lowered risk</li> <li>* Less erosion</li> </ul> </li> <li>* Less soil compaction</li> <li>* It is a cost- effective method</li> </ul>	<ul style="list-style-type: none"> <li>* Water evaporation due to bush was reduced</li> <li>* More ground water available to grasses</li> <li>* Even with less rain, a good grass production can be expected</li> <li>* Drought will have a smaller impact on environment and grasses</li> <li>* Increased profitability of farm               <ul style="list-style-type: none"> <li>Lowered risk</li> <li>* Less erosion</li> </ul> </li> <li>* Less soil compaction</li> <li>* It is a cost- effective method</li> </ul>	<ul style="list-style-type: none"> <li>* Rotational grazing</li> </ul>	<ul style="list-style-type: none"> <li>* Bush died and grass cover increased, carrying capacity increased</li> <li>* Drought risk is less, income/ ha increased</li> </ul>
<b>24</b>	<b>GENERAL FINDINGS AND RECOMMENDATIONS FOR SPECIFIC AREA</b>					
a	<b>Farmer</b>	<ul style="list-style-type: none"> <li>* Farmer advises chemical control, no mechanical or manual control</li> </ul>	<ul style="list-style-type: none"> <li>* I suggest bush control, but after- care is also very important as part of the general farm management plan after control</li> </ul>	<ul style="list-style-type: none"> <li>* I suggest bush control, but after- care is also very important as part of the general farm management plan after control</li> </ul>	<ul style="list-style-type: none"> <li>* Pay attention to the clay % of the soil, in order to increase the dosage of chemical used according to clay percentage</li> <li>* Maintenance of nozzles for spraying is high, seeing that the chemical product is coarse</li> <li>* 1 kg Reclaim to 25 litres of water is too low a concentration (4cc) for effective control</li> </ul>	<ul style="list-style-type: none"> <li>* To provide farmers with the necessary chemicals to do bush control               <ul style="list-style-type: none"> <li>* Chemicals are expensive for farmers to buy</li> <li>* Need subsidies or control of chemical prices</li> </ul> </li> </ul>

b	<p><b>Enumerator</b></p>	<p>* The success of this case of bush control is impressive          * I knew the farm before the bush control took place.          * Bush encroachment by especially <i>C.alex.</i> and others was terrible, ground was nearly bare          I wouldn't recommend to control all the bush, especially not all the <i>C.alex.</i></p> <p>* The vegetation was too uniform, consisting of <i>S.unipl.</i> and NO other perennial grasses, no fodder bush and no herbs, except <i>Indigophera</i> spp. * I only discovered one very big, grazed tuft of <i>C.cil.</i> on the untreated site, none on the very large treated site          * There was no specimen of <i>S.pap.</i> found, even though one should expect it on this soil with certain amount of rainfall this year          * The farmer told me that when they treated the sites they discovered a very hard infestation of grass-cutting termites in the thick litter under the <i>C.alex.</i> When the bush died, the termites were gone.</p>				<p>* I'm very impressed with the bush control trial</p>
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## ANNEXURE 6

**Example of the extended version of the *Bush Expert* question classes for statistical analysis purposes**

**BUSH EXPERT QUESTIONNAIRE - SIMPLIFIED QUESTION CLASSES**  
**(DATABASE FOR BUSH CONTROL METHODS)**

**QUESTIONNAIRE**

**ESTIMATED CARRYING CAPACITY OF TREATED AREA (Before clearing)**  
**(Include map of Carrying capacity)**

***ORIGINAL CLASSES (kg/ ha)***

>45 Kg / Ha	36 – 45 Kg / Ha	31 - 35 Kg / Ha	26 – 30 Kg / Ha	21 – 25 Kg / Ha	16 – 20 Kg / Ha	11 – 15 Kg / Ha	<10 Kg / Ha

***CHANGED: AVERAGE VALUE OF CLASSES (kg/ ha)***

Specific value as given	41 kg/ ha	33 kg/ ha	28 kg/ ha	23 kg/ ha	18 kg/ ha	13 kg/ ha	Specific value as given

**1. RAINFALL (mm)****Long-term average : (> 30 years)*****ORIGINAL CLASSES (mm)***

0-100	100-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	> 600
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***CHANGED: AVERAGE VALUE OF CLASSES (mm)***

50	125	275	325	375	425	475	525	575	Specific value as given
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**Short term average : (last 5 years)*****ORIGINAL CLASSES (mm)***

0-100	100-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	>600
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***CHANGED: AVERAGE VALUE OF CLASSES (mm)***

50	125	275	325	375	425	475	525	575	Specific value as given
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### 3. SOIL TYPE

#### (b) Clay content (%)

##### ORIGINAL CLASSES (%)

0-5 sand	5-10 sand	10-15 sa-lm	15-20 sa-lm	20-25 sa-cl-lm	25-30 sa-cl-lm	30-35 cl-lm	35-40 cl-lm	>40 clay
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##### CHANGED: AVERAGE VALUE OF CLASSES (%)

3 sand	7 sand	13 sa-lm	17 sa-lm	23 sa-cl-lm	27 sa-cl-lm	33 cl-lm	37 cl-lm	Specific value as given
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#### (d) Soil depth (cm)

##### ORIGINAL CLASSES (cm)

0-5cm	5-20cm	20-50cm	50-100cm	>100
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##### CHANGED: AVERAGE VALUE OF CLASSES (cm)

3 cm	12 cm	35 cm	75 cm	Specific value as given
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### 6. VEGETATION (WOODY – PROBLEM SPECIES)- Before control

( Complete Work sheet Annexes A and B and thereafter questionnaire)

(Use vegetation data adjacent to site as guideline)

#### (b) Density of species – before control (All bush and trees – problem and non- problem )

Estimated / Surveyed

##### ORIGINAL CLASSES (/ ha)

<1000	1000-2000	2000-3000	3000-4000	4000-6000	6000-8000	8000-10000	>10 000
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##### CHANGED: AVERAGE VALUE OF CLASSES (/ ha)

Specific value as given	1 500	2 500	3 500	5 000	7 000	9 000	Specific value as given
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#### (c) Height classes – and % contribution ( All bushes and trees)

Estimated / Surveyed

##### ORIGINAL CLASSES (m)

0-0.5 m	0.5-1.0 m	1.0-2 m	2-3 m	3-4 m	>4 m	Other
%	%	%	%	%	%	%

##### CHANGED: AVERAGE VALUE OF CLASSES (m)

0.5 m	1.0 m	2 m	3 m	4 m	Specific value as given
%	%	%	%	%	%

**7. LAND USE (Before clearing – historical background)****(c) Carrying capacity (kg/ha)****ORIGINAL CLASSES (kg/ha)**

< 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	45 - 50	> 50

**CHANGED: AVERAGE VALUE OF CLASSES (kg/ha)**

Specific value as given	13	17	23	27	33	37	43	47	Specific value as given

**10. SIZE OF SITE (ha)****ORIGINAL CLASSES (ha)**

0-10	20-50	50-100	100-200	200-400	400-600	600-1000	>1000

**CHANGED: AVERAGE VALUE OF CLASSES (ha)**

5	35	75	150	300	500	800	Specific value as given

**11. SUCCESS RATE OF CONTROL (%)****ORIGINAL CLASSES (%)**

10-20%	20-40%	40-60%	60-80%	80-100%

**CHANGED: AVERAGE VALUE OF CLASSES (%)**

15%	30%	50%	70%	90%

**13. PERIOD SINCE CONTROL (YEARS)****ORIGINAL CLASSES (years)**

1-2	2-4	4-6	6-8	8-10	10-12	12-15	>15

**CHANGED: AVERAGE VALUE OF CLASSES (years)**

2	3	4	5	6	7	8	Specific value as given

**14. HEIGHT CLASS CONTROLLED****ORIGINAL CLASSES (m)**

0-0.5m	0.5-1.0m	1.0-2m	2-3m	3-5m	>5m	ALL	Other

**CHANGED: AVERAGE VALUE OF CLASSES (m)**

0.5 m	1.0 m	2 m	3 m	4 m	Specific values as given

**16. CHEMICAL CONTROL****(a) Period since control (years)****ORIGINAL CLASSES (years)**

1-2	2-4	4-6	6-8	8-10	10-12	12-15	> 15

**CHANGED: AVERAGE VALUE OF CLASSES (years)**

2	3	4	5	6	7	8	Specific value as given

**(e) Application rate (kg or litre/ ha of original concentrate)****ORIGINAL CLASSES (kg or Litre/ ha)**

0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	>5.0	Other

**CHANGED: AVERAGE VALUE OF CLASSES (kg or Litre/ ha)**

0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	Specific value as given

**(f) Area applied (ha)****ORIGINAL CLASSES (ha)**

0-10	20-50	50-100	100-200	200-400	400-600	600-1000	> 1000

**CHANGED: AVERAGE VALUE OF CLASSES (ha)**

10	35	75	150	300	500	800	Specific value as given

**(g) Duration of control (Man hours per ha)****ORIGINAL CLASSES (man hrs/ ha)**

0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9	10	10-11	Other

**CHANGED: AVERAGE VALUE OF CLASSES (man hrs/ ha)**

1	2	3	4	5	6	7	8	9	10	11	12	Specific value as given

**17. MECHANICAL CONTROL****(a) Period since control (Years)***ORIGINAL CLASSES (years)*

1-2	2-4	4-6	6-8	8-10	10-12	12-15	> 15

*CHANGED: AVERAGE VALUE OF CLASSES (years)*

2	3	4	5	6	7	8	Specific value as given

**(c) Area applied (ha)***ORIGINAL CLASSES (ha)*

0-10	20-50	50-100	100-200	200-400	400-600	600-1000	> 1000

*CHANGED: AVERAGE VALUE OF CLASSES (ha)*

10	35	75	150	300	500	800	Specific value as given

**(f) Duration of control (Man hours per ha)***ORIGINAL CLASSES (man hrs/ ha)*

0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	Other

*CHANGED: AVERAGE VALUE OF CLASSES (man hrs/ ha)*

1	2	3	4	5	6	7	8	9	10	11	12	Specific value as given

**18. MANUAL CONTROL****(a) Period since control (Years)***ORIGINAL CLASSES (years)*

1-2	2-4	4-6	6-8	8-10	10-12	12-15	>15

*CHANGED: AVERAGE VALUE OF CLASSES (years)*

2	3	4	5	6	7	8	Specific value as given

**(c) Area applied (ha)****ORIGINAL CLASSES (ha)**

0-10	20-50	50-100	100-200	200-400	400-600	600-1000	> 1000

**CHANGED: AVERAGE VALUE OF CLASSES (ha)**

10	35	75	150	300	500	800	Specific value as given

**(e) Height class of woody trees manually controlled****ORIGINAL CLASSES (m)**

0-0.5m	0.5-1.0m	1.0-1.5m	1.5-2.0m	2.0-2.5m	2.5-3.0m	3.0-4.0m	>4.0m	Other

**CHANGED: AVERAGE VALUE OF CLASSES (m)**

0.5 m	1.0 m	2 m	3 m	4 m	Specific values as given

**(g) Duration of control (Man hours per ha)****ORIGINAL CLASSES (man hrs/ ha)**

0-4	4-8	8-12	12-16	16-20	20-24	24-28	28-32	32-36	> 36

**CHANGED: AVERAGE VALUE OF CLASSES (man hrs/ ha)**

1	2	3	4	5	6	7	8	9	10	11	12	Specific value as given

**19. BIOLOGICAL CONTROL****(a) Period since control (Years)****ORIGINAL CLASSES (years)**

1-2	2-4	4-6	6-8	8-10	10-12	12-15	>15

**CHANGED: AVERAGE VALUE OF CLASSES (years)**

2	3	4	5	6	7	8	Specific value as given

**(c) Area applied (ha)****ORIGINAL CLASSES (ha)**

0-10	20-50	50-100	100-200	200-400	400-600	600-1000	> 1000

**CHANGED: AVERAGE VALUE OF CLASSES (ha)**

10	35	75	150	300	500	800	Specific value as given

**(e) Height class of woody trees biologically controlled****ORIGINAL CLASSES (m)**

0-0.5m	0.5-1.0m	1.0-1.5m	1.5-2.0m	2.0-2.5m	2.5-3.0m	3.0-4.0m	>4.0m	Other

**CHANGED: AVERAGE VALUE OF CLASSES (m)**

0.5 m	1.0 m	2 m	3 m	4 m	Specific values as given

**21 EVALUATION/MONITORING****WOODY SPECIES**

( Complete Field Data Table first and carry concerted info over to Questionnaire – Se annex C )

**(c) Density AND contribution (%) of each problem species as % of all bush and trees (remain/increase/encroached) /ha****ORIGINAL CLASSES (/ ha)**

<1000	1000-2000	2000-3000	3000-4000	4000-6000	6000-8000	8000-10000	> 10 000
%	%	%	%	%	%	%	%

**CHANGED: AVERAGE VALUE OF CLASSES (/ ha)**

Specific value as given	1 500	2 500	3 500	5 000	7 000	9 000	Specific value as given

**(d) Height class (all bushes and trees)****ORIGINAL CLASSES (m)**

0-0.5m	0.5-1.0	1.0-2m	2-3m	3-4m	>4m	Other
%	%	%	%	%	%	%

**CHANGED: AVERAGE VALUE OF CLASSES (m)**

0.5 m	1.0 m	2 m	3 m	4 m	Specific values as given
%	%	%	%	%	%

**GRASS/HERBACEOUS COMPOSITION**(Objective vegetation sampling with point method on transect or step or walking stick method)**(h) Production of grass sward (kg/ha) – as calculated from 1 x 1m quadrat. Optional.****ORIGINAL CLASSES (kg/ ha)**

0 - 300	301-600	601-900	901-1200	1201-1500	1501-1800	1801-2100	> 2100

**CHANGED: AVERAGE VALUE OF CLASSES (kg/ ha)**

Specific values as given by the land user are used for data analysis purposes
---

(i) Current kg live animal biomass/ha on treated area

**ORIGINAL CLASSES ( kg/ ha or LSU/ ha)**

0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	> 45

**CHANGED: AVERAGE VALUE OF CLASSES ( kg/ ha or LSU/ ha)**

Specific values as given by the land user are used for data analysis purposes
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## ANNEXURE 7

**Complete list of the combined species name groupings for the woody and herbaceous components, for the purpose of statistical analysis**

<b>Separate (species/ group) names</b>	<b>Combined name</b>
<i>Terminalia sericea</i> + <i>Terminalia prunioides</i>	<i>Terminalia</i> spp. ( <i>Terminalias</i> )
All desirable perennial grass species*	Perennials: Desirable
All less desirable perennial grass species*	Perennials: Less Desirable
All annual grass species	Annuals

\* Desirability of grass species were determined by the grazing value of each species:

- High + average grazing value = Desirable
- Low grazing value = Less desirable

## ANNEXURE 8

### List of commonly used herbicidal products for chemical bush control in southern Africa.

Chemical Trade Name	Active ingredient	Active Ingredient(s)	Type of Formulation	Supplier/ Distributor
Access *	Picloram (potassium salt)	240 g/ l	SL	Dow AgroSciences/ Ecoguard Distributors
Bromacil G10	Bromacil	100 g/ kg	GR	Sanachem
Buschwacker *	Bromacil	800 g/ kg	WP	Enviro Industries
Garlon 4	Triclopyr (butoxyl ethyl ester)	480 g/ l	EC	Dow AgroSciences/ Efekto
Grazer GG	Tebuthiuron	200 g/ kg	GG	Bayer Animal Health
Grazer SC	Tebuthiuron	500 g/ litre	SC	Bayer Animal Health
Hyvar X	Bromacil	800 g/ kg	WP	DuPont
Hyvar XG10	Bromacil	100 g/ kg	GR	DuPont
Molopo 20 GG (old Grasslan 20P/ Grazer GG)	Tebuthiuron	200 g/ kg	GG	Sanachem
Molopo SC (old Reclaim/ Grazer SC)	Tebuthiuron	500 g/ l	SC	Sanachem
Savana 500 SC	Bromacil/ Tebuthiuron	250 g/l / 250 g/l	SC	Sanachem
Tordon Super *	Picloram (iso octyl ester)/ triclopyr (butoxyl ethyl ester)	120/ 240 g/ l	OL	Dow AgroSciences
Ustilan 10 GR	Ethidimuron	100 g/ kg	GR	Bayer
Ustilan 20 GG	Ethidimuron	200 g/ kg	GG	Bayer
Ustilan 70 WP	Ethidimuron	700 g/ kg	WP	Bayer

(Grobler *et al.*, 2000)

\* The only herbicides that were used in South African case studies

**Abbreviations:** EC = Emulsifiable Concentrate, SC = Suspension Concentrate, SL = Soluble Concentrate, GG = Macro Granule, GR = Granule, OL = Oil Miscible Liquid, WP = Wettable Powder

## ANNEXURE 9

**A list of the problem woody species which occurred in the study sites of this project (Namibia & South Africa), together with the recommended herbicide for chemical bush control**

Scientific name / active ingredient	Common English name / Name of herbicide + (registration number)	Common Afrikaans name
<i>Acacia erubescens</i>	Blue thorn	Blouhaak
bromacil	Bushwacker (L5624)	
bromacil/tebuthiuron	Savana (L6090)	
ethidimuron	Ustilan (L1666, L3650)	
picloram	Access (L4920)	
tebuthiuron	Molopo (L5854, L6111), Tebusan (L4737)	
<i>Acacia fleckii</i>	Blade thorn	Bladdoring
ethidimuron	Ustilan (L3650)	
<i>Acacia hereroensis</i>	Mountain thorn	Bergdoring
tebuthiuron	Molopo (L6111), Tebusan (L4737)	
<i>Acacia karroo</i>	Sweet thorn	Soetdoring
bromacil	Atlacide (L4188), Bromacil (L2559), Bushwacker (L5624), Hyvar XG (L5869)	
bromacil/tebuthiuron	Savana (L6090)	
diuron/ethidimuron	Ustilan (L1900, L3108)	

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ethidimuron	Ustilan (L0915, L1666, L3650)	
picloram	Access (L4920)	
picloram/triclopyr	Tordon Super (L4921)	
tebuthiuron	Molopo (L5854, L6111), Tebusan (L4737)	
<b><i>Acacia luederitzii</i></b>	<b>Bastard umbrella thorn</b>	<b>Basterhaak-en-steek</b>
ethidimuron	Ustilan (L1666)	
tebuthiuron	Molopo (L5854, L6111), Tebusan (L4737)	
<b><i>Acacia mellifera</i></b>	<b>Black thorn</b>	<b>Swarthaak</b>
bromacil	Atlacide (L4188), Bromacil (L3338, L2559, L4346), Bushwacker (L5624), Hyvar X (L1885), Hyvar XG (L5869), Rinkhals (L5806)	
bromacil/tebuthiuron	Savana (L6090)	
diuron/ethidimuron	Ustilan (L1900, L3108)	
ethidimuron	Ustilan (L0915, L1666, L3650)	
picloram/triclopyr	Tordon Super (L4921)	
tebuthiuron	Molopo (L5854, L6111), Tebusan (L4737)	
<b><i>Acacia reficiens</i></b>	<b>False umbrella thorn</b>	<b>Vals-haak-en-steek</b>
bromacil	Bushwacker (L5624)	
tebuthiuron	Molopo (L6111), Tebusan (L4737)	
<b><i>Acacia senegal</i></b>	<b>Slender three-hook thorn</b>	<b>Slaplout</b>
picloram/triclopyr	Tordon Super (L4921)	
<b><i>Acacia tortilis</i></b>	<b>Umbrella thorn</b>	<b>Haak-en-steek</b>

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bromacil	Atlacide (L4188), Bromacil (L2559), Bushwacker (L5624), Hyvar XG (L5869), Rinkhals (L5806)	
bromacil/tebuthiuron	Savana (L6090)	
ethidimuron	Ustilan (L1666, L3650)	
picloram	Access (L4920)	
picloram/triclopyr	Tordon Super (L4921)	
tebuthiuron	Molopo (L5854, L6111), Tebusan (L4737)	
<i>Asparagus spp.</i>	<b>Wild asparagus</b>	<b>Wilde katbos/ aspersies</b>
imazapyr	Chopper (L3444)	
<i>Catophractes alexandri</i>	<b>Trumpet thorn</b>	<b>Gababos/ Trompetdoring</b>
tebuthiuron	Molopo (L6111), Tebusan (L4737)	
<i>Colophospermum mopane</i>	<b>Mopane</b>	<b>Mopanie</b>
bromacil	Bushwacker (L5624)	
bromacil/tebuthiuron	Savana (L6090)	
picloram/triclopyr	Tordon Super (L4921)	
tebuthiuron	Molopo (L5854, L6111), Tebusan (L4737)	
<i>Grewia bicolor</i>	<b>Bastard raisin</b>	<b>Basterrosyntjie</b>
tebuthiuron	Molopo (L5854, L6111), Tebusan (L4737)	
<i>Grewia flava</i>	<b>Wild raisin</b>	<b>Wilderrosyntjie</b>
bromacil	Bushwacker (L5624)	

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bromacil/tebuthiuron	Savana (L6090)	
ethidimuron	Ustilan (L3650)	
tebuthiuron	Molopo (L5854, L6111), Tebusan (L4737)	
<i>Grewia flavescens</i>	<b>Rough-leaved raisin</b>	<b>Skurweblaarrosyntjie</b>
bromacil/tebuthiuron	Savana (L6090)	
ethidimuron	Ustilan (L3650)	
tebuthiuron	Molopo (L6111), Tebusan (L4737)	
* <i>Tarchonanthus camphoratus</i>	<b>Camphor Bush</b>	<b>Kanferbos</b>
ethidimuron	Ustilan (L3650)	
tebuthiuron	Molopo (L5854, L6111)	
<i>Terminalia prunoides</i>	<b>Purple pod terminalia</b>	<b>Sterkbos</b>
bromacil/tebuthiuron	Savana (L6090)	
<i>Terminalia sericea</i>	<b>Silver Cluster-Leaf</b>	<b>Vaalboom</b>
bromacil	Rinkhals (L5806)	
bromacil/tebuthiuron	Savana (L6090)	
ethidimuron	Ustilan (L1666)	
ethidimuron	Ustilan (L3650)	
picloram	Access (L4920)	
picloram/triclopyr	Tordon Super (L4921)	
tebuthiuron	Molopo (L5854, L6111)	

\* *Tarchonanthus camphoratus* = Not found in the study sites in either of the countries, but does seem to be a problem species in Namibia. From: Grobler & Van Zyl (2003)

## ANNEXURE 10

**Example of the list of the representative bush densities for the Namibian and South African study sites, before and after the application of bush control technologies.**

Case study nr.	1Blo	2Mc	3Blo	4Ch	5Mn	6Ch	7Ch	8Ch	9Ch	10Mn	11Mn	12Ch	13Ch
D before ctrl	1 800	750	1 000	366	550	2 250	1 667	1 632	2 263	2 232	1 298	3 500	1 500
D after ctrl	450	600	250	0	2 250	0	200	134	166	600	1 099	1 750	50

Case study nr.	14Blo	15Ch	16Mn	17Mn	18Mn	19Ch	20Ch	21Ch	22Ch	23Ch	24Ch	25Ch	26Mn
D before ctrl	2 500	2 500	4 650	2 500	2 500	2 500	2 500	17 600	4 600	3 000	2 750	1 300	500
D after ctrl	0	0	150	50	750	250	100	17 400	100	800	1 250	100	50

Case study nr.	27Ch	28Ch	29Ch	30Ch	31Mn	32Mc	33Mc	34Ch	35Mn	36Ch	37Mc	38Mc	39Mn
D before ctrl	3 000	12 650	2 700	1 950	1 500	800	14 050	8 950	1 050	24 550	24 550	6 100	21 800
D after ctrl	200	400	0	150	650	150	6 950	800	150	800	unknown	1 950	1 400

Case study nr.	40Mn	41Mc	42Mc	43Mn	44Ch	45Ch	46Ch	47Ch	48Ch	49Mn	50Ch	51Mc	52Ch
D before ctrl	9 200	10 700	12 100	6 650	6 975	2 350	2 350	2 350	7 900	3 100	3 400	2 600	1 250
D after ctrl	4 700	14 300	4 000	3 050	200	50	0	700	900	5 650	1 450	2 600	200

Case study nr.	53Ch	54Mn	55Ch	56Ch	57Ch	58Ch	59Mn	60Blo	61Mn	62Mc	63Ch	64Ch	65Ch
D before ctrl	750	5 600	2 500	1 050	2 450	2 050	3 050	1 350	450	1 000	1 150	1 400	50
D after ctrl	1 500	150	1 150	400	2 950	350	850	2 000	450	700	1 250	600	0

Case study nr.	66Ch	67Ch	68Mc	69Mc	70Ch	71Ch	72Ch	73Ch	74Ch	75Ch	76Ch	77Mn	78Ch
D before ctrl	250	1 500	1 550	1 200	2 300	1 850	1550	300	50	350	50	2 750	2 850
D after ctrl	550	1 550	1 500	2 650	1 400	1 150	350	250	50	50	0	1 000	150

Case study nr.	79Ch	80Ch	81Ch	82Mn	83Mn	84Mn	85Ch	86Mn	87Ch	88Mn	89Mn	90Ch	91Mn
D before ctrl	7 950	5 300	2 650	1 850	2 750	6 000	3 900	5 700	13 500	9 363	6 100	8 900	7 875
D after ctrl	4 750	1 450	1 000	0	50	1 500	350	250	2 868	unknown	3 000	366	7 875

Case study nr.	92Mn	93Ch	94Ch	95Ch	96Ch	97Ch	98Ch	99Ch	100Mn	101Ch	102Ch	103Ch	104Bio
D before ctrl	550	1 550	1 550	267	1 500	2 500	3 165	5 350	5 350	10 000	7 000	7 000	9 500
D after ctrl	400	250	800	100	250	0	200	600	500	5 025	1 875	900	6 475

Case study nr.	105Ch	106Bio	107Ch	108Ch	109Ch
D before ctrl	9 500	9 500	5 000	5 000	7 000
D after ctrl	6 088	8 950	550	363	663

\* D before ctrl = density of problem woody species before bush control (trees/ ha)

\* D after ctrl = density of problem woody species after bush control (trees/ ha)

## ANNEXURE 11

**List of the problem woody species as indicated in case study surveys for Namibia (100 cases) and South Africa (nine cases - Limpopo Province)**

Scientific name	Common Afrikaans name	Common English name	Country
<i>Acacia erubescens</i>	Blouhaak	Blue thorn	Namibia + South Africa
<i>Acacia fleckii</i>	Bladdoring	Blade thorn	Namibia
<i>Acacia hereroensis</i>	Bergdoring	Mountain thorn	Namibia
<i>Acacia karroo</i>	Soetdoring	Sweet thorn	Namibia + South Africa
<i>Acacia luederitzii</i> var. <i>luederitzii</i>	Baster haak-en-steek	False umbrella thorn	Namibia
<i>Acacia mellifera</i> subsp. <i>detinens</i>	Swarthaak	Black thorn	Namibia
<i>Acacia reficiens</i> subsp. <i>reficiens</i>	Rooihaak-en-steek	Red umbrella thorn	Namibia
<i>Acacia senegal</i> var. <i>rostrata</i>	Driehaakdoring	Three-hook thorn	Namibia
<i>Acacia tortilis</i>	Haak-en-Steek	Umbrella thorn	South Africa
<i>Catophractes alexandri</i>	Trompetterdoring	Trumpet thorn	Namibia
<i>Colophospermum mopane</i>	Mopanie	Mopane	Namibia
<i>Dichrostachys cinerea</i> subsp. <i>africana</i>	Sekelbos	Sickle bush	Namibia + South Africa
<i>Grewia spp.</i> : <i>Grewia flava</i> <i>Grewia bicolor</i> <i>Grewia flavescens</i>	Rosyntjebosse Wilde rosyntjie Basterrosyntjie Skurwerosyntjie	Raisin bushes Wild raisin Bastard raisin Rough-leaved raisin	South Africa
<i>Terminalia prunioides</i>	Sterkbos	Lowveld cluster-leaf	Namibia
<i>Terminalia sericea</i>	Vaalboom/ Sandgeelhout/ Sandvaalbos	Silver-cluster leaf/ Silver Terminalia	Namibia

(Fabian & Germishuizen, 1997; Van Wyk & Van Wyk, 1997; Smit, 1999a; Von Breitenbach *et al.*, 2001; Schmidt *et al.*, 2002)

## ANNEXURE 12

Complete list of the grass species with ecological and grazing values, that occurred in the Namibian case studies.

Grass species	x/100	Annual/ Perennial	Grazing value	Plant succession	Ecological status
<i>Andropogon gayanus*</i>	1	Perennial	High	Climax grass	Increaser I
<i>Anthephora pubescens</i>	3	Perennial	High	Climax grass	Decreaser
<i>Aristidas*</i>	53	Annual / Perennial	(Varies)	(Varies)	(Varies)
<i>Bothriochloa bladhii</i>	27	Perennial	Low	Climax grass	Increaser I
<i>Bothriochloa radicans</i>	3	Perennial	Low	Sub- climax grass	Increaser II
<i>Brachiaria nigropedata</i>	1	Perennial	High	Climax grass	Decreaser
<i>Cenchrus ciliaris*</i>	50	Perennial	High	Sub- climax grass	Decreaser
<i>Dicanthium annulatum</i> var. <i>papillosum</i>	1	Perennial	High	Sub- climax / Climax grass	Decreaser
<i>Enneapogon cenchroides*</i>	1	Annual / Week perennial	Average	Pioneer/ Sub- climax grass	Increaser II
<i>Enneapogon desvauxii*</i>	4	Annual / Week perennial	Average	Pioneer/ Sub- climax grass	Increaser II
<i>Enneapogon scoparius*</i>	15	Perennial	Low	Climax grass	Increaser III
<i>Eragrostis echinochloidea*</i>	10	Perennial	Average	Pioneer/ Sub- climax grass	Increaser II
<i>Eragrostis lehmanniana*</i>	20	Perennial	Average	Sub- climax / Climax grass	Increaser II
<i>Eragrostis micrantha</i>	1	Perennial	Average	Sub- climax grass	Increaser II
<i>Eragrostis nindensis*</i>	10	Perennial	Average	Sub- climax grass	Increaser II
<i>Eragrostis porosa*</i>	6	Annual	Average	Pioneer grass	Increaser II
<i>Eragrostis rigidior*</i>	35	Perennial	Average	Sub- climax grass	Increaser II
<i>Eragrostis rotifer</i>	6	Perennial	Average	Sub- climax / Climax grass	Increaser II
<i>Eragrostis superba</i>	3	Perennial	Average	Sub- climax grass	Increaser II
<i>Eragrostis trichophora*</i>	33	Perennial	Average	Sub- climax grass	Increaser II
<i>Eustachys paspaloides</i>	1	Perennial	High	Climax grass	Decreaser
<i>Fingerhuthia africana</i>	3	Perennial	Average	Sub- climax / Climax grass	Decreaser
<i>Heteropogon contortus*</i>	11	Perennial	Average	Sub- climax grass	Increaser II
<i>Monelytrum luderitzianum</i>	2	Perennial	-	Pioneer grass	-
<i>Melinis repens*</i>	23	Perennial	Low	Pioneer/ Sub- climax grass	Increaser II
<i>Oropetium capense</i>	1	Perennial	Low	Pioneer grass	Increaser II
<i>Panicum lanipes</i>	1	Perennial	High	Climax grass	Decreaser
<i>Panicum maximum*</i>	5	Perennial	High	Sub- climax / Climax grass	Decreaser
<i>Pogonarthria squarrosa*</i>	1	Perennial	Low	Sub- climax grass	Increaser II

Grass species	x/100	Annual/ Perennial	Grazing value	Plant succession	Ecological status
<i>Schmidtia pappophoroides</i> *	39	Perennial	High	Sub- climax / Climax grass	Decreaser/ increaser II
<i>Sporobolus fimbriatus</i>	5	Perennial	High	Climax grass	Decreaser
<i>Stipagrostis hirtigluma</i>	1	Annual / Perennial	Low	Pioneer/ Sub- climax grass	Increaser II
<i>Stipagrostis hochstetterana</i>	2	Perennial	High	Climax grass	-
<i>Stipagrostis uniplumis</i> *	77	Perennial	Average	Sub- climax grass	Increaser II
<i>Tricholaena monachne</i>	2	Perennial	Average	Sub- climax grass	Increaser II
<i>Triraphis ramosissima</i> *	4	Perennial	Average	Sub- climax grass	-
<i>Triraphis schinzii</i> *	4	Perennial	Average	Climax grass	-
<i>Urochloa oligotricha</i> *	6	Perennial	High	Climax grass	Decreaser

( Müller, 1983; Gibbs Russel *et al.*, 1990; Van Oudtshoorn, 1992; Van Oudtshoorn, 1999)

x / 100 = occurrence within the 100 study sites for Namibia

'Annuals' = occurred in 93% of the study sites

'Bare ground' = occurred in 45% of the study sites

'Forbes' = occurred in 32% of the study sites

\* = species included in statistical analysis

## ANNEXURE 13

**Indication of the occurrence of the two most dominant herbaceous (perennial or annual grasses/ *Aristida* spp. or forbs) species or bare ground, after bush control at each of the 100 case study sites in Namibia (in descending order of importance)**

Case number / name	Dominant Herbaceous Species
Case 1 - Okosongoro (OM4a)	<i>Stipagrostis uniplumis</i> / Annuals
Case 2 - Okosongoro (OM5a)	<i>Stipagrostis uniplumis</i> / Annuals
Case 3 - Okosongoro (OM6a)	<i>Stipagrostis uniplumis</i> / <i>Schmidtia pappophoroides</i>
Case 4 - Wesselton (OT I - Camp 16)	<i>Stipagrostis uniplumis</i> / <i>Eragrostis rigidior</i>
Case 5 - Okosongominja (OM7b)	Bare ground / <i>Stipagrostis uniplumis</i>
Case 6 - Wag-'n-Bietjie	<i>Stipagrostis uniplumis</i> / Annuals
Case 7 - Doornkom	<i>Stipagrostis uniplumis</i> / Annuals
Case 8 - Penwood	<i>Eragrostis rigidior</i> / Annuals
Case 9 - Hebron	<i>Eragrostis rigidior</i> / <i>Schmidtia pappophoroides</i>
Case 10 - Dai Papel	Annuals / <i>Eragrostis nindensis</i>
Case 11 - Klarwater	<i>Cenchrus ciliaris</i> / <i>Eragrostis echinocloidea</i>
Case 12 - Uitkyk (OH6)	Annuals / <i>Eragrostis nindensis</i>
Case 13 - Uitkyk (OH7)	<i>Eragrostis lehmanniana</i> / <i>Stipagrostis uniplumis</i>
Case 14 - Helpmekaar	<i>Stipagrostis uniplumis</i> / Forbs
Case 15 - Okakeua (OH12)	<i>Stipagrostis uniplumis</i> / <i>Eragrostis rigidior</i>
Case 16 - Aandrus (SW2)	Annuals / <i>Stipagrostis uniplumis</i>
Case 17 - Ehangeru	<i>Stipagrostis uniplumis</i> / Annuals
Case 18 - Ombirisu	<i>Stipagrostis uniplumis</i> / <i>Schmidtia pappophoroides</i>
Case 19 - Otjinuke (OH15)	<i>Stipagrostis uniplumis</i> / Annuals
Case 20 - Otjinuke (OH16)	<i>Stipagrostis uniplumis</i> / <i>Eragrostis rigidior</i>
Case 21 - Seringboom	Annuals / Forbs
Case 22 - Aandrus (SW1)	Annuals / <i>Cenchrus ciliaris</i> & <i>Eragrostis lehmanniana</i>
Case 23 - Mecklenberg (SW5b)	Annuals / <i>Melinis repens</i>
Case 24 - Mecklenberg (SW6)	Annuals / <i>Eragrostis trichophora</i>
Case 25 - Charity (SW3a)	<i>Stipagrostis uniplumis</i> / Bare ground
Case 26 - Charity (SW4a)	<i>Stipagrostis uniplumis</i> (100%)
Case 27 - Mecklenberg (SW5a)	Annuals / <i>Melinis repens</i>
Case 28 - Voigtland (SW9)	<i>Aristida</i> spp. / Annuals
Case 29 - Karanab / Dirleen (SW7)	Annuals / <i>Eragrostis trichophora</i>
Case 30 - Karanab / Dirleen (SW8)	Annuals / Forbs
Case 31 - Voigtland (SW10)	Annuals / <i>Eragrostis lehmanniana</i>
Case 32 - Krumneck (SW11)	Annuals / Bare ground
Case 33 - Krumneck (SW12)	Annuals / Forbs
Case 34 - Hohenau (SW13)	Annuals / <i>Schmidtia pappophoroides</i>
Case 35 - Hohenau (SW14)	Annuals / <i>Schmidtia pappophoroides</i>
Case 36 - Okaduka (SW15)	Annuals / Forbs
Case 37 - Okaduka (SW16)	Annuals / <i>Aristida</i> spp.
Case 38 - Burnell (Site 6)	Annuals / Forbs
Case 39 - Burnell (Site 7)	Annuals / <i>Eragrostis trichophora</i>
Case 40 - Buffelshoek (Tsumeb-Site 8)	Annuals / Bare ground
Case 41 - Guinas Weide	Annuals / Forbs
Case 42 - Dannenberg	Annuals / Forbs
Case 43 - Geluksanker	Annuals / Forbs
Case 44 - Odussa (Site 14a)	Annuals / <i>Eragrostis trichophora</i>
Case 45 - Odussa (Site 14b)	Annuals / <i>Eragrostis echinocloidea</i>
Case 46 - Odussa (Site 14c)	Annuals / Forbs

## ANNEXURE 13

Case 47 - Odussa (Site 14d)	Annuals / Forbs
Case 48 - Friedrichthal	<i>Schmidtia pappophoroides</i> / <i>Aristida</i> spp.
<b>Case number / name</b>	<b>Dominant Herbaceous Species</b>
Case 49 - Blystroom (SF001)	Annuals / <i>Eragrostis trichophora</i>
Case 50 - Bornholm (SF041)	Bare ground / <i>Aristida</i> spp.
Case 51 - Omarassa	Forbs / <i>Eragrostis lehmanniana</i>
Case 52 - Christiodore / Gemsbokvlei (Camp 2)	<i>Eragrostis trichophora</i> / Forbs
Case 53 - Christiodore / Gemsbokvlei (Camp 6)	<i>Triraphis schinzii</i> / <i>Aristida</i> spp.
Case 54 - Eden	Forbs / <i>Stipagrostis uniplumis</i>
Case 55 - Okamutombe (Oupos)	<i>Eragrostis trichophora</i> / <i>Stipagrostis uniplumis</i>
Case 56 - Arcadia	Annuals / Forbs
Case 57 - Kaitzaas (Camp 16a)	Annuals / <i>Triraphis ramosissima</i>
Case 58 - Kaitzaas (Camp 16b)	Annuals / <i>Aristida</i> spp.
Case 59 - Blystroom (Koedoevos Wes, Site 1)	Forbs / Annuals
Case 60 - Ombona (K35)	<i>Cenchrus ciliaris</i> / Annuals
Case 61 - Ombona (K11)	<i>Cenchrus ciliaris</i> / Annuals
Case 62 - Ozongombo	Annuals / <i>Stipagrostis uniplumis</i>
Case 63 - Omambonde Tal (Camp 16a)	Annuals / Forbs
Case 64 - Omambonde Tal (Camp 16b)	<i>Stipagrostis uniplumis</i> / Annuals
Case 65 - Omambonde Tal (Camp10)	<i>Cenchrus ciliaris</i> (100% - cultivated pasture)
Case 66 - Buffelshoek (Otjiwarongo, Camp5)	Annuals / <i>Stipagrostis uniplumis</i>
Case 67 - Buffelshoek (Otjiwarongo, Camp12)	Annuals / Bare ground
Case 68 - Buffelshoek (Otjiwarongo, Camp21)	Forbs / <i>Eragrostis trichophora</i>
Case 69 - Buffelshoek (Otjiwarongo, Camp24)	<i>Eragrostis trichophora</i> / Annuals
Case 70 - Uitikyk (Case 1)	<i>Eragrostis trichophora</i> / Annuals
Case 71 - Uitikyk (Case 2)	<i>Eragrostis trichophora</i> / Annuals
Case 72 - Uitikyk (Case 3)	<i>Eragrostis trichophora</i> / <i>Aristida</i> spp.
Case 73 - Oukongo Süd (Camp 19/ Site 1)	Annuals / <i>Stipagrostis uniplumis</i>
Case 74 - Oukongo Süd (Camp 19/ Site 2)	<i>Stipagrostis uniplumis</i> / <i>Aristida</i> spp.
Case 75 - Agagia + Oukongo Süd (Camp 31, Site 1)	<i>Stipagrostis uniplumis</i> / <i>Eragrostis lehmanniana</i>
Case 76 - Agagia + Oukongo Süd (Camp 31, Site 2)	Annuals / <i>Eragrostis lehmanniana</i>
Case 77 - Blystroom (SF007)	Annuals / <i>Eragrostis trichophora</i>
Case 78 - Bornholm (SF038)	<i>Stipagrostis uniplumis</i> / <i>Pogonarthria squarrosa</i>
Case 79 - Ossa (SF030)	<i>Urochloa oligotricha</i> / Annuals
Case 80 - Ossa (SF032)	Forbs / Annuals
Case 81 - Highlands (SF034)	Annuals / Forbs
Case 82 - Highlands (SF036)	Annuals / <i>Cenchrus ciliaris</i>
Case 83 - Hulde (SF022)	<i>Eragrostis trichophora</i> / <i>Stipagrostis uniplumis</i>
Case 84 - Hulde (SF024)	<i>Eragrostis trichophora</i> / <i>Stipagrostis uniplumis</i>
Case 85 - Okamutombe (SF028)	Annuals / <i>Aristida</i> spp.
Case 86 - Henta	Annuals / Bare ground
Case 87 - Pasadena	Annuals / <i>Enneapogon scoparius</i>
Case 88 - Onse Rus	Annuals / <i>Enneapogon scoparius</i>
Case 89 - Heidelberg no. 291	Annuals / Forbs
Case 90 - Burnell (Site 5)	Annuals / <i>Enneapogon scoparius</i> & Forbs
Case 91 - Riepe	Bare ground / Annuals
Case 92 - Okosongominja (OM7a)	Bare ground / <i>Stipagrostis uniplumis</i>
Case 93 - Schönfeld (OM10a)	Annuals / <i>Stipagrostis uniplumis</i>
Case 94 - Schönfeld (OM10c)	Bare ground / <i>Aristida</i> spp.
Case 95 - Wesselton (OT II - Camp 11)	<i>Stipagrostis uniplumis</i> / Annuals
Case 96 - Okamaja	<i>Stipagrostis uniplumis</i> / <i>Aristida</i> spp.
Case 97 - Okakeua (OH11)	<i>Stipagrostis uniplumis</i> / <i>Schmidtia pappophoroides</i>
Case 98 - Gamkarab	Annuals / <i>Triraphis ramosissima</i>
Case 99 - GEO (Outjo 'dorpsgronde' - 9+10)	<i>Enneapogon cenchroides</i> / <i>Enneapogon desvauxii</i>
Case 100 - GEO (Outjo 'dorpsgronde' - 9+11)	Annuals / <i>Enneapogon desvauxii</i>

## ANNEXURE 14

### Complete list of the grass species with ecological and grazing values, that occurred in the South African case studies

Grass species	x / 9	Annual/ Perennial	Grazing value	Plant succession	Ecological status
<i>Aristida canescens</i> *	4	Perennial	Low	Sub- climax grass	Increaser II
<i>Aristida bipartita</i> *	1	Perennial	Low	Sub- climax grass	Increaser II
<i>Aristida congesta</i> *	7	Perennial	Low	Pioneer grass	Increaser II
<i>Aristida stipitata</i> *	3	Annual/ Weak perennial	Low	Pioneer/ Sub- climax grass	Increaser II
<i>Bothriochloa insculpta</i> *	2	Perennial	Average	Sub- climax grass	Increaser II
<i>Brachiaria eruciformis</i>	2	Annual	Average	Pioneer grass	Increaser II
<i>Brachiaria serrata</i> *	1	Perennial	Average	Climax grass	Decreaser
<i>Cenchrus ciliaris</i> *	3	Perennial	High	Sub- climax / Climax grass	Decreaser
<i>Chloris virgata</i>	2	Annual/ Weak perennial	Average	Pioneer grass	Increaser II
<i>Cymbopogon plurinodis</i>	2	Perennial	Low	Climax grass	Increaser I + II
<i>Cynodon dactylon</i> *	3	Perennial/ creeping	High	Pioneer grass	Increaser II
<i>Dichantium annulatum</i>	1	Perennial	High	Sub- climax / Climax grass	Decreaser
<i>Digitaria eriantha</i> *	4	Perennial	High	Climax grass	Decreaser
<i>Digitaria monodactyla</i>	1	Perennial	Average	Sub- climax grass	Increaser II
<i>Digitaria ternata</i>	1	Annual	Low	Pioneer grass	Increaser II
<i>Diheteropogon amplectens</i>	1	Perennial	Average	Climax grass	Decreaser
<i>Echinochloa colona</i>	1	Annual	High	Pioneer grass	Increaser II
<i>Elionurus muticus</i>	1	Perennial	Low	Climax grass	Increaser III
<i>Enneapogon cenchroides</i> *	3	Annual/ Weak perennial	Average	Pioneer/ Sub- climax grass	Increaser II
<i>Enneapogon desvauxii</i> *	2	Annual/ Weak perennial	Average	Pioneer/ Sub- climax grass	Increaser II
<i>Enneapogon scoparius</i> *	1	Perennial	Low	Climax grass	Increaser III
<i>Eragrostis biflora</i>	1	Annual	Low	Pioneer grass	Increaser II
<i>Eragrostis lehmanniana</i> *	3	Perennial	Average	Sub- climax/ Climax grass	Increaser II
<i>Eragrostis rigidior</i> *	3	Perennial	Average	Sub- climax grass	Increaser II
<i>Fingerhuthia africana</i> *	1	Perennial	Average	Sub- climax / Climax grass	Decreaser

<i>Heteropogon contortus</i> *	4	Perennial	Average	Sub- climax grass	Increaser II
<b>Grass species</b>	<b>x/ 9</b>	<b>Annual/ Perennial</b>	<b>Grazing value</b>	<b>Plant succession</b>	<b>Ecological status</b>
<i>Ischaemum afrum</i>	2	Perennial/ creeping	Average	Sub- climax / Climax grass	-
<i>Melinis repens</i>	3	Perennial	Low	Pioneer/ Sub- climax grass	Increaser II
<i>Panicum coloratum</i> *	1	Perennial	High	Climax grass	Decreaser
<i>Panicum deustum</i>	2	Perennial	High	Climax grass	Decreaser
<i>Panicum maximum</i> *	9	Perennial	High	Sub- climax/ Climax grass	Decreaser
<i>Pogonarthria squarrosa</i>	1	Perennial	Low	Sub- climax grass	Increaser II
<i>Schizachyrium sanguineum</i>	1	Perennial	Low	Climax grass	Increaser I
<i>Schmidtia pappophoroides</i> *	6	Perennial	High	Sub- climax/ Climax grass	Decreaser/ Increaser II
<i>Setaria verticillata</i>	2	Annual	Average	Pioneer grass	Increaser II
<i>Sporobolus fimbriatus</i>	2	Perennial	High	Climax grass	Decreaser
<i>Themeda triandra</i>	1	Perennial	High	Climax grass	Decreaser
<i>Tragus berteronianus</i>	6	Perennial	Low	Pioneer grass	Increaser II
<i>Urochloa mosambicensis</i>	1	Perennial	High	Pioneer/ Sub- climax grass	Increaser II
<i>Urochloa panicoides</i> *	3	Annual	Low	Pioneer grass	Increaser II

( Müller, 1983; Dannhauser, 1985; Gibbs Russel *et al.*, 1990; Van Oudtshoorn, 1992; Van Oudtshoorn, 1999)

x / 9 = occurrence of each species within the nine study sites for the Limpopo Province

'Bare ground' = occurred in 77.7% of the study sites

'Forbes' = occurred in 77.7% of the study sites

• = species included in statistical analysis

## ANNEXURE 15

**Abbreviations used in the text of Chapter 5 are as follows:**

***Aerub*** - *Acacia erubescens*

***Aflec*** - *Acacia fleckii*

***Akarr*** - *Acacia karroo*

***Alud*** - *Acacia luederitzi*

***Amel*** - *Acacia mellifera*

***Aref*** - *Acacia reficiens*

***Akarr*** - *Acacia karroo*

***Atort*** - *Acacia tortilis*

***Agay***- *Andropogon gayanus*

**Annuals** - All annual grass species combined (only Namibia, South Africa = annual species names are indicated seperately)

***Aristidas*** - All *Aristida* species combined

***Asparag*** - *Asparagus* species

**Bare** - Bare ground

***Binsc***- *Bothriochloa insculpta*

***Bserr***- *Brachiaria serrata*

***Ccil***- *Cenchrus ciliaris*

**Clay%** - Soil clay percentage (%)

***Cmop*** - *Colophospermum mopane*

***Cdac***- *Cynodon dactylon*

**D a ctrl** - Density of problem bush after control (trees/ ha)

**D b ctrl** - Density of problem bush before control (trees/ ha)

***Dcin*** - *Dichrostachys cinerea*

***Deri***- *Digitaria eriantha*

***Ecenc***- *Enneapogon cenchroides*

***Edes***- *Enneapogon desvauxii*

***Escop***- *Enneapogon scoparius*

***Eechin***- *Eragrostis echinochloidea*

***Eleh***- *Eragrostis lehmanniana*

*Enin- Eragrostis nindensis*

*Eporo- Eragrostis porosa*

*Erig- Eragrostis rigidior*

*Etri- Eragrostis trichophora*

*Fafr- Fingerhuthia africana*

**Forbs** - All forb species combined

*Grewias* - *Grewia* species

*Hcon- Heterpogon contortus*

**Lt rain** - Long-term average rainfall (mm)

*Mrep- Melinis repens*

*Pcol- Panicum coloratum*

*Pmax- Panicum maximum*

**Perenn: des.**- Desirable perennial grass species combined

**Perenn: less des.** - Less desirable perennial grass species combined

**Per s ctrl** - Period since bush control (years)

*Psqua- Pogonarthria squarrosa*

*Spap- Schmidtia pappophoroides*

**S size** - Size of the bush control site (ha)

**St rain** - Short-term average rainfall (mm)

**S depth** - Soil depth, effective depth (cm)

*Sunip- Stipagrostis uniplumis*

**Success** - Success rate of bush control (%)

*Terminalias* - *Terminalia* species

*Tprun - Terminalia prunioides*

*Tser - Terminalia sericea*

*Tramos- Triraphis ramosissima*

*Tsch- Triraphis schinzii*

*Uoligo- Urochloa oligotricha*

*Upan- Urochloa panicoides*

\* **Woody component:** Measured as trees/ ha

\* **Herbaceous component:** Measured as abundance or frequency (%)

## ANNEXURE 16

### Pricelist with cost approximations for the implements and equipment needed for bush control

*(Prices were determined during August 2003 and are thus accordingly subjected to change)  
(All prices include VAT (14%), except where indicated otherwise)*

#### Aeroplane flying costs (fixed-wing aircraft)

# R40.00/ ha = for aerial application of granular type herbicides e.g. Molopo GG, irrespective of size of application area (price applicable only if herbicide used is bought from the agent himself, if not, R75.00/ ha)

# Contact person: Mr. Gideon Keyser, Molopo region in the Northern Cape Province, South Africa.  
Contact details: +27 (0)82 578 4294

## R60.00- R100.00/ha (average of R80.00/ha) all expenses included, except costs of chemicals being applied (price will vary, considering the distance the aircraft has to fly to get to the target site as well as the size of the target site)

## Contact person: Mr. Johan Louw at Boland Lugspuitdiens (branches in Western Cape and North West Provinces in South Africa) Contact details: +27 (0)22 482 1108

### Another contact for aerial spraying: Orsmond Aviation in Bethlehem, South Africa  
Tel: +27 (0)58 303 5261 (w)

#### Axe

Hand- axe: R65.00- R 170, varying according to size (\*\*SENWES prices)

#### Bow saw

Between R50.00 - R70.00 (\*\*SENWES prices)

#### Brushes (for applying chemicals to cut stumps)

75mm brush (standard size) = R30.00 - R45.00 (\*\*SENWES prices)

#### Bulldozer

##### Examples of bulldozer prices:

- \* Fiat Allis-Chalmers HDL - D5/D6 = R200.00/ hour
- \* Hanomag - D6/D7 = R280.00/ hour
- \* Caterpillar - D7 = R 300.00/ hour

##### Additional general cost estimations for bulldozer hiring:

- D4 = R250.00/ hour
- D6 = R320.00/ hour
- D7 = R375.00/ hour
- D8 = R500.00/ hour

*(All prices per hour, excludes transport and fuel costs for bulldozers)*

#### Bush cutter

R 750.00/ ha (includes cutting of bush and application of herbicide as supplied by the land user, thus excluding herbicide costs)

(Should the herbicide costs be included, the total costs would be between R950.00 - R1010.00/ ha to control bush)

\*\*\* Contact person: Mr. Pieter Eloff (WES Enterprises), Thabazimbi, South Africa.

Contact details: +27 (0)83 441 7585 (mobile) or +27 (0)14 777 1330 (w).

E-mail: [boskos@intekom.co.za](mailto:boskos@intekom.co.za)

**Chain saw**

STIHL 085 chainsaw (commonly used for bush control, 60cc, 9000rpm) = R 5 505.00

5 litres Chain lube = R 80.00

5 litres STIHL 2-stroke oil = R 160.00 (ratio to fuel = 5litres: 250 litres)

60 tooth chain - 43cm guide bar = R 200.00

Sharpening kit for chain = R 125.00

*(Safety clothing needed when operating this equipment!)*

*(Company supplying the above: Garden & Power Products in Potchefstroom, South Africa*

*Contact details: +27 (0)18 293-2741 (work) or +27(0)18 294 8155 (fax)*

**Clearing saw (Brushcutter)**

STIHL Clearing saw - FS 550 = R 8 600.00

Saw blade = R 320.00

5 litres STIHL 2-stroke oil = R 160.00 (ratio to fuel = 5litres: 250 litres)

*(Safety clothing needed when operating this equipment!)*

*(Company supplying the above: Garden & Power Products in Potchefstroom, South Africa*

*Contact details: +27 (0)18 293-2741 (work) or +27(0)18 294 8155 (fax)*

**Hand saw**

Between R 60.00 - R 90.00, depending on size (\*\*SENWES prices)

**Helicopter flying costs**

(See Annexure 9 for cost estimations)

**Knapsack / 'ruksakspuit'**

12 litre capacity (Hozelock brand)= R 1070.00

16 litre capacity (Miura brand) = R 260.00

(\*\*SENWES prices)

**Mattocks/ 'bospik'**

R 110.00 (\*\*SENWES prices)

**Panga**

Standard panga = R 20.00

Corn knife panga = R 23.00

Double-edge slasher = R 134.00

(\*\*SENWES prices)

**Spade**

R 50.00 - R70.00, price varies according to size and brand (\*\*SENWES prices)

**Tractors**

**Examples of tractor prices:**

John Deere - 45 kW - R 264 000.00 (excl. VAT)

103 kW - R 670 000.00 (excl. VAT)

(\*\*SENWES prices)

**\*\* SENWES = SentraalWes Local Co-operation (Agricultural Services) in the North West  
and Free State Provinces, South Africa**

**Contact details for SENWES: Tel: (018) 464- 7394, Fax: (018) 464- 2573**

**E-mail: [info@senwes.co.za](mailto:info@senwes.co.za) Website: [www.senwes.co.za](http://www.senwes.co.za)**

ANNEXURE 16

**\* Also consult the OTK- website for implement and apparatus prices at the following website:**

**[www.otk.co.za/select\\_again.asp](http://www.otk.co.za/select_again.asp)**

**NB!!** The law requires **ANY** person that will be handling any form of equipment that could pose a threat to their health, to undergo safety and skills training in the handling of equipment.

Contact person for training in South Africa: Mr. Hannes du Plessis at +27 (0)18 293 3718 (w) or +27 (0)82 780 5247 (mobile)

## ANNEXURE 17

### A list of price estimations for bush control machinery according to Müller & Archer (2001)

#### Two-wheel drive tractors (April 2001) - High Power Demand

Tractor	Life	Average	April price 2001 Excl. VAT (R)	Depreciation (R/hr)	Insurance and Licence (R/hr)	Interest (R/hr)	Total fixed costs (R/hr)	Total fixed costs excl. interest (R/hr)	Repairs and maintenance (R/hr)	Fuel (R/hr)	Total variable costs (R/hr)	Total costs (R/hr)	Total costs excl. interest (R/hr)	Fuel usage (L/hr)
12	12000	1000	30858	2.31	0.34	1.95	4.61	2.65	3.09	7.34	10.43	15.04	13.08	2.16
13	12000	1000	78000	5.85	0.86	4.93	11.64	6.71	7.80	7.96	15.76	27.40	22.46	2.34
16	12000	1000	38864	2.91	0.43	2.46	5.80	3.34	3.89	9.79	13.68	19.48	17.02	2.88
18	12000	1000	50944	3.82	0.56	3.22	7.60	4.38	5.09	11.02	16.11	23.71	20.49	3.24
20	12000	1000	116618	8.75	1.28	7.38	17.41	10.03	11.66	12.24	23.90	41.31	33.93	3.60
26	12000	1000	110000	8.25	1.21	6.96	16.42	9.46	11.00	15.91	26.91	43.33	36.37	4.68
33	12000	1000	127220	9.54	1.40	8.05	18.99	10.94	12.72	20.20	32.92	51.91	43.86	5.94
35	12000	1000	96163	7.21	1.06	6.08	14.35	8.27	9.62	21.42	31.04	45.39	39.31	6.30
37	12000	1000	152892	11.47	1.68	9.67	22.82	13.15	15.29	22.64	37.93	60.75	51.08	6.66
40	12000	1000	139000	10.43	1.53	8.79	20.75	11.95	13.90	24.48	38.38	59.13	50.33	7.20
41	12000	1000	132967	9.97	1.46	8.41	19.85	11.44	13.30	25.09	38.39	58.23	49.82	7.38
42	12000	1000	223839	16.79	2.46	14.16	33.41	19.25	22.38	25.70	48.09	81.50	67.34	7.56
45	12000	1000	150293	11.27	1.65	9.51	22.43	12.93	15.03	27.54	42.57	65.00	55.49	8.10
47	12000	1000	155778	11.68	1.71	9.85	23.25	13.40	15.58	28.76	44.34	67.59	57.74	8.46
48	12000	1000	133900	10.04	1.47	8.47	19.98	11.52	13.39	29.38	42.77	62.75	54.28	8.64
51	12000	1000	149083	11.18	1.64	9.43	22.25	12.82	14.91	31.21	46.12	68.37	58.94	9.18
52	12000	1000	152913	11.47	1.68	9.67	22.82	13.15	15.29	31.82	47.12	69.94	60.27	9.36
53	12000	1000	164087	12.31	1.80	10.38	24.49	14.11	16.41	32.44	48.84	73.33	62.96	9.54
54	12000	1000	165206	12.39	1.82	10.45	24.66	14.21	16.52	33.05	49.57	74.23	63.78	9.72
55	12000	1000	209035	15.68	2.30	13.22	31.20	17.98	20.90	33.66	54.56	85.76	72.54	9.90
56	12000	1000	239374	17.95	2.63	15.14	35.73	20.59	23.94	34.27	58.21	93.94	78.80	10.08
57	12000	1000	163000	12.23	1.79	10.31	24.33	14.02	16.30	34.88	51.18	75.51	65.20	10.26
58	12000	1000	184094	13.81	2.03	11.64	27.48	15.83	18.41	35.50	53.91	81.38	69.74	10.44
59	12000	1000	186453	13.98	2.05	11.79	27.83	16.03	18.65	36.11	54.75	82.75	70.79	10.62
60	12000	1000	199292	14.95	2.19	12.61	29.74	17.14	19.93	36.72	56.65	86.39	73.79	10.80
62	12000	1000	192115	14.41	2.11	12.15	28.67	16.52	19.21	37.94	57.16	85.83	73.68	11.16
63	12000	1000	206486	15.49	2.27	13.06	30.82	17.76	20.65	38.56	59.20	90.02	76.96	11.34
64	12000	1000	220171	16.51	2.42	13.93	32.86	18.93	22.02	39.17	61.19	94.05	80.12	11.52
66	12000	1000	182084	13.66	2.00	11.52	27.18	15.66	18.21	40.39	58.60	85.78	74.26	11.88
67	12000	1000	255302	19.15	2.81	16.15	38.10	21.96	25.53	41.00	66.53	104.64	88.49	12.06
70	12000	1000	245870	18.44	2.70	15.55	36.70	21.14	24.59	42.84	67.43	104.12	88.57	12.60
71	12000	1000	300539	22.54	3.31	19.01	44.86	25.85	30.05	43.45	73.51	118.36	99.35	12.78
74	12000	1000	270236	20.27	2.97	17.09	40.33	23.24	27.02	45.29	72.31	112.64	95.55	13.32

77	12000	1000	245910	18.44	2.71	15.5	36.70	21.15	24.59	47.12	71.71	108.42	92.86	13.86
78	12000	1000	232721	17.45	2.56	14.72	34.73	20.01	23.27	47.74	71.02	105.74	91.02	14.04
81	12000	1000	284600	21.35	3.13	18.00	42.48	24.48	28.46	49.57	78.03	120.51	102.51	14.58
82	12000	1000	278645	20.90	3.07	17.62	41.59	23.96	27.86	50.18	78.05	119.64	102.01	14.76
88	12000	1000	358209	26.87	3.94	22.66	53.46	30.81	35.82	53.86	89.68	143.14	120.48	15.84
99	12000	1000	463562	34.77	5.10	29.32	69.19	39.87	46.36	60.59	106.94	176.13	146.81	17.82

(From: Müller, G. S. & Archer, G. 2001. Guide to machinery costs. Directorate of Agricultural Economics. Kwazulu-Natal Department of Agriculture and Environmental Affairs. Hilton, Kwazulu-Natal. 71 p.)

**NOTES:**

- 1.) DEPRECIATION COST PER HOUR = (PURCHASE PRICE - SALVAGE VALUE) / LIFE PERIOD IN HOURS
- 2.) SALVAGE VALUE = 10.00% OF PURCHASE PRICE
- 3.) INTEREST COST PER HOUR = 11.50% OF AVERAGE INVESTMENT / HOURS PER ANNUM
- 4.) INSURANCE & LICENCE = 2.00% OF AVERAGE INVESTMENT / HOURS PER ANNUM
- 5.) REPAIRS AND MAINTENANCE COSTS = 120.00% OF PURCHASE PRICE / LIFE PERIOD IN HOURS
- 6.) FUEL COST: R 3.40 / LITRE
- 7.) FUEL CONSUMPTION IS BASED ON: 60.00% OF KILOWATTS USED
- 8.) LITRES USED PER KILOWATT HOUR: 0.300
- 9.) AVERAGE INVESTMENT = (PURCHASE PRICE + SALVAGE VALUE) / 2

**GENERAL REMARKS:**

- \* Cost per hour is based on clock hours and not tractor meter hours.
- \* The driver/ operator cost is not included in the costs.

## ANNEXURE 17

### A list of price estimations for bush control machinery according to Müller & Archer (2001)

#### Four-wheel drive tractors (April 2001) - High power demand

Tractor (kW)	Life (hrs)	Average (hrs)	April price 2001 Excl. VAT (R)	Depreciation (R/hr)	Insurance and Licence (R/hr)	Interest (R/hr)	Total fixed costs (R/hr)	Total fixed costs excl. interest (R/hr)	Repairs and maintenance (R/hr)	Fuel (R/hr)	Total variable costs (R/hr)	Total costs (R/hr)	Total costs excl. interest (R/hr)	Fuel usage (L/hr)
11	12000	1000	68600	5.15	0.75	4.34	10.24	5.90	6.86	6.82	13.68	23.92	19.58	2.01
16	12000	1000	88800	6.66	0.98	5.62	13.25	7.64	8.88	9.92	18.80	32.06	26.44	2.92
18	12000	1000	58183	4.36	0.64	3.68	8.68	5.00	5.82	11.16	16.98	25.66	21.98	3.28
26	12000	1000	110000	8.25	1.21	6.96	16.42	9.46	11.00	16.12	27.12	43.54	36.58	4.74
31	12000	1000	108000	8.10	1.19	6.83	16.12	9.29	10.80	19.22	30.02	46.14	39.31	5.65
32	12000	1000	168400	12.63	1.85	10.65	25.13	14.48	16.84	19.85	36.69	61.82	51.17	5.84
33	12000	1000	189000	14.18	2.08	11.95	28.21	16.25	18.90	20.47	39.37	67.57	55.62	6.02
35	12000	1000	123845	9.29	1.36	7.83	18.48	10.64	12.38	21.71	34.09	52.57	44.74	6.38
37	12000	1000	161884	12.14	1.78	10.24	24.16	13.92	16.19	22.95	39.13	63.30	53.06	6.75
41	12000	1000	166539	12.49	1.83	10.53	24.86	14.32	16.65	25.43	42.08	66.94	56.40	7.48
44	12000	1000	165350	12.40	1.82	10.46	24.68	14.22	16.54	27.29	43.82	68.50	58.04	8.03
48	12000	1000	153190	11.49	1.69	9.69	22.86	13.17	15.32	29.77	45.09	67.95	58.26	8.76
51	12000	1000	173004	12.98	1.90	10.94	25.86	14.88	17.30	31.63	48.93	74.75	63.81	9.30
52	12000	1000	170308	12.77	1.87	10.77	25.42	14.65	17.03	32.25	49.28	74.70	63.93	9.48
53	12000	1000	189150	14.19	2.08	11.96	28.23	16.27	18.92	32.87	51.78	80.01	68.05	9.67
54	12000	1000	187406	14.06	2.06	11.85	27.97	16.12	18.74	33.49	52.23	80.20	68.35	9.85
55	12000	1000	237280	17.80	2.61	15.01	35.41	20.41	23.73	34.11	57.84	93.25	78.24	10.03
56	12000	1000	269740	20.23	2.97	17.06	40.26	23.20	26.97	34.73	61.70	101.96	84.90	10.21
57	12000	1000	188139	14.11	2.07	11.90	28.08	16.18	18.81	35.35	54.16	82.24	70.34	10.40
58	12000	1000	211028	15.83	2.32	13.35	31.50	18.15	21.10	35.97	57.07	88.57	75.22	10.58
59	12000	1000	200399	15.03	2.20	12.68	29.91	17.23	20.04	36.95	56.63	86.54	73.86	10.76
60	12000	1000	237562	17.82	2.61	15.03	35.46	20.43	23.76	37.21	60.97	96.42	81.40	10.94
62	12000	1000	244928	18.37	2.69	15.49	36.56	21.06	24.49	38.45	62.94	99.50	84.01	11.31
63	12000	1000	244086	18.31	2.68	15.44	36.43	20.99	24.41	39.07	63.48	99.91	84.47	11.49
64	12000	1000	230254	17.27	2.53	14.56	34.37	19.80	23.03	39.69	62.72	97.08	82.52	11.67
65	12000	1000	212083	15.91	2.33	13.41	31.65	18.24	21.21	40.31	61.52	93.17	79.76	11.86
66	12000	1000	228658	17.15	2.52	14.46	34.13	19.66	22.87	40.93	63.80	97.92	83.46	12.04
67	12000	1000	291336	21.85	3.20	18.43	43.48	25.05	29.13	41.55	70.68	114.17	95.74	12.22
70	12000	1000	263821	19.79	2.90	16.69	39.38	22.69	26.38	43.41	69.79	109.17	92.48	12.77
71	12000	1000	339668	25.48	3.74	21.48	50.70	29.21	33.97	44.03	78.00	128.69	107.21	12.95
73	12000	1000	215000	16.13	2.37	13.60	32.09	18.49	21.50	45.27	66.77	98.86	85.26	13.32
74	12000	1000	281283	21.10	3.09	17.79	41.98	24.19	28.13	45.89	74.02	116.00	98.21	13.50
75	12000	1000	285000	21.38	3.14	18.03	42.54	24.51	28.50	46.51	75.01	117.55	99.52	13.68

76	12000	1000	255000	19.13	2.81	16.13	38.06	21.93	25.50	47.13	72.63	110.69	94.56	13.86
77	12000	1000	295845	22.19	3.25	18.71	44.15	25.44	29.58	47.75	77.34	121.49	102.78	14.04
78	12000	1000	271975	20.40	2.99	17.20	40.59	23.39	27.20	48.37	75.57	116.16	98.96	14.23
80	12000	1000	390913	29.32	4.30	24.73	58.34	33.62	39.09	49.61	88.70	147.05	122.32	14.59
81	12000	1000	272649	20.45	3.00	17.25	40.69	23.45	27.26	50.23	77.50	118.19	100.95	14.77
83	12000	1000	278000	20.85	3.06	17.58	41.49	23.91	27.80	51.47	79.27	120.76	103.18	15.14
84	12000	1000	335925	25.19	3.70	21.25	50.14	28.89	33.59	52.09	85.69	135.82	114.58	15.32
85	12000	1000	313512	23.51	3.45	19.83	46.79	26.96	31.35	52.71	84.06	130.86	111.03	15.50
86	12000	1000	282188	21.16	3.10	17.85	42.12	24.27	28.22	53.33	81.55	123.67	105.82	15.69
88	12000	1000	345827	25.94	3.80	21.87	51.61	29.74	34.58	54.57	89.16	140.77	118.90	16.05
91	12000	1000	440800	33.06	4.85	27.88	65.79	37.91	44.08	56.43	100.51	166.30	138.42	16.60
92	12000	1000	307792	23.08	3.39	19.47	45.94	26.47	30.78	57.05	87.83	133.77	114.30	16.78
93	12000	1000	333500	25.01	3.67	21.09	49.77	28.68	33.35	57.67	91.02	140.80	119.71	16.96
97	12000	1000	360000	27.00	3.96	22.77	53.73	30.96	36.00	60.16	96.16	149.89	127.12	17.69
99	12000	1000	440171	33.01	4.84	27.84	65.70	37.85	44.02	61.40	105.41	171.11	143.27	18.06
101	12000	1000	331275	24.85	3.64	20.95	49.44	28.49	33.13	62.64	95.76	145.21	124.25	18.42
103	12000	1000	402335	30.18	4.43	25.45	60.05	34.60	40.23	63.88	104.11	164.16	138.71	18.79
104	12000	1000	467834	35.09	5.15	29.59	69.82	40.23	46.78	64.50	111.28	181.10	151.51	18.97
110	12000	1000	345657	25.92	3.80	21.86	51.59	29.73	34.57	68.22	102.78	154.37	132.51	20.06
112	12000	1000	393000	29.48	4.32	24.86	58.66	33.80	39.30	69.46	108.76	167.41	142.56	20.43
114	12000	1000	553700	41.53	6.09	35.02	82.64	47.62	55.37	70.70	126.07	208.71	173.69	20.79
116	12000	1000	563438	42.26	6.20	35.64	84.09	48.46	56.34	71.94	128.28	212.38	176.74	21.16
117	12000	1000	420000	31.50	4.62	26.57	62.69	36.12	42.00	72.56	114.56	177.24	150.68	21.34
118	12000	1000	452782	33.96	4.98	28.64	67.58	38.94	45.28	73.18	118.46	186.03	157.40	21.52
120	12000	1000	542132	40.66	5.96	34.29	80.91	46.62	54.21	74.42	128.63	209.55	175.26	21.89
125	12000	1000	353434	26.51	3.89	22.35	52.75	30.40	35.34	77.52	112.86	165.61	143.26	22.80

From: Müller & Archer (2001).

#### NOTES:

- 1.) DEPRECIATION COST PER HOUR = (PURCHASE PRICE - SALVAGE VALUE) / LIFE PERIOD IN HOURS
- 2.) SALVAGE VALUE = 10.00% OF PURCHASE PRICE
- 3.) INTEREST COST PER HOUR = 11.50% OF AVERAGE INVESTMENT / HOURS PER ANNUM
- 4.) INSURANCE & LICENCE = 2.00% OF AVERAGE INVESTMENT / HOURS PER ANNUM
- 5.) REPAIRS AND MAINTENANCE COSTS = 120.00% OF PURCHASE PRICE / LIFE PERIOD IN HOURS
- 6.) FUEL COST: R 3.40 / LITRE
- 7.) FUEL CONSUMPTION IS BASED ON: 60.00% OF KILOWATTS USED
- 8.) LITRES USED PER KILOWATT HOUR: 0.300
- 9.) AVERAGE INVESTMENT = (PURCHASE PRICE + SALVAGE VALUE) / 2

#### GENERAL REMARKS:

- \* Cost per hour is based on clock hours and not tractor meter hours.
- \* The driver/ operator cost is not included in the costs.

## ANNEXURE 18

### List of costs involved in aerial application of herbicide (Access\*, spraying) with a helicopter

(Excluding VAT%)  
(Effective as of 1<sup>st</sup> July 2002)

Total ha	Access (price/ specified total ha)	Actipron (price/ specified total ha)	Total chemicals (price/ specified total ha)	Chemicals (R/ha)	Helicopter site establ. (R/ha)	Application costs (R/ha)	Total R/ha (chemicals + helicopter + application)	Total costs in Rand/ specified total ha
100	28354	2919	31273	312.73	35.01	145.00	492.74	49,274.00
150	42531	4378.5	46909.5	312.73	23.34	145.00	481.07	72,160.50
200	56708	5838	62546	312.73	17.50	145.00	475.24	95,048.00
250	70885	7297.5	78182.5	312.73	14.01	145.00	471.74	117,935.00
300	85062	8757	93819	312.73	11.68	145.00	469.41	140,823.00
350	99239	10216.5	109455.5	312.73	10.01	145.00	467.74	163,709.00
400	113416	11676	125092	312.73	8.76	145.00	466.49	186,596.00
450	127593	13135.5	140728.5	312.73	7.79	145.00	465.52	209,484.00
500	141770	14595	156365	312.73	7.01	145.00	464.74	232,370.00
550	155947	16054.5	172001.5	312.73	6.37	145.00	464.10	255,255.00
600	170124	17514	187638	312.73	5.84	145.00	463.57	278,142.00
650	184301	18973.5	203274.5	312.73	5.39	145.00	463.12	301,028.00
700	198478	20433	218911	312.73	5.01	145.00	462.74	323,918.00
750	212655	21892.5	234547.5	312.73	4.68	145.00	462.41	346,807.50
800	226832	23352	250184	312.73	4.39	145.00	462.12	369,696.00
850	241009	24811.5	265820.5	312.73	4.13	145.00	461.86	392,581.00
900	255186	26271	281457	312.73	3.90	145.00	461.63	415,467.00
950	269363	27730.5	297093.5	312.73	3.69	145.00	461.42	438,349.00
1000	263540	29190	312730	312.73	3.51	145.00	461.24	461,240.00
1050	297717	30649.5	328366.5	312.73	3.34	145.00	461.07	484,123.50
1100	311894	32109	344003	312.73	3.19	145.00	460.92	507,012.00
1150	326071	33568.5	359639.5	312.73	3.05	145.00	460.78	529,897.00

\* ACCESS = A chemical bush control product, manufactured and distributed by Dow AgroSciences (SA), +27-11- 709- 0114 (head office)

List obtained from a personal communication (Arnaud le Roux<sup>1</sup>).

<sup>1</sup> Mr. Arnaud le Roux: EcoGuard Project Manager: Selective bush control - southern Africa. Contact details: Mobile:+27-(0)83- 679- 7775 or E-mail: [lepetit5@lantic.net](mailto:lepetit5@lantic.net)

## ANNEXURE 19

**Address list of chemical suppliers and distributors throughout southern Africa**

COMPANY NAME	ADDRESS	TELEPHONE/ FAX
<b>Bayer (Pty) Ltd.</b>	P. O. Box 143, Isando, 1600	+27-(0)11- 921- 5247
<b>Dow AgroSciences SA (Ltd.)</b>	Private Bag x55, Bryanston, 2021	+27-(0)11- 709- 0114
<u>Contact persons in Namibia:</u> Mr. Dawid Botha	P. O. Box 10, Otavi, Namibia	+264-(0)67- 234- 356/ 403 (tel) +264-(0)81- 128- 4844 (mobile)
Mr. Danie Swanepoel	<u>extokaha@iway.na</u> Odussa Trading Okahandja, Namibia	+264-(0)62-501 321/ 564 (tel) +264-(0)81-243 2578 (mobile)
<b>Du Pont de Nemour Int. SA</b>	P. O. Box 3332, Halfway House, 1685	+27-(0)11- 654- 8600
<b>Ecoguard Distributors (Pty) Ltd.</b>	P. O. Box 98634, Sloane Park, 2152 <u>www.ecoguard.co.za</u>	+27-(0)11- 463- 6057 (tel) +27-(0)11- 463- 6462 (fax)
<b>Efekto</b>	P. O. Box 912787, Silverton, 0127	+27-(0)12- 804- 1008
<b>Enviro Industries (Pty.) Ltd.</b>	P. O. Box 13031, Geduld, 1562	+27-(0)11- 887- 8060
<b>Novon SA (Pty) Ltd. (previously Novartis SA)</b>	P. O. Box 92, Isando, 1600	+27-(0)11- 929- 9111
<b>Plaaskem (Pty) Ltd.</b>	P. O. Box 87005, Houghton, 2041	+27-(0)11- 397- 4640
<b>Sanachem (Pty) Ltd.</b>	P. O. Box 1454, Durban, 4000	+27-(0)32- 230-111

(From: Grobler *et al.*, 2000)

## ANNEXURE 20

### List of questions that form part of the on-line *Grass Expert* database consultation phase

(with droplist answer options)

#### **1(a) What does the problem in the area consist of?**

(no image supplied)

Bare patches (80% of the problem area consist of bare patches) - The plant cover of the problem area is about 20%

Pioneer species (20% bare patches) - Mainly pioneer grass species, such as *Aristida*, *Tragus* and *Eragrostis* species are present, with small bare patches

Slope and bare patches (erosion) - Bare patches with sheet erosion (little or none of the A-Horizon is present) - mainly caused by the slope in the problem area

Bush invasion and bare patches - e.g. *Acacia* encroachment occurs in the problem area, while bare patches are present

Old land - the problem area was cultivated before

other - if none of the above refers to your problem

#### **1(b) What is the size of the problem area?**

(no image supplied)

Small patches (up to 20 m in size)

Camp ( +/- 10 ha)

Number of camps (10-50 ha)

Very large area (> 50 ha)

other - if none of the above refers to your problem

#### **1(c) Was the soil previously cultivated?**

(no image supplied)

Yes - the problem area was cultivated before, e.g. old land

No - the soil was never disturbed before by a mechanical implement

#### **2(a) What is the average annual rainfall?**

(see "Rainfall map of South Africa" image)

651-700mm/yr

601-650mm/yr

551-600mm/yr

501-550mm/yr

451-500mm/yr

401-450mm/yr

351-400mm/yr

301-350mm/yr

251-300mm/yr

201-250mm/yr

151-200mm/yr

100-150mm/yr

other

**3(a) What is the texture class (clay content)?**

(no image supplied)

Sand - <10%

Loam sand - 10-15%

Sandy loam - 15-20%

Sandy clay loam - 20-35%

Clay loam - 27-40%

Sandy clay - 35-55%

Clay- >55

other

**3(b) What is the soil colour?**

(no image supplied)

Red

Yellow

Yellowish-brown

Gray

Black

other

**3(c) What is the soil type?**

(See *soil type booklet* with images)

Includes a help-function where the soil profile images from the electronic version of the Soil Classification Workgroup\* (1991) can be viewed.

Hutton

Glenrosa

Mispah

Swartland

Valsrivier

Avalon

Oakleaf

Clovelly

Sterkspruit

Addo

Katspruit

Namib

Shortlands

Constantia

Kinkelbos

Westleigh

Fernwood

Sepane

Bonheim

other

**3(d) What is the thickness of the A-horizon?**  
(no image supplied)

- None (<10mm)
- 10-50mm
- 50-100mm
- 100-150mm
- 150-200mm
- 200-250mm
- 250-300mm
- <300mm
- >300mm

**4(a) What is the terrain's topographical unit?**  
(see image for indication of *topographical unit*)

- Crest
- Free hang
- Scarp
- Midslope
- Footslope
- Valley bottom
- other

**4(b) What is the slope?**  
(see diagram for *image of slope*)

- Flat (0-2%)
- Mild (2.1-8%)
- Mild steep (8.1-15%)
- Steep (15.1-25%)
- Very steep >25.1 %
- other

**5(a) Are mechanical implements available?**  
(no image supplied)

- Yes
- No

**5(b) What type of mechanical implement is available?**  
(Consult images for indication of different *mechanical implements*)

Dyker plough  
Dyker plough and ripper  
Planter  
Ripper  
Harrow  
Ripper and harrow  
Ripper and Mouldboard plough  
Grooved disc harrow  
Chisel plough  
Mouldboard plough  
Cultivator  
Vlekploeg  
other  
None

**5(c) Is seed available?**  
(no image supplied)

Yes  
No

**5(d) What type of organic material is available?**  
(no image supplied)

Cattle dung  
Sheep dung  
Hay  
Branches  
Fertiliser  
other

\* Soil Classification Workgroup (1991)

ANNEXURE 21

**List of questions that form part of the on-line**

***Bush Expert* database consultation phase**

(with dropdown answer options)

1) Specify country:

Namibia
South Africa
Zimbabwe
Botswana
Kenya
Other

2) What type of farm management system is this?

Commercial
Communal
Other

3) In what vegetation type does this farm occur?  
(select a vegetation type by consulting the inclosed map)

Northern Namib
Saline Desert with Dwarf Savanna
Forest Savanna and Woodlands
Camel Thorn Savanna
Mixed Tree and Shrub Savanna
Central Namib
Southern Namib
Desert and Succulent Steppes
Semi Desert and Savanna Transition
Mopani
Mountain Savana and Karstveld
Thom Bush Savanna
Highlands Savanna
Dwarf Shrub Savanna
Khomas-Bergland-Savanna (mountain savanna)
Khomas-Bergland-Savanna (open thorn tree-savanna)
Thorn tree Savanna
Other

4) Farming regions?

(select a farming region by consulting the inclosed map)

Caprivi
Erongo
Hardap
Karas
Kavango
Khomas
Kunene
Ohangwena
Omaheke
Omusati
Oshana
Oshikoto
Oujzondjupa
Other

**5) Farming district?**

Gobabis
Grootfontein
Karasburg
Karibib
Keetmanshoop
Maltehohe
Mariental
Okahandja
Omaruru
Ondangwa
Opuwo
Otavi
Otjiwarongo
Outjo
Rundu
Tsumeb
Windhoek
Other

**6) Agro-Ecological Zone (AEZ):**

(select an AEZ by consulting the inclosed map - many AEZs exist, thus they will not be listed here)

**7) Fairly Homogeneous Farming Area (FHFA):**

(Too many FHFAs exist, thus they will not be listed here)

**8) Long-term average rainfall (> 30 years) (mm):**

< 100 mm
100- 250 mm
251- 300 mm
301- 350 mm
351- 400 mm
401- 450 mm
451- 500 mm
501- 550 mm
551- 600 mm
> 600 mm
Other

**9) Short-term average rainfall (< 5 years) (mm):**

< 100 mm
100- 250 mm
251- 300 mm
301- 350 mm
351- 400 mm
401- 450 mm
451- 500 mm
501- 550 mm
551- 600 mm
> 600 mm
Other

**10) Soil type?**

Addo
Avalon
Bonheim
Clovelly
Constantia
Fernwood
Glenrosa
Hutton
Katspruit
Kinkelbos
Mispah
Namib
Oakleaf
Sepane
Shortlands
Sterkspruit
Swartland
Valsrivier
Westleigh
Other

**11) Soil clay percentage?**

0- 5% Sand
6- 10% Sand
11- 15% Sa-Lm
16- 20% Sa-Lm
21- 30% Sa-CI-Lm
31- 40% CI-Lm
> 41% CI
Other

**12) Problem species found at this site as a % of the total bush?**

(all the listed species are indicated in the questionnaire (see Annexure 22) for a list of these species), a percentage for each species needs to be chosen from the drop lists and should add up to a total of 100%)

None
0- 10%
10- 20%
21- 30%
31- 40%
41- 50%
51- 60%
61- 70%
71- 80%
81- 90%
91- 100%
Other

**13) Height classes and percentage contributions of the problem species?**

(all the listed height classes are indicated in the questionnaire, a percentage for each of the classes needs to be chosen from the drop lists and should add up to a total of 100%)

0- 10%
10- 20%
21- 30%
31- 40%
41- 50%
51- 60%
61- 70%
71- 80%
81- 90%
91- 100%
Other

**14) Total density of all the species?**

< 1 000/ ha
1 001- 2 000/ ha
2 001- 3 000/ ha
3 001- 4 000/ ha
4 001- 6 000/ ha
6 001- 8 000/ ha
8 001- 10 000/ ha
> 10 000/ ha
Other

**15) Use of the problem species after control?**

Charcoal
Timber
Firewood
Browsing
Charcoal + Browsing
Charcoal + Firewood
Other
No use

**16) Is this site part of an old land?**

Yes
No
Other

**17) Is there a watering point near or in this site?**

Yes
No
Other

**18) Specify the aim of the bush control:**

Natural grazing
Cultivated pastures
Crop production
Eco- tourism
Hunting
Job creation

Bush utilization
Natural grazing + Job creation
Natural grazing + Bush utilization
Natural grazing + Other
Natural grazing + Cultivated pastures
All
Natural grazing + Eco- tourism + Hunting
Natural grazing + Hunting
Other

**19) Indicate the animal type and % contribution of each type:**

(all the listed animal types are indicated in the questionnaire, a percentage for each of the animal types needs to be chosen from the drop lists and should add up to a total of 100%)

None
0- 10%
10- 20%
21- 30%
31- 40%
41- 50%
51- 60%
61- 70%
71- 80%
81- 90%
91- 100%
Other

**A. Chemical control**

**1) What type of herbicide will be used?**

Access
Bromosil
Bushwacker
Grasslan
Grazer
Molopo GG
Molopo SC
Reclaim
Savana
Tordon 155
Tordon 225
Tordon Super
Ustilan
Other

**2) Choose the application method that will be used:**

None
Aeroplane
Spoon
Spray (stem)
Spray (leaf)
Spray (soil)
Brush on stump
Other

**3) Indicate frequency of frost:**

None
Infrequent

Frequent
Other

4) Is this an after-care application?

No
Yes
Other

5) If yes, was the previous control method successful?

No
Yes
Other

**B. Mechanical control**

1) What type of mechanical implement is available?

None
Bulldozer
Bulldozer and Roller
Bush Eater
Bush Cutter
Bush Harvester
Other

2) Choose the appropriate working depth:

None
Under ground
Above ground < 0.5 m
Above ground > 0.5 m
Other

3) Indicate frequency of frost:

None
Infrequent
Frequent
Other

4) Is this an after-care application?

No
Yes
Other

5) If yes, was the previous control method successful?

No
Yes
Other

320

Controlled fire
Other

2) Indicate frequency of frost:

None
Infrequent
Frequent
Other

**C. Manual control****1) What type of implement is available?**

None
Axe
Hand saw
Chain saw
Bush Cutter
Mattocks "Bospik"
Stemburning
Combination

**2) Choose the appropriate working depth:**

None
Under ground
Above ground < 0.5 m
Above ground > 0.5 m
Other

**3) Indicate frequency of frost:**

None
Infrequent
Frequent
Other

**4) Is this an after-care application?**

No
Yes
Other

**5) If yes, was the previous control method successful?**

No
Yes
Other

**D. Biological control****1) Choose the type of control that will be used:**

None
Goats
Fire
Controlled fire
Other

**2) Indicate frequency of frost:**

None
Infrequent
Frequent
Other

**3) Is this an after-care application?**

No
Yes
Other

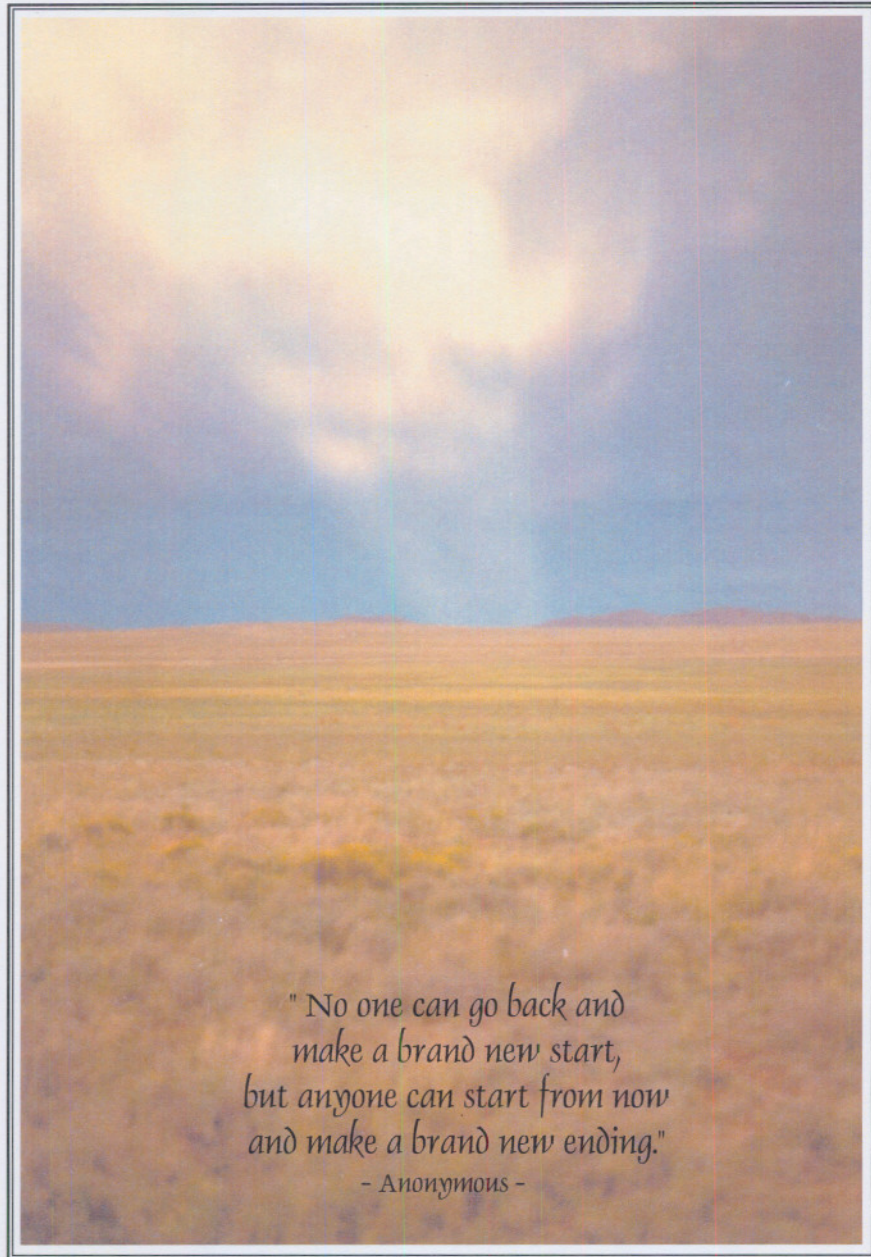
**4) If yes, was the previous control method successful?**

No
Yes
Other

## ANNEXURE 22

**Problem tree species listed in the on-line *Bush Expert* database consultation phase**

<i>Acacia erubescens</i>	(blouhaak / blue thorn)
<i>Acacia fleckii</i>	(bladdoring / blade thorn)
<i>Acacia hereroensis</i>	(bergdoring / mountain thorn)
<i>Acacia karroo</i>	(soetdoring / sweet thorn)
<i>Acacia luederitzii</i>	(baster haak-en-steek / false umbrella thorn)
<i>Acacia mellifera</i>	(swarthaak / black thorn)
<i>Acacia reficiens</i>	(rooihaak-en-steek / red umbrella thorn)
<i>Acacia senegal</i> var. <i>rostrata</i>	(driehaakdoring / three-hook thorn)
<i>Catophractes alexandri</i>	(trompetterdoring / trumpet thorn)
<i>Colophospermum mopane</i>	(mopanie / mopane)
<i>Combretum apiculatum</i>	(harige rooiboswilg / hairy red bushwillow)
<i>Croton gratissimus</i>	(laventelkoorsbessie / lavender fever berry)
<i>Dichrostachys cinerea</i>	(sekelbos / sickle bush)
<i>Grewia</i> spp.	(rosyntjiebosse / raisin bushes)
<i>Prosopis glandulosa</i> var. <i>torreyana</i>	(Suidwesdoring / glandular mesquite)
<i>Rhigozum trichotomum</i>	(drie-doring / three thorn)
<i>Terminalia prunioides</i>	(sterkbos / lowveld cluster-leaf)
<i>Terminalia sericea</i>	(vaalboom or sandgeelhout / silver-cluster leaf)



*" No one can go back and  
make a brand new start,  
but anyone can start from now  
and make a brand new ending."*

*- Anonymous -*