

The evaluation and promotion of best practices for the restoration of arid- and semi-arid rangelands in southern Africa

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Without green plants, all things would perish, and the Earth would revert to its original barren state. Mankind survives on the Earth only because green plants grow here. Indeed, "all flesh is grass".
(McLuhan, 1994)

ABSTRACT

Land degradation and desertification are threatening the livelihoods of millions of people all over the world, especially those living in sub-Saharan Africa. The problem is mainly ascribed to climatic factors, exacerbated by anthropogenic factors such as bad management practices. To combat the problems associated with land degradation and desertification, various approaches and technologies have been developed and implemented by land users, managers and scientists. These approaches and technologies are, however, seldom summarized, analyzed and presented in a single document.

This study has been initiated as part of the Desert Margins Program (DMP), which operates in nine countries in East, Southern and West Africa. The DMP aims to determine the causes, extent and severity of biodiversity loss and ecosystem degradation in selected arid and semi-arid regions in Africa. This study has been conducted in concurrence with the objectives identified by the DMP and consists of four parts: (1) an overview of National and International environmental legislation in SA pertaining to land degradation and desertification, and the mitigation thereof, (2) an overview of the approaches and technologies used for the restoration of degraded rangelands in South Africa in the DMP target areas, (3) a summary of conservation, restoration and alternative livelihood technologies used in the nine DMP partner countries, and (4) the evaluation of a drought tolerant grass species (*Cenchrus ciliaris*), commonly used in restoration technologies in South Africa and other countries.

The first part of this study summarized environmental legislation in South Africa concerned with land degradation, conservation and the restoration of natural resources. The country has a comprehensive environmental legislative system that includes a range of International and National legislation. South Africa is also a signatory to a number of International conventions such as the United Nations Convention to Combat Desertification (UNCCD). In accordance with these conventions, various National Action Programs (NAPs) have been developed. Jointly with the NAPs and the Constitution of South Africa, a large number of environmental Acts, such as the National Environmental Management Act (NEMA), form the baseline for conservation and restoration activities in the country. It was, however, observed that, even though efficient

environmental legislation is in place, the regulation of the actions set out by the legislation is often problematic and ineffective. The emphasis should therefore be on knowledge transfer and capacity building for all levels of stakeholder involvement to ensure the effective implementation and regulation of environmental legislation.

In the second part of the study, the focus was on determining similarities and differences in perceptions about land degradation and desertification, as well as approaches towards the conservation and restoration of natural resources in three different land use systems, i.e. conservation areas, commercial farming and communal or small-holder farming. The study was carried out in the four DMP target areas in the Northern Cape and North West Provinces of South Africa, i.e. Molopo, Kalahari, Namaqualand and Suid Bokkeveld. The majority of land users from all land use types felt that land degradation is characterized by a change in plant species composition, the presence of bare areas and poor condition of livestock. Even though most land users indicated that land degradation is a problem, less than half of them have implemented any conservation and restoration technologies to address the problem. The technology most commonly used by land users from all sectors is resting, while active restoration technologies include the eradication of alien plants, the establishment of wind breaks in croplands and the over-sowing of perennial herbaceous species into natural rangelands. A lack of ownership and financial constraints are the most important factors limiting the adoption and implementation of conservation and restoration technologies in South Africa.

The third part of this study investigated approaches and technologies implemented in the different DMP partner countries to mitigate the effects of land degradation and desertification and improve livelihoods. Each of the countries is signatory to one or more international conventions, which has led to the development of various NAP documents. National environmental legislation in the countries deals with aspects relating to forestry, water, pasture, wildlife and agriculture. The technologies observed in this study have been divided into three different categories, i.e. restoration, conservation and alternative livelihood technologies. In the Southern and Eastern DMP partner countries, technologies have focussed on the conservation and the restoration of natural rangelands, such as resting, dune stabilization and the control of alien invader species. In these countries alternative livelihood technologies such as food gardens and bee keeping have been applied. In an attempt to increase the productivity of the natural resources, technologies in

West African DMP partner countries included more restoration and alternative livelihood technologies, such as the Vallerani system and African Market Gardens. The major constraint in the adoption and implementation of all observed technologies is the limited technical and financial resources available to land users.

The last part of this thesis dealt with the evaluation of the effects of drought stress on the germination, physiology and morphology of *Cenchrus ciliaris*. *Cenchrus ciliaris* is a popular cultivated pasture in semi-arid and arid areas and is often used in over-sowing technologies in South Africa and other African countries, as concluded from the previous parts of the study. Extreme environmental conditions however regularly hamper the germination, establishment and growth of this species. Seed of *C. ciliaris* was used in three different laboratory and glasshouse experiments. The laboratory experiments showed that the germination capacity decreased with an increase in drought stress. In addition, the seedlings suffered decreased morphological development of roots and stems. The physiological measurements taken on mature plants indicated that, even though this species showed sensitivity to drought stress, no significant changes occurred. It is therefore concluded that drought conditions negatively influenced germination, seedling establishment and morphology, while it had very little effect on the physiological processes of mature plants.

This study provides a baseline document, summarizing information concerning legislation and technologies used for combating land degradation and the improvement of livelihoods. The information gained through this study can give land users the necessary ‘know-how’ to apply these technologies in their specific situations. It is, however, essential that the results of this research are implemented over the long-term as this would facilitate the adoption and implementation of the ‘best-bet’ technologies identified by this study.

Keywords: Land degradation, desertification, conservation, restoration, alternative livelihoods, environmental legislation, *Cenchrus ciliaris*, drought stress

OPSOMMING

Landdegradasie en verwoestyning bedreig die bestaan van miljoene mense reg oor die wêreld, veral in die ariede en semi-ariëde lande suid van die Sahara. Die probleem word hoofsaaklik toegeskryf aan klimaatsfaktore wat vererger word deur menslike aktiwiteite, soos swak veld bestuurspraktyke. Verskeie benaderings en tegnologieë is deur grondgebruikers, bestuurders en navorsers ontwikkel in 'n poging om bogenoemde probleme te probeer oplos. Baie min van hierdie benaderings en tegnologieë is egter in 'n enkele dokument beskryf en opgesom.

Hierdie studie is onderneem as deel van die Desert Margins Program (DMP), wat werkzaam is in nege lande in oos, suidelike en wes Afrika. Die DMP poog om die oorsake en omvang van biodiversiteit verlies en ekosisteem degradasie in geselekteerde ariede en semi-ariëde areas in Afrika te bepaal. Die studie is uitgevoer in ooreenstemming met die doelwitte geïdentifiseer deur die DMP en bestaan uit vier dele, (1) 'n oorsig van Nasionale en Internasionale omgewingswetgewing in Suid Afrika van toepassing op landdegradasie en verwoestyning, sowel as die voorkoming en verligting daarvan, (2) 'n oorsig oor die benaderings en tegnologieë wat gebruik word vir die restourasie van gedegradeerde areas in Suid Afrika, (3) 'n opsomming van bewarings, restourasie en alternatiewe lewensinkomstetegnologieë wat gebruik word in die nege DMP lande, en (4) die evaluasie van 'n droogte weestandbiedende grasspesie (*Cenchrus ciliaris*) wat algemeen gebruik word in restourasie projekte in Suid Afrika en ander lande.

In die eerste deel van die studie word die omgewingswetgewing in Suid Afrika met betrekking tot landdegradasie, bewaring en die restourasie van natuurlike hulpbronne opgesom. Suid Afrika het 'n omvattende omgewingswetgewing netwerk wat 'n groot hoeveelheid Internasionale en Nasionale wetgewing insluit. Suid Afrika het verskeie konvensies onderteken, onder andere die Verenigde Nasies Konvensie vir die Bekamping van Verwoestyning (UNCCD). In ooreenstemming met die konvensies is verskeie Nasionale Aksie Programme (NAPs) ontwikkel. Verskeie omgewingswette, soos die Nasionale Omgewings Bestuur Wet vorm saam met die Nasionale Aksie Programme en die Grondwet van Suid Afrika, die basis vir bewaring en restourasie aktiwiteite in die land. Dit is egter waargeneem dat alhoewel goeie omgewingswetgewing in plek is, die regulasie van die voorgeskrewe aktiwiteite geweldig

problematies en oneffektief is. Die klem moet dus val op die oordrag van kennis en die bou van kapasiteit op alle vlakke van deelname. Dit sal verseker dat omgewingswetgewing effektief geïmplementeer en gereguleer word.

Die tweede deel van die studie het gefokus op die ooreenkomste en verskille in persepsie ten opsigte van landdegradasie en verwoestyning, sowel as die benaderings tot die bewaring en restourasie van natuurlike hulpbronne in drie verskillende landbousektore in Suid Afrika, naamlik bewaringsareas, kommersiële en kommunale of klein-boer boerdery. Die studie is uitgevoer in vier DMP teikengebiede in die Noord Kaap en Noordwes provinsies van Suid Afrika, naamlik Molopo, Kalahari, Namakwaland en Suid Bokkeveld. Die meerderheid van die grondgebruikers het gevoel dat landdegradasie gekarakteriseer word deur 'n verandering in die plantspesiesamestelling, die voorkoms van kaal kolle en die algemene swak toestand van vee. Alhoewel die meerderheid van grondgebruikers aangedui het dat landdegradasie 'n probleem is, het minder as die helfte enige bewarings en restourasie tegnologieë geïmplementeer om die probleem te beheer of op te los. Die tegnologie wat die mees algemeenste deur grondgebruikers van alle sektore toegepas is, is die rus van veld, terwyl ander aktiewe tegnologieë soos die verwydering van indringerplante, die vestiging van windbreke in landerye en die saai van meerjarige grasspesies ook toegepas is. Eiendomsreg en finansiële beperkings is die belangrikste faktore wat 'n rol speel by die aanneming en toepassing van bewarings en restourasie tegnologieë in Suid Afrika.

Die derde deel van hierdie studie handel oor die benadering en tegnologieë wat gebruik word in die verskillende DMP lande om die effek van landdegradasie en verwoestyning te verlig en die lewenstandaard van mense te verbeter. Elkeen van hierdie lande het een of meer Internasionale konvensie onderteken wat gelei het tot die ontwikkeling van verskeie NAPs binne elke land. Nasionale omgewingswetgewing in die verskillende lande sluit aspekte soos bosbou, water, weiveld, wild en landbou aktiwiteite in. Die tegnologieë wat waargeneem is gedurende die studie is opgedeel in drie kategorieë, naamlik restourasie, bewaring en alternatiewe lewensinkomstetegnologieë. In die suidelike en oostelike DMP lande het tegnologieë gefokus op die bewaring en restourasie van natuurlike areas, insluitende rus, duin stabilisering en die beheer van uitheemse indringer spesies. Alternatiewe lewensinkomstetegnologieë, soos die gebruik van groentetuine en byekorwe is ook geïmplementeer. Tegnieke in Wes-Afrika het gefokus op

restourasie en alternatiewe lewensinkomstetegnologieë soos die “Valerani” sisteem en “African Market Gardens” om sodoende die produktiwiteit van die natuurlike hulpbronne te verhoog. Die grootste beperking vir die aanneming en toepassing van die waargeneemde tegnologieë is ‘n beperkte hoeveelheid tegniese en finansiële hulpbronne beskikbaar aan grondgebruikers.

Die laaste deel van die studie handel oor die effek van droogtestremming op die ontkieming, fisiologie en morfologie van *Cenchrus ciliaris*. *Cenchrus ciliaris* is ‘n gewilde spesie vir aangeplante weiding in semi-ariëde en ariëde areas en uit die vorige dele van die studie is bepaal dat hierdie spesie ook gereeld in hersaai tegnologieë in Suid Afrika en ander Afrika lande gebruik word. Uiterste omgewings kondisies beïnvloed egter die ontkieming, vestiging en groei van hierdie spesies. Saad van *C. ciliaris* is gebruik in drie verskillende laboratorium- en glashuiseksperimente. Die laboratoriumeksperimente het aangedui dat die ontkiemingskapasiteit van die sade afneem met ‘n toename in droogtestremming. Die saailinge het ook verlaagde morfologiese ontwikkeling van die wortels en stingels getoon. Fisiologiese meetings geneem op volwasse plante het aangedui dat alhoewel hierdie spesie ‘n sensitiwiteit toon ten opsigte van droogtestremming het daar geen betekenisvolle veranderinge plaasgevind gedurende die eksperimentele periode nie. Die gevolgtrekking is dus dat die ontkieming, saailing vestiging en morfologie van die spesie negatief beïnvloed word tydens blootstelling aan droogtestremmingtoestande, maar dat droogte ‘n beperkte effek het op die fisiologiese prosesse van volwasse plante.

Hierdie studie voorsien ‘n basis ten opsigte van wetgewing en tegnologieë wat gebruik word vir die bekamping van landdegradasie en verwoestyning sowel as die verbetering van lewenstandaarde. Die inligting wat ingewin is deur hierdie studie kan grondgebruikers voorsien met die nodige kennis om hierdie tegnologieë in hulle spesifieke situasie toe te pas. Dit is egter noodsaaklik dat die resultate van hierdie studie oor die langtermyn toegepas moet word om die aanneming en implimentering van die beste tegnologieë, soos geïdentifiseer deur die studie, te fasiliteer.

Sleutelwoorde: Landdegradasie, verwoestyning, bewaring, restourasie, alternatiewe lewensinkomste, omgewingswetgewing, *Cenchrus ciliaris*, droogtestremming

RESUME

La dégradation des terres et la désertification menacent la vie de millions de personnes dans le monde, particulièrement en Afrique sub-Saharienne. Le problème est principalement attribué aux facteurs climatiques, exacerbé par les facteurs humains tels que les pratiques inappropriées de gestion. Plusieurs approches et technologies ont été développées et mises en pratique par les fermiers, gestionnaires des terres et chercheurs. Cependant, beaucoup sont rarement analysées et présentées dans un document synthétique.

Cette étude a été initiée dans le cadre du Programme des zones en marge de désert (DMP), qui opère dans neuf pays en Afrique de l'Est, Australe et de l'Ouest. Le DMP vise à déterminer les causes, l'étendue et la sévérité de la perte de biodiversité et la dégradation des écosystèmes dans quelques régions arides et semi-arides en Afrique. Cette étude a été conduite en rapport aux objectifs identifiés par le DMP et se compose de quatre parties : (1) un aperçu de la législation environnementale nationale et internationale en Afrique du Sud concernant la dégradation des terres, la désertification et la mitigation, (2) un aperçu des approches et technologies utilisées pour la restauration des terres de pâturages en Afrique du Sud, (3) un recensement des technologies de conservation, restauration et des options alternatives de subsistance mises en œuvre dans les neuf pays partenaires du DMP, et (4) l'évaluation d'une espèce herbacée tolérante à la sécheresse (*Cenchrus ciliaris*), communément utilisée en restauration des terres en Afrique du Sud et dans d'autres pays.

La première partie de cette étude fait un résumé sur la législation environnementale en Afrique du Sud en matière de dégradation des terres, la conservation et la restauration des ressources naturelles. L'Afrique du Sud est doté d'un système législatif environnemental compréhensif articulé autour d'un ensemble de législations internationale et nationale. Le pays est signataire d'un certain nombre de conventions internationales telles que la convention des Nations Unies sur la lutte contre la désertification (UNCCD). Différents programmes d'action nationaux (NAP) ont été élaborés. Conjointement à ces NAP et à la Constitution du pays, le principe des activités de conservation et de restauration dans le pays repose sur un certain nombre de lois (Actes) environnementales, telles que la loi nationale sur la gestion de l'environnement (NEMA). Malgré

l'existence d'une législation environnementale efficace, la régulation des actions définies par cette législation est souvent problématique et inefficace. L'accent doit donc être mis sur le transfert de connaissances et la formation à tous les niveaux d'implication des acteurs pour assurer une implémentation et régulation effectives de la législation environnementale.

Dans la deuxième partie de cette étude, l'accent était mis sur la détermination des similitudes et des différences de perceptions sur la dégradation des terres et la désertification, ainsi que les approches de conservation et de restauration des ressources naturelles au sein de trois systèmes de gestion des terres, à savoir, aires de conservation, systèmes de gestion privé et communal. Cette étude a été conduite dans quatre zones cibles du DMP, dans les provinces du Nord Cape (Namaqualand et Suid Bokkeveld) et Nord Ouest (Molopo et Kalahari) en Afrique du Sud. La majorité des exploitants au sein des trois systèmes ont estimé que la dégradation des terres se caractérise par un changement de la composition herbacée, la présence de zones dénudées, et le mauvais état du cheptel. Bien que la dégradation des terres soit un problème, moins de la moitié n'ont implémenté aucune des technologies de conservation et de restauration pour combattre le problème. Laisser la terre en "repos" La technologie la plus utilisée est la "mise en repos" ; les autres technologies actives de restauration incluent l'éradication des plantes aliènes, l'établissement de brise-vent au niveau des aires agricoles et les ensemencement d'herbacées pérennes dans les aires de pâturages. Le problème de propriété foncière et les contraintes financières sont les facteurs les plus importants limitant l'adoption et la diffusion des technologies de conservation et de restauration des terres en Afrique du Sud.

La troisième partie de cette étude a porté sur les approches et technologies implémentées dans les différents pays partenaires du DMP pour réduire les effets liés à la dégradation des terres et la désertification et ainsi améliorer les conditions de vie des populations. Chacun des pays est signataire d'une ou plusieurs conventions internationales ayant conduit à l'élaboration des programmes d'actions nationaux (NAP). La législation environnementale nationale dans ces pays traite des aspects relatifs à la foresterie, l'eau, le pâturage, la faune et l'agriculture. Trois catégories de technologies ont été répertoriées ; technologies de restauration, de conservation et les options alternatives de subsistance. Dans les pays en Afrique Australe et de l'Est, les technologies ont porté sur la conservation et la restauration des aires naturelles de pâturages, telles que la mise en repos, la stabilisation des dunes et le contrôle des espèces aliènes

envahissantes. Dans ces pays, les options alternatives de subsistance telles que les jardins maraîchers et l'exploitation du miel ont été mises en oeuvre. Afin d'accroître la productivité des ressources naturelles, les technologies en Afrique de l'Ouest étaient plus orientées vers la restauration des terres et les options alternatives de subsistance, telles que le système de Vallerani et les Jardins Potagers Africains. Les contraintes techniques et financières limitent principalement l'adoption et diffusion de ces technologies par les exploitants terriens.

La dernière partie de cette thèse a traité de l'évaluation des effets de la sécheresse sur la germination, la physiologie et la morphologie de *Cenchrus ciliaris*. Cette espèce est souvent utilisée en technologies d'ensemencement en Afrique du Sud et dans d'autres pays africains, mais les extrêmes conditions environnementales limitent régulièrement la germination, l'établissement et la croissance de l'espèce. Des semences de *Cenchrus ciliaris* ont été utilisées dans trois différentes expérimentations en laboratoire et en serre. Les expérimentations en laboratoire ont montré une diminution de la capacité germinative avec un accroissement du stress à la sécheresse. En plus, les plantules ont souffert d'une diminution du développement morphologique des racines et des tiges. Les mesures physiologiques prises sur les plantes à maturité ont montré que malgré le stress à la sécheresse montré par cette espèce, aucun changement significatif ne s'est produit. On a conclu que la germination, l'établissement des plantules et la morphologie étaient négativement influencés lorsque exposés aux conditions de sécheresse, alors que celle-ci exerçait peu d'effet sur les processus physiologiques des plantes mûres.

Cette étude constitue un document de base, résumant de l'information relative à la législation et les technologies utilisées pour combattre la dégradation des terres et l'amélioration des conditions de vie des populations rurales. L'information dérivée de cette étude peut servir comme guide de « savoir-faire » sur comment utiliser ces technologies en fonction des spécificités locales. Il est cependant important que les résultats de cette recherche soient mis en application dans le long terme car ceci faciliterait l'adoption et l'exécution des meilleures technologies identifiées à travers cette étude.

Mots-clés : Dégradation des terres, désertification, conservation, restauration, options alternatives, législation environnementale, *Cenchrus ciliaris*, stress à la sécheresse

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*** Follow after appendages**

CD*

**ENVIRONMENTAL LEGISLATION IN SOUTH AFRICA WITH
SPECIAL REFERENCE TO DEGRADATION AND
RESTORATION**

CD CONTENTS

- Index
- Hierarchy of legislation
- Definitions
- Links
- Conventions
- Acts
- Current initiatives

* *CD follows after appendices*

BOOKLET*

RESTORATION, CONSERVATION AND ALTERNATIVE LIVELIHOODS: TECHNOLOGIES IN SELECTED COUNTRIES IN AFRICA

BOOKLET CONTENTS

- Title page
- Citation
- Acknowledgements
- Introduction
- Restoration technologies
 - Brushpacking
 - Dune stabilization
 - Eradication of invader plants
 - Erosion control
 - Half moons
 - Micro-dosing
 - Nurseries
 - Over-sowing of grass species
 - Reforestation
 - Soil loosening
 - Stone walls
 - Vallerani
- Conservation technologies
 - Conservation of trees
 - Fencing
 - Forum for Integrated Resource Management (FIRM) and Local Level Monitoring (LLM)
 - Live fences
 - Protected areas
 - Rural wood markets
 - Sahelian Eco-farm
 - Zai

- Alternative livelihood technologies
 - African Market Garden (AMG)
 - Bee-keeping
 - Chicken production
 - Cultivation of rooibos tea (*Aspalathus linearis*)
 - Date palms (*Phoenix dactylifera*)
 - Food gardens
 - Mopane worm harvesting
 - Small stock exchange program
- For more information

*** *Booklet follows after appendices***

ACRONYMS AND ABBREVIATIONS

AMG	African Market Garden
APPA	Atmospheric Pollution Prevention Act
CARA	Conservation of Agricultural Resources Act
CBNRM	Community Based Natural Resource Management
CBO	Community Based Organization
CCI	Chlorophyll Content Index
CDI	Combined Degradation Index
CEC	Committee for Environmental Co-ordination
CITES	Convention on International Trade in Endangered Species
CONSERE	Council of Natural Resources and the Environment
CPEA	Communal Plans for Environmental Action
DEAT	Department of Environmental Affairs and Tourism
DMP	Desert Margins Program
DoA	Department of Agriculture
DPLG	Department of Provincial and Local Government
DWAF	Department of Water Affairs and Forestry
ECA	Environment Conservation Act
EDA	Environmental Development Agency
EMA	Environment Management Act
EMCA	Environmental Management and Coordination Act
EMG	Environmental Monitoring Group
ENAE	National Action Plan for the Environment
FAO	Food and Agriculture Organization
FIRM	Forum for Integrated Resource Management
GEF	Global Environment Facility
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IER	Institut d'Economie Rurale
ISCW	Institute for Soil, Climate and Water
ISFM	Integrated Soil Fertility Management
ISTA	International Seed Testing Association
KARI	Kenya Agricultural Research Institute
KCS	Kalahari Conservation Society
LADA	Land Degradation Assessment
LLM	Local Level Monitoring
MA	Millennium Ecosystem Assessment
MDG	Millennium Development Goals
MET	Ministry of Environment and Tourism
MPRDA	Minerals and Petroleum Resources Development Act
NAP	National Action Program
NAPCOD	Namibia's Program to Combat Desertification

NBI	National Botanical Institute
NBSAP	National Biodiversity Conservation Strategy and Action Plan
NARS	National Agricultural Research Systems
NCB	National Coordinating Body
NCC	National Coordinating Committee
NCU	National Coordinating Unit
NEMA	National Environment Management Act
NEMBA	National Environment Management: Biodiversity Act
NGO	Non-Governmental Organization
NRLD	National Review of Land Degradation
NWA	National Water Act
OP	Operational Program
PAR	Participatory Action Research
PCAE	Communal Plans for Environmental Action
PEG	Polyethelene Glycol
PLAAS	Program for Land and Agrarian Studies
RWC	Relative Water Content
SafMA	Southern African Millennium Assessment
SDI	Soil degradation Index
SEA	South and East Africa
SERI	Society for Ecological Restoration International
SUPAR	Sustainable Utilization and Protection of Agricultural Resources
SWC	Soil-Water-Conservation
TSBF	Tropical Soil Biology and Fertility Institute
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
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework for the Convention of Climate Change
VDI	Veld Degradation Index
VPR&D	Veld Products Research and Development
WA	West Africa
WfW	Working for Water
WMA	Wildlife Management Areas
WOCAT	World Overview of Conservation Approaches and Technologies
WoF	Working on Fire

CHAPTER 1

Introduction

1.1 Background

It is estimated that land degradation has affected between 6 000 000 and 12 000 000 square kilometers of land world-wide (UNEP, 2006) and that 73% of the worlds grazing land has deteriorated to such an extent that it has lost at least 25% of its animal carrying capacity (Harrison & Pearce, 2000). Each year, approximately 20 000 000 hectares of agricultural land become too degraded for crop production (UNEP, 2006). The consequences of the increased occurrence of land degradation and drought include decreased food security, famine and poverty (UNEP, 2006). The effect of land degradation is highest in the arid and semi-arid lands of the world. The most widely accepted definitions of arid and semi-arid lands are the following:

- **Arid lands** are areas characterized by low annual rainfall of less than 250mm (European Environment Agency, 2006).
- **Semi-arid lands** describe areas that receive low annual rainfall, usually between 250 and 500mm (Koundouri, 2006; Syngenta Foundation for Sustainable Agriculture, 2007).

In South Africa however, arid areas are described as areas receiving an annual rainfall of 400mm or less, while semi-arid areas receive less than 600mm annually (Botha & Fouché, 2000). It is calculated that approximately 25% of the natural arid and semi-arid rangelands in South Africa are already degraded (Kellner *et al.*, 1999). Land degradation in these areas can mainly be ascribed to factors such as: poor grazing practices, the incorrect use of fire, the clearing of woody plants (deforestation), poor soil conditions such as erosion and salination, mining, industry, urbanization and other land use types (Hoffman and Ashwell, 2001). The degradation of arid and semi-arid grasslands by overgrazing can be regarded as a type of disturbance of natural resources and is part of the wider problem of desertification. **Desertification** is a global process defined all over the world as land degradation in arid, semi-arid, and sub-humid areas resulting from anthropogenic activities not adapted to the land use in these regions (UNEP, 1992; UNCCD, 2003a). For detailed definitions of land degradation and desertification, refer to Chapter 2.

Over 250 000 000 people are directly affected by land degradation and desertification. In addition, some one billion people in over 100 countries are at risk (UNCCD, 2003). Within the last century, land degradation and desertification have become the biggest environmental threat in arid and semi-arid countries throughout the world and were of the first major international environmental issues, attracting international public attention much earlier than some of the high profile environmental concerns of today, such as biodiversity loss, climate change and deforestation (Chasek & Corell, 2002). Characteristic of Africa is the fact that 90% of the surface is arid, semi-arid or dry-subhumid and falls within the definition of the United Nations Convention to Combat Desertification (UNCCD, 1995). Some 23 of the 40 countries in continental Africa are characterised by arid lands and approximately one third of the world's 'man-made' deserts are in Africa (Le Hou  rou & Gillet, 1986). It has been estimated that 34% of the surface of Africa is under the threat of land degradation and desertification. The estimation includes the degradation/desertification of cultivated areas as well as non-transformed ecosystems.

About one-sixth of the world's agricultural land area is degraded to the point of impaired productivity because of overgrazing and poor farming practices. Erosion and nutrient depletion are not the only ways in which soils become degraded. Irrigation eventually causes salination of some soils, rendering them permanently unusable (Esler, 2002). In many areas of the sub-humid tropics, the abandonment of croplands due to a loss in fertility is not followed by the regeneration of natural vegetation, thereby increasing the degradation/desertification potential (IFPRI, 2003).

To combat the problems of degrading rangelands, especially those which will not recover easily, restoration technologies have to be implemented. The fact that conservation of existing ecosystems is simply not enough to ensure the future of living populations, and that degraded systems often do not recover through natural successional processes in arid and semi-arid systems within a short period of time, has made restoration an absolute necessity (Van den Berg, 2002). Restoration of an ecosystem is always difficult and costly to be obtained, and a complete recovery may often be impossible because some components of the ecosystem may have been eliminated during the degradation process (Ravera, 1989). A large variety of restoration technologies have been applied all over the world by land users, managers and scientists in conservation and agriculturally managed areas. Chapter 4 aims to summarize some technologies

that have been applied in selected arid and semi-arid areas in South Africa, while Chapter 5 deals with approaches and technologies applied in other African countries.

Policy interventions such as the ratification of various conventions, amongst others, are perceived to have had a positive influence in decreasing land degradation in South Africa (Hoffman & Ashwell, 2001). A vast and confusing array of acts and regulations concerning issues affecting the environment exist and it is important to consider which are most applicable for certain circumstances (Chapter 3). The Desert Margins Program (DMP), inter alia, has been developed in response to a recommendation made to the international research community at the United Nations Conference on Environment and Development (UNCED) (Anon, 2004) to consider contributions for the implementation of the three United Nations International Conventions i.e. United Nations Convention of Biodiversity (UNCBD), Framework for the Convention of Climate Change (UNFCCC) and United Nations Convention to Combat Desertification (UNCCD).

1.2 Desert Margins Program (DMP)

The goal of the Desert Margins Program (DMP) is to ensure integrated natural resource management, to determine the causes, extent and severity of biodiversity loss, as well as the physical processes of soil and land degradation in selected arid and semi-arid sub-Saharan regions in Africa, which harbour globally significant biodiversity (Smith & Koala, 2003). The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is the executing agency, while the Global Environment Facility (GEF) is the primary funding agency, with co-funding contributions from national and provincial departments of Agriculture and Conservation, Universities, Non-Governmental Organizations (NGOs) and other donors. The implementing agency is the United Nations Environment Program (UNEP), with support from the United Nations Development Program (UNDP) (Koala & Tabo, 2004).

Currently, the Desert Margins Program (DMP) operates in three sub-Saharan regions and includes nine countries: eastern Africa (Kenya), western Africa (Burkina Faso, Mali, Niger and Senegal) and southern Africa (Botswana, Namibia, South Africa and Zimbabwe). The DMP governance is organized at three complementary levels: national, regional (western-, southern, and East Africa) and global (e.g. UNEP, GEF) levels. The governing body is a steering

committee which provides policy guidance and direction. National Agricultural Research Systems (NARS) and NGOs are at the center of the organizational structure. Activities in each member country are carried out through National Coordinating Committees (NCC) which forms part of the National Coordination Unit (NCU) (Koala & Van Duivenbooden, 1999). The DMP started in 2002 in South Africa and is executed in four target areas in two provinces i.e. Molopo (North-West Province), Mier (Kalahari), Paulshoek and Suid Bokkeveld (in the Northern Cape Province). All of the target areas in South Africa were mainly decided upon due to the collaboration and networking that could be initiated between South Africa and neighboring countries i.e. Botswana and Namibia.

The objectives of the DMP include the following:

- The collection and assessment of current dryland management practices, including traditional small-holder knowledge.
- Understanding the causes, extent, severity and physical processes of soil and land degradation.
- Developing improved soil, water and biodiversity management strategies that are ecologically sound, economically viable and acceptable to the people of the desert margins.
- Designing policies, programs and institutional options that would serve as incentives to people living in the desert margins to adopt these improved practices.
- Enhancing the institutional capacities of Program member countries to conduct research on sustaining the desert margins.
- Spreading the word: disseminate the knowledge gained to farmers, policy-makers and other stakeholders and catalyze action plans based on it (Koala & Tabo, 2004).

1.3 Aims of this study

This study forms part of the Desert Margins Program (DMP) – South Africa, and aims to provide an overview of legislation, approaches and technologies used for the restoration of degraded rangelands in South Africa and other Desert Margins Program partner countries in Africa. It does not focus on the causes of land degradation, but rather on the perceptions of land users towards land degradation and their approaches and technologies to combat this problem. Also included is an evaluation of a drought tolerant grass species, *Cenchrus ciliaris* L. (Blue Buffalo

Grass), which is commonly used in restoration activities in arid and semi-arid rangelands, especially in southern and East Africa.

As part of the DMP in South Africa, the following objectives were included in this study:

- The documentation of existing policies and legislation regarding restoration and rehabilitation of biodiversity and the degradation of the natural resources in South Africa, especially in arid and semi-arid rangeland regions.
- To identify and document the best restoration practices, including traditional methods, to conserve and restore biodiversity in the identified study areas in the DMP target areas.
- To evaluate and characterize the best approaches and practices of restoration technologies in the DMP partner countries.
- The evaluation of *Cenchrus ciliaris* (Blue Buffalo Grass) as drought tolerant species to be used in restoration practices.
- To strengthen the knowledge base of all stakeholders with regard to restoration through training and capacity building, as well as farmer to farmer sharing activities, in order to enhance the adoption of restoration applications.

1.4 Format of the thesis

This thesis consists of eight chapters. The present chapter provides a general background to the study, while Chapter 2 gives a detailed introduction and literature study on land degradation processes and restoration treatments. Chapter 3 deals with environmental legislation in South Africa and is supplemented by a CD containing a webpage linking to various institutions and extracts of legislation.

An account of the perceptions of land users in the DMP – South Africa target areas concerning land degradation, and their approaches towards conservation and restoration are given in Chapter 4. In Chapter 5 the experiences, approaches and technologies used by land users for improved alternative livelihoods, conservation and restoration are explained. Chapter 5 is also supplemented by a booklet containing the best-bet alternative livelihood, conservation and restoration technologies applied by land users in the DMP partner countries.

Chapter 6 gives an account of the performance of *Cenchrus ciliaris* (Blue Buffalo Grass) under drought stress conditions. This includes morphological and physiological parameters to evaluate the various responses of this species under drought stress conditions. Some general conclusions and recommendations concerning all of the components of this study are given in Chapter 7. A complete list of references and Appendices follows at the end of this thesis (Chapter 8).

CHAPTER 2

Literature review

2.1 Land degradation and desertification

Over the past 45 years, about 11% of the Earth's vegetated soils became degraded to the point that their original biotic functions are damaged (Okin, 2002; UNEP, 2006). Land degradation implies the reduction of resource potential by one, or a combination of processes. These processes include water erosion, wind erosion and long-term reduction in the amount or diversity of natural vegetation (UNEP, 1992). Land degradation can happen on a local scale, or over vast areas and is recognized as a forerunner of desertification, which is viewed as a gradual process rather than a simple switch from vegetated areas to deserts (UNCCD, 2002; UNCCD, 2006a).

Desertification cannot be understood or addressed simplistically. The biological, social, political and economic aspects of the problem must all be borne in mind (Hoffman & Ashwell, 2001, King & Hobbs, 2006). Desertification must therefore include both biophysical and socio-economic dimensions concerning the processes that have an impact on the sustainability of natural resources. Box 2.1 contains the definitions of land degradation and desertification as it is used in this dissertation.

Box 2.1: Definitions of land degradation and desertification

Degradation

Degradation pertains to subtle or gradual changes that reduce ecological integrity and health (SER, 2002).

Degradation is seen as the reduction or loss of the biological or economic productivity in arid, semi-arid and dry sub-humid areas (UNCCD, 1995). This results from over-utilization by land uses or from a combination of processes, including processes arising from human activities and habitation patterns, such as:

- Soil erosion caused by wind and/or water
- Deterioration of the physical, chemical and biological or economic properties of soil; and
- Long-term loss of natural vegetation (UNCCD, 1995, Glossary of Environment Statistics, 1997).

Desertification

Desertification is a global process defined all over the world as land degradation in arid, semi-arid, and sub-humid areas resulting from anthropogenic activities not adapted to the land use in these regions (UNEP, 1992, Reigh *et al.*, 2001; Swearingen, 2006).

Everyone in the world depends on nature and ecosystem services to provide the conditions for a decent, healthy and secure life, but the degradation and desertification of natural resources invariably influence ecosystem services and goods. Ecosystem services are the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfill human life (Freeman & Myrick, 2003; Hassan *et al.*, 2005; Boyd & Banzhaf, 2006). These include services such as the dispersal of seeds and cycling and movement of nutrients. Ecosystem services maintain biodiversity and the production of ecosystem goods, such as forage and timber (Daily, 1997; Nunes *et al.*, 2003). An understanding of the changes in ecosystem goods and services due to land degradation and desertification is of fundamental importance for devising sound management and conservation strategies. Currently, the loss of ecosystem services is a significant barrier to the reduction of poverty, hunger and disease (MA Board, 2005).

Natural or semi-natural ecosystems mainly characterized by indigenous, natural vegetation are often referred to as “rangelands”, which cover large land areas in Africa (Palmer & Ainslie, 2002). These rangelands can potentially be used for different production systems and are defined as: ‘those areas of the world, which by reason of physical limitations, low and erratic precipitation, rough topography, poor drainage, or cold temperatures, are unsuited for cultivation, and which are a source of forage for free ranging native and domestic animals, as well as a source of wood products, water and wildlife’ (Miller, 1997). Most of these rangelands are classified as being drylands, i.e. those areas where the ratio of the mean annual precipitation to the mean annual evaporation is in the range of 0.05 – 0.65 and according to the UNCCD (2006a) includes all the arid and semi-arid areas in the world. According to Harris *et al.* (1996), rangelands fall into the following land use capability class: Land with severe limitations that restrict its use to rough grazing. Land capability classes are interpretive groupings of land units with similar potentials and continuing limitations or hazards. More than 80% of the land area in southern Africa is characterized as rangelands and livestock production is the dominant form of land use in the rangelands (Hoffman & Ashwell, 2001). Rangelands are the main source of fodder for most of the 13 964 000 cattle, 28 952 000 sheep and 698 000 goats in the country (DoA, 2006). The range resource should be seen as a critical component of food security at local and national level, but it is evident that the condition of rangelands in South Africa is under a continuous threat of land degradation (Kiunsi & Meadows, 2006).

There are four broad categories of land tenure in South Africa. Approximately 70% of the country is commercial farmland under freehold tenure, 14% is allocated to communal areas with leasehold tenure, 10% is formally conserved and the remaining 6% is used for mining, urban and industrial development (Palmer & Ainslie, 2002). According to Barnard (2002), 14 000 000 of the total South African population of 40 580 000 people live in the former homelands where the soil is unsuitable for farming to a large extent. Both the high population densities in the former homelands and the unbalanced distribution of land, rather than farming methods, have contributed to massive soil erosion. An estimated 1 200 000 hectares of rangelands in marginal areas of South Africa are viewed to be lost to production because of overgrazing. The highest soil erosion rates globally are in Asia, Africa and South America (30 – 40 tons/ha/year), while the lowest are in Europe and North America (17 tons/ha/year) (Mosley-Thompson, 2006). Food insecurity, leading to poverty and famine, is the most important consequence of soil and land degradation in the world. Africa has experienced widespread food shortages in 2005 and in southern Africa ten million people are suffering due to food scarcity (GEO, 2006).

In 1997 the National Botanical Institute of South Africa (NBI) and the Program for Land and Agrarian Studies (PLAAS) undertook to report on the status of land degradation in South Africa i.e. the National Review of Land Degradation in South Africa (NRLD). The process followed an integrated approach and included issues such as water, soil and vegetation resources, which led to a combination of soil (SDI) and veld (VDI) degradation indices to produce a single combined index of land degradation (CDI) (Figure 2.1) (Hoffman & Ashwell, 2001). This study was the most comprehensive of its kind in South Africa and shows that large areas in the arid and semi-arid areas of the country are moderately to severely degraded. The following section aims to give a more detailed description of land degradation and desertification processes.

2.1.1 Land degradation/desertification processes

Global population increases, a limited source of natural resources, erratic climatic conditions along with an insufficient consideration of the limited carrying capacity of the drylands, are the underlying causes of land degradation and desertification (Dregne, 1986; Aronson *et al.*, 2002, Reynolds & Stafford Smith, 2002, Xue & Fennessy, 2002). Land degradation/desertification, exacerbated by natural or man-induced mechanisms, is manifested by intricate steps of vegetation and soil deterioration which could result in an irreversible decrease or destruction of the biological potential of the land and its ability to support populations (Mainguet, 1991).

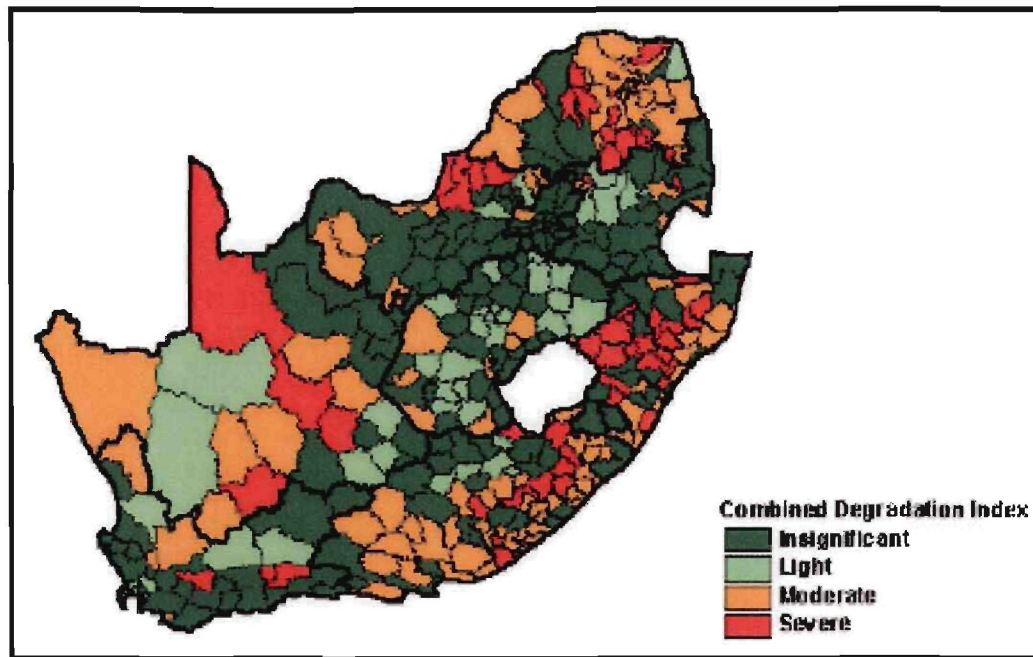


Figure 2.1 The Combined Degradation Index (CDI) for South Africa (taken from Hoffman & Ashwell, 2001).

Figure 2.2 shows the various different components of land degradation. All the different components are interlinked, forming a hierarchical framework where components interact with each other and combine to form bigger problems. In most cases, areas are deforested, over-cultivated and overgrazed, causing environmental problems such as soil compaction, reduced organic matter and salinization. Once soils have been rendered fragile and depleted and plant cover has been lost, wind and water erosion will aggravate the damage by loosening topsoil and leaving behind a highly infertile mix of transported sand, leading to a loss of biodiversity and climate change and ultimately to land degradation (IFAD, 2006).

Land degradation and desertification in South Africa have been attributed to a number of bio-physical and socio-economic causes, such as overgrazing, poverty, over-population and droughts (Hassan, 2000; Sundquist, 2003; AIACC, 2005). According to Varis and Kajander (2006), the FAO estimated in 1996 that overgrazing is the main factor contributing to land degradation in Africa and Australia, while deforestation is the main contributor to land degradation in Asia, Europe and South America. In Africa and Australia, arable farming and deforestation are the second and third most important factors, respectively (IFAD, 2006).

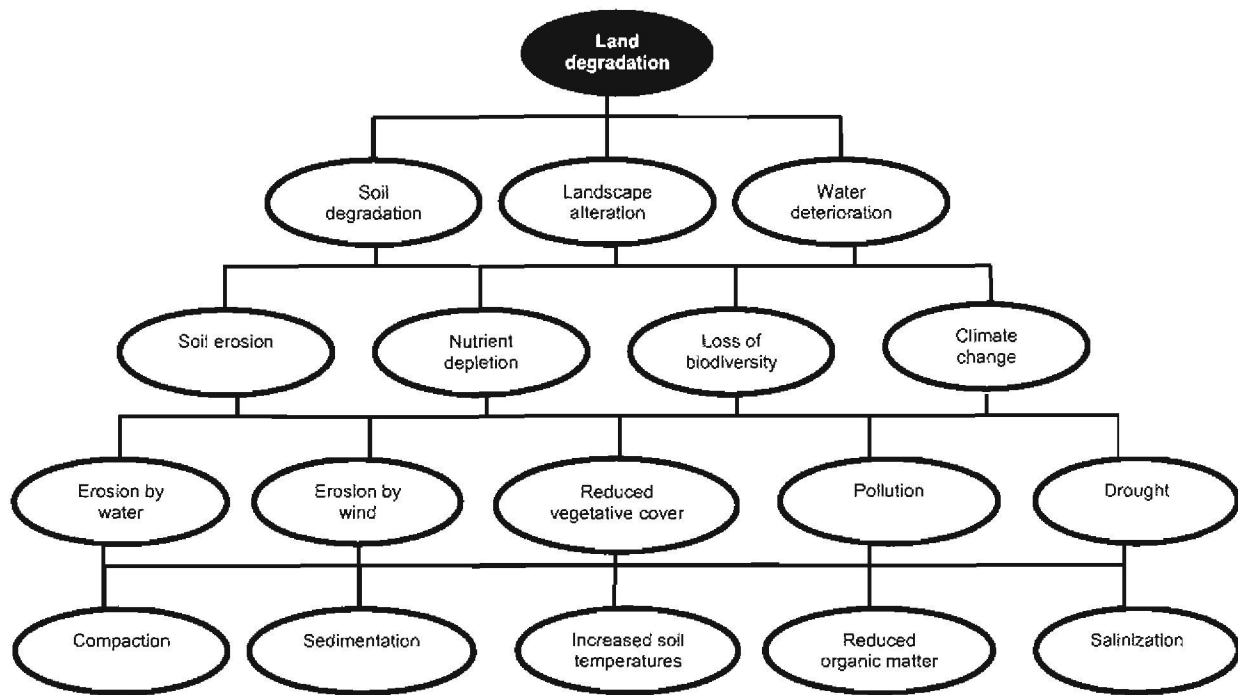


Figure 2.2 A schematic representation of the different components of land degradation (Stocking & Murnaghan, 2001).

The following types of land degradation are recognized in South Africa (Hoffman *et al.*, 1999; DoA, 2006):

- **Loss of cover** largely as a result of the grazing and trampling patterns of domestic livestock.
- **Change in species composition** of the vegetation, largely as a result of the selective grazing patterns of domestic animals.
- **Bush encroachment** as a result of the increase in cover and density of indigenous trees and shrubs.
- **Alien plant invasions**
- **Deforestation** as a result of the removal of trees and shrubs by people, usually for fuel energy or construction purposes.
- **Other** forms of land degradation, which usually encompass the clearing of rangeland and forest areas (deforestation) for the planting of agricultural crops or mining and other development activities.

The subsequent sections investigate the most important factors contributing to land degradation in South Africa including erratic precipitation patterns, overgrazing, bush encroachment, soil erosion and deforestation.

2.1.2 Erratic precipitation patterns

Land degradation/desertification is most often attributed to a myriad of human activities, particularly overgrazing, but it may be triggered or exacerbated by climatic variability (Reynolds & Stafford Smith, 2002; Fernandez *et al.*, 2002; Harou, 2002; Zhou *et al.*, 2002). Climatic factors, mainly associated with a decrease in rainfall, are prominent underlying driving forces of land degradation/desertification (Runnstrom, 2000; Geist & Lambin, 2004). There is mounting evidence that drought and environmental degradation are reinforcing each other if both are severe, and degradation could become irreversible (Smith & Wangari, 1996). Drylands are particularly vulnerable to climatic variability, of which precipitation is the most important component. Temperature, humidity or wind can, however, be important in some places such as coastlines and wetland areas (Grimshaw, 1992; Ojima *et al.*, 1999; Adams, 2002; Nicholson, 2002; Reynolds & Stafford Smith, 2002). Semi-arid regions generally share these characteristics, but to a lesser degree and it is a widely accepted fact that rainfall variability generally increases with aridity (Livingstone & Belshaw, 2001; Aronson *et al.*, 2002; Hulme *et al.*, 2005).

Drought and famine have affected much of sub-Saharan Africa for a long time, but more aggressively since the late 1960's. In recent years the situation seems to have worsened, reaching disastrous proportions in certain regions (Smith & Wangari, 1996; Teague & Dowhower, 2003; IFAD, 2006). Dregne (1986) implies that drought places additional stress on the biological resources and if resource management is good, little, if any, permanent damage is done. Drought is a period during which the water availability to plants and people is less than expected under normal climatic conditions. Usually it is droughts that last for the major part of a growing season, and involve a reduction in grazing, food or water, which attract the attention of policy makers (See Chapter 3).

Short-term changes in the environment caused by climatic fluctuations should not be confused with land degradation (Hoffman & Ashwell, 2001). Well-managed land recovers rapidly after

drought, whereas degraded land is less resilient (Hoffman & Ashwell, 2001). Even though the cycles of drought years and climatic changes can contribute to the advance of desertification (Cao & Prince, 2005), it is mainly caused by changes in the ways man uses the natural resources. This includes uses such as overgrazing, land clearance, cultivation of marginalized land and deforestation of woodlands (Koochafkan, 1996; Prince, 2002).

2.1.3 Specific land degradation processes

The following section deals with specific processes leading to land degradation in arid and semi-arid regions in Africa, with special reference to South Africa.

2.1.3.1 Overgrazing

Livestock production is an integral part of farming systems in arid and semi-arid regions and animals are kept for a wide variety of reasons including the supply of milk, manure, security, meat, hides and for cultural reasons (Chinombo, 2006). Livestock also plays an important role in establishing the status of wealth of the farmer (Kunene *et al.*, 2003; Catley *et al.*, 2005). Table 2.1 indicates the total number of domestic animals in South Africa at the end of 2005, indicating that sheep and goats are the dominant livestock in the country (Directorate: Agricultural Statistics, 2005). Artificial watering points can lead to expanding pastures and livestock populations (mainly cattle and sheep) and ultimately contribute to the desertification process (Dube & Pickup, 2001; Geist & Lambin, 2004). Grazing, trampling and dung deposition by herbivores often result in a zone of attenuating impact on many vegetation and soil parameters around and away from watering points (piosphere effect) (Thrash *et al.*, 1993; Thrash & Derry, 1999; Derry, 2004; Sparrow, 2006). Animals will walk long distances for preferred food species with reports of generally negative impacts two – three kilometres away from the water sources and affecting up to 28km² from a single point source (Noble *et al.*, 1998; James *et al.*, 1999; Pringle, 2000). Such grazing gradients represent a potential opportunity for differentiating the long-term effects of livestock activity from other environmental patterns (Todd, 2006).

Table 2.1 The total number of different domestic animals in South Africa at the end of 2005.

Cattle	Pigs	Sheep	Goats
138 000 000	1 656 000	22 236 000	2 138 000

Grazing by domestic livestock, in association with rainfall, are the most important factors influencing rangeland condition (Hoffman & Ashwell, 2001; Adams, 2002; Okin, 2002). When there is heavy pressure on rangelands, the animals consume palatable vegetation faster than the vegetation can regenerate and eventually only unpalatable or no vegetation remains (Wang & Guo, 1993; Kawanabe *et al.*, 1998; Todd & Hoffman, 1999; Wang *et al.*, 2002; Sombroed & Hadji, 2004). Animals do not only remove mature plants, but they also eat flowers, thus reducing the seed set and decreasing the soil seed bank composition. Animals also trample and kill young seedlings (Dean *et al.*, 1995; Finlayson *et al.*, 2002; Van der Wal & Brooker, 2004). Trampling by animals causes soil deformation through soil compaction by the high-ground pressure of hooves and soil homogenization by shear effects (Pietola *et al.*, 2005). Destroyed soil structure increases surface runoff and consequently increases the vulnerability to water erosion (Proffitt *et al.*, 1995). It has been repeatedly observed that, in most heavily grazed rangelands, dominant perennial palatable grasses without persistent seed banks are displaced and eliminated from the above-ground canopy as well as from the soil seed bank (O'Connor & Pickett, 1992).

The degradation of arid and semi-arid rangelands by overgrazing can be regarded as a type of disturbance of natural resources and is part of the wider problem of desertification (UNEP, 1999; Xue & Fennessy, 2002) (Figure 2.3 (a) and (b)). Land users all over the world have developed ways to overcome and mitigate the causes and effects of land degradation and desertification. Chapters 4 and 5 of this thesis deal with the approaches and technologies used by land users to overcome the problem of land degradation due to overgrazing.

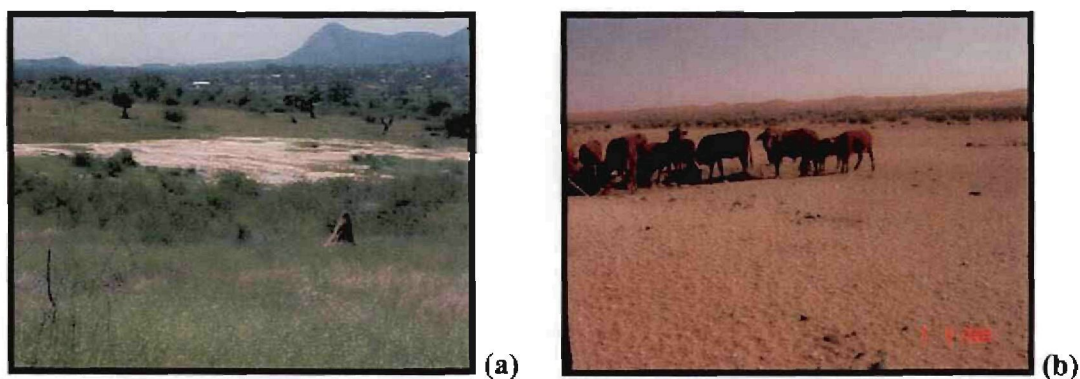


Figure 2.3 Land degradation in communal areas due to overgrazing by livestock forming bare patches in the natural grazing area (a) as well as around watering points (b).

2.1.3.2 Bush encroachment and alien plant invasion

The increased density (thickening) and cover, i.e. the encroachment of woody shrubs and trees in arid and semi-arid grasslands, savannas and woodlands are perhaps the most obvious and commonly cited form of desertification (Figure 2.4 (a)) (Ludwig & Tongway, 1995; Hoffman & Ashwell, 2001). Degradation of desert grasslands is often characterized by the replacement of perennial herbaceous species by long-lived woody shrubs and by an associated reduction in the capacity of the ecosystem (water and sunlight) (Havstad *et al.*, 2000; Wiegand *et al.*, 2006). If shrubs encroach, grass production will decrease and cattle and sheep production may be reduced as the shrubs are often unpalatable to domestic livestock (Donaldson, 1980; Walker *et al.*, 2002; Wiegand *et al.*, 2006).

Over 8% of South Africa has been invaded by alien vegetation and millions of hectares are affected by bush encroachment (Barnard & Newby, 1999, Ward, 2005, DoA, 2006a). It has been estimated that the control of alien invasive plants could cost as much as \$100 million per year for the next 20 years (Versveld *et al.*, 1998).

Bush encroachment includes the concept of bush thickening (Figure 2.4 (b)). It encompasses the large-scale conversion of former grassland vegetation to a savanna physiognomy by encroaching indigenous trees, as well as the increase in size and density of woody plants within historical savanna areas (Smit *et al.*, 1999; Hoffman & Ashwell, 2001). Bush encroachment is, in theory, reversible over a relatively short period, given sufficient knowledge, financial and other resources, such as fencing and the removal or reduction of livestock. However, the majority of land users do not have sufficient resources, and cannot remove their livestock for periods long enough to allow the rangeland to recover, which leads to a decrease in the condition of the rangeland to an ecological state that has passed the threshold of natural recovery (Reed, 2004). If this change has occurred, active interventions are necessary to restore the degraded rangeland to a better state or system (See Section 2.1).

An alien invasive species is one that was introduced, through human activities, into an area where it did not previously occur. Alien species have the ability to outperform resident life forms, mostly because they can grow faster, breed more profusely, disperse more widely, tolerate a wider range of conditions or simply grow bigger than the resident species of the invaded system (Connor, 2006). Most alien invasive species are introduced species without natural enemies to control their invasion. These species contribute to the loss in biodiversity, as well as

the valuable natural agricultural systems upon which people depend (Matthews & Brand, 2004). Alien invasive species can transform the structure and composition of ecosystems by repressing or excluding native species – either directly by out-competing them for resources (water and sunlight), or indirectly by changing the way nutrients are cycled through the system (Matthews & Brand, 2004). In the majority of cases the alien plant occupies a similar environmental niche than the native species and responds better to the distribution of resources and competitors in the system, thereby out-competing them directly or indirectly (Scholes & Walker, 1993; Amarasekare, 2003). According to the Conservation of Agricultural Resources Act (42 of 1983) of South Africa, land users are obliged to eradicate alien invader species (Chapter 3). The short-term cost-benefit ratio is, however, very low when removing alien invaders and it is usually coupled with the size of the invaded area, type of invader species and whether seed of natural species still persists in the soil seed bank.

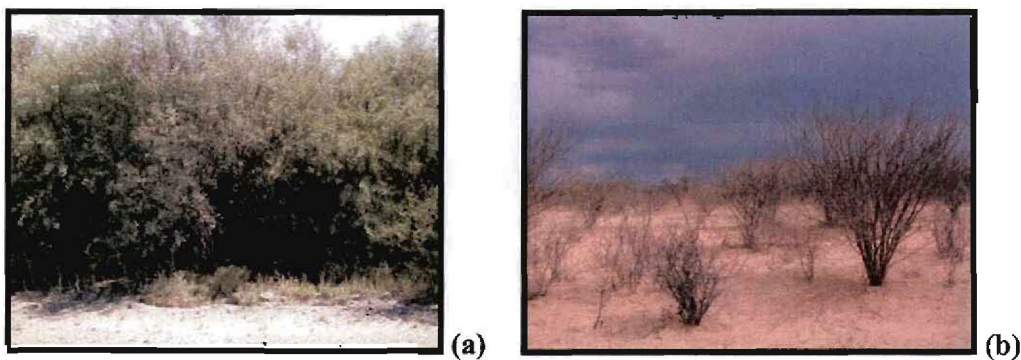


Figure 2.4 Bush encroachment by an alien invasive species (*Prosopis* sp.) (a), and bush thickening by an indigenous species (*Acacia* sp.) (b) of natural grazing areas in South Africa.

2.1.3.3 Soil erosion

Soil is the final product of weathering, and is defined as that portion of rock and mineral fragments which is capable of supporting plant life. Soils can generally be grouped as either residual (soils formed on bedrock) or transported (soils formed on material that has been moved to its current location (Tandarich *et al.*, 2002; Carnicelli, 2003). Soil erosion involves the movement (transportation) of this weathered material to a place of deposition (Carnicelli, 2003).

Soil erosion may occur in two fundamental types – natural or geological erosion, and man-made or accelerated erosion. The former is a continual process that takes place extremely slowly and includes processes such as exfoliation, carbonation and hydration of rock (Roux & Opperman, 1986). Man-made or accelerated erosion has now become the dominant type of erosion over much of Africa's land surface (Snyman, 1999; Lang, 2006). Both water erosion (Figure 2.5 (a)) and wind erosion (Figure 2.5 (b)) contribute to the large extent of soil erosion in the country. It is estimated that 5% of soils in South Africa are affected by water erosion, and that the average soil loss is two and a half tonnes per hectare per year, with a maximum of 60 tonnes per hectare per year (Barnard & Newby, 1999). According to Tongway and Hindley (1995), as cited by Coetzee (2005), five different forms of soil erosion are most prevalent (Box 2.2).

Box 2.2: Forms of soil erosion

Rills and gullies are channels cut by flowing water. They may have been initiated by water flowing down stock paths or roads. Their presence is a sure sign that water flows rapidly off the landscape, carrying both litter and soil with it.

Terracettes are abrupt walls about 1 – 10 cm high, aligned with the local contour. Terracettes are progressively cut back up-slope by water flow, the eroded material being deposited in an alluvial fan down-slope of the feature.

Sheet erosion is the progressive removal of very thin layers of soil across extensive areas by wind and water. This is not always easy to detect with assurance and may need to be inferred from other soil surface features, such as eroded materials or surface nature. When at an advanced stage, many sheeted surfaces are covered by layers of gravel or stone left behind after the erosion of finer material.

Hummocking is confined to soils with sandy-textured surface layers and is the result of re-sorting of sand by wind resulting in the sand accumulating around obstructions, often to depths of many centimeters or even meters. A consequence of hummocking is that fine-grained materials and litter are widely dispersed during windy phases and are lost to the system.

Pedestalling is the result of soil removed by erosion from an area to a depth of at least several centimeters, leaving the butts of surviving plants on a column of soil above the new general level of the landscape. Exposed roots are typical of this erosion form. This is a sign that the soil type itself is very erodable and that loss of vegetation in the landscape was preceded by erosion, and not the other way around.

A loss in the organic matter of the rich surface soil (topsoil) is known to decrease soil quality, which in turn reduces productivity. Organic matter is the primary source of food for the soil fauna and for a great majority of microscopic organisms, such as bacteria and fungi. These

microscopic organisms play a vital role in aeration and soil productivity (Tainton & Hardy, 1999). Less topsoil also decreases the moisture storage capacity of soils (Verity & Anderson, 1990; Okin, 2002). Although some plants penetrate soil to a considerable depth for nutrient and water extraction, they rely on topsoil during their initial growth and for much of their development. Eroded soils become more compacted when topsoil is removed. Soil compaction reduces root penetration and soil aeration (Montalvo *et al.*, 2002).

The higher the raindrop impact, the more soil will be loosened, which contributes to increased erosion. On the other hand raindrop impact also contributes to soil degradation through crust formation (Morin & Van Winkel, 1996; Girmay & Shuichi, 2005). The basal and canopy cover provided by the vegetation therefore protects the soil surface from raindrop impact (Snyman, 1999). The protection that grasses provide against soil erosion is superior to that provided by most woody shrub and tree species. The reason for this is that, with an equal canopy cover, a tuft of grass offers a better protective cover than a woody shrub. Grass has a further advantage, as it binds the soil better with its typical root network system, whereas most woody shrubs are less effective in this respect, owing to the fact that they generally have a taproot system (Cowling *et al.*, 1986; Venter, 1988; Howell, 1998; Striebig, 1999; TILZ, 2005). Although little quantitative data is available regarding soil losses through wind erosion, it is perceived to be a big problem in arid areas in Africa (Sterk *et al.*, 1998). The presence of vegetation provides protection for soil against wind erosion (Snyman, 1999).

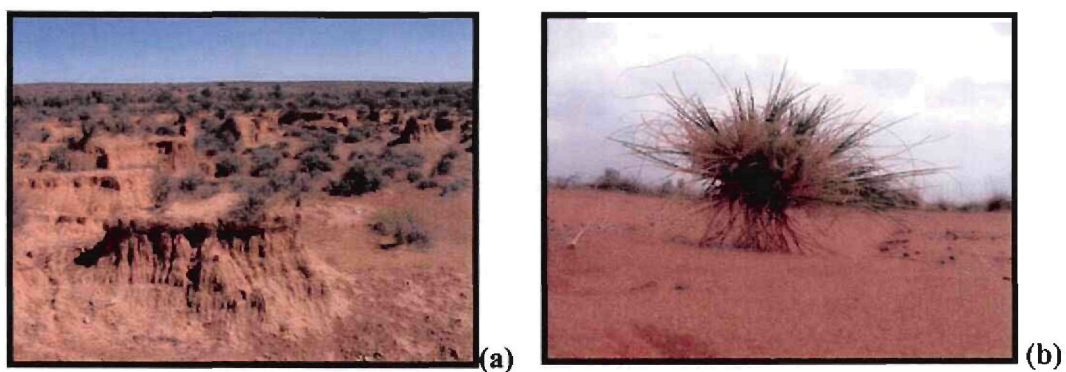


Figure 2.5 Gully formation through water erosion (a), and the exposure of plant roots through wind erosion (b) in the arid parts of the country.

2.1.3.4 Deforestation

Deforestation is a consequence of growing populations and the extension of subsistence farming and marginal grazing activities. Eighty percent of the forests that originally covered the Earth have been cleared, fragmented or are otherwise degraded (UNEP, 1999; Barraclough & Ghimire, 2000). The increase of herding on marginal lands also has a significant impact on forests. In many instances, farmers are forced to harvest forest products to feed their livestock herds. Not only do these practices reduce Africa's forest resources, but they also accelerate the process of desertification. Figure 2.6 indicates the annual rate of deforestation in selected countries in tropical Africa. All countries show a decrease in forests, while Gambia shows a positive rate of re-forestation. As seen from Figure 2.6, the rate of deforestation in Niger is very high compared to the other countries. This is ascribed to the fact that only 1% of Niger is forested and the country loses approximately 3.17% of forests annually. The high rate of deforestation in Niger is due to the fact that wood is the primary fuel source in the country and is used for 95% of all energy needs (Issa, 2004). Even though Gambia is the only country that shows a positive rate of re-forestation, this restoration activity is also carried out in other countries in Africa, such as Kenya and Senegal. Most of the re-forestation is taking place in areas close to cities as land users plant fruit trees and sell the produce in the city (Tiffen *et al.*, 1994).

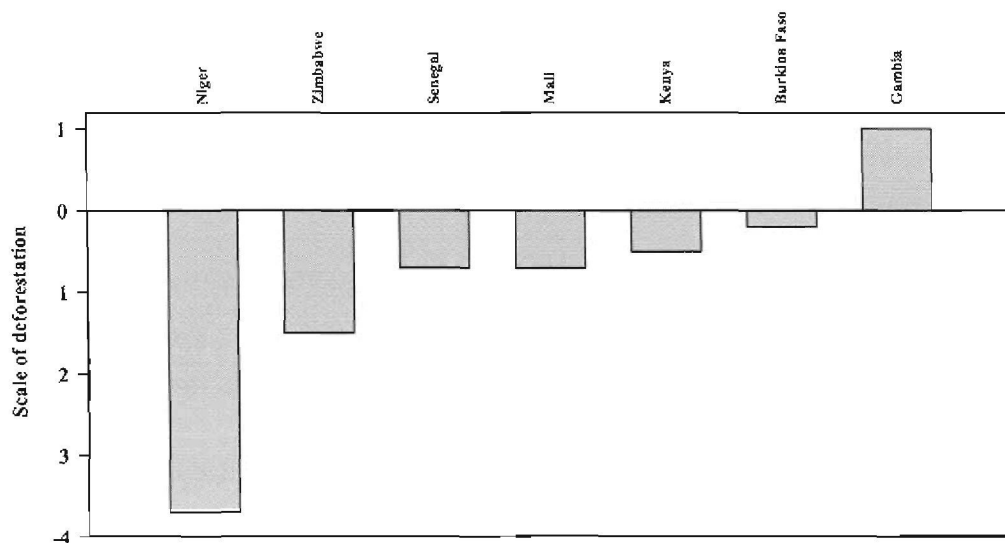


Figure 2.6 Annual deforestation rates in selected countries in tropical Africa (1990 – 2000) (FAO, 2003).

The underlying socio-economic driving forces behind deforestation are poverty, population and economic growth, urbanization and the expansion of agricultural lands (UNEP, 1999). Another contribution to the problem of deforestation is that many Africans depend on the use of forest products, primarily for building materials, as well as wood and charcoal to meet their cooking and heating needs (Figure 2.7 (a) & (b)). Currently, almost 90% of Africans depend on firewood, charcoal and other biomass fuels for basic energy needs (The Global Change Game, 2000). It is estimated that, for every 28 trees cut down, only one tree is replanted (Hennig, 2006). This de-forestation leads to huge negative environmental impacts such as a loss of biodiversity, erosion and ultimately to the siltation of dams.

In South Africa, natural woody vegetation provides rural communities with a wide range of resources, including fuelwood, poles for construction, poles for fences and animal pens, wood for carving utensils and implements, edible fruit, bark and roots for traditional medicine, as well as leaves for livestock fodder (Dovie *et al.*, 2002). Major changes in resource-harvesting patterns have occurred over the last two decades in the communal lands in South Africa, ultimately leading to land degradation. The following three pertain particularly to trees:

- Resources such as fuelwood, traditional medicine and wood for the making of furniture are increasingly being harvested from village commons by non-residents ('outsiders').
- Harvesting of fuel wood and traditional medicines for commercial purposes has increased dramatically.
- Fuel wood is increasingly being transported by vehicles instead of in bundles carried on women's heads or in wheelbarrows, leading to an increase in the amounts removed (Twine, 2005).

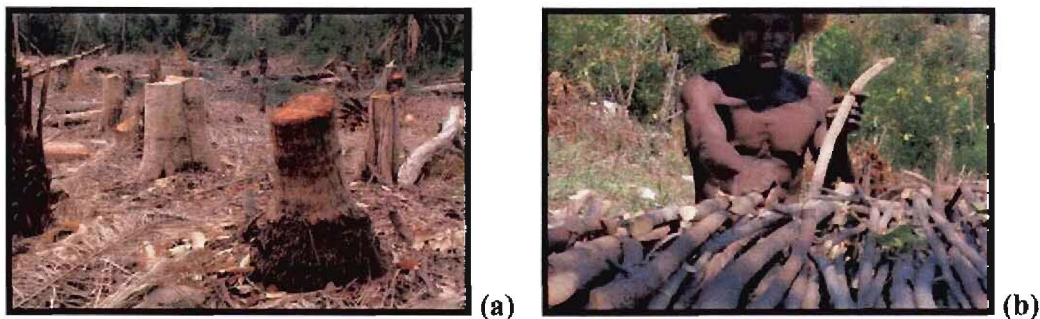


Figure 2.7 Deforestation caused by human pressures on forest areas (a) and the use of forest products for building materials (b).

2.2 Restoration ecology

Realising that the conservation of existing ecosystems is simply not enough to ensure the future of living populations, and that degraded systems often do not recover by natural successional processes in mainly arid and semi-arid systems within short periods of time to a potential that can be used for crop and livestock production, active intervention has become an absolute necessity to sustain livelihoods on earth (Van den Berg, 2002). Restoration is an option once transitions and range conditional states have crossed the threshold boundaries for natural recovery (Kellner, 2000). Many definitions exist for such rangeland improvement actions, i.e. reclamation, reinforcement, restoration, rehabilitation and re-vegetation (Bainbridge, 2003; Cao, 2006; EEION, 2006). In the context of this study, however, the following definitions were used to describe restoration ecology.

Box 2.3: Definitions of restoration ecology

Reclamation

Reclamation is a process by which previously unusable land is returned to a state whereby some use may be made of it (Harris *et al.*, 1996). The main objectives of **reclamation** include the stabilization of the terrain, assurance of public safety, aesthetic improvement, and usually a return of the land to an useful purpose (SER, 2002).

Reinforcement

Rangeland **reinforcement** is the adding of more acceptable grazing plants (e.g. by over-sowing) and/or the adding of necessary plant nutritive materials by means of fertilization (Harris *et al.*, 1996).

Restoration

Ecological **restoration** is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER, 2002; SER, 2004; Bainbridge, 2007). According to Harris *et al.* (1996), ecological **restoration** is the process of repairing damage caused by humans to the diversity and dynamics of indigenous ecosystems to the way they were prior to degradation of any sort. In 2006, Aronson *et al.* added that ecological restoration is a process that recovers and improves the functionality of ecosystems within landscapes consisting of lands in agricultural production as well as set-aside nature reserves.

Rehabilitation

Rehabilitation emphasizes the repair of ecosystem processes, productivity and services (SER, 2002). **Rehabilitation** applies to areas that formerly had no plant growth at all, but with careful fertilization and landscaping works may be used to grow a limited number of plant species (Harris *et al.*, 1996; Geerken and Illaiwi, 2004).

Re-vegetation

Re-vegetation implies the establishment of a stabilizing plant cover, without involving any ecosystem reconstruction (Rogers, 1996).

For the purpose of this study, all of the above mentioned terms would indefinitely mean to improve land area for the sustainable use by land users. According to the Society for Ecological Restoration International (SERI) (2002), the term restoration encompasses all the above mentioned terms and will therefore be the only term used in this thesis. This study focuses on the restoration of degraded rangelands and does not include the restoration of mining and other industrial development areas.

Many efforts to restore denuded and eroded areas have not succeeded, with the only reminder of the expenditure of funds and effort being stone-lines or fence posts among the rocks and sand (De Groot *et al.*, 1992). Restoration of an ecosystem is always difficult and costly to obtain and a complete recovery may often be impossible because some components of the ecosystem may have been eliminated during the degradation process or a sound restoration plan has not been followed (Ravera, 1989).

Due to past historical conditions and cultural diversity in South Africa, the restoration of natural resources was not always possible due to high monetary implications and the fact that most of the focus fall on health and education issues, rather than the sustainable management of natural resources. Restoration of degraded ecosystems and landscapes includes a conservation strategy which expands the possibilities for protecting and enhancing the earth's biological diversity (Geist & Lohnert, 1999). Whichever technology is used, it should be communicable, simple and familiar to the user. A holistic approach that involves the participation of the community and addresses both bio-physical and socio-economic issues should therefore be followed.

Figure 2.8 shows the concept of returning a disturbed system from a degraded state to a desired state over a period of time. Westoby *et al.* (1989) described these changes in their State and Transition model for alternative stable states. In the state and transition model, the vegetation types are called 'states' and the processes that cause states to change from one to another are called 'transitions' (Bestelmeyer *et al.*, 2003; Briske *et al.*, 2003). The state and transition model was accurate in its description of the changes in vegetation composition and the factors influencing these changes, but did not explain the inability of certain states to return to former conditions (De Wet, 2001). Restoration efforts may not result in a goal that is wanted because the developing system may be locked in an alternative stable state e.g. rangelands returning to planted pasture after restoration efforts, as opposed to natural grazing areas. Friedel (as quoted by Dodd, 1994) then added the idea of thresholds to the state and transition model. Thresholds

are phenomena that essentially inhibit transition between different relatively stable states of ecosystems, because they are limits of resiliency i.e. spatial and temporal boundaries between two states. Once a state moves beyond its limit (certain thresholds), return to the previous state can only be achieved through intervention (Jordaan, 1997).

Figure 2.8 shows that if veldt condition remain above the threshold level with high resilience, the rangeland can recover to its original 'good' veldt condition, but once it drops below the threshold, full recovery is not possible and the rangeland 'recovers' (changes) to a different state (Aronson *et al.*, 1993a ; Tainton, 1999; Carpenter *et al.*, 2001; Reynolds & Stafford Smith, 2002). If a degraded ecological system is continuously utilized in the same manner as in the past, it will remain in a similar state, but if the pressures increase, the condition of the degraded state will decline even further. If an intervention i.e. restoration occurs, the system can recover to the desired state or alternative states, where it can remain if the system is managed in a sustainable way. The more thresholds that have been passed, the more time and energy will be required for the restoration of ecosystems (Aronson *et al.*, 1993a). According to Figure 2.8, the level of complexity/function (represented on the y-axis) will increase over time, if restoration is applied, until the desired state is reached.

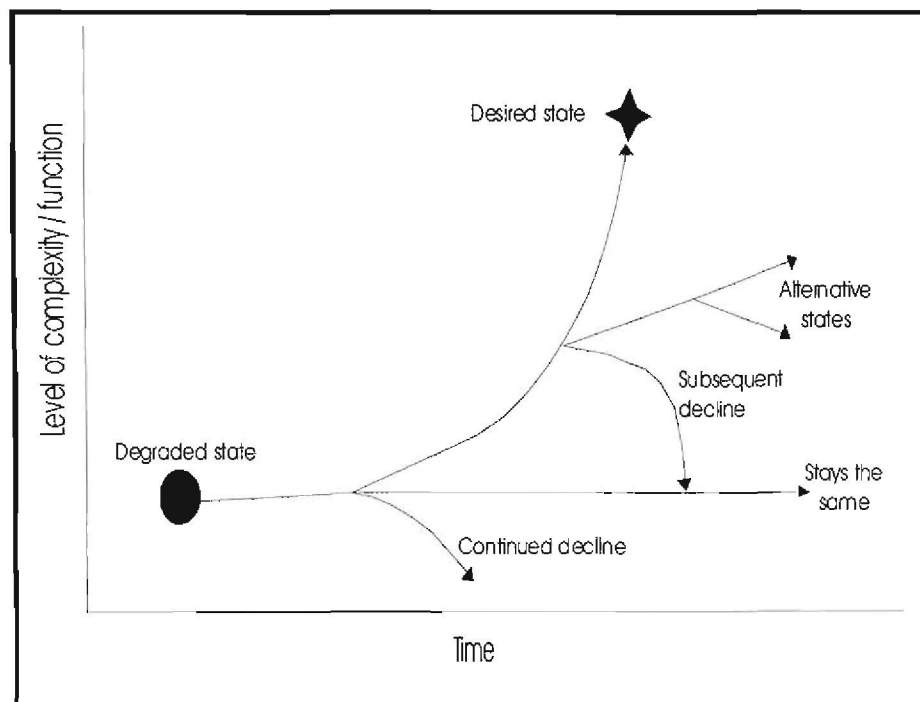


Figure 2.8 The concept of returning a degraded system from a degraded state to a desired state (Hobbs & Norten, 1996; Van Andel & Aronson, 2006).

Climatic and edaphic conditions, as well as socio-economic and cultural impacts/reactions, will determine the rates at which either restoration or rehabilitation can proceed (Aronson *et al.*, 1993b; Morgental, 2000). According to De Beer (2000), recognising the role of climatic factors and management practices in vegetation community development holds important practical implications for species composition and also the conditional state of the vegetation. Environmental conditions of the specific study areas must be taken into account when planning a restoration project in drylands (see 2.2.1) (Aronson *et al.*, 2002).

2.2.1 Planning and methods of restoration

According to the Society of Ecological Restoration International (SERI, 2002), thorough planning should always precede any restoration treatment to ensure the success thereof. Plans for restoration should always include the following:

- A process-based understanding as to why restoration is needed;
- an ecological description of the site designated for restoration;
- a statement of the goals and objectives of the restoration treatment;
- a designation and description of the reference;
- an explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials;
- explicit plans, schedules and budgets for site preparation, installation and post-installation activities, including a strategy for making prompt mid-course corrections;
- well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated; and
- strategies for long-term protection and maintenance of the restored ecosystem.

According to Milton & Dean (1995), restoration technologies are grouped into active and passive restoration technologies (Figure 2.9). Rangelands which have retrogressed beyond a certain threshold and cannot recover by passive technologies, such as the resting from utilization or the implementation of better grazing strategies, can only be restored by active methods (Snyman, 2003a). Active restoration technologies include cultivation, with or without re-vegetation practices, together with soil disturbance technologies, such as rip ploughing (Allen, 1995; Collins, 2001). It is generally accepted that compacted substrates must be de-compacted to

allow better water infiltration into the soil layers for the roots of germinating plants (Montalvo *et al.*, 2002). Germination of seeds and establishment of seedlings is also enhanced in such a way. These restoration practices, which include cultivation methods, might also enhance the establishment of species by exposing the dormant seeds in the seed bank to favourable light and aeration conditions, as well as increasing water infiltration rates for better root growth and development (Bakker & Berendse, 1999). The restoration of the original soil condition and plant communities, as suggested by the historical background, may be enhanced by the modification of soils and the introduction of species as seeds or plants belonging to the original plant community (McDonald *et al.*, 1996). Successful restoration of such sites requires the selection of suitable plant species and the modification of the soil at the restoration sites (Rao & Tarafdar, 1998).

Passive restoration technologies entail the removal of the stresses that caused the original land degradation, such as heavy grazing or air pollution and then allowing natural succession to take place (Milton & Dean, 1995; Whisenant, 1995). Passive restoration will allow for resting to facilitate seeding, seedling establishment and/or the restoration of stored carbohydrate reserves in desirable grass species. Resting is also recommended to accumulate fodder reserves to be used during the dormant season or in droughts (Van Heerden, 2002). The optimum resting period will depend on the range type and condition, environmental- and growing conditions, as well as climatic factors (Gambiza, 1996).

Figure 2.9 shows the division of restoration technologies into active and passive technologies. Active technologies are further divided into chemical, organic and structural restoration technologies. Chemical restoration entails the use of fertilizer and seed enhancements during restoration, while organic restoration includes the use of natural products such as animal dung, re-seeding and brushpacking. Organic restoration is frequently used in combination with other mechanical restoration technologies (Van der Merwe, 1997; De Wet, 2001; Van den Berg, 2002). Structural restoration uses mechanically engineered structures and implements to enhance restoration by breaking the soil surface, increasing water infiltration and retention as well as preparing soil for organic treatments such as re-seeding.

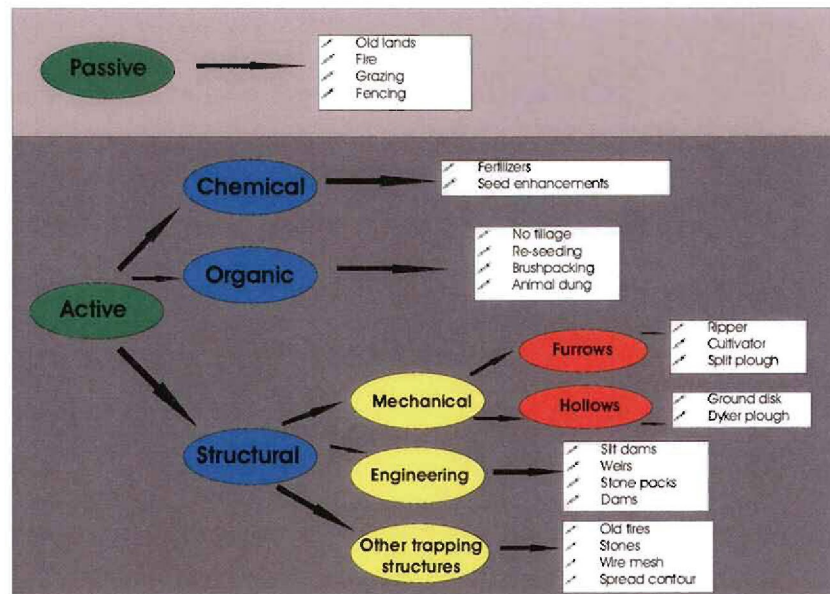


Figure 2.9 A diagrammatic representation of active and passive restoration technologies (Kellner, 2000).

Even though Figure 2.9 gives an indication of a number of active and passive restoration technologies, not all of them have been covered in this study. On the other hand, however, technologies such as conservation and alternative livelihoods, not mentioned in Figure 2.9, have been included.

Where passive restoration is still possible, the ecosystem resilience is higher and functional damage relatively limited. Only small inputs, which are less costly and need fewer management skills, may be required, even if relatively long periods of time are needed for the ecosystem to recover. Conversely, in situations where active restoration is undertaken, larger cost and energy inputs are required initially, but long periods of time must be anticipated as well (Aronson *et al.*, 2002).

The application of restoration treatments to landscapes must be coupled with other land management practices. For such treatments to be effective in the long-term, grazing pressures on the land must be reduced. Reducing livestock numbers can decrease grazing pressure and restored areas can be fenced to keep out large herbivores (Ludwig & Tongway, 1995). Monitoring should form a firm basis during any restoration process to determine the effect of the process over the short- and long-term.

Various active and passive restoration technologies applied in selected countries in Africa will be the focus of the rest of this thesis. Special reference will be made to the approaches to environmental restoration and the implementation of the different technologies. Chapter 4 deals with restoration technologies applied in the Desert Margins Program (DMP) target areas in South Africa, while Chapter 5 covers technologies used in other DMP partner countries in West, southern and East Africa.

CHAPTER 3

Policies and legislation concerning degradation and restoration in South Africa

(Supplemented with Policy Compact Disk)

This chapter aims to provide a summary of legislation in South Africa dealing with land degradation, conservation of natural resources and restoration. The information included in this chapter should provide the reader with a clear understanding of the obligation that the country (National Government) and individual land users have towards the conservation and sustainable use of natural resources in the country. It is necessary to realize that some of the technologies mentioned in Chapter 4 are implemented as a result of international and national legal obligations, such as the large-scale clearing of alien invasive species.

3.1 Broad overview of legislation in South Africa

The successful implementation of policy is largely a function of political will, adequate funding, good integration and co-ordination between the leading agency and other agencies to which functions and responsibilities have been delegated, as well as a well-trained group of staff to manage programs and projects (Fakir *et al.*, 1999). Policy and legislation are mostly driven jointly by the government department involved and by relevant non-governmental organizations, stakeholders and other interest groups. Usually the government aims at being inclusive and transparent and offers unprecedented opportunities for public participation.

3.1.1 Introduction to law in South Africa

When the need for a new law arises, a Bill is introduced in the National Assembly by the Cabinet Minister responsible for that matter. The Bill is debated by the members of the National Assembly, who may propose amendments to the Bill. Eventually the members vote on whether the Bill should be passed. After approval by the National Assembly, the Bill is referred to the National Council of Provinces for approval. Only after the National Council of Provinces approves the Bill, it is referred to as a statute or an Act (Streetlaw, 2006).

3.1.2 Hierarchy of legislation

After the elections of 1994, South Africa's governmental landscape underwent a massive reconstruction (Moikangoa, 2003). A number of conventions and treaties were signed and ratified, thus binding South Africa to international law (Section 3.2.3.1). South Africa was subdivided into nine provinces and although the National Government remained, and had the power to execute all the laws made by the national legislature, many responsibilities relating to governing the country were passed along to newly formed Provincial Governments. Provinces were given the power to create and pass their own legislation and contribute to national policy development (South African Government, 2004). Figure 3.1 shows the hierarchy of legislation in the country, including international, national, provincial and local legislation.

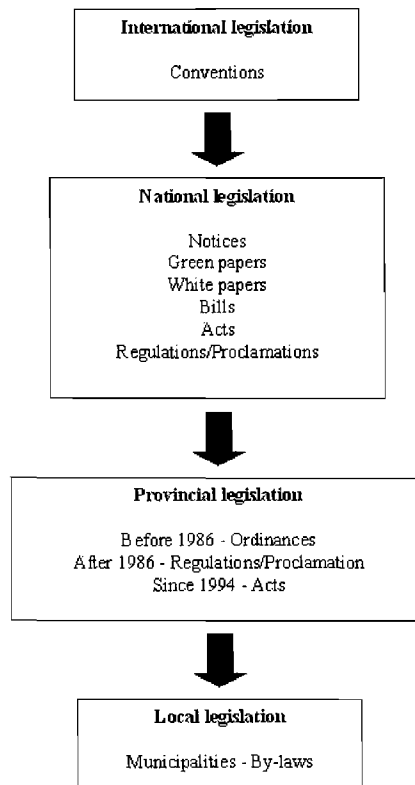


Figure 3.1 Hierarchy of relevant legislation in South Africa, from international to local legislation.

Provincial governments play an important role in implementing or carrying out policy. Provincial governments also play an important part in setting provincial norms and standards, and in assisting local governments to carry out their role in policy (Aguilar & Sala, 1997). Provincial and local governments operate within the national framework of sustainable

development and integrated management. Where necessary, provincial and local governments may apply stricter norms and standards to ensure the protection of human health and well-being and ensure environmental sustainability (DEAT, 1999).

The following section deals with environmental legislation as a component of South African legislation. Various components of environmental legislation, such as conventions, environmental laws and current initiatives will be discussed. The main focus of this discussion will fall on environmental legislation dealing with, or referring to, **land degradation, conservation and restoration**.

3.2 Environmental legislation in South Africa

According to Section 24 of the Constitution of the Republic of South Africa, 1996 (see Section 3.2.3.2), the government has a duty to manage the environment and especially what people do to it. It must be done in a sustainable way so that it protects the environment and helps people at the same time. Many government departments share the job of looking after the environment, such as the National Department of Agriculture (DoA), Department of Environmental Affairs and Tourism (DEAT) and the Department of Water Affairs and Forestry (DWAF). To achieve integrated and holistic environmental management, the government must guide, supervise and monitor all government departments in all spheres of government. It must also settle conflicts between government departments. The government is accountable for creating environmental policy, and for monitoring and enforcing it. The government must create opportunities to develop the people's understanding, skills and general capacity concerning the environment. This will enable people to participate in achieving sustainable development and the sustainable use of resources (DEAT, 1999).

3.2.1 Definition of Environmental Law

There are various definitions of environment, but the one provided by The National Environmental Management Act (NEMA) is probably most widely used. See Box 3.1 for the definition of environment, as used in this dissertation.

Box 3.1 Definition of environment**Environment**

Environment means the surroundings within which humans exist and that are made up of:

- i) Land, water and atmosphere of the earth,
- ii) Micro-organisms, plant and animal life,
- iii) Any part or combination of (i) and (ii) and the interrelationships among and between them; and
- iv) The physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being (Act 107 of 1998).

Brooks *et al.* (2002) provides a definition indicating that environmental law is that body of law aimed at the protection and enhancement of the environment and the sustainable development of natural resources. Environmental law can also be defined as the legal rules involving the conservation of the natural resources of the earth on the one hand, and the control of environmental pollution and desertification on the other. Environmental law applies not only to the problems concerning the control and prevention of environmental damage, but also has the responsibility to ensure an adequate environment for mankind (for example, resource conservation and management). This definition could also include land-use planning, as environmental and ecological criteria should be incorporated in decisions regarding land use, land development and land redistribution.

The sources of environmental law are the common law, legislation and international law (Fuggle & Rabie, 1983). As the sources are spread over a wide terrain, it is not always easy to find it. Environmental law is an evolving system that changes from day to day and these changes may have a beneficial or detrimental effect on the environment or industry depending on the perspective from which it is approached. The law stands in service of society; it regulates the relationship between people themselves as well as between people and the environment. The law is not a loose entity; environmental law would not be in existence if a need had not been identified in society. Environmental law is not a field on its own - it cannot be drafted without for example, scientific, political, sociological and economic input. No single law encompasses environmental legislation in South Africa and what exists is disjointed in nature (Esler *et al.*,

2003). Any legal principle which relates to environmental management, whether directly or indirectly, or which has an actual or potential impact on the environment, should fall within the purview of environmental law (Kidd, 1997).

Environmental law has only recently (1970s) been recognised as a separate branch of the law. It is difficult to define environmental law as it is a conglomerate of rules taken from different branches of the law that all deal with various aspects of the environment. Besides the introduction of an environmental clause in the Constitution, several policy and other review and reform processes concerning the environment have been initiated since 1994. South Africa has a vast and confusing array of acts and regulations affecting the environment, directly or indirectly (Section 3.2.3.2). The most notable of these are the Conservation of Agricultural Resources Act (CARA), the Atmospheric Pollution Prevention Act (APPA), the National Water Act (NWA), the Environment Conservation Act (ECA), the National Environmental Management Act (NEMA), the National Environmental Management: Biodiversity Act, the proposed Sustainable Utilization and Protection of Agricultural Resources Bill (SUPAR) and the regulations published under these acts. The acts mentioned above are administered by independent departments of government, with the result that the public seldom knows where to report incidents of environmental abuse; and even if such incidents are reported, there is little effective action taken against the offenders (Cock & Kock, 1991).

3.2.2 Environmental law and land degradation/desertification

Policy interventions, amongst others, are perceived to have had a positive influence on the decrease of land degradation, particularly in commercial farming areas (Hoffman & Ashwell 2001). A constraint on ecological restoration stems from the existence of significant institutional weaknesses in government, economy and civil society which restrict the extent to which science can be developed into policy (Adams, 2002). Although policies and acts that address environmental management, resource conservation (including restoration and rehabilitation) and land reform matters are in place, they are often not applied or enforced (Kellner, 2000). Cock & Kock (1991) feel that environmental laws are only effective as safeguards if they are creatively and vigorously enforced.

Restoration is an important, but often ignored, aspect of environmental law. Understanding the pathways of dryland change is crucial for designing appropriate policy interventions. To achieve sustainable management of dryland ecosystems, interventions have to be fine-tuned to the region-specific dynamic patterns associated with desertification (Geist & Lambin, 2004).

One main difficulty facing decision makers concerned with developing appropriate demographic and environmental policies for an arid region is the absence of any agreed theoretical framework for handling population-biodiversity interactions (Ayyad, 2003). To date, land use scenarios have often used top-down rationalisations of the process, assuming that once a policy is formulated it automatically has a beneficial outcome on the ground at grassroots level (Lemon & Seaton, 1999).

3.2.3 Specific environmental law in South Africa

As mentioned in Section 3.1.2, environmental law consists of international law, national, provincial and local legislation. In the following section, South Africa's international obligations, the Constitution of the Republic of South Africa as well as the different acts concerning environmental law in South Africa, will be discussed.

3.2.3.1 International legislation

International law is concerned with the relationship (rights and duties) between countries. International law is important, as environmental problems are not confined to the boundaries of a particular country (e.g. acid rain, shared waterways, and pollution). Although some international environment treaties date back to the early 20th century, it was not until the 1960s that concern about environmental pollution and the depletion of natural resources led to the kind of binding multilateral environmental agreements that we know today (UNEP, 1999). Even though there are numerous pieces of legislation in the world concerned with the environment, only those important for this project will be discussed.

Conventions and treaties

Conventions are written agreements between states which are important because they constitute a direct means of creating rights and duties for states and because of the increasing need for co-operation across national boundaries. Treaties bind only the states which formally agree to be bound by them, normally by depositing an instrument of ratification or accession (Birnie, 1992). No state is bound by a treaty unless it has given its consent to it. But before a treaty can be said to contain binding rules of international law, it must first come into force. After a convention is adopted, it must be ratified by a specified number of states before it can enter into force. Once states have ratified a convention by including its regulations in their national legislation, they become parties to the convention (Chasek & Corell, 2002). In the case of multilateral treaties, the normal requirement is ratification by a predetermined number of states (Bowman, 2002).

The National Department of Environment and Tourism (DEAT) is responsible for all conventions ratified by South Africa. Even though a large number of conventions and treaties have been developed and ratified by South Africa, only three will be discussed in more detail. The most common conventions, which form part of the theme of degradation and restoration, include the Convention on International Trade in Endangered Species (CITES), United Nations Convention on Biological Diversity (UNCBD), United Nations Convention to Combat Desertification (UNCCD), United Nations Framework Convention on Climate Change (UNFCCC) and the RAMSAR Convention on Wetlands. During the United Nations Conference on Environment and Development (UNCED) (the “Rio Conference”) in 1992, the following conventions were adopted (Hoffman *et al.*, 1999) and will be discussed in the following section:

- The United Nations Convention to Combat Desertification (UNCCD),
- The United Nations Convention on Biological Diversity (UNCBD), and
- The United Nations Framework Convention on Climate Change (UNFCCC).

In addition to the adoption of the conventions, the two week “Rio Conference” was the climax of a process of planning, education and negotiations among all Member States of the United Nations, leading to the adoption of Agenda 21, a wide-ranging blueprint for action to achieve sustainable development world-wide. Agenda 21 addressed various issues such as combating poverty, protecting the atmosphere and managing fragile ecosystems (UNEP, 2005a).

- ***United Nations Convention to Combat Desertification (UNCCD)***

In January 1995, South Africa became a signatory to the United Nations Convention to Combat Desertification (UNCCD) and the ratification thereof followed in September 1997. The UNCCD has as its primary objective "to combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification, particularly in Africa, through the effective action at all levels, supported by international cooperation and partnership arrangements, in the framework of an integrated approach which is consistent with Agenda 21, with a view to contributing to the achievement of sustainable development in affected areas" (Article 8(f)). At the heart of the UNCCD are the National Action Programs (NAPs) developed by each country, which provide the blueprint for implementation of the Convention (Glowka, 1998; Chasek & Corell, 2002). National Action Programs may include early warning systems, drought contingency plans, strengthened food security systems, alternative livelihood projects, and sustainable irrigation programs (Hoffman & Ashwell, 2001; Chasek & Corell, 2002). Given that the NAP cuts across many sectors, this instrument provides a framework of partnerships that calls for all government structures, communities and their leaders, NGOs and the private sector to work together and for the international community to help provide the necessary knowledge base, capacity development and financial resources (DoA, 2003).

The UNCCD is regarded as the first sustainable development treaty, since it considers economic and social development needs while also addressing the physical and biological aspects of desertification (Chasek, 1997). It is unique in that it encourages involvement of local populations and non-governmental organizations (NGOs) in its implementation – the so-called ‘bottom-up approach’ (Chasek & Corell, 2002; Ahmad, 2003). Affected people must be fully involved in decision-making, design and implementation of programs to combat desertification (Hoffman & Ashwell, 2001). In the past, development planners tended to ignore the people in spite of the fact that the poor communities know more than anyone else about the fragile ecosystem with which they have been endeavouring throughout their lives. They should be the keys to combat the desertification. The Convention acknowledges this and recognizes that development must be human-orientated if it is to be sustainable (Ahmad, 2003). (For more information on The United Nations Convention to Combat Desertification, visit: <http://www.unccd.int>).

As a result of the fact that South Africa has signed and ratified the UNCCD, the government has formulated a National Action Program (NAP) (See Current initiatives in South Africa). The South African NAP aims to combat land degradation to alleviate poverty, and this is resulting in environmental projects being implemented throughout the country. Although these projects are mainly focused on alternative income generation and poverty alleviation, they might contribute to land users' awareness of environmental problems and solutions.

- ***United Nations Convention on Biological Diversity (UNCBD)***

The United Nations Convention on Biological Diversity (UNCBD) has been signed by 150 government leaders at the 1992 “Rio Conference” and has been ratified by South Africa in November 1995. The UNCBD was conceived as a practical tool for translating the principles of Agenda 21 into reality. The aim of the UNCBD is to effect international cooperation in the conservation of biological diversity and to promote the sustainable use of living natural resources worldwide. It also aims to bring about the sharing of the benefits arising from the utilisation of natural resources (<http://www.environment.gov.za/Enviro-Info/env/intro.htm>).

It recognizes that biological diversity is about more than plants, animals and micro-organisms and their ecosystems – it is about people and our need for food security, medicines, fresh air and water, shelter and a clean and healthy environment in which to live. (For more information about the UNCBD visit: <http://biodiv.org>).

In accordance with the UNCBD, the Government has developed a National Biodiversity Conservation Strategy and Action Plan (NBSAP) for South Africa with assistance from GEF/UNDP. The NBSAP sets out a framework and five-year plan of action for the conservation and sustainable use of South Africa's biological diversity and the equitable sharing of benefits derived from this use. It contains a National Biodiversity Implementation Plan that sets out five strategic objectives to achieve the overall goal, which is to “conserve and manage terrestrial and aquatic biodiversity to ensure sustainable and equitable benefits to the people of South Africa, now and in the future”. These strategic objectives are: 1) An enabling policy and legislative framework integrates biodiversity management objectives into the economy; 2) Enhanced institutional effectiveness and efficiency ensures good governance in the biodiversity sector; 3) Integrated terrestrial and aquatic management across the country minimizes the impact of

threatening processes on biodiversity, enhances ecosystem services and improves social and economic security; 4) Human development and well-being is enhanced through sustainable use of biological resources and equitable sharing of benefits; 5) A network of conservation areas conserves a representative sample of biodiversity and maintains key ecological processes across the landscape and seascape.

- ***United Nations Framework Convention on Climate Change (UNFCCC)***

The United Nations Framework Convention on Climate Change was signed by 154 governments in Rio de Janeiro during the United Nations Conference on Environment and Development (UNCED) in June 1992. The convention addresses the threat of global climate change by urging governments to reduce the sources of greenhouse gases. The ultimate objective of the convention is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system of the world. The Convention was ratified by South Africa in August 1997 (<http://www.environment.gov.za/Enviro-Info/env/intro.htm>).

The Convention recognizes that it is a ‘framework’ document – something to be amended or augmented over time so that efforts to deal with global warming and climate change can be focussed and made more effective. The first addition to the treaty, the Kyoto Protocol, was adopted in 1997. (For more information about the UNFCCC visit: <http://www.unfccc.de>).

As a result of the ratification of the UNFCCC, the Department of Agriculture (DoA) has launched a number of projects to minimize the effects of climate change, such as developing appropriate tillage practices. The UNFCCC emphasizes the principle of stakeholder participation in all activities and processes, resulting in education, training and the raising of public awareness of issues related to climate change. The South African government has also prepared a national communication report in compliance with the convention.

International funding organizations

Even though there are a large number of international funding organizations, only those related to this project will be discussed.

- ***The United Nations Environment Program (UNEP)***

The United Nations Environment Program (UNEP) was a product of the Stockholm process when governments met at Stockholm to set up a new United Nations (UN) Environment Program to 'protect and enhance the quality of the human environment for present and future generations' (Thacher, 1992). It was established in 1973, in accordance with General Assembly resolution 2997 of December 1972.

UNEP is headquartered in Nairobi and has no executive powers. Its mandate, elaborated by the General Assembly following the Stockholm Conference, has been to monitor, coordinate and catalyse the effects of degradation and desertification (Elliot, 1998). The United Nations Environment Program (UNEP) is largely responsible for putting desertification on the global agenda and focused on improving the definition and the knowledge and understanding of land degradation and desertification (Chasek & Corell, 2002). On assessment and mapping of desertification/land degradation, UNEP published two editions of the *World Atlas of Desertification* in 1992 and 1997 to illustrate the global nature of the problem (UNEP, 1997). (For more information on the UNEP visit: www.unep.org).

Global Environment Facility (GEF) (See The Global Environment Facility (GEF) and the World Bank) funds are deployed through implementing agencies such as UNEP. UNEP is the implementing agency for the Desert Margins Program (DMP) (See Section 1.1) and the funds received from GEF for the DMP project is therefore deployed by UNEP.

- ***The United Nations Development Program (UNDP)***

The United Nations Development Program (UNDP) is the United Nations' (UN's) global development network, an organization advocating for change and connecting countries to knowledge, experience and resources to help people build a better life. The UNDP helps developing countries to attract and use aid effectively. Currently the UNDP is active in 166 countries, working with them on their own solutions to global and national development challenges. The UNDP and UNEP are working together very closely and in 2002 they have forged a partnership to obtain the Millennium Development Goals (MDG's). The UNDP has set

out eight MDG's to be achieved by 2015. The eight MDG's break down into 18 quantifiable targets that are measured by 48 indicators. The eight MDG's include the following:

- Eradicate extreme poverty and hunger.
- Achieve universal primary education.
- Promote gender equality and empower women.
- Reduce child mortality.
- Improve maternal health.
- Combat HIV/AIDS, malaria and other diseases.
- Ensure environmental sustainability.
- Develop a global partnership for development.

(For more information on the UNDP visit <http://www.undp.org>).

• ***The Global Environment Facility (GEF) and the World Bank***

Developing countries have tended to argue that financial mechanisms should be established under the control of the parties to any convention, separate from existing institutions such as the World Bank which, with its weighted voting system, is seen to favour the donor countries. While there was some initial support for this approach, evidenced in the establishment of the interim fund under the Montreal Protocol, the developing countries have generally supported the use of existing institutions (UNEP, 2006a; UNIDO, 2006). Under the amended Montreal Protocol, the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention on Biological Diversity (UNCBD), the financial mechanism is to be the Global Environment Facility (GEF).

The GEF was established by the World Bank, the United Nations Development Program (UNDP) and United Nations Environment Program (UNEP) at a meeting in Paris in November 1990 as a pilot program to finance projects and training programs that would aim to limit the negative global environmental impact of development projects (Thacher, 1992). The GEF is an international financial organization with 175 countries as members. The purpose of the GEF is to provide 'grant funding' for innovations that protect the global environment - through investment, technical assistance and, to some extent, research. The Facility's terms of reference

restrict it to funding environmental projects which are of global, rather than local significance and which are therefore assumed to be of benefit to the world at large.

The GEF has four objectives: (1) to support energy conservation, the use of energy sources which will not contribute to global warming, forestry management, and reforestation to absorb carbon dioxide, in order to limit the increase in greenhouse gas emissions; (2) to preserve areas of rich ecological diversity; (3) to protect international waters, where transboundary pollution has had damaging effects on water purity and the marine environment; and (4) to arrest the destruction of the ozone layer (Elliot, 1998; Chasek & Corell, 2002). The GEF Operational Strategy lays the foundation for the GEF's efforts in focal areas and operational programs. The six focal areas include biodiversity, climate change, international waters, ozone depletion, land degradation and persistent organic pollutants. As of 2003, there are 15 operational programs (OPs) through which the GEF provides grants for projects. One of the projects funded by the GEF through OP 1 is the Desert Margins Program (DMP).

The Desert Margins Program (DMP) first took shape as the Desert Margins Initiative in 1994, following a chain of international events that culminated in 1992 (Koala & Van Duivenbooden, 1999). The Desert Margins Program (DMP) has been developed in response to a recommendation made to the international research community at the United Nations Conference on Environment and Development (UNCED) (Koala and Tabo, 2004) to consider contributions for the implementation of the three United Nations International Conventions i.e. United Nations Convention of Biodiversity (UNCBD), Framework for Convention of Climate Change (UNFCCC) and United Nations Convention to Combat Desertification (UNCCD).

The GEF's interest in financing activities to prevent and control land degradation comes from the nature and extent of its link to global environment change. Even though GEF - OP 15 (Sustainable land management) deals with land degradation, it was only established in 2002, resulting in the fact that the DMP program falls within GEF - OP 1 (Arid and semi-arid zone ecosystems) under the biodiversity focus area. The objective of OP 1 is the conservation and sustainable use of biological resources in arid and semi-arid zone systems. It is stated that the conservation of ecosystems and integrated land use will also naturally alleviate the problems of land degradation. The fact that the DMP falls under OP 1 and not OP 15 is currently causing administrative, funding and implementation problems in South Africa which negatively influence the processes and activities implemented on ground level at the different target areas

(For more information on the GEF and the World Bank visit: www.gefweb.org and www.worldbank.org).

Current Initiatives in South Africa

The following are environmental initiatives that currently exist in South Africa on National level, concerned with aspects of land degradation/desertification, restoration, poverty alleviation and improved livelihoods. All of the initiatives have been implemented as a result of international influences and obligations. Even though more initiatives are currently present and active in South Africa, only a few will be discussed.

- ***National Action Program (NAP) for the UNCCD***

One of the most important elements of the UNCCD is the formation of a National Action Program (NAP) by signatories, which is actually linked-up with the implementation of this Convention. In practice, the NAP is to be drawn up by a democratic process, which will require the participation of all stakeholders. Since National Action Programs are the backbone of the implementation mechanisms of the UNCCD, it is desirable that the local communities be considered throughout all the development processes involving formulation, implementation and monitoring stages of plans (Ahmad, 2003). The NAP specifies the respective roles of government, local communities and land users and the resources available and needed (Kellner, 2000). The NAP is to be fully integrated into other national policies for sustainable development and will focus on awareness raising, education and training.

The South African NAP has been finalized and approved in 2004 and future activities include the monitoring and evaluation of the NAP to revise and improve the current version (NAP 2.0). The aim of the South African National Action Program: Combating land degradation to alleviate rural poverty is "to identify the factors contributing to desertification and practical measures necessary to combat desertification and mitigate the effects of drought" (DEAT, 1999a; NAP, 2004; Kidd, 2003). The NAP aims to:

- Be a prime contributor to sustainable rural development.

- Follow an integrated approach, simultaneously addressing the natural and socio-economic aspects of the processes of land degradation and drought.
- Integrate strategies for poverty eradication into efforts to combat land degradation and mitigate the effects of drought.
- Determine institutional mechanisms, if appropriate, keeping in mind the need to avoid duplication.
- Promote the use of existing bilateral and multilateral financial mechanisms and arrangements that mobilize and channel substantial financial resources to affected developing country parties in combating land degradation and mitigating the effects of drought.

According to a Cabinet decision, the Department of Environmental Affairs and Tourism (DEAT) is responsible for coordinating South Africa's NAP. A National Coordinating Body (NCB), made up of representatives of DEAT, the Department of Agriculture (DoA), the Department of Foreign Affairs, the Environmental Development Agency Trust (EDA) and the Environmental Monitoring Group (EMG)¹, is the main decision-making body. Environmental Monitoring Group is a non-governmental organisation that coordinates participation of civil society in the NAP. (For more information visit <http://www.environment.gov.za>).

- ***Desert Margins Program (DMP)***

For a description of the DMP, refer to Section 1.1.

- ***Working for Water (WfW), Working for Wetlands and Working on Fire (WoF)***

Working for Water (WfW) was launched in 1995 in an effort to tackle the problem of invading alien plants and unemployment. It is also a flagship initiative that reflects the Government's commitment to create jobs and combat poverty, particularly in rural areas. It is a multi-departmental initiative led by DWAF and DEAT. The program aims to improve ecological integrity, restore the productive potential of land, promote sustainable use of natural resources

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and invest in the most marginalized sectors of South African society (Gorgens & Van Wilgen, 2004).

The WfW initiative has the following objectives:

- Hydrological: To enhance water security and to promote equity, efficiency and sustainability in the supply and use of water.
- Ecological: To improve the ecological integrity of natural systems and to protect and restore biological diversity.
- Social: To invest in the most marginalised sectors of society and to enhance their quality of life.
- Natural Resources: To restore the productive potential of the land, in partnership with the LandCare initiative (see section 3.3.4.2) and to promote the sustainable use of natural resources.
- Economic: To develop the economic benefits (for land, water, wood and people) from clearing invading alien plants, by facilitating training, economic empowerment and the development of secondary industries (Kellner, 2000).

The WfW program has initiated a partner program in 2000, i.e. the Working for Wetlands program. This program is also governed by DEAT, DWAF and DoA and its focus is on the rehabilitation, protection and sustainable use of wetlands for the numerous economic, ecological and social benefits that they provide.

Working on Fire (WoF) is another program that has been initiated by the WfW program which was formally launched in 2003. This program seeks to prevent and control wild fires, with a strong focus on training, empowerment and capacity building. It is a partnership between DWAF, the Department of Provincial and Local Government (DPLG), DoA and DEAT, with strong support from the private sector (particularly from the forestry sector) (Baijnath & Charlton, 2005). (For more information visit <http://dwaf.gov.za/wfw>).

Under these three programs, various provincial projects dealing with a variety of issues have been implemented. Most of the projects focus on the eradication of alien invader species and many land users in the DMP target areas have been employed within these projects. This contributed to job creation and alternative income generation in these areas. Unfortunately, some of these projects are short-lived and even though land users are trained in certain skills to

combat the effects of land degradation, these projects do not contribute to the people's awareness of the cause of the problem.

- ***The South African LandCare Initiative***

The LandCare concept was conceived in 1986 in Australia, from an alliance between the National Farmers Federation and the Australian Conservation Foundation (Waters & Shaw, 2003). The LandCare concept has been launched in South Africa in 1997 and is implemented by the DoA. Based on the ideal of sustainable agricultural resource utilization, it includes natural resource, sociological, political and economic dimensions, as the basis for establishing a conservation ethic. The vision of LandCare in South Africa is to be a community-based program supported by both the public and private sectors through a series of partnerships. It is a process focussed towards the conservation of the natural resources and in addition it seeks to address rural poverty by means of sustainable job creation (Nduli, 2000; Waters & Shaw, 2003). Unfortunately, it has happened in the past that the main focus of LandCare projects in South Africa fell on job creation and not on caring for the land. If there is not enough focus on caring for the land, it will be difficult to ultimately conserve natural resources. Most of the projects in South Africa have been focussed in rural, communal areas, but recently two projects, which will be implemented on commercial farms, have been approved in the North West Province. This could have dual benefits – the owner of the land and the land itself will benefit from the actual implementation of the project, while additional land users will gain financially through employment within the project.

The LandCare program in the North West and Northern Cape Provinces collaborates with various other initiatives to ensure optimal participation and results during projects. The LandCare program supports DMP projects in South Africa, especially in the Northern Cape Province. Most of these projects, however, are focussed on the establishment of infrastructure and poverty alleviation. One of the products of such collaboration between LandCare, DMP and the North West University: Potchefstroom Campus is the creation of a restoration database, which can be consulted by anyone with access to the internet. (For more information visit <http://nda.agric.za/docs/LandCarepage>).

- ***Millennium Ecosystem Assessment (MA)***

The Millennium Ecosystem Assessment (MA) is a four-year international effort to assess the capacity of ecosystems to provide the services needed to support human well-being and life on earth. Ecosystem services include i) provisioning services such as food and water; ii) regulating services such as flood and disease control; iii) cultural services such as spiritual, recreational and cultural benefits; and iv) supporting services such as nutrient cycling, which maintain the conditions for life on earth (Stokstad, 2005). Several hundred social and natural scientists from all over the world are conducting the MA. In addition to evaluating the current condition and recent trend of ecosystem services, the assessment explores future scenarios and response options with respect to the provision and management of ecosystem services.

The MA is funded by the World Bank, donor countries and private foundations, which are represented on the MA Board, together with representatives of various user groups and United Nations organizations (Giles, 2005). At the global scale, the MA primarily serves multilateral environmental agreements such as the UNCBD, UNCCD and the RAMSAR Convention on Wetlands. A novel feature of the MA is that the assessment is also being conducted at regional and local scales in several parts of the world, serving users at those scales. The “Southern African Millennium Assessment” (SAfMA) is one of the sub-global assessments contributing to the global MA. This document reports on the regional-scale aspect of SAfMA and is aimed at improving decision-making in southern Africa at national to regional scales.

This assessment of ecosystem services in Africa south of the equator forms part of the Millennium Ecosystem Assessment (MA). It is a four-year global effort to provide decision-makers with information on the consequences of ecosystem change for human well-being. An assessment is not a research project. It is a social process whereby existing information is collected and evaluated by scientists for use by society (Biggs *et al.*, 2004). The MA

- takes stock of the condition of ecosystems and their services around the year 2000,
- helps understand trends in ecosystem services, using indicators,
- identifies the underlying and immediate causes (‘drivers’) of ecosystem change,
- explores scenarios of plausible future change,
- highlights the importance of ecosystem services in people’s lives,
- creates awareness of the consequences of change for human well-being, and

- suggests courses of action which can maintain and promote the capacity of ecosystems to continue providing services that support human well-being (Biggs *et al.*, 2004).

- ***Land Degradation Assessment Program (LADA)***

The Land Degradation Assessment (LADA) program is an international UN-initiative supported by GEF, UNEP, the Secretariat and the Global Mechanism of the UNCCD and the Food and Agriculture Organization (FAO), and is being executed by FAO (LADA, 2002). The LADA-project aims to assess causes, status and impact of land degradation in drylands in order to improve decision making for sustainable development in drylands at local, national, sub-regional and global levels (FAO, 2002). The LADA responds to the needs of all stakeholders concerned by the land degradation, and in particular the ones involved in the implementation of the action programs of the UNCCD.

The LADA-program's purpose is to develop and test an effective assessment methodology for land degradation in drylands. By marshalling the extensive knowledge and varied expertise already available worldwide, by creating a new, more interactive and comprehensive framework of assessment methods and by capacity building and testing this framework in real-world situations, LADA is putting together the pieces of a global challenge of land degradation and desertification (Bunning & Lane, 2003). Once the tools and the data required in order to understand the root causes, driving forces and functioning of the degradation puzzle are in place, it will be possible to assess land degradation at global, national and sub-national levels to identify:

- The **status and trends** of land degradation in drylands in all its components including biodiversity;
- The **hotspots**: the areas with the most severe land constraints and the actual degradation of such areas at risk of degradation, drought or flooding;
- The **bright spots**: the areas where conducive policies and actions have slowed or reversed the degradation and the priority areas where the conservations and rehabilitation of fragile lands could be most cost-effective. Such information will assist communities and governments in the design of effective remedial measures and supportive policies.

Initially, only three countries were involved in the two year preparatory phase of methodology development and capacity building (FAO, 2002), but currently South Africa is one of six pilot countries in the world participating in the LADA-project.

- ***World Overview of Conservation Approaches and Technologies (WOCAT)***

Apart from the initiatives mentioned above, South Africa participates in the World Overview of Conservation Approaches and Technologies (WOCAT) under the aegis of DoA, which contracts the Institute for Soil, Climate and Water (ISCW) as national project leader (Van der Merwe *et al.*, 2004). The goal of WOCAT is to contribute to sustainable use of soil and water through collection, analysis, presentation and dissemination of soil and water technologies and approaches world-wide, to promote improved decision-making and land management (Liniger, 2000). WOCAT's mission is to provide tools (questionnaires, databases, guidelines and manuals) which allow Soil-Water-Conservation (SWC) specialists to share their valuable knowledge in soil and water management, which assist them in their search for appropriate SWC technologies and approaches, and which support them in making decisions in the field and at planning level. The main outputs and products of the WOCAT are documents on approaches and technologies, as well as maps indicating SWC achievements all over the world.

Contributions on restoration have been made and included in a South African database for Soil-Water-Conservation, which is coordinated by ISCW. Results from this study could positively contribute to the information contained in the WOCAT databases and maps, as various technologies mentioned in Chapter 4 and 5 deal with soil and water conservation (For more information on WOCAT visit: www.wocat.net).

3.2.3.2 National, provincial and local legislation

National legislation is a collective term used for all Acts, Bills and Regulations implemented in South Africa on National level. However, as mentioned in Figure 3.1, very little or no provincial and local legislation deal with land degradation/desertification and restoration. Therefore, only National legislation dealing with these issues will be discussed. The next section gives a

description of National Acts and Bills pertaining to environmental aspects concerned with land degradation/desertification and the conservation and restoration thereof.

Constitution of the Republic of South Africa, 1996

The Constitution of the Republic of South Africa, 1996, read with the Environmental Conservation Act (Act 73 of 1986) and its policy, as well as the National Environmental Management Act (Act 107 of 1998), forms the framework of environmental legislation in South Africa. Section 24 of the Constitution of the Republic of South Africa states that:

Everyone has the right -

1. To an environment that is not harmful to their health or well-being; and
2. To have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that -
 - a. Prevent pollution and ecological degradation;
 - b. Promote conservation; and
 - c. Secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

This study deals specifically with points 2a and 2b mentioned above, additionally investigating alternative livelihood and income generating activities for the improvement of the way people live.

Acts

In concurrence with the Constitution of South Africa, the following acts are mentioned and discussed as they all contain sections and parts dealing with the problem of land degradation/desertification as well as guidelines and regulations on ways to combat these processes. The sections and parts of the Acts and Bills have been highlighted in the links to the web page on the Policy CD – Environmental legislation in South Africa; with special reference to land degradation and restoration (CD follows after Appendices).

- ***National Environmental Management Act 107 of 1998 (NEMA)***

The purpose of NEMA is to provide for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment. The Act institutes a National Environmental Advisory Forum (section 306) and a Committee for Environmental Co-ordination (CEC) (sections 7-10) which advise the Minister on environmental management and governance as well as the promotion of integrated and co-ordinated environmental functions by organs of state. Article 31A – Q of the NEMA states that environmental inspectors have been appointed to enforce legislation pertaining to the management of the environment.

The NEMA further states that every person who causes, or has caused, significant degradation of the environment must take reasonable measures to prevent such degradation from occurring, continuing or recurring. In addition to that, it states that where degradation can't be stopped, it should be minimized and rectified.

- ***National Environmental Management: Biodiversity Act (NEMBA) (10 of 2004)***

The Act is currently the main legal platform on which biodiversity conservation in South Africa is based. The Act provides for the management and conservation of South Africa's biodiversity within the framework of the National Environmental Act, 1998; the protection of species and ecosystems that warrant national protection; the sustainable use of indigenous biological resources; the fair and equitable sharing of benefits arising from bio-prospecting of genetic material derived from indigenous biological resources; the establishment and functions of a South African National Biodiversity Institute; and for matters connected therewith. The objectives of the NEMBA, however, reach beyond the mentioned objectives, since it also aims to provide for co-operative environmental governance practices. It essentially aims to facilitate co-operation between national, provincial and local spheres of government.

Section 38 of the NEMBA provides for the preparation and adoption of a national biodiversity framework by the year 2007. This framework must provide for an integrated, co-ordinated and uniform approach to biodiversity management by organs of state in all spheres of government, NGO's, the private sector, local communities, other stakeholders and the public. The framework must also identify priority areas for conservation action and the establishment of protected areas,

reflect regional co-operation on issues concerning biodiversity management in southern Africa, and determine norms and standards for provincial and municipal environmental conservation plans.

Part 1 of the NEMBA provides for the publication of national and provincial lists of threatened ecosystems according to certain categories, which include: critically endangered ecosystems; less critically endangered ecosystems; less endangered ecosystems, vulnerable ecosystems and protected ecosystems.

Part 2 provides for the listing of critically endangered species, endangered species, vulnerable species and protected species. Furthermore, Chapter 5 of the Act deals with the prevention of unauthorized introduction and spread of alien and invasive species to ecosystems and habitats where they do not naturally occur; management and control of alien and invasive species to prevent and minimize harm to the environment and to biodiversity in particular; and the eradication of alien and invasive species from ecosystems and habitats where they may harm such ecosystems or habitats. This implies that the Act can be used as a guideline during restoration technologies concerned with the eradication of alien invasive species as well as the conservation and restoration of the biodiversity in the country.

- ***Conservation of Agricultural Resources Act 43 of 1983 (CARA)***

As the Conservation of Agricultural Resources Act 43 of 1983 (CARA) is the most important piece of national legislation dealing with degradation/desertification and restoration in South Africa, it will be discussed in more detail than the previously mentioned Acts.

The objects of this Act, as stipulated in Section 3, are to provide for the conservation of the natural agricultural resources of South Africa through the maintenance of the production potential of land, by the combating of erosion and weakening or destruction of the water sources, and by the protection of the vegetation and the combating of weeds and invader plants.

Section 5 of the CARA Act states that seed which is used for agricultural purposes, and contains any weed, should be returned to the place of origin, destroyed or forwarded to a specific place in order to have the weed removed. This has the implication that seed sold to land users by seed

companies should be of a prescribed quality, i.e. containing no weed or invader plant seeds. In addition, seed mixtures used for restoration and re-vegetation purposes should be cleaned before it is used to ensure that the mixtures contain no weed or invader species.

Land users should adhere to control measures prescribed by Section 6 of the CARA Act. Although the control measures are only listed in the Act, they are explained in the regulations (Regulations 1 – 15) of the Act (Nr. R. 1048) published in the Government Gazette (1984). For the purpose of this study, the control measures and regulations will be listed and only those applicable to restoration will be highlighted and discussed. The control measures and their appropriate regulations include the following:

- *The cultivation of virgin soil.*
- *Cultivation of land with a slope.*
- ***Protection of cultivated land against erosion through the action of water.***

Every land user shall protect cultivated land on his farm unit from excessive soil loss as a result of erosion through the action of water, by using measures specified in the regulations.

- ***Protection of cultivated land against erosion through the action of wind.***

Every land user shall protect cultivated land on his farm unit from excessive soil loss as a result of erosion through the action of wind, by using measures specified in the regulations.

- *The prevention of water logging and salinization of irrigated land.*
- *The utilization and protection of vleis, marshes, water sponges and water courses.*
- *The regulation of the flow pattern of run-off water.*
- ***The utilization and protection of the veld.***

Every land user shall protect the veld on his farm unit effectively against deterioration and destruction through the following measures:

- **The veld concerned shall be utilized in alternating grazing and rest periods.**
- **Animals of different kinds shall be kept on the veld concerned.**
- **The number of animals kept on the veld concerned shall be restricted to not more than the number of large stock units that may be kept thereon in terms of regulation 11.**
- **A suitable soil conservation work shall be constructed and thereafter maintained.**

- If the veld concerned shows signs of deterioration, the number of animals shall be suitably reduced; the portions showing signs of deterioration shall be withdrawn from grazing until they have recovered sufficiently; or a suitable grazing crop shall be established thereon in addition to the existing vegetation.
- Veld shall be protected from erosion through the action of wind.
- *Grazing capacity of veld.*
The grazing capacity of veld, expressed as a specified number of hectares per large stock unit, shall be as indicated by a topocadastral map and a copy thereof shall be available for inspection. If an executive officer is satisfied that the actual grazing capacity of the veld of a farm unit differs appreciably from that specified on the map, he may determine another grazing capacity that shall apply in respect of the veld of that farm unit.
- *Number of animals that may be kept on veld.*
Every land user shall restrict the number of animals, expressed as large stock units, kept on the veld of his farm unit.
- *The prevention and control of rangeland fires.*
- *Restoration and reclamation of eroded land.*
Every land user shall effectively restore or reclaim the land on his farm unit on which excessive soil loss due to erosion occurs or has occurred.
- *Restoration and reclamation of disturbed or denuded land.*
If a land user disturbs or denudes any land on his farm unit, such land user shall effectively restore and reclaim that disturbed or denuded land through as many of the following measures as necessary:
 - Topsoil shall be removed, stored and used to stabilise and reclaim the disturbed or denuded land.
 - Excavations shall be removed so far from boundary fences that the sides thereof can be finished and stabilized without encroaching upon adjoining land.
 - The flow pattern of run-off water, the topography and the slope shall, depending on the volume of material exploited or removed, be restored as closely as possible to the original condition.
 - Suitable vegetation shall be established on the land concerned in order to expedite the restoration and reclamation thereof.

- **The land concerned shall be fenced off and withdrawn from grazing until such time as vegetation has sufficiently restored or established.**
- **A suitable soil conservation work shall be constructed and thereafter maintained in order to protect the land concerned against excessive soil loss through the action of water or wind or in order to collect sediment from run-off water.**

Even though the CARA Act deals with a number of environmental issues, the current focus is aimed at the control of erosion in high production agricultural croplands and the control of invader plant species.

Through the CARA Act, a land user can be ordered to comply with a control measure (Section 6) with regard to a specific area, thus implying that a land user can be ordered to restore a piece of land belonging to him. If the land user does not comply with the Act, the Minister has the authority to expropriate that land. This is extremely difficult in communal areas as the land does not belong to the land users, resulting in the fact that nobody can be held accountable. The government may grant subsidies in respect of the restoration or reclamation of eroded, disturbed, denuded or damaged land as well as to restrict the detrimental effect of a drought on that land e.g. the drought relief scheme in South Africa. This is, however, dependent on the provincial funding which is available for subsidies. Other initiatives such as LandCare comply with regulations (Regulation 15 and 16) set out by the Act concerning the combating of weeds or invader plants.

The CARA Act makes provision for four problem plant groups: The first three groups consist of undesirable **alien** plants and are covered by Regulation 15, while the fourth includes **indigenous** plants that require sound management practices to prevent them from becoming problematic and is covered by Regulation 16. The undesirable alien plants are divided into Category 1, Category 2 and Category 3 plants. Category 1 plants (declared weeds) include species that will no longer be tolerated on land or on water surfaces, neither in rural nor urban areas such as *Lantana* sp. and *Nerium oleander*. These plants may no longer be planted or propagated, and all trade in their seeds, cuttings or other propagative material is prohibited. Category 2 includes plants with the proven potential for becoming invasive, but which nevertheless have certain beneficial properties that warrant their continued presence in certain circumstances. Category 2 plants (commercial value) such as *Ricinus communis* can be retained in special areas demarcated for that purpose,

but those occurring outside demarcated areas have to be controlled. Category 3 plants (ornamental value) are undesirable because they have the proven potential for becoming invasive, but most of them are nevertheless popular ornamentals or shade trees that will take a long time to replace. Category 3 plants will not be allowed to occur anywhere unless they were already in existence when these regulations came into effect. Propagative material of these plants, such as seeds or cuttings, may no longer be planted, propagated, imported, bought, sold or traded in any way (DoA, 2003).

The biggest problem of the CARA Act is that all the control measures and regulations of the Act are implemented on farm units. In the commercial farming sector this is an effective scale to work on, but no farm units exist in communal areas. This results in the fact that the CARA Act cannot efficiently be implemented in communal areas. This problem will, however, be addressed in the Sustainable Utilization and Protection of Agricultural Resources Bill (SUPAR) (see next section).

Another problem with the CARA act is that no provision is made for the monitoring of the extent of degradation or the combating thereof. This is a major shortcoming as monitoring is one of the most important aspects of the restoration process (Barker, 2001; Schneider & Bartoszek, 2002).

- ***Sustainable Utilization and Protection of Agricultural Resources Bill (SUPAR), 2004***

This bill repeals the Conservation of Agricultural Resources Act (Act 43 of 1983), but has not been enacted as the Bill still needs to be published for public participation. Even though the SUPAR Bill repeals the CARA Act, the CARA regulations can be used with the Bill in their current format. The SUPAR Bill provides for the establishment of incentive programs, prescribing of standards, control measures and law enforcement to ensure sustainable development, utilization, management and protection of the natural agricultural resources in support of biodiversity and the combating of desertification.

According to SUPAR, an exit plan for any conservation and best practices program will be the development of a comprehensive, long-term strategy for improving and maintaining all natural resources by farmers or land users of natural agricultural resources. The LandCare program is implemented in South Africa as specified in the Bill. At the local level, the LandCare program

focuses on sustainable production, re-vegetation and restoration of degraded land. The Bill also stresses the importance of capacity building and training to ensure the accelerated adoption of programs and processes for sustainable resource management and development.

Chapter 3 of the Bill deals specifically with rehabilitation, regulation, standards and control measures thereof. The Minister may prescribe standards and control measures to regulate the sustainable development, utilization, management and protection of natural resources. Standards and control measures may relate to:

- The development, cultivation, utilization, management and protection of natural agricultural resources on agricultural land including state-owned land;
- The irrigation of agricultural land;
- The prevention or control of water-logging or salinization of agricultural land;
- The development, utilization, management and protection of riparian habitats on agricultural land;
- The regulation of the flow pattern of run-off water on agricultural land;
- The utilization and protection of vegetation;
- The reclamation of degraded agricultural land;
- The protection of natural agricultural resources against agricultural industrial pollution;
- The planning, design, construction, maintenance, alteration or removal of resource management infrastructure on agricultural land;
- The control of weeds, invader plants and bush encroachment on agricultural land;
- The sub-division of agricultural land;
- The protection, development, management and utilization of high-potential and unique agricultural land;
- The impact of other activities on agricultural land;
- The side-effects of agricultural land use on the catchment;
- The management and use of water on agricultural land;
- Development, utilization, management and protection practices that are unacceptable;
- Agricultural resource impact assessments;
- The change of land use on agricultural land;
- Management of agricultural resources in drought conditions;
- Flood damage to agricultural resources;
- Declaration of sustainable resource use;

- Protection of bio-diversity on agricultural land, and
- Any other matter that the Minister may deem necessary to achieve the objectives of the Act.

In addition to these standards and control measures for rehabilitation, the Minister may declare any plant to be an invader or weed species or an indicator species thereof. According to the Bill, land users and land owners are obliged to eradicate weeds and natural invader species.

- ***Minerals and Petroleum Resources Development Act 28 of 2002 (MPRDA)***

The purpose of the Minerals and Petroleum Resources Development Act 28 of 2002 (MPRDA) is to make provision for equitable access to, and sustainable development of, the nation's mineral and petroleum resources and to provide for matters connected with the use of the resources (Du Plessis & Bosman, 2004). The Act also places a duty on mining permit holders to rehabilitate and remediate environmental impacts of land during and after prospecting and mining operations (Du Plessis & Bosman, 2004).

The integrated environmental management of mining areas are dealt with according to principles set out in the NEMA, as set out in the MPRDA. According to the MPRDA, the holder of mining rights is responsible for any environmental damage, pollution or ecological degradation as a result of mining activities. The act further states that the holder of mining rights is obliged, as far as it is reasonably practicable, to rehabilitate/restore the area affected by mining operations and activities. The area must be rehabilitated/restored to its natural state, or a predetermined state or land use, which conforms to the generally accepted principle of sustainable development.

- ***National Forest Act 84 of 1998***

The National Forest Act 84 of 1998 is the only Act that deals specifically with forests and trees. The Act makes provisions for the promotion and development of criteria, indicators and standards for sustainable forest management. The Act also provides for the special protection of certain forests and trees as well as the promotion of community forestry (Du Plessis, 2004). The

Act specifies that no person may cut, disturb, damage or destroy any indigenous living tree in a natural forest.

The Minister can also declare any forest area, a tree, a group of trees, a woodland or a species of tree as protected. Part 4 of the National Forest Act gives the Minister the power to intervene urgently to prevent deforestation and to rehabilitate deforested areas. If the Minister is of the opinion that urgent steps are required to prevent the deforestation or rehabilitate a natural forest or a woodland, he or she may declare it a controlled forest area. In addition, the Minister may require the owner to take special steps to prevent deforestation or rehabilitate the natural forest or woodland.

- ***Plant Improvement Act 53 of 1976***

This Act provides for the registration of premises from which the sale of certain plants or the cleansing, packing and sale of certain propagating material may be undertaken. Furthermore, the Act prescribes the conditions to which such plants or propagating material must adhere before it is sold for the purpose of cultivation. Additionally, it also provides for a system of certification of plants and propagating material with the objective of maintaining the quality of certain plants and propagating material to ensure the usefulness of the products for agricultural and industrial purposes. This holds the implication that less seed of natural rangeland species, such as grasses and dwarf shrubs, are commercially available for restoration activities, as the seed must adhere to the requirements set by the Plant Improvement Act 53 of 1976. These requirements are usually difficult to obtain, especially if seed were harvested from high diversity areas such as road verges.

3.3 Conclusion

This chapter aimed to summarize international and national legislation in South Africa concerned with land degradation and the conservation and restoration of natural resources. It tries to address the causes that lead to land degradation and desertification discussed in Chapter 2, namely overgrazing and over-utilization of the rangelands by livestock, bush encroachment and alien plant invasion, soil erosion, deforestation, loss in biodiversity and other forms of land

degradation. It is evident that South Africa has a comprehensive environmental legislative system relevant to this subject and includes an array of international and national legislation.

Recently the ratification of various environmental conventions (especially the UNCCD and UNCBD) has forced South Africa to develop a National Action Plan (NAP) as well as a National Biodiversity Strategy and Action Plan (NBSAP) to combat land degradation, desertification and biodiversity loss. The effects of the objectives, as set out by these documents, have, however, not been felt on the 'ground' by the land users at grass roots level. Similarly to national legislation, there is a lack in resource capacity, resulting in the fact that the legislation cannot effectively be implemented. A large number of initiatives and projects dealing with environmental issues have, however, been established and implemented as a result of measures set out by international legislation and funding provided by international funding agencies, such as the GEF. The GEF has funded the implementation of large environmental conservation and restoration projects throughout the country, including the DMP program.

Most of the current initiatives, such as the MA, serve multilateral international conventions, including UNCBD, UNCCD and the RAMSAR Convention on Wetlands, while other initiatives are governed only by the National Government of South Africa. This might result in differences in the scale and level of implementation, as well as the objectives of these initiatives.

Even though a comprehensive national environmental legislative system is in place, the regulation of the actions set out by the legislation is often problematic and ineffective (De Wet, 2005; Feris, 2006; Morgan, 2008). Ultimately, the implementation and enforcement of the environmental legislation in South Africa is the responsibility of the National Government, and various departments are responsible for the enforcement of control measures and regulations set out by the various Acts. In most cases there is a lack in resource capacity, which includes human and financial capacity, leading to regulations not being enforced. Existing administrative and agricultural extension systems are often not conducive to effective actions and emphasis therefore has to be placed on developing a system that functions more efficiently and facilitates collaboration between various environmental and agricultural departments in South Africa. To effectively enforce the environmental legislation, as is the case with all legislation, it is necessary that the cooperation between the national and provincial government, as well as the land users is optimal. This will enhance the enforcement of environmental legislation.

From the discussions concerning the CARA Act it is clear that, in most cases, the existing environmental legislation focuses on commercial farming areas. This makes the enforcement of the regulations of these Acts very difficult in communal areas, as nobody in these areas can be held accountable for the activities. In most cases land users, especially in rural areas, are not aware of, or interested in legislation pertaining to environmental issues, as social and economic issues are usually much higher on their agendas (See Chapter 4).

In effect, all the different pieces of legislation dealing with the environment are linked, but ultimately it is the responsibility of the executive officers of the various Acts in each province to use this overlap and linkages to successfully implement and enforce environmental legislation in the country. Due to this overlap and linkage, there are a number of other Acts in the country that might be of importance with regard to the restoration and conservation of degraded or desertified areas, but were therefore not discussed in this chapter. These include Acts such as the National Water Act (NWA) (36 of 1998), Fertilizers, Farm feeds, Agricultural Remedies and Stock Remedies Act (36 of 1947) and National Heritage Resource Act (25 of 1999). Co-operative governance may serve as a useful method to address the fragmentation of environmental management in South Africa, with the ultimate aim to establish aligned and integrated structures, processes and tools for sustainable resource use and protection.

The Desert Margins Program (DMP) has been developed to contribute primarily to the implementation of the three United Nations Conventions i.e. UNCCD, CBD and UNFCCC (see Section 1.1), and operates within the National Action Plan (NAP) of South Africa and various other pieces of legislation. The knowledge gained through this study regarding perceptions of degradation and technologies to combat degradation could serve as a guideline for legislators when revising or writing new environmental legislation.

CHAPTER 4

Land users' views on land degradation and restoration in the South African DMP target areas

4.1 Different views on degradation and restoration

Land degradation manifests itself in many ways and is clearly an issue of concern to rural communities, land users and natural land resource managers, who experience the effects first hand (Hoffman & Ashwell, 2001). If land degradation poses a threat to productivity of natural resources, land users tend to be much more aware of it as it would have a direct influence on their livelihoods. A land user's perspective regarding land degradation will usually be more practical than the scientific explanation (Stocking & Murnaghan, 2001). People living in rural areas may see degradation in entirely different ways. For example, a woman engaged in collecting firewood and fetching water will be more concerned about the scarcity of these natural resources and the burden of having to travel long distances to collect wood than a farmer who will notice damage to the plough caused by the increasing number of stones on the soil. Figure 4.1 shows vastly different perceptions by stakeholders arising from concerns over land degradation and in particular the occurrence of erosion gullies. Scientists would be concerned about the fertility of the soil, vegetation cover and the condition of their animals, while tourists would be more concerned about the esthetical value of the gullies.

At the national level, it is possible to justify combating environmental degradation on the basis of long-term benefits, while programmes at the local (on-farm) level need to demonstrate tangible benefits to land users in order to attract their interest and maintain their support (Smith & Wangari, 1996). Any research work that is being conducted should not only be of scientific nature, but land users should also be able to understand the application and uses of the different research outcomes. Most of the time land users have useful inputs into the research work that is being carried out, but land users will mainly participate in research activities when they feel that it would add value to their daily existence (De Groot *et al.*, 1992).

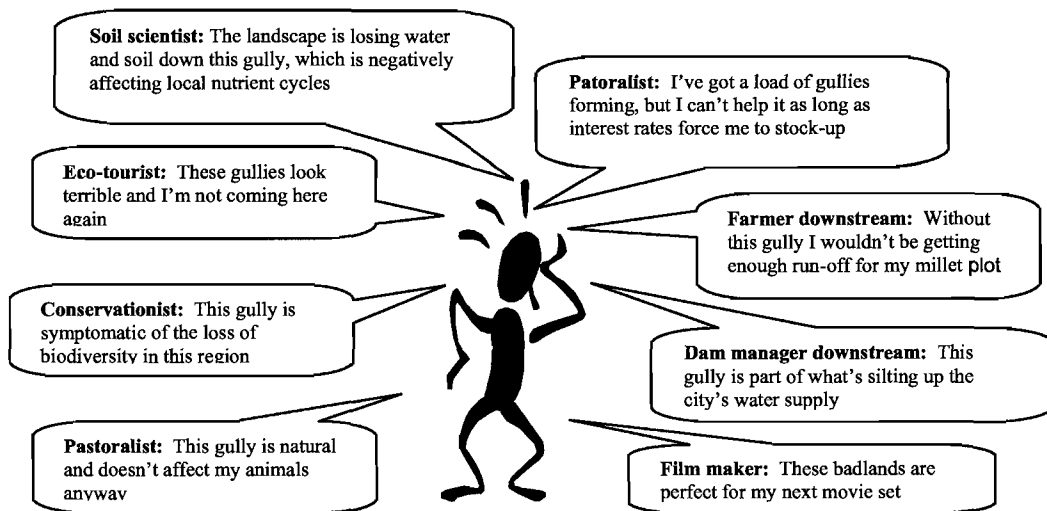


Figure 4.1 Different perceptions by stakeholders arising from concerns over land degradation and in particular the occurrence of erosion gullies (Reynolds & Stafford Smith, 2002).

Land users are often not aware of what land degradation and desertification are, let alone the restoration of these degraded areas. Most of the restoration practices that are carried out in South Africa are managed and financed by National and Provincial Government Incentives. As soon as the financial support is reduced or stopped, restoration is halted and not sustained or managed over the long-term. On the other hand, rangeland managers, scientists, conservationists and land users have been applying a variety of conservation and restoration technologies over different periods of time and at various environmental conditions, in order to combat or reduce the process of land degradation. Land users are usually innovative and experiment in many areas – they try new varieties and technologies, vary planting dates and test different conservation measures. Through generations, land users have accumulated knowledge and experience based on what they found works well for their own situation by means of innovation, experimentation and adaptation. These technologies have mostly been applied on a trial-and-error basis, which are often not documented or quantitatively assessed (Van der Merwe & Kellner, 1999). It is therefore important to document technologies and approaches in such a way that it will be easily accessible and repeatable by all land users.

According to Stocking & Murnaghan (2001), restoration technologies developed by scientists and technicians on research stations may prove to be inappropriate when introduced to land users, since research plots rarely mirror the actual conditions pertaining to rangelands in a specific region. According to O'Sullivan and Lithgow (1999), it is important to involve rangeland managers and land users in the managing and monitoring of their own land. Land user participation in the design of conservation technologies, evaluation and monitoring is needed to assure the sustainability and adoption thereof (Ashby *et al.*, 1987; Chambers *et al.*, 1989; Hagman *et al.*, 1998).

There are three main advantages of adopting a land users-perspective approach to land degradation assessment. Firstly, measurements are far more realistic regarding actual field-level processes. Secondly, assessments utilize the integrated view of the ultimate client for the work, the land user. Thirdly, results provide a far more practical view of the types of interventions that might be accepted and adopted by other land users. Land user participation results in generating a broader range of technologies that are scientifically sound, practical and adoptable, but also includes the significant potential for improving farming methods, yields and household food security (Rusike *et al.*, 2000). On the other hand, however, a land user's perspective assessment has limitations relating to accuracy, extrapolation and reliability and has to be assessed in a scientific way (Stocking & Murnaghan, 2001). Community participation in development planning also brings numerous unanticipated benefits through the contributions of local knowledge, both traditional and contemporary (De Groot *et al.*, 1992).

In Figure 4.2 a description is given of the stages in the adoption process of restoration practices and principles by farmers. Ffolliet *et al.* (1998) explain that people should first be aware of the problems, such as degradation, and then have an interest in the methods of combating degradation and desertification. An understanding of the problem and solution is essential before any trials, such as restoration actions, can be conducted. After successful trials, it is inevitable that the methods and approaches are adopted by using appropriate awareness, training and capacity building actions. Experience has shown that appropriate technologies are not always adopted, even where the need is obvious (Seager & Gardner, 2005; Miller *et al.*, 2007). Land users may reject or abandon certain technologies that have been useful, and adopt others in their

place, since they consider a variety of factors, such as financial constraints and cultural values, when deciding whether or not to adopt particular conservation practices (McDonald & Brown, 2000). McDonald and Brown (2000) further indicated that land users rarely sustain the technical solutions offered by external interventions in the long-term, unless consideration is given to the various socio-economic, cultural and institutional, as well as bio-physical and technical factors. Such factors could be land user-, farm-, resource- and technology specific.

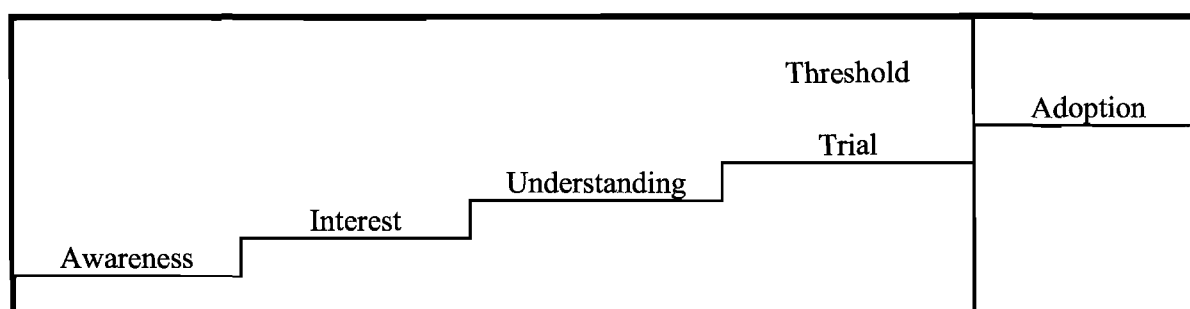


Figure 4.2 Stages in the adoption process, showing the factors that should be taken into consideration when planning and proposing activities (Ffolliot *et al.*, 1998).

The incorporation of traditional and local knowledge can greatly strengthen the legitimacy of an assessment process in the eyes of indigenous and local communities (MA, 2003). Effective incorporation of different types of knowledge in an assessment can both improve the findings and help to increase their adoption by stakeholders, only if they believe that their information has contributed to those findings (MA, 2003).

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 who may be experiencing similar problems. Traditional knowledge is often transferred orally from one generation to another and has its roots in trial and error, and lessons learned over many centuries of successes and failures (Folke *et al.*, 1998). Traditional knowledge systems include a combination of economic, ecological and ethical factors and deal with issues concerning community experiences. Technical experts, researchers, non-governmental organizations

(NGO's) and voluntary associations are called on to bring skills and expertise in response to locally perceived challenges. The challenge, however, is to link traditional knowledge with formal knowledge through a bottom-up, participatory approach.

Participatory Action Research (PAR) has emerged in recent years as a significant methodology for intervention, development and change within communities and groups. The research aspects of PAR attempt to avoid the traditional scientific extractive method, where experts go to a community, study their subjects, and take away their data to write papers, reports and theses. Research in PAR is designed to address specific issues identified by local people and the results are directly applied to the problems at hand. It aims to simultaneously contribute both to the practical concerns of people in an immediate problematic situation and to further the goals of social science. Thus, there is a dual commitment in action research to study a system and concurrently to collaborate with members in the system in changing it in what is regarded as a “desirable direction” at local level (ABL Group, 1997). Participatory Action Research usually starts with small cycles of planning, acting, observing and reflecting, which can help to define issues and assumptions more clearly. Evidence from many parts of the world suggests that the lack of control over resources is another major reason for the degradation of natural resources (Hu, 1997; Rohde *et al.*, 2006).

4.2 Land tenure

The natural rangelands in South Africa fall within a number of different land tenure and land use systems. These systems range from formal conservation areas to commercial, communal and subsistence farming systems. Differences in land tenure usually indicate differences in financial and natural resources, which contribute to ownership and management of these land tenure systems. Property rights are the foundation of resource use, management and conservation. In communal rangelands, an individual acting in his own self-interest will continue to exploit a common resource, even when it is being over-used and degraded, because the benefits from such behaviour accrues to him alone, while the constraints are divided among members of the

community as a whole (Pamo & Pamo, 1991). Certain technologies such as rangeland restoration are inherently long-term, requiring security of tenure over land for an extended period of time.

The problem of land tenure and ownership will remain a major problem in the rural areas of South Africa and has a negative effect on the adoption of initiatives that have to be carried out by the land managers (Kellner, 2000). It is suggested that the solution to natural resource management problems in southern Africa is to be found in a combination of institutional arrangements that combine the best attributes of private, common and government owned property. During this study, four different land tenure systems have been identified i.e. conservation areas, commercial and communal farming systems as well as small-holder and subsistence farming systems. For the purpose of this study, communal and small-holder farming systems are regarded as being similar. See Box 4.1 for definitions as referred to in this thesis.

Box 4.1: Definitions of communal rangelands, small-holder land users, commercial land users and conservation areas

Communal rangelands are rangelands used by an identifiable community of interdependent users. The rangelands are regulated by members of the local community. Within the community, rights to the resources are of equal access and use (Baden & Noonan, 1998).

A **small-holder land user** (or small-holder) is usually a land user who is relatively resource poor, who cultivates crops or keeps animals, or both, often on a small plot. These land users may or may not have access to larger common land for keeping livestock (Food and Trees for Africa, 2006).

A **commercial land user** refers to the following:

- A land user who owns or hires large pieces of land; and/or
- A land user who produces products intended for the market to be commercially delivered, sold or stored at commercial structures; and/or
- A land user who produces products intended to be sold to end-consumers (feedlots, poultry farms, dairies, etc.) fellow land users and direct exports; and
- A land user who uses machinery and chemicals intensively.

- A land user who retains a portion of his produce on his farm for own consumption, e.g. human consumption, animal feed (own feedlot included) or seed; and
- A land user who makes profit by selling a large part of his produce; and

Conservation area means:

- Any protected area designated and managed mainly or wholly for one of the following purposes:
 - Science or wilderness protection;
 - Ecosystem protection and recreation;
 - Conservation of specific natural features;
 - Conservation through management interventions;
 - Landscape/seascape conservation and recreation; and
 - The sustainable use of natural ecosystems.

(Organization of African Unity, 1968)

In addition to the definitions given in Box 4.1, the following perceptions also exist regarding these three land tenure systems. Although there is no universal agreed definition for small-holder farmers in sub-Saharan Africa, they are usually defined as those farmers farming on areas smaller than the average farm size at provincial or national level (Dent, 1989). However, farm size alone is not always a good criterion for characterizing farming activities. Throughout South Africa, small-holders typically occupy communal areas in more 'fragile' and 'marginal' environments, with poor extension services and reduced levels of subsidies (Whiteside, 1998; Francis, 2001). Communal rangelands are defined as those areas where agriculture is largely subsistence-based (Mutsaers *et al.*, 1997), and where rangelands are generally communally-owned and managed, as opposed to private or individual ownership (Tainton, 1999). People get their food, fuel, building materials and spiritual nourishment from natural resources and, either consciously or unconsciously, manage these resources through the local rules, taboos and belief systems that they have developed in particular contexts (Allsopp *et al.*, 2003; Fabricius & Koch, 2004).

In South Africa, these communal areas comprise the previous homelands and constitute approximately 12% of the country (Tainton, 1999). The fact that land users have access to fewer (often marginal) resources under communally-owned tenure arrangements often force them to over-exploit these resources in order to maintain their standard of living (Avoka, 2002). A pattern that emerges repeatedly within South African drylands is that communal lands exhibit significantly greater degradation than commercial areas (Hoffman & Todd, 2000; Okin, 2002). Environmental threats such as desertification are not high on the priority list and basic needs, such as water, food, proper housing and sanitation are much more in need in rural communities (Kellner, 2000). The management of communal rangelands is a dynamic and challenging process as the diversity of stakeholders and socio-economic conditions makes it difficult to apply formal management practices (Van Heerden, 2002).

The South African agricultural sector is progressively characterized by extensive farms in the possession of a limited number of private persons and companies. Commercial farmers implement controlled management practices, such as rotational grazing, to ensure the sustainable use of their agricultural land. Commercial farming usually includes the following activities for commercial purposes:

- The growing of field crops, fruit, grapes, nuts, seeds, trees in a nursery, bulbs, vegetables and flowers in the open air or under cover;
- Operations at nurseries excluding those predominantly engaged in re-selling;
- The cultivation of tea, coffee and sugar;
- The raising of livestock, game, poultry, rabbits, freshwater fish, furbearing and other animals; and
- The production of milk, wool, fur, eggs and honey (Statistics South Africa, 2006).

The establishment of conservation areas is a widely used technique for reducing anthropogenic threats (Margules & Pressey, 2000). It is crucial to identify areas of high conservation value, including areas with high biodiversity or irreplaceability value, and those with a high threat or vulnerability value (Pressey & Taffs, 2001). South Africa is a country characterized by abundance in faunal and floral species. To conserve the natural resources in South Africa, 21 National Conservation Areas (National Parks) have been established. In addition to the National

Conservation Areas, 63 Private Conservation Areas and numerous private game farms aim to conserve the rich biodiversity of the country (Fabricius & Koch, 2004).

Land users in the Northern Cape and North West Province DMP target areas in South Africa (Chapter 1 and Figure 4.3) have various perceptions concerning degradation and ways to combat and restore these processes. This chapter aims to highlight and summarize some of the perceptions of degradation and restoration technologies used by land users in the three land use systems to halt or reverse land degradation, improve livelihoods and address poverty related issues.

4.3 Study areas in South Africa

Within the Desert Margins Program (DMP), four target areas in the arid and semi-arid parts of South Africa were identified which represented different land use systems and boasted areas with high diversity (Figure 4.3). The specific study sites in the North West and Northern Cape Provinces were selected as they border Namibia, Botswana and Zimbabwe (contributing to cross-border research), as well as the fact that current projects in these areas were similar to the activities planned for the DMP projects. As this study is conducted as part of the DMP, the same study sites were used in this investigation. The DMP has specific objectives (See Chapter 1) and the aims and results of this particular study contribute to the program as a whole.

For this study, one site in the North West Province i.e. Molopo target area, and three sites in the Northern Cape Province i.e. Mier in the Kalahari, Paulshoek in Namaqualand (with special reference to the Leliefontein and Komaggas communal areas) and the Suid Bokkeveld (with special reference to Niewoudtville) target area (Fig 4.3) were selected.

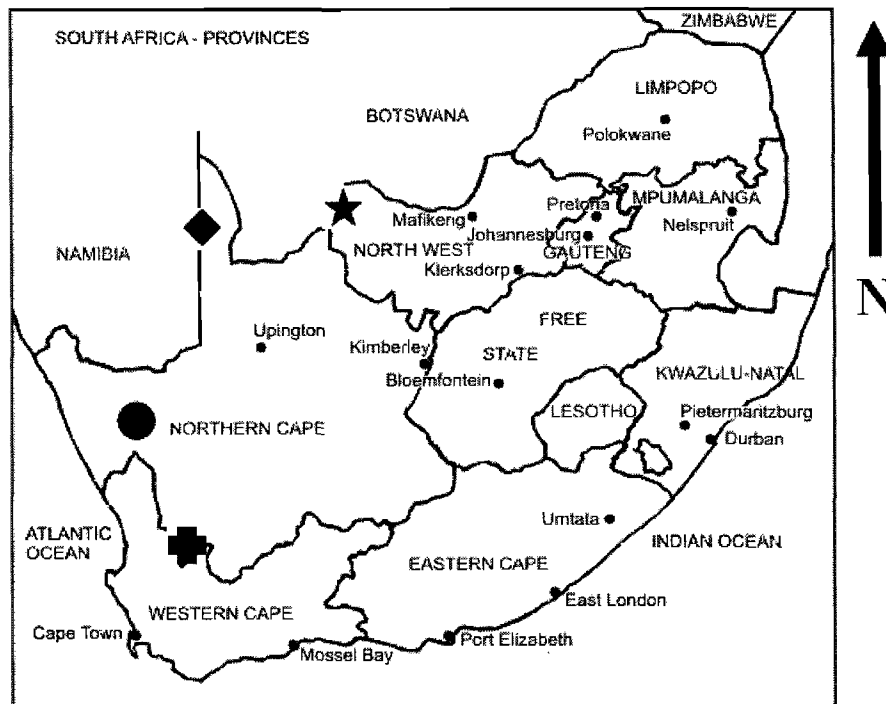


Figure 4.3 Map indicating the position of the four Desert Margins Program (DMP) target areas in South Africa. The Molopo target area in the North West Province (★), the Mier (◆), Paulshoek (●) and Suid Bokkeveld (+) target areas in the Northern Cape Province.

The purpose of this study is not to define degradation severity in the DMP target areas, but rather to identify perceptions about land degradation, as well as approaches and technologies used by land users to combat degradation. Due to the fact that this study composes of four parts, as explained in Chapter 1.3, the geographic and environmental descriptions of the study sites are intertwined with the results and discussion for each study site. This ensured continuity in this part of the study and allowed for easy comparison between the different study sites.

From 1997, Hoffman and Ashwell (2001) investigated the extent and severity of land degradation in South Africa by using literature reviews, statistical records, case studies and perceptions of agriculturalists and extension workers gained at workshops on municipal level (Hoffman and Ashwell, 2001). They investigated soil (SDI) and vegetation (VDI) degradation indices throughout South Africa and calculated a combined degradation index (CDI) for the country.

Although this degradation index may be outdated and based on subjective observations by technicians and extension officers, it is the only source currently available for determining the severity of land degradation in South Africa and is widely used by policy makers on national and provincial levels. A follow-up survey is currently undertaken, but the data and results were not yet available during this study. The CDI by Hoffman & Ashwell (2001) will therefore be used in the following sections to describe the degradation severity in the four DMP target areas.

4.3.1 Geographic and environmental information of the Mier study site

This study area is situated in the southern Kalahari, Northern Cape Province, South Africa. The Kalahari “duneveld” falls within a summer rainfall area and the mean annual rainfall ranges from 150 mm in the southwest to 350 mm in the northeast. The months with the highest rainfall are usually January to April. Temperature extremes range from minimum winter temperatures (-10°C) to maximum summer temperatures of up to 45°C (Van Rooyen, 2001). Due to the fact that this study covers a large part of the southern Kalahari, no specific rainfall and temperature figures are presented. The sands of the Kalahari were blown into linear dunes which were subsequently fixed by savanna vegetation. The north-north-west to south-south-east trending parallel dunes east of the Namibian highlands and north of the Orange River are 5 – 15 meters high with interdune/street spacing of 200 – 400 meters (Thomas & Shaw, 1991; Van Rooyen & Van Rooyen, 2000). Most of the area (dunes and interdunes) are characterized by sandy soils and are thus sensitive to wind erosion.

Vegetation structure on Kalahari sands has been shown to be influenced by sand depth, soil moisture and disturbance regimes (Chilides & Walker, 1987). According to Low & Rebelo (1996), the Mier study site is part of the Savanna biome and falls within the Shrubby Kalahari Dune Bushveld. The Shrubby Kalahari Dune Bushveld covers approximately 374 341 km² of South Africa and is characterised by scattered shrubs of mainly Grey Camel Thorn trees (*Acacia haematoxylon*) with a few individuals of Camel Thorn trees (*Acacia erioloba*) and the Shepherd's tree (*Boscia albitrunca*). The shrublayer is poorly developed and individuals of Bastard Roughleaf Raisin (*Grewia retinervis*) and Kalahari Currant (*Rhus tenuinervis*) occur as widely

scattered individuals. The grass layer is well developed and gives the impression of grassland. Grasses such as Kalahari Coach Grass (*Stipagrostis amabilis*), Lehmann's Love Grass (*Eragrostis lehmanianna*), Giant Stick Grass (*Aristida meridionalis*) and Gha Grass (*Centropodia glauca*) as well as Kalahari Sour Grass (*Schmidtia kalahariensis*) are conspicuous on these plains (Low & Rebelo, 1996). The sparse tuftedness of the grass and the looseness of the virtually bottomless sand make this rangeland extremely vulnerable to overgrazing. The area is mainly used for ecotourism in the Kgalagadi, with livestock and game farming in neighbouring areas (Low & Rebelo, 1996).

Although most of the Kalahari is covered by sand at varying depths, there is a flat, stony part to the south which is generally referred to as the “hardveld”. The hardveld habitat is dominated by dwarf shrubs and the grass layer is poorly developed (Van Rooyen, 2001). Even though the hardveld covers only a small part of the southern Kalahari, a large number of people rely on the commons around Rietfontein, the largest town in the Mier region, to raise livestock. In the hardveld, degradation generally starts with the formation of smaller bare areas or patches which expand or join together to form large bare and denuded areas (Kellner and Bosch, 1992). The loss of herbaceous cover results in factors such as increased soil erosion, formation of soil crusts and loss of favourable micro-habitats necessary for the germination and establishment of seedlings (Winkel *et al.*, 1991; Dean *et al.*, 1995).

There are three basic land use types in the study area: (1) conservation areas (national, private or communally owned), (2) commercial farming, and (3) small-holder subsistence farming. The local people highly depend on agriculture for a living, as the area holds no other livelihood options from natural resources due to the harsh environmental conditions (Van Rooyen 1998). This leads to severe degradation of the arid and semi-arid areas of the Kalahari through overgrazing, contributing to a reduction in the natural production potential of the area. Continuous overgrazing of perennial grasses and dwarf shrubs in the “duneveld” and “hardveld” increases the occurrence of the woody *Rhigozum trichotomum* (Three Thorn) shrub. It can rapidly invade its natural habitat, forming dense infestations, which excludes almost all other species. Encroached areas do not recover spontaneously once the agents of degradation (livestock) have been removed, as this shrub prevents the establishment of perennial grasses

(Ellis, 2002). According to the combined degradation index (CDI) developed by Hoffman and Ashwell (2001), the Mier study site is characterized as being severely degraded.

4.3.2 Geographic and environmental information of the Paulshoek study site

This area is a major tourist destination with a high potential for ecotourism. This is due to the extensive spring flower displays which occur mainly where annual plants colonize old and disturbed cultivated lands during the rainy season. The mean annual rainfall is estimated at approximately 200 mm and falls mainly during the winter season (May – August), but occasional summer thunderstorms do occur. The mean annual temperatures in the area range from 2.6°C to 36°C (Hahn *et al.*, 2005).

The study site is situated in the Succulent Karoo biome. The Succulent Karoo biome is widely considered as the richest succulent desert in the world (Cowling & Pierce, 1999). The area studied falls within three vegetation classes according to Low & Rebelo (1996) i.e. The Upland Succulent Karoo, the Lowland Succulent Karoo and the Mountain Renosterveld. The Upland Succulent Karoo Veldtype covers approximately 38 672 km². The Quiver Tree (*Aloe dichotoma*) characterises much of this vegetation while other succulent species, particularly within the Vygie Family (Mesembryanthemaceae), are the dominant dwarf shrubs. Grasses are generally not common in this vegetation type, although species such as Common Ehrharta (*Ehrharta calycina*), do occur. Many annuals occur in this vegetation type, mainly species of the Daisy (Asteraceae) and Vygie (Mesembryanthemaceae) Families.

The Lowland Succulent Karoo covers approximately 309 978 km² (Low & Rebelo, 1996). Round termitaria or 'heuweltjies' are characteristic of this region, together with a wide range of succulent growth forms. It is the Vygie Family (Mesembryanthemaceae), however, which dominates much of the lowlands, with species such as *Ruschia* spp., *Drosanthemum* spp., *Malephora* spp. and *Delosperma* spp. Old lands and other disturbed areas are often dominated by Kraalbos (*Galenia africana*), while many annual and geophyte species may be seen after good

rains. Palatable, non-succulent shrubs, such as Bietou (*Tripteris sinuatum*), occur in protected and well-managed areas.

At higher altitudes, the typical Kamiesberg mountain flora (Mountain Renosterveld) is dominated by shrubs with minute, rolled leaves, and species such as the Renosterbos (*Elytropappus rhinocerotis*) are common. Local farmers call the Mountain Renosterveld 'sourveld' as vegetation is unpalatable to livestock during the cold winter months.

In Namaqualand, a heavy, continuous grazing by domestic livestock, especially in association with communal land tenure, is perceived as the most important threat to the region's biodiversity. Todd & Hoffman (1999) have shown that, at one site in Namaqualand, heavy, continuous grazing leads to the replacement of perennial succulent and non-succulent palatable shrubs and grasses by annuals, geophytes and unpalatable perennial shrubs. Plant cover, volume, flower production and seedling recruitment of palatable, forage species are all significantly reduced in communally managed rangelands (Todd, 1997). The low, but predictable winter rains stimulate the growth of shrub species, especially those succulents which store water in their leaves, roots or bulbs. The lack of summer rains results in almost no grasses being prevalent in the vegetation type. According to the combined degradation index (CDI) developed by Hoffman and Ashwell (2001), the Paulshoek study area is characterized as being moderately degraded.

Three land use types were identified in this study area i.e. conservation areas, commercial farming and communal small-holder farming areas. The following communal areas were included in this study – Leliefontein (Paulshoek, Rooifontein and Leliefontein villages) and Komaggas (Buffelsrivier village).

4.3.3 Geographic and environmental information of the Suid Bokkeveld study site

The Suid Bokkeveld is situated at the western edge of South Africa's Great Karoo plateau in the southern part of the Northern Cape Province. Winter rainfall (May – August) of between 150 mm and 400 mm supports fynbos vegetation and succulents, geophytes and shrubs. The mean

annual temperature varies between 9°C and 22°C (Koopman *et al.*, 2005). The area lies within the transition zone between the Cape Fynbos and the Succulent Karoo Biomes. According to Low & Rebelo (1996), the Suid Bokkeveld forms part of the Upland Succulent Karoo veldtype, as described in the previous section. The area is characteristically rich in geophyte diversity, with a total of about 309 species occurring in the area (Manning & Goldblatt, 1997). This rich geophyte biodiversity makes the area a sought after destination for eco-tourism, attracting large numbers of tourists during the rainy season. According to the combined degradation index (CDI) developed by Hoffman and Ashwell (2001), the Suid Bokkeveld study site is characterized as being lightly to moderately degraded.

The area is home to a community of small-holder farmers (land owners and tenants), and some large-scale commercial farmers. Farming practices in the study site are mainly concentrated on rooibos tea cultivation, which is also the primary economic activity in the area, and small stock production, with sheep and goat herds being the most important. Farmers mostly apply conventional grazing systems with large camps (Turpie, 2003, DMP, 2004). The winter rainfall and the acid soils provide ideal conditions for the cultivation of rooibos tea. Some farmers allow their livestock to graze in the rooibos plantations after the annual rooibos harvest. Small-holder and commercial farmers employ other members of the community to prepare lands, plant, cultivate, harvest, process and sell the rooibos tea products. The Heiveld Co-operative Limited, owned by local small-holder farmers, provides a processing service to its members, purchasing raw rooibos from them, processing and packaging the product for overseas markets (Heiveld Co-operative Ltd, 2006¹). According to the combined degradation index (CDI) developed by Hoffman and Ashwell (2001), the Suid Bokkeveld study site is characterized as being moderately to severely degraded.

¹ Heiveld Co-operative Ltd, 2006. P.O. Box 154, Niewoudtville, 8181. Phone: +27 (0)27 218 1318. Email: marketing@heiveld.co.za

4.3.4 Geographic and environmental information of the Molopo study site

The study site is situated in the Bophirima District of the North West Province, South Africa. This area falls within the Savanna biome in the summer rainfall area (October – April), and the vegetation is classified as Kalahari Plains Thorn Bushveld (Low & Rebelo, 1996). The average annual rainfall is 300 mm and temperatures vary between -9°C and 42°C, with an average of 18°C (Mangold *et al.*, 2002). Due to the fact that this study covers a large part of the target area (approximately 300 km² between Vryburg and the Botswana border), no specific rainfall and temperature figures are presented.

The Kalahari Plains Thorn Bushveld vegetation type (Low & Rebelo, 1996) is characterized by a fairly well-developed tree stratum with Camel thorn (*Acacia erioloba*) and Shepherd's Tree (*Boscia albitrunca*) as the dominant trees, along with scattered individuals of Belly Thorn (*Acacia luederitzii*) and Silver Clusterleaf (*Terminalia sericea*), which may be locally conspicuous. The shrub layer is moderately developed and individuals of Black Thorn (*Acacia mellifera*), Weeping Candle Thorn (*Acacia hebeclada*), Karee-thorn (*Lycium hirsutum*), *Grewia flava* and *Acacia haematoxylon* dominate this layer. The grass cover depends on the amount of rainfall during the growing season. Grasses such as Lehmann's Love Grass (*Eragrostis lehmanniana*), Sour Bushman Grass (*Schmidtia kalihariensis*) and Silky Bushman Grass (*Stipagrostis uniplumis*) are conspicuous (Low & Rebelo, 1996).

Three land use systems have been identified in the DMP Molopo study site i.e. conservation areas, commercial farms and small-holder communal farming areas (Southey district). These land use types will be used during this study to determine the similarities and differences concerning land degradation and restoration. According to Hoffman and Ashwell (2001), land degradation is fairly serious in the North West Province, particularly in the communal areas and the combined degradation index (CDI) for the study area indicates that the study site is moderately degraded.

4.4 Materials and methods

During the study, land user's views and perceptions about land degradation, as well as the approaches and technologies people use to cope with land degradation through the application of various restoration technologies, were evaluated. A questionnaire was developed and used as part of a semi-structured interview with individual land users (Appendix A). The questionnaire was developed after consultation with various individuals using similar techniques for data sampling. The questionnaire was compiled to provide quantitative and qualitative data and therefore included closed as well as open format questions. Closed format questions usually take the form of multiple-choice questions which allows for easy calculation of percentages and other statistical data, while open format questions are those that ask for opinions where the respondent is free to answer however he/she chooses. The advantage of asking open format questions is that the variety of responses could more truly reflect the opinions of the respondents. The disadvantage however is that there is no way to perform statistical analysis on open format questions (Boniface & Burchell, 2000; Russell, 2006; O'Brien, 2007).

Five categories were included in the questionnaire, which included questions concerning general information, land use type, livestock information, erosion information, and degradation and restoration information.

The category dealing with **general questions** included aspects such as personal details (farm name, size and contact details), the way individuals gained their knowledge on farming practices and the period the person has been farming. The latter would give an indication of the experience land users have concerning farming practices and resource management. Also included in this category are questions pertaining to the use of natural materials and products harvested for personal and marketing use (e.g. medicinal plants). These questions included the frequency at which natural materials and products were harvested.

The **land use questions** dealt only with the type and distribution of water sources (amount and tenure – who owns the water sources?) available to land users. The purpose of this category was

to determine whether the availability of water is problematic or not, and whether land users have implemented strategies or technologies to cope with water scarcity.

The questions concerning **livestock** included the type and amount of animals owned, what these animals are used for (i.e. products and services), as well as the average size of the herds. It was also enquired whether the livestock only graze on natural rangelands or whether they receive supplementary fodder. These questions would give an indication of the type of farming and livestock management system implemented by the various land users.

The **degradation and restoration** categories dealt with the extent of degradation caused by natural and man-made processes and included the land users' perceptions about the degradation of natural resources. Land users were also questioned about methods and technologies applied to address the erosion and degradation problems, such as loss of vegetation cover and changes in species composition. The restoration category also included questions concerning the presence and use of old croplands and whether these old croplands have been restored. Land users were asked about different technologies that they apply to conserve and restore degraded rangelands.

As explained in the previous sections, the study sites for this thesis included the four target areas of the DMP (South Africa) i.e. (1) Mier, (2) Paulshoek, (3) Suid Bokkeveld and (4) Molopo target areas. Within the four target areas, the following land use systems were identified i.e. conservation areas, commercial and small-holder farming systems (see Box 4.1). A total of 64 land users were interviewed and Table 4.1 indicates the number of respondents from each land use system in all the study areas. During the semi-structured interviews used for the investigation, questionnaires were completed by the researcher with inputs from the land user on an individual basis. Land users within each target area were randomly chosen after suggestions made by agricultural extension officers, scientists and other participating farmers. Most of the participants have already been involved in the DMP prior to this study, thereby decreasing the possibility of duplication. Interviews were conducted regardless of the age and gender of respondents and therefore no distinction was made during the analysis thereof. To determine trends and correlations, data analysis from the questionnaires were carried out by means of the computer package Excel and the statistical package SPSS (Statistical Package for Social Science)

(Field, 2005). Statistical Package for Social Science (SPSS) is one of the most widely available and powerful statistical software packages (Einstein & Abernethy, 2000). It covers a broad range of statistical procedures that allows one to summarize data (e.g. means and standard deviations), determine whether there are significant differences between groups (e.g. analysis of variance), examine relationships among variables (e.g. correlations) and graph results (e.g. bar charts). For the purpose of this study the SPSS package was used to perform descriptive statistics on the collected data. These analyses are represented in the rest of this thesis through tables and bar graphs.

Table 4.1 Summary of the number of land users from each land use system included in the survey.

	Conservation	Commercial farmers	Small-holder farmers	Total
Mier	0	9	5	14
Paulshoek	2	12	25	39
Suid Bokkeveld	0	0	1	1
Molopo	0	4	6	10
				64

As this study forms part of the DMP in South Africa, the survey mostly focussed on land users currently involved in DMP activities. In the event that no land users from a specific land use type were involved in DMP activities, respondents from those land use types were chosen randomly. Unfortunately, only one respondent from the Suid Bokkeveld study area was included in the study. The respondent, however, has been farming for most of his life and is very knowledgeable concerning the farming and environmental activities in the area. In addition, the respondent is involved in various farming practices, 'on-farm' research activities, as well as environmental projects implemented by the National Government and various NGO's. Therefore, he could provide valuable information concerning a variety of issues.

4.5 Results and discussion

Due to the variance in the land use systems and the number of land users interviewed in each of the study sites, as well as the fact that the study sites differ in climatic, habitat and vegetation conditions, no direct correlations were made between the different sites. Each experimental site is discussed separately in the following section. In the conclusion section, general trends were identified between the different sites.

Completed questionnaires from Mier stemmed from commercial farmers ($n = 9$) and small-holder farmers ($n = 5$), representing 23% and 8% of the total number of commercial and small-holder farmers in the study area², respectively. No respondents from the conservation sector were included, as the Kgalagadi Transfrontier Park in the Kalahari does not form part of the DMP. The questionnaires for the Paulshoek study site included conservation areas ($n = 2$), commercial farms ($n = 12$) and small-holder farms and communal areas ($n = 25$). This represented 100% of the conservation areas and 25% of the small-holder³ farmers in the Namaqualand DMP target area. No quantification was, however, made for the total percentage of commercial farmers in the Namaqualand DMP target area which were included in this study, as the investigated area reaches across various municipal districts and included various farmer unions and farmer associations.

As discussed in the previous section, only one respondent (small-holder) from the Suid Bokkeveld was included in the study, representing 1.5% of the total number of small-holder farmers in this study area⁴. The survey in the Molopo study site included data of questionnaires from commercial farms ($n = 4$) and small-holder farms and communal areas ($n = 6$). This represented 13% of the total number of commercial farmers in the Molopo DMP target area⁵ and 21% of the total number of communal farmers in the Southey District of the Molopo area, which

² Data provided by Mr. K Mouton, Mier Municipality, Tel: 054 531 0019 / 072 355 4725.

³ Data provided by Mr. I Samuels, Agricultural Research Council, Tel: 073 257 1067; Mr. K Waldeck, Farmer – Rooifontein, Tel: 027 672 1754; Ms. A Boyce, Tel: 027 718 1860; Ms. S.N. Beukes, Leliefontein Municipality, Tel: 027 672 1808.

⁴ Data provided by Mr. N Oettlé, Environmental Monitoring Group (EMG), Tel: 027 218 1117.

⁵ Mr. L Bruwer, Farmer – Molopo, Tel: 082 776 0523.

falls in the DMP⁶. No respondents from the Molopo Nature Reserve were included, as the Provincial Government was in the process of appointing a new Reserve Manager at the time of the survey, resulting in the fact that no knowledgeable individuals, with regards to land degradation and restoration in the Reserve, were available for interviews (Table 4.1).

4.5.1 Land users' views at the Mier study site

Size of land use areas and length of farming experience

According to Table 4.2, a large difference between the minimum and maximum size of commercial farms exists (min 6320 ha, max 46 133 ha, Std. dev 15 374.05 ha), whereas little differences in small-holder farm size occurred (min 1903 ha, max 2983, Std. dev 432.6). This is explained by the fact that commercial land users have the financial means to acquire more land, while most of the small-holder land users only lease the land from the local government and often do not have the means to purchase their own land. If they do purchase land, only small farms can be afforded. In some cases, commercial farmers inherit large family farms from their parents or form large family enterprises. The length of farming experience varied between eight and 50 years, but approximately 80% of the respondents indicated that they have been farming for more than ten years. It is evident that most of the respondents had a thorough understanding of farming practices due to their experience (Table 4.2).

⁶ Data provided by Mr. I Makhwana, Extension officer, Tel: 082 296 0391.

Table 4.2 The minimum, maximum and average farm size (ha) of the respondents (*n*) per land use type, as well as the minimum, maximum and mean years which participating land users have been farming in the Mier area.

	<i>n</i>	Minimum	Maximum	Average	Std. Deviation
Size of farm (ha) – total	14	1 903	46 133	11 381.57	13 885.283
Size of commercial farm (ha)	9	6 320	46 133	16 320.78	15 374.05
Size of small- holder farm (ha)	5	1 903	2 983	2 491	432.6
Length of farming experience (years)	14	8	50	24.91	13.103

Knowledge of farming

Figure 4.4 indicates the way in which land users in the Mier area gained their knowledge concerning farming. It is clear that almost 65% of all respondents gained their understanding of farming practices through knowledge transfer from their parents. Only 20% (all from the commercial land user group) gained their knowledge from tertiary academic institutions, such as agricultural colleges and universities. Seventeen percent (17%) of the respondents indicated that they gained their knowledge of farming through other sources, such as working on commercial farms as well as own experience.

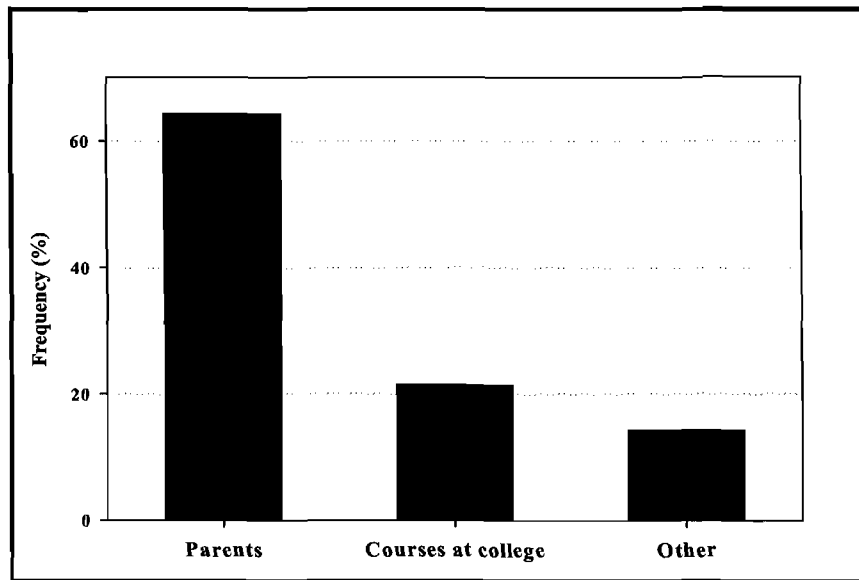


Figure 4.4 Graph indicating the way in which the respondents from the Mier area gained their knowledge of farming practices ($n = 14$).

Materials used from the environment

Respondents were asked whether they use materials from the natural environment for personal use which could be contributing to rangeland degradation. From Table 4.3 it is clear that only 64.3% of all respondents use materials from the environment. Most respondents using material from the natural environment are from the commercial farming sector (66.7%), compared to the small-holder group (33.3%). The products used consist mostly of firewood, which is used for purposes such as barbeques, cooking and heating (wood distributed to farm labourers). A total of 35.7% of the interviewed land users ($n = 14$) indicated that they do not use materials from the natural environment.

Table 4.3 The number of respondents in the Mier area, per land user group, who use materials from the natural environment.

	Frequency	Percent (%)
Yes (Total)	9	64.3
Yes (Commercial)	6	66.7
Yes (Small-holder)	3	33.3
No (Total)	5	35.7
No (Commercial)	3	60
No (Small-holder)	2	40

Farming systems and animal types

Livestock production is the main activity carried out by land users at the study site in the Mier target area. Of the interviewed land users, 7.1% own only sheep, while 92.9% own a combination of cattle and sheep. No interviewed respondent mentioned that he/she was using goats in his/her farming system. This is very strange and could be a mistake of undersampling, as it has been observed by Kriel (2006) that many land users in the Kalahari region do have goats in their livestock production system.

Figure 4.5 (a) shows that 36% of respondents kept/owned between 100 and 500 animals, while the majority (43%) kept/owned between 501 and 5 000 animals. The percentage of respondents keeping/owning more than 5 000 animals (total 21%) are notably less than the other two categories. All of the respondents from the small-holder land use group with land less than 2983 ha kept/owned less than 500 animals. It is evident that small-holder land users keep/own less animals than commercial farmers, but cross tabulation of size of farm with total number of animals showed no significant correlation between the two parameters ($p = 0.342$) (Figure 4.5 (b)). The fact that small-holder land users keep/own less than 500 animals can be attributed to the fact that the land owned or leased by land users is smaller, allowing only for a limited number of animals.

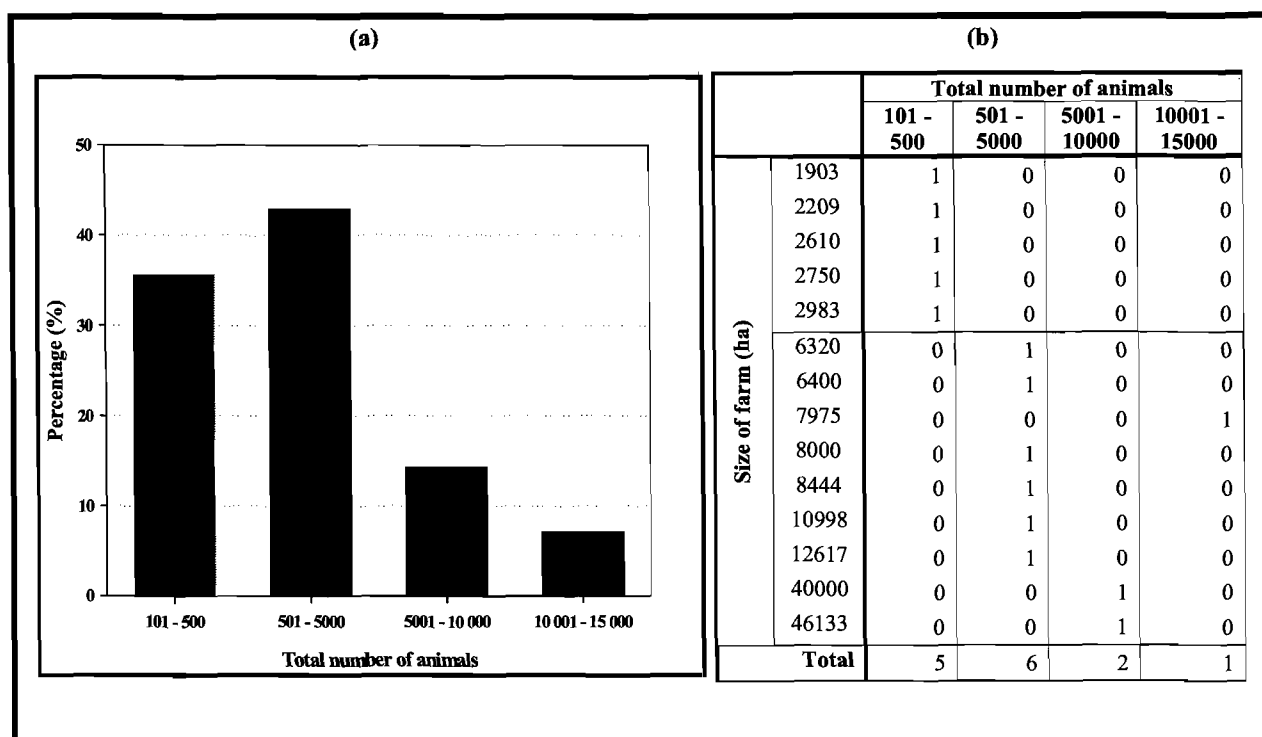


Figure 4.5 (a) Graph indicating the total number of animals, sub-divided into range classes per percentage land users and (b) Cross tabulation between the size of farms in the Mier study site and the total number of animals.

Twelve respondents used rotational grazing as a management strategy, while two respondents (one commercial and one small-holder) used a continuous grazing system. All 14 respondents made use of man-made watering points to provide water for their livestock as natural surface water is limited in this arid region of the Kalahari DMP target area. Sixty three percent (63%) of land users keep/own livestock for meat production, while 38% use the animals for other purposes, such as milk production, hides and cultural ceremonies. Roets & Kirsten (2005) indicated that commercial farmers in South Africa keep Angora goats for mohair production (with surplus stock being marketed in the goat meat sector) and Boer goats specifically for meat production (Roets & Kirsten, 2005). Although all of the respondents indicated that they have enough natural grazing on their farms, 14.3% stated that they use supplementary fodder when necessary. In most cases, the supplementary fodder is provided in the winter months (May –

August) as part of the National Government's drought relieve scheme, while some commercial farmers use it as part of their management system.

Due to the fact that cultivation is excluded from this study site and the area is characterized by linear sand dunes and low rainfall, all of the respondents indicated that water erosion poses no threat to their farming systems. Although it is known that wind erosion degrades dune systems through the removal of fine soil and organic material particles (Ellis & Galvin, 1994; Thomas, 2002; Radatz, 2005), none of the respondents indicated that it plays a major role in land degradation. In accordance with the response that soil erosion is not a problem, all of the land users indicated that they have taken no measures to combat soil erosion on their farms.

Perceptions regarding land degradation

Land users were also asked to describe their perception of degraded rangelands. From the answers it was clear that 50% of the land users felt that land degradation is characterized by a combination of factors such as an increase in bare dune crests and a decrease in grass tuft density. In the previous paragraph, all of the respondents indicated that erosion is not a problem, but the largest proportion (50%), however, felt that bare dune crests are the main characteristic feature of land degradation in this area. From this response it is obvious that land users are not aware that these two problems are connected. They seem to believe that bare dune crests are only a result of overgrazing. Twenty eight percent (28%) felt that degradation is caused by an increase in bare areas in the interdune areas/streets (Figure 4.6). Twenty percent (20%) of respondents explained that a change in species composition and an increase in unwanted, encroacher species, such as *Rhigozum trichotomum* (Three Thorn), is a result of degradation (13% and 7%, respectively). *Rhigozum trichotomum* normally occurs locally in small groups in the interdune/street areas, especially in shallow areas such as those around pans (Leistner, 1967; Palmer & Van Rooyen, 1998). These plants increase to very high densities where the grass layer is removed, and are capable of suppressing the grass layer once established (Moore, 1989; Du Toit, 2002). Even though farmers felt that an increase in *R. trichotomum* shrubs is an indicator of land degradation,

very few have determined the extent of the problem on their land. No surveys have been carried out to determine the total extent of *R. trichotomum* invasion in the Kalahari target area.

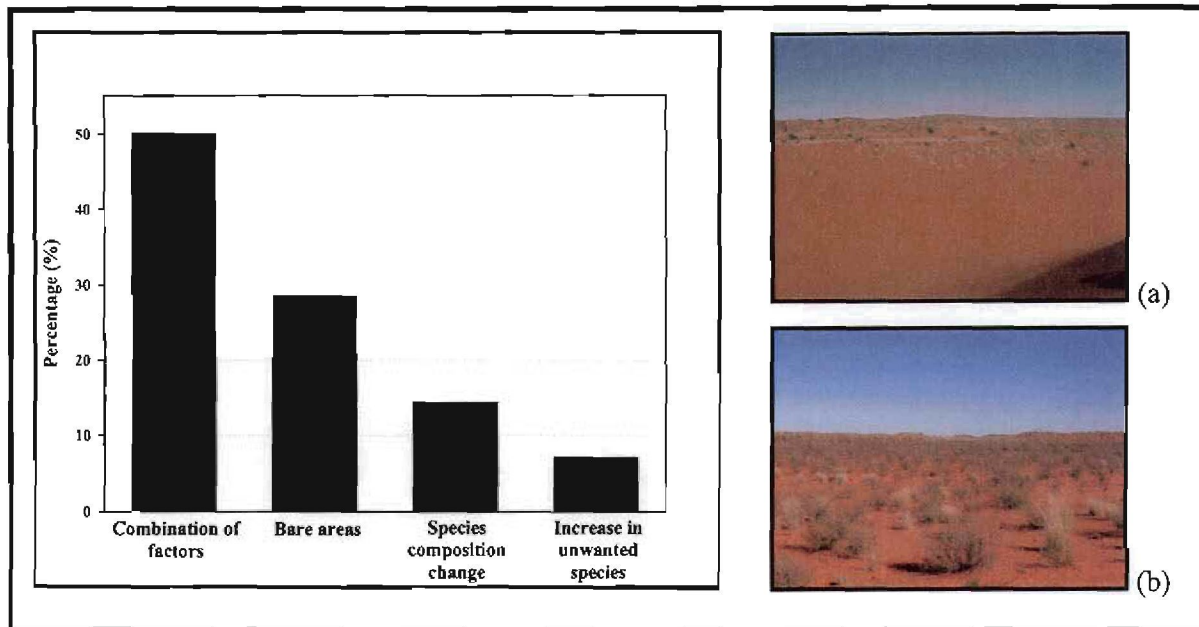


Figure 4.6 Graph indicating the percentage (%) perception of degradation according to the total number of land users ($n = 14$). Bare areas as a result of over-utilization (a), and (b) shows an increase in *Rhigozum trichotomum* shrubs in degraded rangelands.

Land degradation control / Application of restoration technologies

Table 4.4 shows that of the 13 respondents who were interviewed, 92.9% applied some kind of restoration technology, as well as the respective proportion of small-holder versus commercial land users who have applied restoration treatments (61.5% and 38.5%, respectively). From this response it is clear that all of the small-holder land users and all but one commercial land user have applied restoration treatments. Generally, commercial land users are more likely to carry out restoration treatments, as they often have more financial and technical resources available for this purpose and they have secure land tenure (Van den Berg, 2002). The fact that all of the small-holder land users interviewed have applied restoration treatments can be explained by the

fact that they have received assistance from National Government programs and initiatives, such as LandCare (See Chapter 3.2.3.1). The LandCare program is a community based natural resource management program which offers financial support to LandCare community groups, who identify, implement and monitor the conservation activities needed to deal with the land degradation problems they experience (Schutte, 1999). The LandCare project in the Mier area educates and trains land users on how to apply restoration technologies by stabilizing shifting sand dunes and eradicating alien and 'unwanted' invasive plants such as *R. trichotomum*. These treatments have, however, not been adopted on a large-scale, as land users feel it is too expensive for them to apply, and it is always dependent on the funding and administration by National and Provincial Government. This restoration technology is therefore not sustainable in the long-term, as the financial position of the majority of the small-holder land users are not bound to improve in the near future and Governmental projects are usually only implemented for a limited number of years.

Table 4.4 Indication whether land users ($n = 14$) have applied any restoration technologies, subdivided into different land user groups (Commercial and small-holders) in the Mier area.

	Frequency	Percent (%)
Yes (Total)	13	92.9
Yes (Commercial)	8	61.5
Yes (Small-holder)	5	38.5
No (Total)	1	7.1
No (Commercial)	1	100
No (Small-holder)	0	0

When land users were asked what restoration treatments have been applied, 36% indicated that they eradicate invaders, 13% said they lower their animal numbers, while most of the respondents (43%) indicated that they use a combination of both treatments to restore degraded areas (Figure 4.7). All of the respondents who have applied restoration treatments felt that their restoration attempts were successful and that their rangelands are currently in a good condition. Even though 92.9% off all the land users interviewed indicated that they have applied restoration technologies, the most important question still remains. How sustainable will these technologies

be in the future? It is evident that the majority of the respondents only applied certain technologies as part of a Nationally funded project, and it is unsure what the adoption rate of the technologies will be once the financial and technical assistance by Government ends.

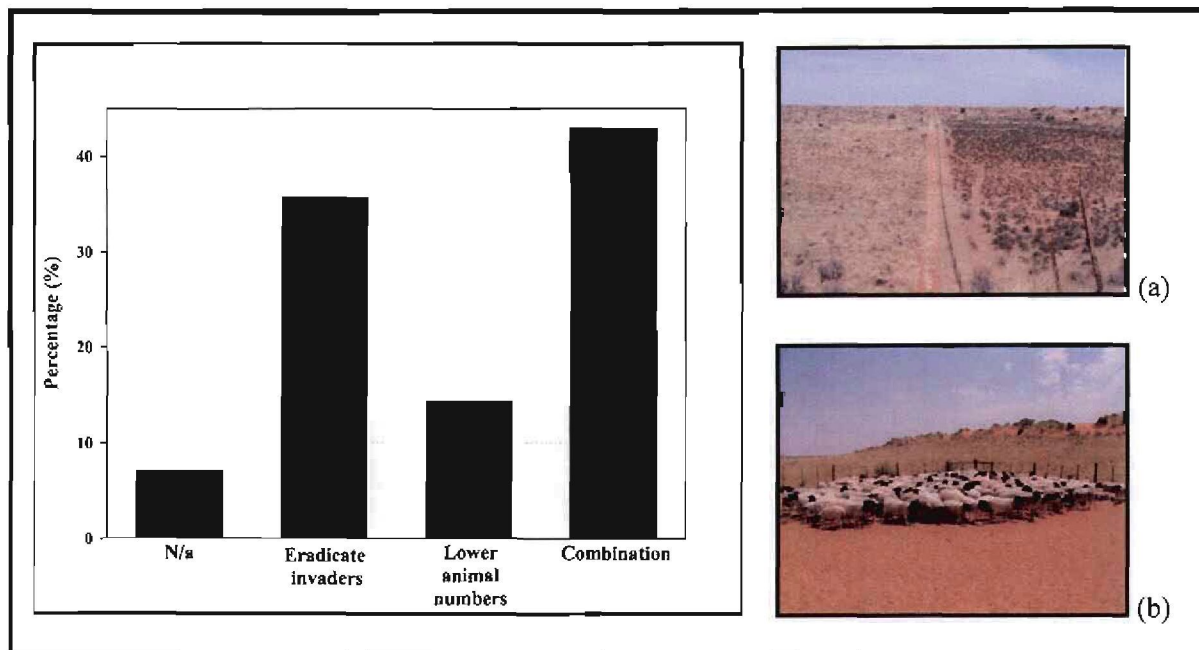


Figure 4.7 Graph indicating the methods and technologies land users in the Mier area indicated they used to restore degraded rangelands. The eradication of invader shrubs through chemical technologies (a), and sheep being prepared for marketing (b).

4.5.2 Paulshoek study site

Size of land use area and length of farming experience

The Goegab National Park is 15 000 ha in size, while the Namaqua National Park covers a significantly larger area (73 619 ha). The size of the smallest commercial farm owned is only 850 ha, while the largest covers an area of 8 000 ha. The average commercial farm covers only 4224.58 ha. The exclusion of small-holder land users from Table 4.5 is explained by the fact that the respondents from this group only utilize the commons surrounding Rooifontein, Buffelsrivier,

Paulshoek and Leliefontein for cultivation and grazing purposes and people interviewed do not lease or own individual farms.

In response to the question regarding the length of farming, 15 people responded that they have been farming less than ten years, while 17 people mentioned that they have farming experience of between ten and 40 years. Seven people (mostly originating from the small-holder group) indicated that they have been farming for more than 40 years (Table 4.5). On average, land users interviewed in the Paulshoek study site have been farming for 21.5 years.

Table 4.5 The minimum, maximum and average farm size of the respondents per land use group (excluding small-holder farmers), as well as the minimum, maximum and mean years which land users have been farming ($n = 39$) in the Paulshoek area.

	<i>n</i>	Minimum	Maximum	Average	Std. Deviation
Size of conservation area (ha)	2	15 000	73 619	44 309.5	41 449.89
Size of commercial farm (ha)	12	850	8 000	4 224.583	2 570.785
Length of farming experience (years)	39	1	65	21.5	18.1

Knowledge of farming

Figure 4.8 shows that a large proportion (76%) of all respondents indicated that they gained their knowledge of farming practices and systems from their parents. Only 7% of all respondents (all of which were commercial land users) gained their knowledge of farming by attending tertiary institutions, such as colleges and universities. Eighteen percent (18%) indicated that they gained their knowledge of farming from other sources, such as working as labourers on large commercial farms.

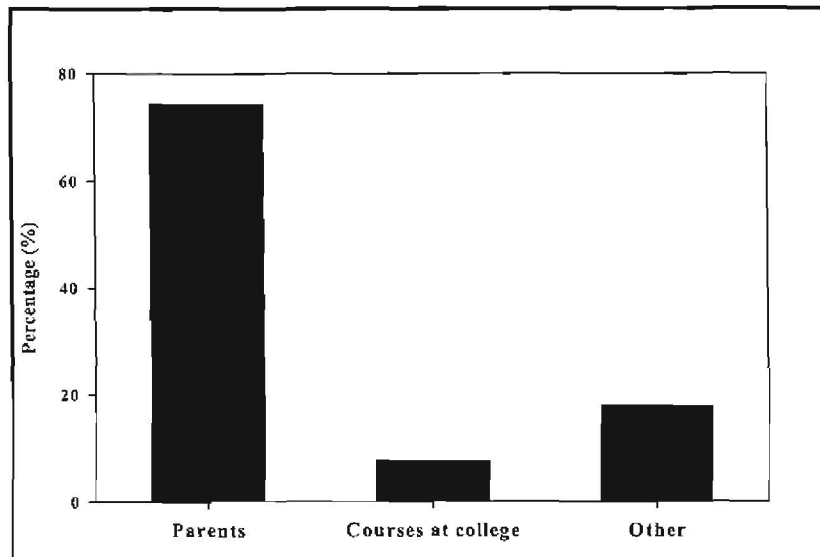


Figure 4.8 Graph indicating the way in which the respondents from the Paulshoek area gained their knowledge of farming ($n = 39$).

Materials used from the environment

Table 4.6 shows that a total of 66.7% of respondents, of which 73% are small-holder land users, indicated that they use materials from the environment to sustain their livelihoods. Individuals who indicated that they did not use material from the environment usually obtain materials from other sources such as buying it in cities and towns.

The product most commonly used by people living from the commons is wood for cooking, heating and light (collected by hand or donkey cart) (Figure 4.9 (a), (b)). In some instances, the respondents used reeds and rocks for building their houses and 'kookskerms' (Robins, 1997) as well as plants for medicinal purposes (May *et al.*, 1997). 'Kookskerms' is a term used for the structure where people prepare food, rest and hold meetings and gatherings (Figure 4.9 (d)).



Figure 4.9 (a) A small-holder collecting wood for cooking and heating (by hand), (b) people transporting large quantities of wood for cooking and heating, (c) woman making a mat from reeds and (d) a 'kookskerm' used for cooking. Photos (b) and (c) taken by Nicky Allsopp⁷.

Only one of the respondents from the conservation areas ($n = 2$) indicated that they only used natural materials from the environment, such as shrubs for the construction of the reception and information areas, as well as other buildings in the National Parks. Commercial farmers (23.1%) indicated that they use building material, such as sand, for the construction of buildings when necessary. Commercial farmers also collect firewood on a small scale for recreational purposes, such as camp fires and barbeques.

Table 4.6 The number of respondents from the Paulshoek area, per land use group, who use materials from the natural environment.

	Frequency	Percent (%)
Yes (Total)	26	66.7
Yes (Conservation)	1	3.9
Yes (Commercial)	6	23.1
Yes (Small-holder)	19	73
No (Total)	13	33.3
No (Conservation)	1	7.8
No (Commercial)	6	46.2
No (Small-holder)	6	46.2

⁷ Dr. Nicky Allsopp. ARC-Range and Forage Institute, c/o University of the Western Cape, Private Bag X17, Bellville, 7535, South Africa. Tel: +27 (0)21 959 3373. Fax: +27 (0)21 959 1376. E-mail: nallsopp@uwc.ac.za

Farming systems and animal types

Livestock production, in conjunction with crop cultivation, is the main livelihood activity in the Paulshoek study area, including the large commercial farming enterprises (Figure 4.10 (a)). No livestock production or crop cultivation is carried out in the conservation areas. In the communal grazing systems, individual land users keep/own herds of animals ranging from 1 – 300 animals, as well as portions of croplands ranging between one and 22 hectares, which are mostly used for subsistence cropping around households. Although less important than in the past, cropping still forms an important part of the agricultural production system of communal farmers. Marinus (1998) indicated that 41% of land users in the communal areas had access to croplands, but only 17% were actively engaged in cultivation at that time due to unfavourable climatic conditions and high input costs. This impacts greatly on land degradation, as no attempt is made to restore these old lands, making them vulnerable to grazing impacts, as well as wind and water erosion. During the cropping season, grazing is restricted to non-cropping areas. After the harvest, the fields are opened in the summer months so that animals can feed on crop residues. The croplands which are annually used for cropping contribute to land degradation as they are affected by wind and water erosion, while the fallow, old lands are areas which are most commonly inhabited by unpalatable shrubs, such as Kraalbos (*Galenia africana*).

Although all of the respondents indicated that they have enough natural grazing for their livestock, 94.9% stated that they use supplementary fodder when needed or available. In most cases, the supplementary fodder is provided as part of the National Government's drought relieve scheme. In the communal areas, crops such as wheat, barley, oats and rye are grown largely for livestock fodder and stubble grazing after the harvest (Moleele & Perkins, 1998).

Ground water is the major source of water for human consumption in the Paulshoek study area (May *et al.*, 1997). This type of water is either collected by hand or acquired from boreholes fitted with diesel or solar pumps. Results pointed out that only 71.8% of the interviewed land users have access to watering points. The 28.2% of land users who do not have access to watering points are living in the Buffelsrivier communal area where none of the boreholes and wind pumps is in a working order, due to a lack of maintenance. Currently people in the

Buffelsrivier communal area are using water from natural sources (fountains and wells) and private water sources (from homesteads) for their animals. The portion of land users who have access to watering points indicated that 74.4% of the watering points they use are man-made. These include boreholes and wind pumps, wells and other man-made structures (Figure 4.10 (b)). The 7.7% natural watering points mostly consist of natural springs, ephemeral rivers and hollows in solid rock which are filled during the rainy season. Another major source of water in the Paulshoek study area is derived from run-off from a large granite dome in the village. The community has built a low wall around this dome to catch water during the rainy season. Large amounts of water are collected, stored and mixed with poor quality borehole water to improve the general quality of the water for household purposes (King, 1996).

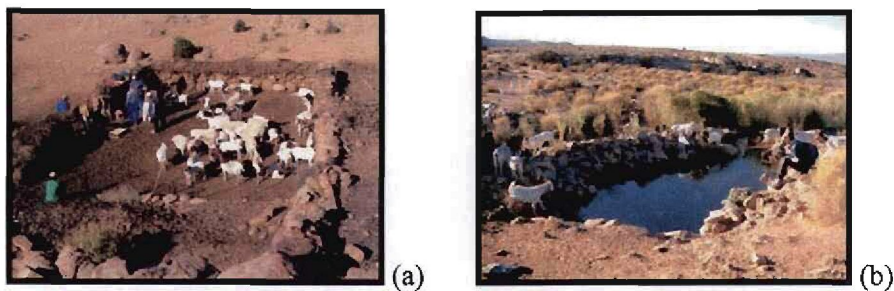


Figure 4.10 (a) Livestock raising is the most important livelihood option in the Paulshoek area and (b) daily convergence of livestock around man-made watering points during a drought period in Paulshoek. Photos taken by Nicky Allsopp².

The number and type of animals kept/owned for farming practices varied between different land use systems. Large game species were noted in the conservation areas, but no large game species were found in the communal grazing systems. From Figure 4.11 it is evident that the majority of land users own a combination of livestock species (66.7%). The commercial farms showed mixed farming systems with small numbers of game included in some. According to the respondents, sheep is the most dominant livestock species in the commercial farming system, while most of the small-holders own more goats than sheep. Cattle comprise only 2.6% of the total number of animals and are mostly owned by commercial farmers. Previous studies show

that cattle production is less important in communal areas than small stock production (Kröhne & Steyn, 1991). The game species (5.1%) originating from conservation areas included species such as Gemsbok, Springbok and Zebra. Respondents from the conservation area ($n = 2$) indicated that no products are derived from game species, but that they are used for eco-tourism purposes. Similar to findings of the study carried out by May *et al.* (1997), livestock is sold commercially for meat (17.9%) in both the commercial and communal land use systems, but in the communal systems, livestock is used for a combination of commercial marketing and the provision of products to households on a regular basis (71.8%), such as meat and milk.

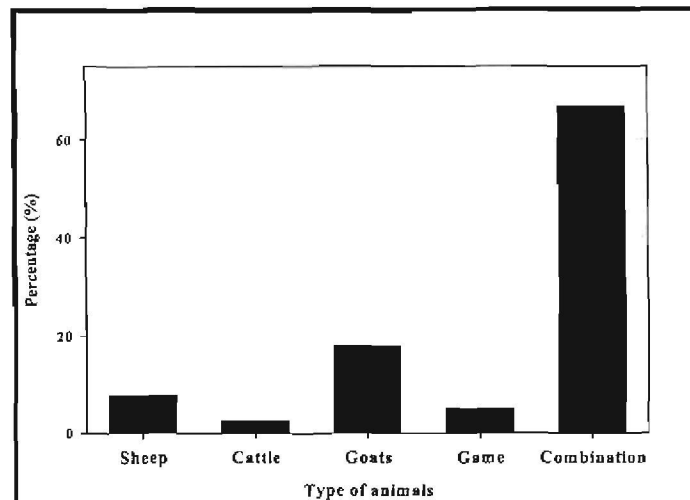


Figure 4.11 Graph indicating the proportions of various animals owned by the total number of respondents in all land use systems ($n = 39$) in the Paulshoek area.

As in the case of the Mier study site, Figure 4.12 indicates a high variation in the amount of animals owned by individuals. All of the respondents from the communal areas owned fewer than 500 animals (average 97.8 animals), while animals kept/owned in commercial and conservation areas were between 100 and 5 000 animals (average 643.3 and 315, respectively). No cross tabulation was possible between the size of farms and the amount of animals owned, as land users in the communal rangeland do not own land, but use the whole of the commons to graze.

As opposed to the conservation areas where grazing is managed through a continuous grazing system, and commercial farms where rotational grazing is the main management system, communal land users make use of stock posts, herding and kraaling to manage their livestock. The stock posts range from permanent sites that have been continuously occupied for more than 50 years, to semi-nomadic and easily dismantled shelters, which are moved every few months, depending on available water and grazing condition.

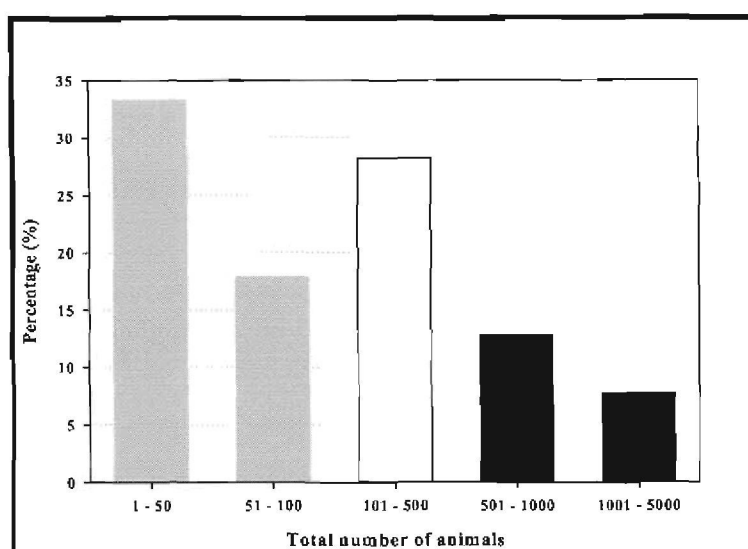


Figure 4.12 Graph indicating the total number of animals, sub-divided into range classes per percentage land users. ■ – Total number of animals in the range classes 1 – 50 and 51 – 100 belonging only to communal land users. □ – Communal land users, commercial land users and one conservation area own a total number of animals falling into this range class. ■ – Both commercial land users and one conservation area own a total number of animals falling into these range classes.

Fifty one percent (51%) of the respondents felt that erosion is only a minor problem on their farms, while 33.5% felt that erosion is a much bigger problem contributing to land degradation (Figure 4.13). Only 10% of the respondents indicated that erosion is a severe problem influencing their farming practices. All of the respondents pointed out that water erosion are

more common than wind erosion. Even though 66.7% of all respondents indicated that erosion is a problem, only 43.6% have taken measures to prevent erosion or restore eroded areas. A number of treatments have been applied to control or repair the damage caused by erosion. The most common erosion control measure in grazing areas applied by land users is the placing of stone packs in erosion gullies, while building stone walls or cutting down vegetation (shrubs and invader trees) and using it for brush packing in the gullies, are also used. Land users provide the financial and technical resources to carry out these erosion control activities themselves. For the control of water erosion in croplands, land users use contour ploughing in an attempt to decrease water run-off. A small scale experiment using grass plugs in erosion gullies was carried out by one commercial land user. Most of the interviewed land users who applied erosion control measures, such as stone packing, felt that it was successful (56.4%).

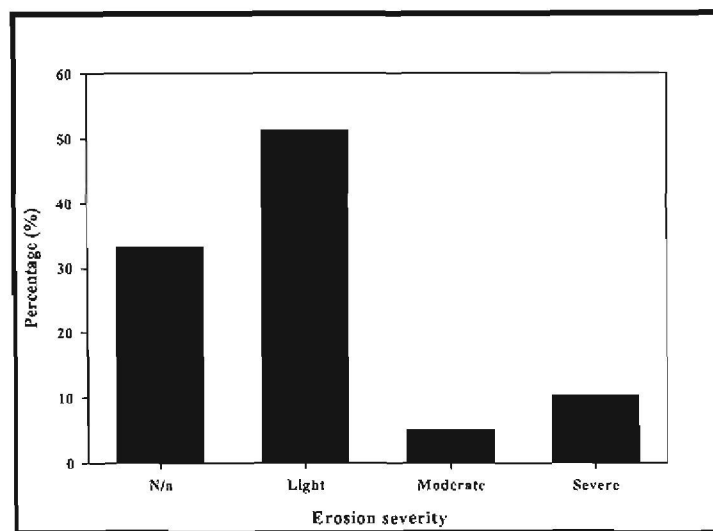


Figure 4.13 Graph indicating the erosion severity experienced by all respondents in the Namaqualand area ($n = 39$).

Perceptions regarding land degradation

From Figure 4.14 it is clear that peoples' perceptions of degradation vary within the different land use types. Respondents from the conservation areas indicated that the occurrence of bare areas and the increase in *Galenia africana* (Kraalbos), are indicators of degradation, while

commercial land users felt that trampling (42%) and the increase in *G. africana* (42%) are the most important indicators of degraded land. Even though these two indicators were identified by the commercial land users as being the most important, the following indicators also contributed to respondents' perception of degradation: increase in poisonous plants (17%), increase in Renosterbos (*Dicerothamnus rhinocerotis*) (25%), erosion (8%), change in vegetation composition and density (17%), no grass plants between shrubs (8%) and bare areas (8%).

Communal land users, on the other hand, feel that an increase in poisonous plants (40%) and the condition of their animals (12%) indicate the severity of degradation in their grazing areas. If their animals are in a poor condition, it is an indication that there is limited grazing and that the animals are suffering to find enough fodder/grazing. Related to this is the fact that communal farmers feel that drought is correlated with degradation (16%) and causes the grazing area to appear "less green" (4%). Other perceptions by respondents from the communal areas about degradation include the following: increase in Kraalbos (*G. africana*) (12%), increase in Renosterbos (*D. rhinocerotis*) (8%), trampling (4%), change in vegetation composition and loss in density and cover (12%) and bare areas (12%). Land users also felt that a decrease in the number of ephemeral plants (very little opslag) is also an indication of degraded land.

If the perceptions for the commercial and communal land use respondents are combined, it is clear that an increase in poisonous plants (28.5%), an increase in Kraalbos (*G. africana*) (27%) and trampling (23%) are the most important factors contributing to land degradation (Figure 4.14).

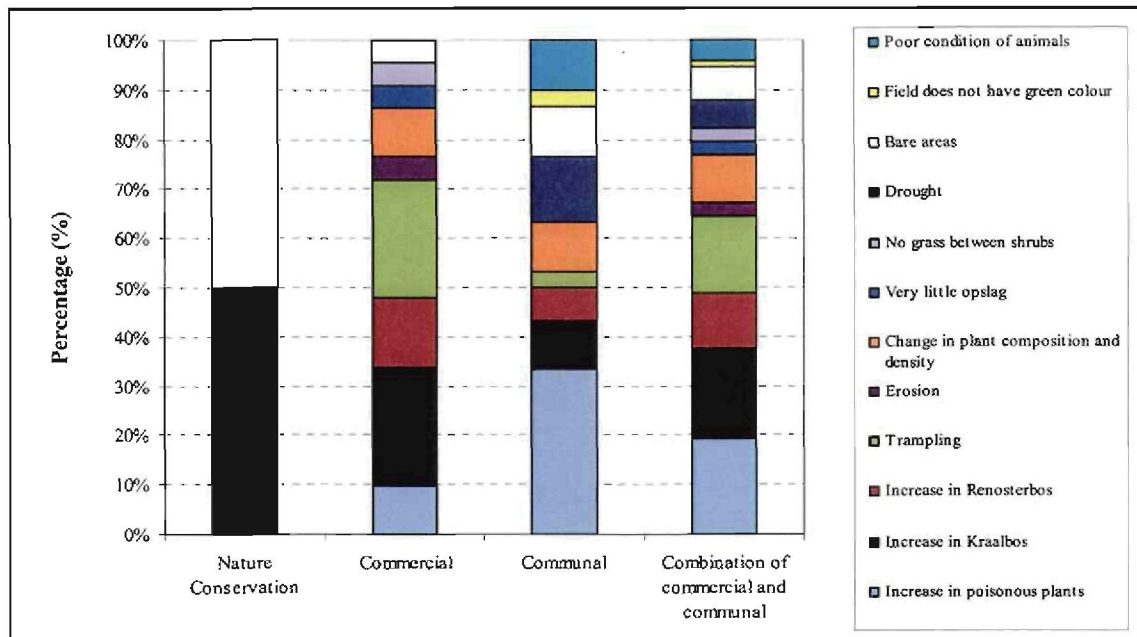


Figure 4.14 Perceptions of degradation within the three land use systems in the Namaqualand area, as well as a combination of the perceptions of the commercial and communal land users. The data showed in the graph is a representation of proportions and should only be used for comparison. The percentages given in the text represent the original data.

Land degradation control / Application of restoration technologies

Most of the respondents feel that there has been a decrease in the amount of rainfall received, and this, combined with an increase in input costs, has contributed to the fact that cropping in this area is not sustainable any longer. None of the land users however indicated that impaired rainfall infiltration contributed to this problem. Even though most of the land users interviewed showed that they have old lands (areas which were previously cultivated) on their farms, as well as in the commons (59%), only farmers from the commercial sector indicated that they have carried out active restoration treatments to improve the grazing condition of the old croplands. All the respondents from the communal areas indicated that the old lands in the commons were left to recover through natural succession processes. Commercial land users have carried out

some experimentation on old lands by loosening the soil and sowing seeds of various species to accelerate the increase in vegetation cover and density, as well as biodiversity.

Table 4.7 shows the number of respondents, in the different land use systems, who indicated that they have carried out restoration activities on their farm, other than erosion control and the restoration of old lands. It is clear that most restoration measures were undertaken by commercial farmers (80%), while no restoration treatments were applied in the conservation areas and only a small number of communal farmers have carried out some restoration treatments (20%). The lack of implemented restoration technologies in the conservation areas could be explained by the fact that the Namaqua National Park has only been established in 1998, making it a relatively 'young' National Park.

In the past, land users received subsidies to carry out restoration activities and this could have contributed to the 80% of commercial land users who have applied restoration treatments. Unfortunately, the new South African Biodiversity Bill provides no tax concessions or other benefits to land users who leave virgin land unploughed or who restore their land (Botha, 2001). In addition, the fact that no restoration activities have been carried out in the conservation areas could be ascribed to the fact that these areas have been established less than ten years ago and restoration activities might not yet have been implemented.

The largest number of respondents who indicated that they have applied restoration treatments used passive technologies, such as lowering their stock numbers to allow grazing areas to rest, as well as providing more watering points in each camp to lessen the effect of trampling (commercial farmers). Three respondents indicated that they have a second farm in other regions, such as the Bushmanland, to which they move their animals during the summer months. According to Archer *et al.* (1989), commercial farmers living in the drier, less productive areas of South Africa, often own second farms in the higher rainfall regions, thereby increasing their management options between seasons. Some commercial farmers indicated that they also tested other small-scale experimental restoration technologies, including the following:

- Over-sowing various plant species, such as grass species and Old man saltbush (*Atriplex nummularia*).

- The eradication of exotic tree species, such as Poplar trees (*Populus* sp.) and Pepper trees (*Schinus molle*).
- Establishing rye grass (*Lolium* sp.) fields for planted pastures.
- Improved water utilization by building dams and boreholes.

Most of these restoration activities have been carried out by land users to increase their fodder flow, improve the rangeland condition on their farming land, as well as to conserve biodiversity. The land users who have carried out restoration activities all felt that they have been successful but that the input costs were too high.

Table 4.7 Indication of land users in the Paulshoek area applying restoration technologies, for the total number of respondents ($n = 39$) divided into different land user groups (conservation, commercial and small-holder communal farmers).

	Frequency	Percent (%)
Yes (Total)	5	12.8
Yes (Conservation)	0	0
Yes (Commercial)	4	80
Yes (Small-holder)	1	20
No (Total)	34	87.2
No (Conservation)	2	5.9
No (Commercial)	8	23.5
No (Small-holder)	24	70.6

4.5.3 Suid Bokkeveld study site

One small-holder farmer in the Suid Bokkeveld study site was interviewed as part of this project. The reason why only one land user was interviewed in the Niewoudtville target area is ascribed to the fact that the respondent is a mentor farmer with a large amount of knowledge concerning different farming systems in this area, and practices a diverse number of farming enterprises himself.

Size of land use area, length of farming experience and knowledge of farming

Currently the respondent owns two farms (900 and 2 000 ha, respectively). The respondent stated that farming has been in his family for decades and that he has gained most of his knowledge concerning farming from his parents, like most of the other farmers in this target area. In addition, he has worked as a labourer on large commercial farms, thereby increasing his knowledge about farming. The respondent indicated that he has been farming for 20 years and that he has learned a lot from trial and error activities. Prior to 1996, his farms were mainly used for crop cultivation (grains and wheat), but after 1996 the respondent started to cultivate Rooibos tea (*Aspalathus linearis*).

Materials used from the environment

According to the respondent, people in the Niewoudtville area use materials from the natural environment on a regular basis. Materials such as firewood are collected on a daily basis, while materials are also used as medicinal plants, reeds and clay when needed. Wild rooibos tea is also harvested regularly from the natural environment. The cultivation, harvesting and marketing will be discussed in more detail later in this section, as it forms part of the DMP.

Farming systems

Even though the respondent stated that the cultivation of rooibos tea is the most important farming practice in this area, he indicated that most land users also own livestock. Livestock is usually managed by means of a rotational grazing system, as this ensures that not all of the veldt is grazed simultaneously. In most cases, natural or man-made watering points are present in each camp. Water is provided through boreholes and fountains. The National LandCare program (See Chapter 3.2.3.1) has provided assistance to construct camps, erect water tanks and build sand dams on various farms in the area. The respondent indicated that he keeps/owns 230 animals in total, comprising of sheep and goats. He pointed out that the animals are mainly used for meat

production and that they are marketed commercially, but that land users keep some animals for personal use to provide meat and milk. As in the case of the Mier and Paulshoek study areas, animals are given additional fodder all year round, which consists mainly of maize and lucerne. In drought years, land users are also assisted with livestock feed provided by the drought relieve scheme implemented by National Government.

Two separate types of rooibos tea are harvested in the Suid Bokkeveld target area i.e. wild rooibos (present in the natural environment) and cultivated rooibos (planted in croplands). Wild rooibos is harvested on a sustainable basis during the late summer months in the natural environment, while arable lands of suitable soil type are planted with cultivated rooibos. According to the respondent, rooibos tea is cultivated for six years after which it is rotated with legumes for two years.

Perceptions regarding land degradation

The respondent's perception of the degradation of rangelands (used for livestock production) mainly included trampling and a change in vegetation composition, while degradation in the croplands is mainly characterized by the removal of fertile soil. According to the respondent, wind erosion is the main contributor to land degradation in the cultivated areas, especially wind blowing from a south-east direction.

Land degradation control / Application of restoration technologies

The respondent indicated that, in the Niewoudtville area, land users have applied a variety of technologies to combat land degradation. The technologies include skills introduced by National and International incentives, such as LandCare and programs supported by GEF, World Bank and others, as well as technologies tested and implemented by land users. Passive technologies are mainly used to restore degraded rangelands and old cultivated lands, which include the resting of rangelands for at least five years to stimulate the natural succession processes. Resting has been

made possible by the National LandCare program, which provided the infrastructure and material to fence different camps and supply water reticulation in order to set up rotational grazing systems. Land users have applied the following active restoration technologies to combat degradation in the rangelands and cultivated areas:

Water erosion control

The erosion gullies have mainly been restored by filling them with rocks and natural materials originating from areas cleared for cultivation. In addition, lands have been cultivated parallel with the slope of the area.

Eradication of invader species

Programs that are supported by International agencies, such as the GEF, assisted the community to eradicate invader species (which included mostly tree species), by cutting down trees and pulling them out by means of a tractor. Mentor farmers in the community are used as facilitators during these processes, contributing to the capacity building of the land users at grassroots level.

Control of wind erosion

The erosion by wind in the established cultivated rooibos tea lands is mainly combated through the construction of wind breaks in the lands.

The respondent indicated that the idea originated from his parents who used reed strips on the edge of their vegetable garden to prevent damage caused by the wind and wild animals. Wind breaks of approximately 10 m in width are created at 30 m intervals in the rooibos tea lands. According to the respondent, the wind breaks are not made perpendicular to the direction from where the wind blows, but rather in a direction in which the wind is guided away from the cultivated strips. The buffer strips consist of a reed strip (mostly species of the Restionaceae family), with mulching on both sides of the strips to cover the soil and often seedlings that have been planted. In some cases, seed of natural species are sown in this mulched area to increase the

plant density and cover, as well as to stabilize the soil (Figure 4.15). When new rooibos tea lands are made, strips of natural vegetation are often left in the cultivated lands to serve as wind breaks and buffer zones. The latter is more advantageous, as new reed strips do not have to be planted in the cultivated areas, decreasing labour and financial inputs.

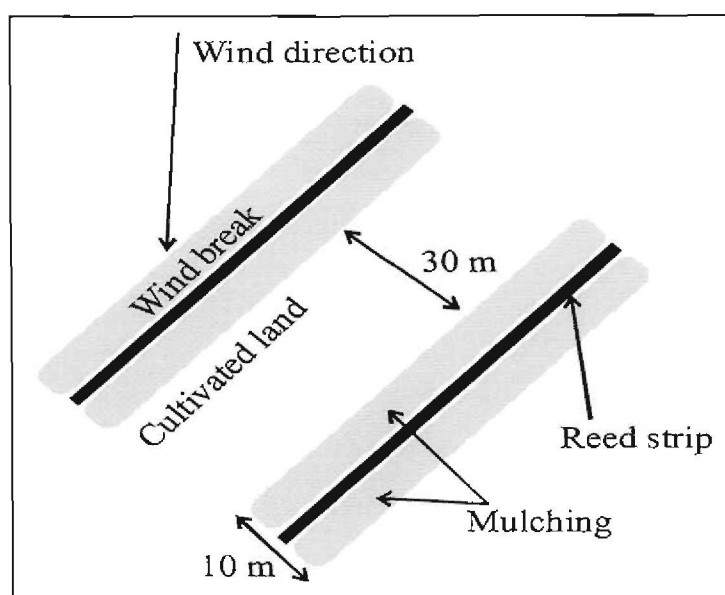


Figure 4.15 Diagrammatic representation of the technology used to construct wind breaks in rooibos tea lands to prevent wind erosion.

Figure 4.16 shows the difference between unprotected and protected rooibos tea lands. The unprotected land is much more prone to wind erosion than the one where wind breaks have been constructed. In addition, the windbreaks and mulched areas provide suitable habitats for the establishment of natural vegetation, which contributes to the protection and restoration of biodiversity in the area. The respondent feels that this technology is very successful in conserving the soil fertility in his cultivated rooibos tea lands. He however indicated that no formal monitoring and scientific evaluation of the success has been conducted. The only proof for success was that he obtained higher rooibos tea yields and less soil erosion on his lands.

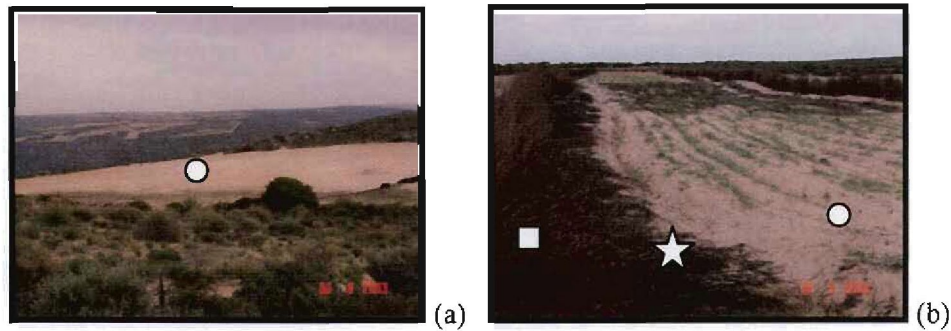


Figure 4.16 (a) Photograph of an unprotected rooibos tea land (○) in the Niewoudtville area where wind erosion occurs easily and (b) rooibos tea land with protective wind breaks (□) and mulching (☆) between cultivated lands (○). Photos taken by Klaus Kellner⁸.

4.5.4 Molopo study site

Size of land use area and length of farming experience

None of the respondents from the communal farming sector knew the total size of the communal grazing area or the number of different camps that occurred in their communal grazing area. The commercial farm sizes varied between 750 ha and 25 000 ha, which explains the large standard deviation. The average commercial farm size at the four study sites where farmers were questioned, was 4 461.6 ha (Table 4.8). All of the respondents from the commercial farming sector have been farming for ten years or longer, while the length of farming experience of the communal land users varied between six and 60 years. The average length of farming was therefore 29.8 years (Table 4.8). Ninety percent (90%) of the respondents have been farming for more than ten years, which contributed to a vast knowledge base concerning farming and management practices in the study site of the Molopo target area.

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Table 4.8 The minimum, maximum and average farm size as indicated by the respondents from the commercial sector ($n = 4$), as well as the minimum, maximum and mean (average) years which land users have been farming ($n = 10$) in the Molopo area.

	<i>n</i>	Minimum	Maximum	Average	Std. Deviation
Size of commercial farms (ha)	4	750	25 000	4 461.60	7 826.410
Length of farming experience (years)	10	6	60	29.80	17.756

Knowledge of farming

Figure 4.17 shows the way in which land users gained knowledge concerning farming practices. It is evident that 80% of land users gained knowledge and experience about farming through the information transfer by their parents. Twenty percent (20%) of the respondents, all from the commercial sector, attended agricultural colleges after finishing secondary school. One respondent from the commercial sector indicated that he had attended an agricultural high school, after which he received formal tertiary education.

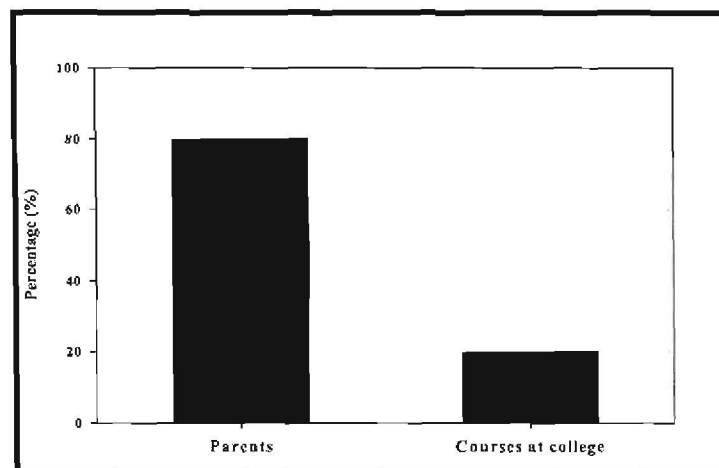


Figure 4.17 Graph indicating the way in which the respondents gained their knowledge of farming practices ($n = 10$).

Materials used from the environment

Ninety percent (90%) of respondents pointed out that they use materials from the natural environment on a daily basis (Table 4.9). The total number of respondents from the commercial sector who used materials from the environment indicated that it was mainly the collection of wood for heating and cooking. They stated that the firewood is mainly for their farm labourers and that the wood is collected and distributed once every two weeks. The land users from the communal area using materials from the natural environment indicated that it was mainly for firewood (66.6%). Wood is collected by hand and transported by hand or horse/donkey cart to the village. Respondents stated that, if the firewood is collected by hand, it is done once a day, while wood is only collected once every two weeks if a horse/donkey cart is used, as wood can then be transported from greater distances.

Table 4.9 The number of respondents from the Molopo area who use materials from the natural environment per land use group.

	Frequency	Percent (%)
Yes (Total)	9	90
Yes (Commercial)	3	33.3
Yes (Communal)	6	66.6
No (Total)	1	10
No (Commercial)	1	100
No (Communal)	0	0

Farming systems

According to the total number of land users interviewed, livestock production is the main farming practice in the Molopo study site, which is supported by the State of the Environment Report: North West Province (Mangold *et al.*, 2002). Most of the respondents (90%) kept/owned a combination of livestock species, including cattle, sheep, goats, donkeys, horses and game. One respondent, however, owned only cattle (Figure 4.18), as he is a stud-breeding farmer. Seventy percent (70%) of the respondents used a rotational grazing system, while 30% used a continuous

grazing system. Respondents from the Koganjane communal area explained that grazing camps have previously been erected by Governmental organizations, and that four of the camps are still intact. The existing camps are currently being used as part of a four-camp rotational grazing system and all members of the community adhere to this management strategy. With the exception of one respondent, all of the land users interviewed indicated that they use their livestock for a combination of products and services. Eighty percent (80%) of the land users own livestock for meat production (Figure 4.18 (a)), but also use livestock for other purposes including milk production, trophy hunting and as draught-animals (Figure 4.18 (b)).

All of the respondents, both from the commercial and communal sectors, indicated that water for their livestock is provided by man-made boreholes. Fifty percent (50%) of communal land users, however, indicated that they also have private boreholes in their yards from which they collect water for livestock during kraaling in the evenings. Even though all the respondents indicated that there is enough natural grazing for their livestock, 40% said that they use supplementary fodder when necessary. Seventy five percent (75%) of commercial land users indicated that they use planted pastures on their farms as a source of supplementary fodder, while communal land users indicated that they sometimes receive supplementary fodder in the winter months (May – August) as part of the National Government's drought relieve scheme. This often results in the fact that land users keep more animals than recommended during unfavourable conditions, which ultimately contributes to increased land degradation.

Sixty percent (60%) of the total number of respondents kept/owned fewer than 100 animals. All of respondents keeping/owning less than 100 animals were from the communal land use sector. Half of the respondents (50%) from the commercial sector owned between 101 and 500 animals, while the other half (50%) owned more than 1001 animals. It is evident that communal land users owned fewer animals than commercial land users, but no correlations and cross tabulations were possible, as land users in the communal rangeland do not own land, as well as the fact that the sizes of the communal grazing areas were not known.

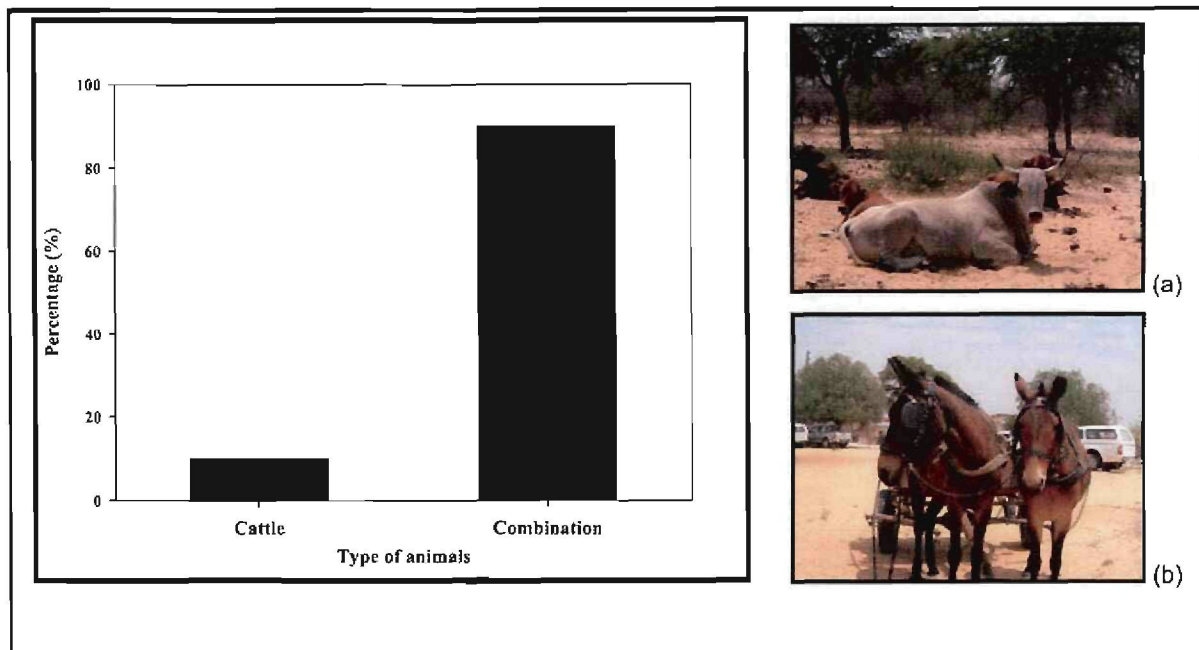


Figure 4.18 Graph indicating the proportion of various animals owned by the total number of respondents in all land use systems ($n = 10$) in the Molopo area. Figure 4.18 (a) shows cattle carcasses, while (b) shows horses which are used for transport.

Perceptions regarding land degradation

A large proportion of land users (70%) felt that erosion is a problem in their farming system (Figure 4.19). The highest proportion of respondents (40%) felt that erosion is a severe problem, while 30% felt that it is only a slight to moderate problem. All of the respondents who indicated that erosion is a severe problem are from the communal land use areas, while only one land user from the commercial sector felt that erosion is a problem on his farm. He indicated that the erosion problems occurred in his croplands and that he has implemented contour ploughing in an attempt to decrease erosion runoff. According to Blankenbicker (2005), contour ploughing is an efficient way to decrease runoff from croplands. Even though a large proportion of the respondents felt that erosion is a severe problem, only 20% have taken any measures to combat or halt the erosion. This could be a result of a lack of finances and ownership, as well as the fact

that land users often have no knowledge regarding easy and cheap technologies to prevent degradation or restore affected areas. In most of these cases land users rely on Government assistance to solve these problems.

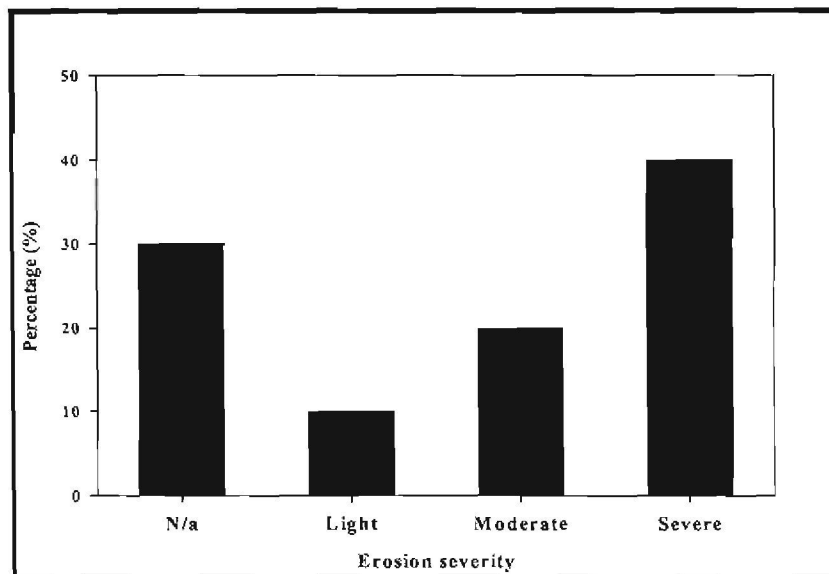


Figure 4.19 Graph indicating the erosion severity experienced by all respondents in the Molopo study site ($n = 10$).

From the interviews in the Molopo study site, it is evident that 60% of the respondents felt that a combination of factors contributed to their perception of degraded rangelands (Figure 4.20). These factors included a change in species composition, trampling, and an increase in poisonous plants as well as the presence of erosion gullies. Twenty percent (20%) of the respondents felt that degradation is only characterized by a change in species composition, while other respondents felt that a decrease in grass size or the occurrence of bare areas is characteristic of degraded areas (10% and 10%, respectively). None of the respondents indicated that an increase in invader species contributed to their perception of degradation; even though 20% of the respondents pointed out that they have eradicated invader species as part of a restoration program.

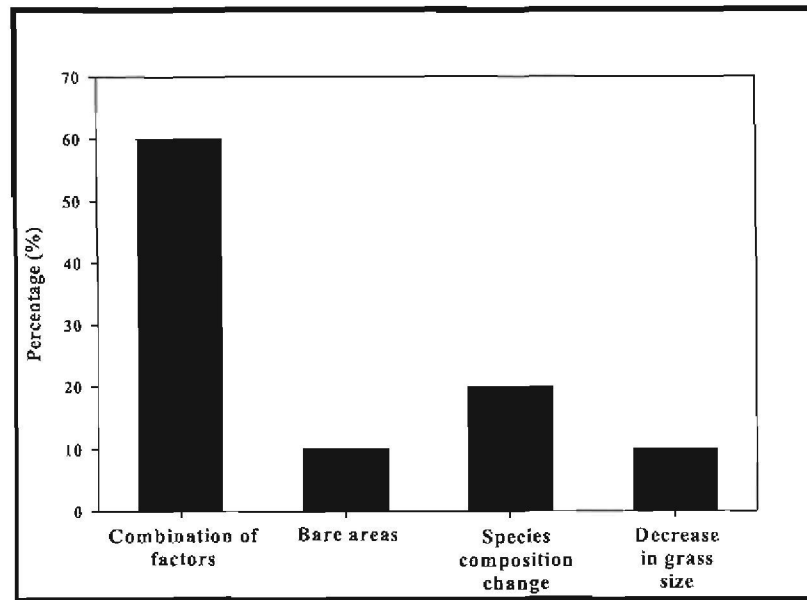


Figure 4.20 Perceptions of degradation within the commercial and communal land use system in the Molopo study site.

Land degradation control / Application of restoration technologies

When asked whether they have old croplands on their farms, 70% indicated that old croplands do occur in some areas. Only 30% of the respondents who indicated that they have old lands have taken any measures to restore these lands, while the remaining 40% pointed out that they have left the old croplands to recover through natural succession. Twenty percent (20%) of the respondents who indicated that they have taken measures to restore old croplands are currently using the old lands as planted pastures. Even though planted pastures are not recognized as a formal restoration technology, the land users felt that it contributes to an improvement in livelihoods and should be noted as a restoration technology. The species mainly used for planted pastures include *Anthephora pubescens* (Wool Grass) and *Cenchrus ciliaris* (Blue Buffalo Grass). These grasses are used for additional fodder when needed. Ten percent (10%) of land users interviewed indicated that they have fenced off the old croplands in an attempt to restore them by preventing animals to graze in these areas.

In addition to old land restoration and erosion control, 70% of the respondents indicated that they have applied restoration treatments on other areas of their farm, such as grazing lands. Thirty percent (30%) of land users from the communal sector pointed out that they only use passive restoration technologies such as rotational grazing as a management strategy. This allows parts of their rangeland to recover through resting for a season and provides an opportunity for the herbaceous vegetation to recover, set seed and contribute to the soil seed bank in the area (Dean *et al.*, 1995). All of the respondents from the commercial sector indicated that they have applied active restoration technologies on their farms. The technologies included the following:

- The broadcast sowing of seed of *A. pubescens* into the natural rangelands. No cultivation or soil loosening application was used in combination with the sowing of the seed, as these technologies are too cost intensive.
- The establishment of *Pennisetum purpureum* (Banna Grass) pastures. The Banna Grass is cut down for fresh livestock feed, as well as for supplementary fodder in the winter months.
- The eradication of invader woody species by means of manual and chemical treatments.

4.6 Conclusion

In the course of this study a total of two individuals from conservation areas, 25 commercial land users and 37 small-holder, subsistence or communal farmers were interviewed. Due to the fact that small-holder and communal land users were congregated in villages, respondents from this land use sector were more accessible than land users from the other sectors. This is why a large percentage of this sector was interviewed. As a result of the fact that the four study sites varied in climatic and vegetation conditions, the number and types of livestock kept/owned differed at the different sites. Land users in the Mier and Paulshoek study sites mainly kept/owned sheep and goats, while land users in the Molopo study site mostly kept/owned cattle. This is explained by the fact that the vegetation composition and structure differed at the three sites. The savanna vegetation in the Kalahari and the Nama-Karoo vegetation in the Namaqualand are more suited for small-stock production, while the savanna vegetation in the Molopo is more suited to keep large-stock and game. Although the respondent from Niewoudtville indicated that he kept/owned livestock, their farming activities are mainly focused on rooibos tea cultivation.

The aims of this chapter were to highlight and summarize some of the perceptions of degradation and restoration technologies used by land users in the three different land use systems to halt or reverse land degradation, improve livelihoods and address poverty related issues. The parameters that were addressed during the study included the size of land use areas, length of farming experience, materials used from the environment, farming systems (including livestock numbers and use) and access and type of water sources. The various issues and perceptions regarding land degradation and restoration technologies were also investigated during this study. These issues will be discussed individually in the rest of this chapter.

- **Size of land use area**

No comparison has been made between the size of conservation areas, farms and communal grazing areas within the four study sites due to the fact that not all the different land use systems were represented in each experimental sample from each site. In addition, no size comparisons have been made due to the fact that the climate and vegetation differ at all the study sites, which contribute to differences in the size of economic units in each area. Even though no direct comparisons have been made between the sizes of the land use areas, it is evident that, on average, the conservation areas were the largest, while small-holder farms were the smallest. The minimum and maximum size of conservation areas were 15 000ha and 73 619 ha, respectively, while the minimum and maximum farm size for commercial farms were 750 ha and 46 133ha. The minimum size of all the small-holder farms was 1 903 ha and the maximum 2 983 ha. Communal land users were excluded from this part of the study, as no communal land user owned land and mostly used the commons for grazing.

- **Length of farming experience**

Considering the length of farming for interviewed respondents from all four study sites, it is evident that the land users taking part in farming practices have a very good knowledge of these systems. This could be ascribed to the fact that the majority of interviewed land users have been

farming for ten years or longer (Average – 24.5 years). This knowledge has, in general, been transferred from generation to generation with the exception of some land users who have gained knowledge from tertiary academic institutions or other sources, such as working as labourers on commercial farms. The total number of the respondents who indicated that they had the opportunity to gain knowledge through tertiary academic education were from the commercial and conservation sectors. Even though most of their farming knowledge was passed on from their parents, the majority of the land users felt that trial and error experiences contributed to the way that they are currently managing the natural resources on their farms.

- **Materials used from the environment**

The majority of land users interviewed in all four study sites indicated that they use materials from the natural environment on a regular basis (80%). It is, however, clear that land users from the communal and small-holder sectors are more dependent on the materials from the environment for subsistence living on a daily basis (68%). Land users indicated that firewood, which is mainly used for cooking and heating, is the material most commonly collected. Firewood is carried by hand if it is collected on a daily basis, but a horse or donkey cart is used if firewood is collected once a month or if the collection is done further away from the village. Land users also indicated that if they use a horse or donkey cart, firewood is collected further away from villages contributing to the depletion of natural resources in those areas. Two commercial land users indicated that they use vehicles to collect firewood, after which they distribute it to their farm labourers. Other materials collected include reeds, sand for building and medicinal plants, but respondents pointed out that these materials are only collected when necessary. In the Paulshoek and Suid Bokkeveld study areas, some respondents indicated that natural materials are still extensively used for the construction of homes and shelters ('kookskerms'). Generally land users from rural areas are aware that the collection and use of materials from the environment could lead to degradation, they have no other choice as this is their only source for survival.

- **Farming systems and animal types**

In the Mier, Paulshoek and Molopo study sites, livestock production (large- and small stock is the main farming activity, while rooibos tea (*Aspalathus linearis*) cultivation is the primary farming activity carried out by land users in the Niewoudtville area. Due to the differences in climate and vegetation conditions between the four study sites, a large variety of animal species was recorded during the surveys. In addition to the variety of animals, there were also differences in the number of animals per species kept/owned by land users. These differences are mainly ascribed to commercial and communal farming practices. The species included games species, such as gemsbok, zebra and springbok, mostly occurring in the conservation areas and on some commercial farms in all of the study sites. Cattle, sheep and goats were mainly used for commercial meat production, but were also used for meat and milk production for personal use. Species such as horses and donkeys were mostly kept for transport purposes. In general, communal and small-holder land users owned less than 500 animals, while commercial land users owned between 500 and 15 000 animals.

Conservation areas use a continuous grazing system, while commercial and some small-holder land users use a rotational grazing system. In communal rangelands, land users use various grazing management strategies. In most cases, animals graze continuously during the day, but are kraaled during the night. In the Koganjane communal area, some camps still exist and farmers use a rotational grazing system, while land users in the Namaqualand are using herding to ensure that their livestock make maximum use of the vegetation in the natural rangelands.

- **Amount and type of water sources**

It is evident that the majority of land users from all land use systems (92%) have access to watering points (natural and man-made) including dams, boreholes and wells, as surface water is limited in these arid and semi-arid regions. Respondents indicated that ground water is the major source of water in all the study areas. The remaining eight percent (8%) who responded that they did not have access to water sources were from the Buffelsrivier communal area. These land

users indicated that watering points (boreholes) were present in the commons, but they are not functioning as a result of a lack of maintenance. Land users from these areas indicated that even if they wanted to repair or maintain boreholes, they do not have the financial resources to do it. Fifty percent (50%) of the respondents from the Molopo study site indicated that they make use of private boreholes near their homesteads to provide water for livestock during kraaling.

Natural water sources in the study sites mainly consist of ephemeral rivers and streams and, in the Paulshoek study site, land users indicated that water is collected in hollows in rocks during the rainy season. In the Suid Bokkeveld study site, the LandCare program has provided assistance to erect water tanks and build earthen dams on various farms in the area, in addition to the existing boreholes and dams.

- **Perceptions regarding land degradation**

Even though, according to this evaluation, land users are aware of land degradation in their specific areas, several respondents stated that this phenomenon is basically caused by drought and size of the grazing area being inadequate for livestock grazing. A large proportion of interviewed land users indicated that land degradation is characterized by a change in herbaceous species composition and an increase in unwanted and poisonous species (44%). In addition to a change in herbaceous species composition, some land users also evaluate the condition of their land by looking at the structure of individual grass species. The shorter the grass, the higher the grazing pressure and, in their view, the more degraded. Individuals from all land use sectors (45%) pointed out that the presence of bare areas is an indication of land degradation. Communal land users, who depend on natural resources for sustaining their daily livelihoods, have slightly different perceptions about degradation than commercial farmers. They indicated that the condition of their livestock is the most important factor contributing to their perception of degradation of natural rangelands. If there is no fodder available, their animals would be in a poor condition and vice versa.

In the commercial sector, land users from all four study sites felt that erosion is not a problem, while most of the communal and small-holder land users felt that both wind and water erosion is a severe problem (58%). None of the land users from the Mier study site indicated that water erosion is a problem on their farms due to the environmental conditions, such as a very low precipitation in the more arid areas.

None of the land users from the Mier study site indicated that they have old croplands on their farms. This is ascribed to the environmental conditions in the area, which limits cropping activities, such as low precipitation and very deep, sandy soils with little moisture holding capacity. In the Paulshoek and Molopo study sites, most of the land users indicated that there are many old croplands on their farms and in the grazing areas (68%), since cropping is no longer sustainable in these areas due to high inputs costs and erratic climatic conditions.

- **Land degradation control / Application of restoration technologies**

Even though the majority of land users from all four study sites indicated that land degradation is a problem, fewer than half of the interviewed land users have applied restoration technologies (41.9%). The results of this investigation indicated that 25.4% of the respondents from the commercial sector of all four target areas have applied some restoration technologies, while only 16.5% of respondents from the communal sector have applied any land degradation control procedures. Resting is the technology most commonly used by land users, as it is also the most cost effective, especially when supported by National and International programs. This is carried out through the implementation of a rotational grazing system, allowing pieces of land to rest for certain lengths of time. It is evident that commercial and small-holder land users have applied more active restoration treatments than communal land users, which can be ascribed to the fact that commercial farmers generally have more resources (mainly financial) to use for the testing of restoration treatments. The active restoration technologies applied by commercial and small-holder land users include the following:

- The eradication of invader woody and alien plant species.

- The sowing of seed of perennial herbaceous species into natural rangelands (without cultivation).
- The establishment of planted pastures (herbaceous and other species).

The fact that some of the land users effectively used over-sowing of herbaceous species as a restoration technology to increase the vegetation cover, density, biomass and biodiversity, identified the need for an experiment to test a grass species to be used in similar technologies in the arid- and semi-arid areas in South Africa. As *Cenchrus ciliaris* has been used successfully in various restoration technologies all over the world, and the fact that it is commercially available, it was a suitable species to be used in the drought stress experiment (Chapter 6).

Forty-two percent (42%) of land users from all the target areas indicated that they have applied erosion control measures. The applied control measures mostly included active technologies, such as the creation of stone walls in gullies, contour ploughing and the filling of gullies with woody species and waste material (old tyres). In the Suid Bokkeveld, large-scale wind erosion control measures have been implemented by small-holder land users, while some small-scale measures have been taken by individual land users in the commercial and communal sectors. In all of the cases where land users have applied erosion control measures they felt that they were successful.

The majority of the commercial land users indicated that they have converted the old lands to planted pastures, which are used as supplementary fodder when needed. In most of the cases, farmers have used *Cenchrus ciliaris* grass for the planted pastures. This emphasizes the importance of this species and the need for a better understanding of the effect of drought conditions on the germination and establishment of this species. Most of the land users from the communal sector indicated that the old lands have been left to recover through natural succession processes. In the Suid Bokkeveld, old lands are restored by creating wind barriers, with species from the Restionaceae family, including mulch strips to protect the bare soil. The restoration practice is usually enhanced by the sowing of seed of natural vegetation in the mulch layer.

From this study it is evident that land users' perceptions concerning the degradation of natural resources differ and that people implement various coping strategies to overcome difficult times, especially during periods of drought. Peet & Watts (1993) and Dejene *et al.* (1997) found that peoples' perceptions of environmental hazards are generally structured by existing socio-economic arrangements and these perceptions have important implications for decision-making in land restoration. In this study it seems that land users apply technologies according to the symptoms of the degradation problems (i.e. what can be done) rather the cause of the problem (i.e. what needs to be done). If problems are articulated in terms of the causes of degradation, land users might find innovative technologies to solve these problems.

It is also clear that the difference in land tenure and ownership is probably the determinant factor why people approach the restoration of degraded rangelands differently. In addition, the availability of water also plays an important role in decisions concerning grazing strategies. From the results of this study, it is clear that land tenure i.e. commercial and communal, is one of the major factors influencing the approach land users have towards restoration of natural rangelands, as well as the practices land users apply to combat degradation. In most of the cases, the results show that land users from the commercial sector apply restoration practices on a large-scale, as they feel they will benefit in the long run.

CHAPTER 5

Technologies for conservation, restoration and livelihood improvement in DMP partner countries

(Chapter 5 supplemented with booklet – Appendix C - Restoration, Conservation and Alternative livelihoods: Technologies in selected countries in Africa. Desert Margins Program (DMP). South Africa)

5.1 Introduction

In Africa, where two thirds of the population are dependent on natural resources for their livelihood and subsistence, agriculture and pastoralism form the backbone of the economy (Macdonald & Richardson, 1989; Drechsel *et al.*, 2005; Scoones *et al.*, 2005). Most of Africa's poor communities are rural, and most people in these areas rely largely on natural resources for their livelihoods. According to Harrison (1987), 66% of all holdings in rural parts of Africa are smaller than 2 ha, while Ker (1995) suggests that nearly 96% cover less than 10 ha. People living in subsistence economies in these rural areas are faced with few alternatives to depleting their natural resources to survive. The most immediate and frequent consequence of these survival strategies is the increased over-exploitation of accessible natural resources such as land, water and natural pastures.

The total area in Africa affected by the over-exploitation and degradation of natural resources is between 6 million and 12 million square kilometres (MA, 2005). The direct and most severe impact of land degradation and desertification in Africa is food insecurity that may ultimately result in famine (UNEP, 2005). Land users have traditionally satisfied increasing demand for food by ploughing new or marginal land, but opportunities for expansion are limited. Throughout Africa, thousands of hectares of forests and woodlands disappear yearly due to clearance for new croplands. Furthermore, small-holder land users have little or virtually no access to credit to purchase products, such as fertilizers and improved seeds, resulting in severe soil degradation in the dryland areas of Africa (Drechsel *et al.*, 2005; Amsalu & De Graaff, 2006). Various coping strategies have been developed to mitigate soil erosion problems, which include Soil-Water-Conservation (SWC) measures (Scoones *et al.*, 1996; Okoba & Sterk, 2006). Soil-Water-Conservation is defined as activities at the local

level which maintain or enhance the productive capacity of the soil in erosion prone areas through: prevention or reduction of erosion, conservation of soil moisture, and the maintenance or improvement of soil fertility (Van Lynden *et al.*, 2006).

In addition to SWC technologies, Integrated Soil Fertility Management (ISFM) was introduced in sub-Saharan Africa to improve soil fertility. Integrated Soil Fertility Management (ISFM) is a holistic approach to soil fertility research that embraces the full range of driving factors and consequences of soil degradation, namely biological, physical, chemical, social, cultural, economic and political factors. ISFM aims to replenish soil nutrient pools, maximize on-farm recycling of nutrients, reduce nutrient losses to the environment and improve the efficiency of external inputs. There is a strong emphasis in ISFM-research in understanding and seeking to manage the processes that contribute to changes in soil fertility (Hilhorst & Toulmin, 2000). Various ISFM-approaches and technologies have been documented and disseminated through the WOCAT initiative to improve decision-making and land management (See Chapter 3.2.3.1).

Besides soil degradation, large areas of natural woodlands and rangelands are degrading due to overgrazing and the excessive cutting of wood (See Chapter 2.1.3.4). Over the last 20 years, about 300 million hectares of forest have been converted to other land uses, such as croplands and pastures. Human activities, exacerbated by poverty and population pressures on the one hand and human greed on the other, are by far the dominant causal factors in forest degradation (ITTO, 2002). Most of the wood harvested within Africa's forests and woodlands is used to meet local energy needs (The Global Change Game, 2000). Non-timber forest products, including bark, tubers, leaves, flowers, seeds, fruits, resins, honey, fungi and animal products play an important role in the households of the urban poor and forest-dwelling communities. They are used as medicines, tools and building materials and for food, primarily within local villages and households. If properly managed, restored or rehabilitated, degraded and secondary forests have the potential to generate significant environmental and livelihood benefits.

Pastoral systems, where livestock is an integral part of the agricultural system, are found across large areas of the arid and semi-arid regions of Africa. In Africa, the following four main types of pastoral systems are practiced in arid and semi-arid rangelands:

- The nomadic/transhumant pastoral system;
- The sedentary livestock grazing system;
- Cattle and sheep ranching; and
- Wildlife (game farming).

Through generations, people and communities have adapted to different ecological conditions, especially in the large dryland areas throughout the continent (UNEP, 1999). Rangeland managers, scientists, conservationists and other land users are applying a variety of conservation and restoration technologies over different periods of time and at various environmental conditions in order to combat or halt the process of land degradation and desertification. In the past, research has tried to assist land users through technologies tested in research stations and ‘on-farm’ experimentation, but in most cases these technologies have not been adopted by the land users. According to Drechsel *et al.* (2005), common management and restoration practices are subdivided into the following categories with regard to their origin:

Traditional practices – Individuals and rural communities have a strong knowledge of their environments and how to manage it according to their cultural tradition and objectives.

Exogenous practices – Practices mainly introduced through national and international agricultural institutions, NGO’s and individual initiatives.

Improved practices – Originating both from traditional and exogenous practices as a result of research activities or intensive modification by land users.

Over time, land users have accumulated knowledge and experience based on what they see works well for their own situation by means of innovation, experimentation and adaptation. These technologies have mostly been applied on a trial-and-error basis, which is often not documented or quantitatively assessed.

Due to the fact that few comparative studies have been carried out with regard to land degradation and restoration activities in Africa, this study has been initialized in the nine DMP partner countries. As described in Chapter 1.2, some of the broader objectives valid for this part of the study of the Desert Margins Program (DMP) include the following:

- A better understanding of the causes, severity and physical processes of land degradation in traditional crop, tree and livestock production systems, including the relationship between natural and human factors.
- The documentation and evaluation of current initiatives and technologies concerning soil, water, nutrient, vegetation and livestock management practices for arresting land degradation.

In accordance with the broader objectives of the DMP, the following objectives were therefore identified for this study.

- To document approaches and legislation regarding the restoration of degraded natural resources in the DMP partner countries.
- To identify, document and characterize the best-bet technologies, including traditional methods for restoring and conserving biodiversity in the identified DMP partner countries. The detailed description of all the technologies encountered during this study is given in Appendix C – Restoration, Conservation and Alternative livelihoods: Technologies in selected countries in Africa. It is however known that many more technologies exist in these African countries, but only technologies that have been encountered during the investigation for this study are described.
- To communicate results of different technologies to DMP partners and scientific organizations in order to enhance the adoption of restoration technologies in the identified DMP partner countries.

5.2 Study areas

The nine countries involved in this study included the following: West African (WA) region - Burkina Faso, Mali, Niger and Senegal: South and East African (SEA) region - Botswana, Kenya, Namibia, South Africa and Zimbabwe (See Chapter 1.2 for a detailed description of the DMP). The nine participating countries are currently administered regionally and will therefore be discussed in the same way, namely in the WA and SEA regions (Figure 5.1). The approach used in the DMP project was to select benchmark sites in each of the nine participating countries. These sites would serve as field laboratories for demonstrations and

research activities related to monitoring and assessment of biodiversity status, testing of most promising natural resource management options, developing sustainable alternative livelihoods and policy guidelines (Koala & Tabo, 2004). This study will mainly be focusing on the DMP benchmark sites within each of the participating countries, with inputs from various individuals involved in the DMP project.

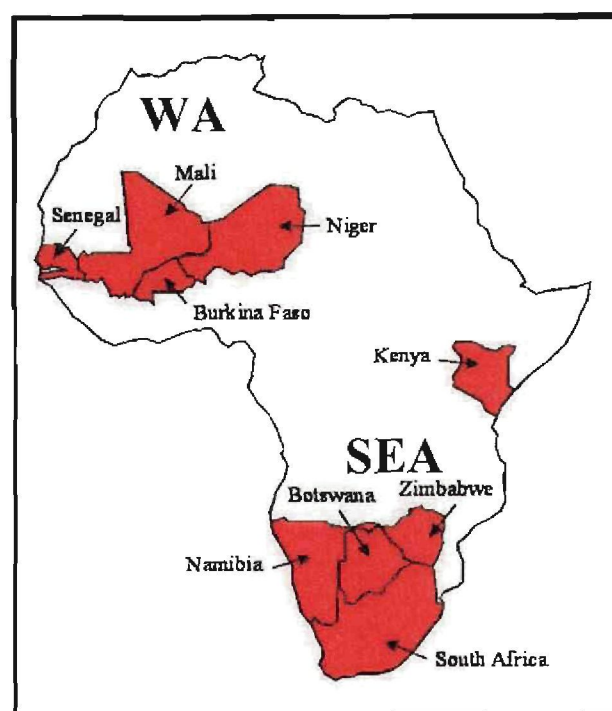


Figure 5.1 Map of Africa with countries involved in the Desert Margins Program countries (South, East and West African countries) indicated in red.

In the following section a brief description of the DMP partner countries in SEA and WA will be given, after which improved livelihood strategies such as conservation, restoration and alternative livelihoods will be discussed in the results and discussion section.

5.2.1 West African (WA) region

5.2.1.1 Burkina Faso

Burkina Faso lies to the west of the continent and forms part of the landlocked West African region. Burkina Faso is bordered by Mali to the north, Niger to the east, Benin to the south-

east, Togo and Ghana to the south, and Côte d'Ivoire to the south-west (Figure 5.1). The total land area of Burkina Faso is 274 200 km² with a population density of 51 people/km² (<http://news.bbc.co.uk>). The population of Burkina Faso is approximately 13.9 million inhabitants with an estimated growth rate of 3% in 2006. Located on the southern fringes of the Sahara Desert, the country is mostly a wide, flat plain with higher lying land in the west and far south-east. Three main rivers cut through the country i.e. Black, Red and White Volta. Burkina Faso has a primarily tropical climate with two very distinct seasons: the rainy season and the dry season. The rainy season lasts approximately 4 months, May/June to September, but is shorter in the north of the country. Over 80% of the population of Burkina Faso is engaged in subsistence agriculture and nomadic livestock keeping. The main export products from Burkina Faso include cotton, animal products and gold.

5.2.1.2 Mali

Mali is a landlocked country consisting of vast flat plains fed by two major rivers, the Senegal on its western edge and the great Niger River flowing through the center of the country (Figure 5.1). It borders Algeria to the north, Niger to the east, Burkina Faso and the Côte d'Ivoire to the south, Guinea to the south-west, and Senegal and Mauritania to the west. The central part of the country is arid grazing land, called the Sahel, while the north of the country is true desert with the exception of a few oases. The total land area of Mali is 1.25 million km² with a population density of 9.6 people/km². The total population is 11.7 million with an estimated growth rate of 2.63% in 2006 (<http://news.bbc.co.uk>). Mali has a subtropical to arid climate. Agriculture forms 44% of the GDP of the country and the agricultural products produced include millet, cotton, groundnuts, rice, sugarcane, vegetables and maize. The main export products from Mali are cotton, gold and livestock.

5.2.1.3 Niger

The total land area of Niger is 1.27 million km² with a population density of 9.9 people/km². The total population is 12.5 million people with a growth rate of 2.92% in 2006 (<http://news.bbc.co.uk>). Niger is a land-locked country bordered by Nigeria and Benin to the

south, Burkina Faso and Mali to the west, Algeria and Libya to the north and Chad to the east. The Niger River in the south-west flows through an area which is considered the country's only fertile area. The rest of the country is classified as being semi-arid. Niger's agriculture and livestock sectors are the mainstay of 80% of the population, with millet, sorghum and cassava being Niger's principle rain-fed subsistence crops. Niger mainly has a dry climate with considerable temperature ranges. The rainy season stretches from June until September. The terrain is predominantly desert plains and sand dunes, with flat rolling savanna in the south and hills in the north. The main exports from Niger include uranium and livestock products.

5.2.1.4 Senegal

The total land area of Senegal is 196 722 km² with a population density of 62 people/km² (<http://news.bbc.co.uk>), which is the highest of all DMP countries (Figure 5.1). Senegal is bounded by the Atlantic Ocean to the west, Mauritania to the north, Mali to the east, and Guinea and Guinea-Bissau to the south. Gambia lies almost entirely within Senegal, surrounded to the north, east and south; from its western coast. Temperatures are high throughout the year and annual rainfall is almost entirely limited to the summer wet season, which lasts up to six months in the south and decreases to three months in the north. There are four major rivers which flow west into the Atlantic – The Senegal, Saloum, Gambia and Casamance.

The population of Senegal is estimated at 11.9 million with an estimated annual growth rate of 2.34%. About 61% of the population is rural with about 70% of the population employed in agriculture. The distribution and kinds of crops are closely tied to the amount, distribution and timing of rainfall. Rain-fed (dryland) cultivation consists of cash crops dominated by ground nuts and subsistence crops dominated by millet and sorghum. The main export products from Senegal include fish, peanuts, petroleum products, phosphates and cotton.

5.2.2 South and East African (SEA) region

5.2.2.1 Kenya

The total land area of Kenya is 582 646 km² with a population density of 61 people/km² (<http://news.bbc.co.uk>). The country borders with Ethiopia to the north, Sudan to the north-west, Uganda to the west, Tanzania to the south and Somalia to the north-east (Figure 5.1). To the east lies the Indian Ocean. The country is divided into four regions: the arid deserts of the north, the savanna lands of the south, the fertile lowlands along the coast and the shores of Lake Victoria; and the highlands in the west. The population of Kenya is approximately 34.7 million with an estimated growth rate of 2.57% in 2006. There are two primary rainy seasons: the long rains roughly from April to June and the short rains during October and November. The lowlands are hot but mainly dry, while the highlands are more temperate with four seasons. Agriculture makes up 19.3% of the GDP of the country with agricultural products such as maize, millet, cassava, beans, tea, coffee, sugar, cattle, sisal, cut flowers and hides. The main export products from Kenya include tea, coffee, horticultural and petroleum products.

5.2.2.2 Botswana

The total land area of Botswana is 581 730 km² with a population density of 2.8 people/ km² (<http://news.bbc.co.uk>). The total population of Botswana is 1.6 million people with an estimated growth rate of -0.04% in 2006. Botswana is bordered by South Africa to the south, Namibia to the west and north-west and Zimbabwe to the east (Figure 5.1). There are two main river systems feeding Botswana, one is the Okavango and the other the Chobe River. Much of the country is covered with the thick sand layers of the Kalahari Desert. The climate is semi-arid with warm winters and hot summers. The climate in the eastern parts, where most people live, is mild with more fertile soils. Rainfall is low, erratic and unevenly distributed. Livestock remains the focus of the traditional and modern agricultural sector, with four fifths or more of the population remaining dependent on these activities. The main export products from the country include diamonds, copper, nickel and beef.

5.2.2.3 Namibia

The total land cover of Namibia is 824 290 km² with a population density of 2.5 people/km² (<http://news.bbc.co.uk>), which is the lowest of all the DMP partner countries. The population of Namibia is 2 million with an estimated annual growth rate of 0.59%. Namibia is a large and mainly arid country sharing borders with Angola to the north, Botswana to the east, South Africa to the south and, in the Caprivi Strip, a narrow handle of Namibian territory jutting from the north-east corner of the country, with Zambia and Zimbabwe (Figure 5.1). To the west lies the most desolate and lonely coastline in the world, namely the Namib Desert. Along its entire length, the vast shifting sand dunes of the Namib Desert spread inland. In the interior, the escarpment of a north-south plateau slopes away to the east into the vast interior sand Basin of the Kalahari. In the far north-west, the Kaokoland Mountains run along the coast, while further inland lie the Etosha Pan (a dried-out saline lake), surrounded by grasslands and bush, which support a large and varied wildlife. The climate is arid with a usually brief rainy season between October and March. The major industries and export products in the country include the following: mining, meat packing, fish processing, dairy products and livestock.

5.2.2.4 South Africa

The total land area of South Africa is 1.22 million km² with a population density of 36 people/km² (<http://news.bbc.co.uk>). The total population is 44 million people with an estimated annual growth rate 0.4%. South Africa is situated at the most southern tip of the African continent and is bordered by Namibia, Botswana, Zimbabwe and Mozambique to the north and the Indian and Atlantic Oceans to the east, west and south (Figure 5.1). The country has a great variety of climate zones, from the extreme desert of the southern Namib in the farthest north-west to the lush subtropical climate in the east. South Africa has a large agricultural sector, but even though this sector is well developed, people in rural areas still depend on subsistence agriculture. The main export products include gold, diamonds, metals and minerals, cars, machinery and fresh produce.

5.2.2.5 Zimbabwe

Zimbabwe is a land-locked country which is bordered to the north by Zambia, to the east by Botswana, to the west by Mozambique and to the south by South Africa. The Limpopo and Zambezi rivers form borders in the south and the north, respectively (Figure 5.1). The total land area of Zimbabwe is 390 759 km² with a total population of 12.9 million people. The estimated annual growth rate of the country is 0.62%. The population density of Zimbabwe is 33.01 people/km² (<http://news.bbc.co.uk>). The climate is subtropical due to the high altitude of the central plateau, resulting in the lowlands being warm and dry, while the mountainous regions are wetter. Zimbabwe has one very short rainy season (November to March), which is characterized by heavy storms. Agriculture and livestock production remains the backbone of Zimbabwe's economy and contributes 16% of the country's GDP. The main export products include tobacco, cotton, agricultural products, gold and minerals.

5.3 Materials and methods

The impact of land degradation and restoration on the natural environment, the impact of socio-economic and legislative factors, as well as participatory research efforts were investigated in some selected areas in the nine countries discussed. In each country, meetings were held with the National DMP coordinator as well as other DMP project participants. One or more of the DMP target sites in each country were also visited. At each site, visual and photographic records were made of various livelihood improvement technologies, including restoration and conservation strategies.

Questionnaires and interviews were used to assess the implementation of conservation and restoration practices in each DMP partner country (Appendix B). The questionnaire was developed using similar procedures as for the questionnaire used in the South African DMP target areas. The questions however differed as only the DMP coordinator and other DMP project participants were interviewed in each of the DMP partner countries, while interviews were conducted with land users in the South African DMP target areas. In order to obtain as much information as possible, the DMP partner country questionnaire was subdivided into the following categories concerning the above-mentioned issues:

- Legislation and policy.

- Land degradation.
- Restoration.
- Participation.
- Methodologies to combat land degradation.

The **legislation and policy** category contained questions dealing with international and national legislation pertaining to degradation, restoration and conservation in each country. Also included were questions about the country's collaboration and involvement in international conventions. Questions were included to inquire about other organizations (private or government) involved in the combating of degradation and the application of restoration and conservation strategies.

The **land degradation** category included questions dealing with perceptions of land degradation, causes of degradation, as well as the different types of degradation occurring in the country. People interviewed were also asked which land user group or sector was mostly affected by the degradation of natural resources.

The **restoration** category comprised of questions about existing national and regional programs in the country which promote the restoration of degraded natural resources, as well as the overall goal of restoration. This category also dealt with the extent to which social, economic and natural (bio-physical) factors are taken into consideration when planning and executing restoration projects.

The **participation** category contained questions about the individuals and institutions involved in approaches to combat land degradation and the execution of such practices and technologies. Factors such as the adoption rate of technologies, capacity building and knowledge transfer were also addressed in this category.

The **methodologies** category dealt with specific technologies in each country, and especially within the DMP program implemented to combat land degradation. Results from this category were included in a booklet entitled: Restoration, conservation and alternative livelihoods: Technologies in selected countries in Africa (Appendix C).

5.4 Results and discussion

5.4.1 West African (WA) region

Land users in the West African region implementing the traditional crop-tree-livestock farming systems struggle with a range of problems. These include frequent droughts, nutrient poor soil, lack of credit and finances, limited access to new technologies and undeveloped markets. Various international, national and local initiatives and activities have been implemented to improve livelihoods in these countries. The following sections give a more detailed description of some of the approaches and technologies applied in the West African DMP Region to combat the effect of land degradation and improve livelihoods.

5.4.1.1 Burkina Faso

Many international and national institutions are stakeholders in the management of natural resources in Burkina Faso. At an international level, various donors and research and development institutions are involved in environmental programs and projects, while ministerial departments, with their various decentralized agencies, are involved on national level. In addition, many integrated rural development and non-governmental organizations (NGOs) are involved in projects concerned with the conservation of natural resources. These projects are effective to a limited extent, as only a small number of land users are usually involved in each project.

The sustainable management of species and populations has always been a concern in Burkina Faso. In order to attain these objectives, legislative and regulatory measures have been taken to improve environmental conservation. The legislature uses policies and regulations covering all the aspects of environmental protection and promotion. In a specific way, these legal provisions apply to land, forestry, wildlife, fishery, water, agricultural and livestock systems. The following are the most important policies and regulations pertaining to the conservation of natural resources in the country:

- *The Constitution of Burkina Faso* accords a special importance to the protection and management of the environment.

- *Agrarian and Land Reform.*
- *Environment Code.*
- *Forestry Code.*
- *Mining Code.*
- *Water Code.*
- *Pastoral Code.*
- Signature and ratification of many international treaties, conventions and agreements concerning the management of natural resources.
- Traditional and customary regulations (traditional hunting and fishing, sacred woods, taboos).

The customary land system is almost the same everywhere in Burkina Faso. It is based on the collective ownership of land. The collective ownership of land is exercised by the village chief or headman. The chief or headman distributes land or he authorizes land use in accordance with the village or community needs. Therefore, individuals in the village or community acquire a user right, which must not be mistaken for ownership right. However, after the death of the applicant, his heirs will settle and exploit the same land without the chief or headman intervening.

Degradation in Burkina Faso is caused by a decrease in the amount of rainfall received, as well as increased human pressures on the natural resources (Gray, 1999; Mazzucato & Niemeijer, 2001; FAO, 2002). It is, however, felt that land degradation has stabilized over the last five years as people are becoming more concerned about the environment. Degradation influences all types of land users and is typified by a decrease in woody vegetation as well as an increase in soil erosion. Soil fertility is not restored and the penning of animals at night, after harvests, constitutes the main form of soil fertilization in croplands. The inputs of chemical fertilizers are negligible.

In an attempt to combat soil erosion, the Zai planting technology has been developed (World Bank, 2005). The Zai is an improved traditional technology in which holes are dug during the dry season and filled with compost and manure. The holes extend favourable conditions for

infiltration, which will contribute to an increase in crop yields if correctly managed (See Figure 5.4 (b) for a photographic representation of the Zai planting technology).

To counter deforestation, large-scale forestry and agro-forestry initiatives are being implemented throughout the country (EarthTrends, 2003a). Re-forestation and agro-forestry programs help to restore degraded ecosystems, prevent the loss of biodiversity and contribute to poverty alleviation. This is done by planting trees such as *Acacia senegal* (Gum Arabic Tree), which can be used by both humans and animals after short periods of time, due to the fast growing potential of this tree (Raddad & Luukkanen, 2007). These re-forestation initiatives involve all stakeholders throughout the planning, implementation and evaluation phases. Funding for restoration efforts are provided from international organizations with co-funding from the Government, while land users and extension services are more involved in technical support. Restoration is mainly introduced to land users and farmers by using demonstration sites and people are capacitated in restoration and conservation issues through physical training sessions at agricultural centres as well as ‘on-farm’ research sites.

Even though soil erosion control, soil fertility increase and re-forestation are the most important restoration and conservation practices applied in Burkina Faso, the following technologies have also been applied in the country (see Appendix C for detailed description of each technology):

Restoration

- The establishments of tree seedling nurseries to provide seedlings for restoration efforts.
- Planting of tree seedlings of various multi-purpose species, which provide fuel, fodder and fruits.
- Half moons to increase water infiltration and prevent soil erosion (Figure 5.2 (a)).
- The creation of stone walls to decrease water runoff and erosion (Figure 5.2 (b)).
- Micro-dosing to increase soil fertility and minimize the amount of water used.

Conservation

- The Zai planting technology to improve soil fertility and increase crop yields.
- The use of Rural Wood Markets to harvest natural fuel wood resources in a sustainable way (Figure 5.2 (c)).



Figure 5.2 (a) Half moons to increase water infiltration, (b) stone walls to decrease runoff and erosion and (c) Rural Wood Markets to ensure sustainable fuel wood harvesting used in Burkina Faso.

In most cases, land users and farmers are involved in restoration efforts as this contributes to the improvement in their livelihoods, but if the technical and financial inputs necessary to do restoration are too high, technologies are not adopted. Only if restoration techniques are small and involve very little technical and financial inputs, such as the Zai planting technology, it will readily be adopted by land users. Technologies introduced by donor and funding organizations are usually not sustainable over the long-term as land users do not adopt these technologies. Generally, land users cease to implement the introduced technologies once the funding ends, as the individual inputs then become too much.

5.4.1.2 Mali

In Mali, where arid and hyper-arid areas comprise more than half of the country, it is perceived that the degradation of natural resources is mainly attributed to a decrease in the amount of rainfall received over the past decade, as well as an increase in the length of the dry season. Many authors have attributed soil erosion and vegetation degradation to negative rainfall trends and frequent droughts (Charney *et al.*, 1975; Stancioff *et al.*, 1986; Helldén, 1988; Gonzalez, 2001). The increase in the length of the dry season (mid October – mid April) has caused an increase in the utilization of the natural resources, which led to a decrease in vegetation cover and soil water content. Degradation in Mali is mostly characterized by desert encroachment in the northern parts of the country, vegetation loss (woody and herbaceous), soil and wind erosion, as well as soil compaction and crusting (Berry *et al.*, 2003).

The Ministry of Agriculture, Livestock and Fisheries, through the Institut d'Economie Rurale (IER) and other partners, including a number of NGOs, are involved in awareness raising and capacity building programs concerned with the sustainable use of natural resources in villages. Most of these efforts are focused around micro-financing, human rights, agricultural technologies and the establishment of food gardens. Environmental awareness is also promoted through mediums such as radio and television.

Mali has ratified a number of international conventions, such as the UNCCD, and in accordance with this, Communal Plans for Environmental Action (CPEA) have been developed. In addition to international obligations, Mali also has a national environmental legislation concerned with the environment and especially degradation and restoration of natural resources. The most important Codes for environmental legislation are listed below.

- *Forestry Code.*
- *Pastoral Code.*
- *Mining Code.*
- *Water Code.*

The main goal of restoration efforts in Mali is to re-establish indigenous trees and other vegetation in areas where it previously occurred. This forms part of an initiative to improve livelihoods, as well as the creation of alternative income generation plans, by planting woody species for fuel, fodder and fruits (EarthTrends, 2003a). Restoration is approached in a participatory way in the country and village members and committees, in collaboration with the Government and other stakeholders, are all involved in identifying problems and constraints. All the stakeholders are also actively involved in suggesting possible solutions to these problems. Funding for restoration efforts is mainly provided by the Government, NGOs and international donors, while local land users' contributions are mainly 'in kind', such as supplying implements and labour.

Restoration approaches and technologies are introduced to land users mainly by using demonstration sites, but people are capacitated and trained to plant trees and care for them, as well as in the promotion of other conservation strategies, such as dune stabilization and erosion control. The most important restoration activity undertaken in Mali is the re-forestation of degraded areas by planting seedlings of multi-purpose tree species, such as

Acacia senegal (Gum Arabic Tree) and *Adansonia digitata* (Boabab Tree) (Gebauer *et al.*, 2006). These are tree species which are used for a large variety of products and services, such as fruits, fodder, shade and wood. Other restoration, conservation and alternative livelihood technologies in Mali include the following (see Appendix C for detailed description of each technology):

Restoration

- The protection of soil through erosion control measures to improve rain use efficiency.
- Dune stabilization through the planting of trees in the Northern part of the country (Figure 5.3 (a)).
- The establishment of tree seedling nurseries to provide seedlings for re-forestation activities by initiatives through the DMP project (Figure 5.3 (b)). These seedlings are provided to land users as part of the DMP projects.

Conservation

- Exclusion plots to demonstrate what happens when an area is rested from grazing and the implementation of better grazing strategies (Figure 5.3 (c)).

Alternative livelihoods

- Planting of date palm trees (*Phoenix dactylifera*) as an alternative livelihood option.



Figure 5.3 (a) Dune stabilization through the planting of trees, (b) tree seedling nursery and (c) exclosures to rest areas from grazing, as applied in Mali.

5.4.1.3 Niger

The challenges faced by Niger concerning land degradation and biodiversity conservation are vast. Over the years, water and wind erosion have caused land degradation, soil crusting and low soil fertility, which adversely affect crop yields and food production. This impacts negatively on the livelihoods of the rural communities, as more than 80% of the population depend on the natural environment for their livelihood (See section 5.2.1.3) (Graef & Stahr, 2000; Hebden, 2006).

People living in remote rural areas have adapted to the local conditions and depend on the natural resources to supply food, medicines, fibres, fuel, building materials and other needs. Due to the high population, resulting in increased pressures by humans and livestock, large areas in Niger are threatened by degradation and desertification. The respondents consulted in this country pointed out that the degradation and desertification are emphasized by a decrease in rainfall, as well as the fact that ecosystems are decreasingly resilient, which implicates that even small pressures such as food harvesting can lead to severe degradation.

The degradation of natural resources in Niger is characterized by a loss of vegetation and soil compaction, as well as a decrease in soil fertility (Varis & Kajander, 2006). Livestock owners and farmers are the first to be affected, but eventually almost all people living in the country are affected by degradation. To prevent farmland encroaching into forests, the improvement of soil fertility in cropland is essential. This is achieved through the use of both mineral and organic fertilizer e.g. micro-dosing and the ‘warrantage’ system (Batiano *et al.*, 2006; Coulter, 2006). Micro-dosing involves the application of small quantities of fertilizer to vegetation in planting holes to increase fertilizer use efficiency, improve yield and reduce input costs (Tabo *et al.*, 2005; Pender *et al.*, 2006).

The “warrantage” system allows farmers affiliated with a community-based organization (CBO) to store portions of their annual yields at warehouses based in their home villages. These reserves then serve as collateral on cash loans that farmers use to finance income-generating activities during the dry season. The farmers can also withdraw and consume or sell their deposits. The sustainability of the “warrantage” system is guaranteed by a fair but

effective credit management process. If a farmer defaults on a loan, the CBO will sell his or her harvest to recoup its loss, and it will return any surplus from the sale to the producer.

As most of the research concerning restoration is being conducted ‘on-farm’ or ‘on-station’, there are direct links between Government, researchers, extension services and land users in this regard. International organizations, local NGOs and CBOs, as well as universities and research and development institutes, such as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), are involved in restoration efforts by providing technical and financial support. Restoration projects are mainly funded by international organizations and the National Government, while contributions by land users and farmers are mostly ‘in kind’, such as supplying labour and maintenance. Legislation in Niger concerned with the environment and especially degradation and restoration of natural resources include the following:

- *Forestry Code.*
- *Environmental Code.*
- *Water Code.*
- *Mining Code.*
- *Pastoral Code.*
- Acts for the conservation of natural resources, biological diversity and the effects of climate change.

On National and Regional level, the Government has implemented projects from as early as the 1960’s to regenerate vegetation. Currently, the following restoration, conservation and alternative livelihood technologies are applied in Niger (see Appendix C for detailed description of each technology):

Restoration

- The establishment of stone walls for erosion control.
- Half moons to increase water infiltration and prevent soil erosion. This is carried out by hand and with large implements (Vallerani system) (Figure 5.4 (a)).
- The creation of banquettes (small spreader banks) to decrease water runoff and increase water infiltration.

- Micro-dosing to increase soil fertility and maximize water use efficiency (Figure 5.4 (b)).
- Sahelian Eco-farms for integrating high value multi-purpose plants with soil-water-conservation (Figure 5.4 (c)).
- Eradication of invader species such as *Typha australis* (Cattail) (Figure 5.4 (d)).

Conservation

- The Zai planting technology to improve soil fertility and to increase crop yields (Figure 5.4 (e)).
- The establishment of conservation areas.

Alternative livelihoods

- African Market Gardens (AMG) for increased vegetable and fruit production (Figure 5.4 (f)).

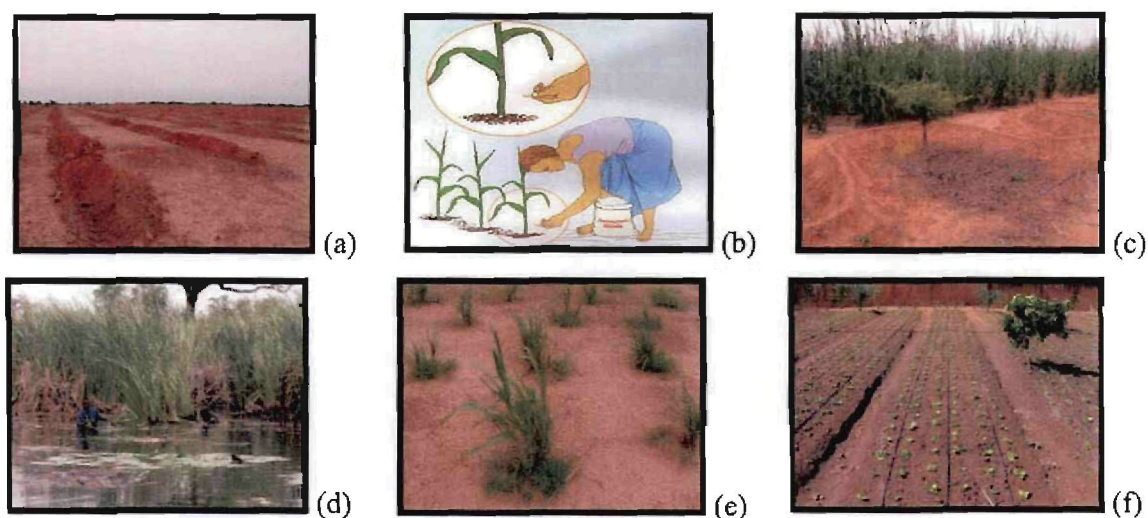


Figure 5.4 Technologies applied in Niger: (a) Half moons made by the Vallerani system, (b) Micro-dosing, (c) Sahelian Eco-farm, (d) Eradication of *Typha australis* (cattail), (e) Zai planting technology to improve soil fertility and (f) African Market Garden.

The adoption of restoration technologies depends on how badly the area is degraded and to what extent the restoration practice will improve livelihoods. If restoration activities require a lot of input and maintenance, it will be less frequently adopted, for example the creation of

half moons by means of mechanical implements. Technologies which can easily be applied on a small scale without much input would be more readily accepted, such as the Zai planting technology (Appendix C).

Restoration technologies and results are communicated through demonstrations, farmers' days and information sessions on radio or television. People are capacitated through training sessions, for example by demonstrating the correct way of planting trees for food, fodder and fuel.

5.4.1.4 Senegal

In Senegal, the degradation of natural rangelands is ascribed to an increase in population numbers, coupled with a decrease in the area of land available for people to keep livestock and for cultivation practices (Perez *et al.*, 1998; Nicholson, 2000; Tappan *et al.*, 2000). This unavailability of land contributes to the fact that more natural vegetation is removed to make way for cultivated lands. This results in a loss of floral biodiversity in the country. It is the opinion that the degradation problem in Senegal is further increased by the fact that the amount of rainfall received, as well as the length of the rainy season, has decreased over the last 20 years (Woomer *et al.*, 2004).

It is felt that land users and livestock owners are mostly affected by the degradation of the natural resources. Most of the conservation and restoration efforts in Senegal are focussed on re-forestation, but the following restoration, conservation and alternative livelihood technologies have also been noted (see Appendix C for detailed description of each technology):

Restoration

- The establishment of tree seedling nurseries to provide seedlings for restoration efforts.
- The planting of a variety of tree seedling species during restoration efforts (agro-forestry).
- The protection of soil through erosion control efforts (Figure 5.5 (a)).

Conservation

- The establishment of protected areas for conserving floral and faunal biodiversity (Figure 5.5 (b)). The total area currently protected in Senegal is about 7 135 618 ha (JICA, 1999).

Alternative livelihoods

- The establishment of food gardens as part of livelihood improvement and alternative livelihood options (Figure 5.5 (c)).
- Alternative income generation e.g. honey produced in *Eucalyptus* sp. plantations (Townsend, 1998; Wilson, 2006).

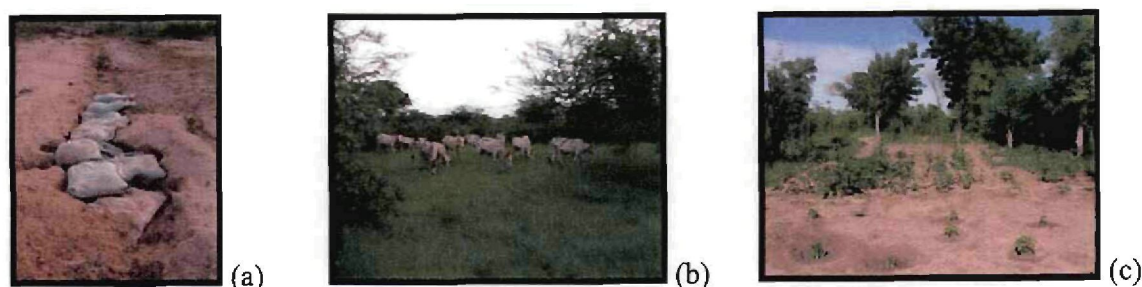


Figure 5.5 Technologies applied in Senegal: (a) The protection of soil through erosion control efforts, (b) the establishment of protected areas for conserving biodiversity and (c) the establishment of food gardens for livelihood improvement.

Restoration efforts are approached in a participatory way and stakeholders and land users are involved in all aspects of the restoration process, including planning, implementation and monitoring. The overall goal of restoration in Senegal is to capacitate people, through tree planting and tree management demonstrations. The planting of trees increase the biodiversity in the country and species such as *Acacia senegal* (Gum Arabic Tree), *Acacia albida* (Ana Tree) and *Adansonia digitata* (Boabab Tree) can be used for alternative income generation (Townsend, 1998; Gebauer *et al.*, 2006). These species are utilized for medicinal purposes, fuel wood and fodder. Most of the restoration efforts are controlled by the Government in collaboration with various national and international partners (e.g. NGOs), research organizations, as well as international programs, such as the DMP. Although most of the restoration efforts focus on re-forestation, the planting of only trees would not be sufficient to combat land degradation. The establishment of good ground cover is essential to protect the soil against further degradation.

The establishment of conservation areas is a widely used technique for reducing anthropogenic threats in Senegal (Margules & Pressey, 2000; EarthTrends, 2003b). The ‘*mis en defens*’ technology is applied, where the conservation of forest ecosystems are entrusted to the rural communities. The community takes the responsibility of managing the forest and animal resources in the surroundings of their village. Through this concept, the communities agree on a number of regulations and procedures for the use of products from these protected areas.

The Government uses media, such as television, newspapers and radio on a regular basis to create awareness concerning conservation, while the DMP and other initiatives are using demonstration sites to capacitate people in all processes concerning conservation, restoration and sustainable land management. The Government has implemented land user exchange programs, where land users visit other areas and farmers to observe and learn other ways and methods people use to conserve, restore and manage natural resources.

The respondents interviewed during the study indicated that the High Council of Natural Resources and the Environment (CONSERE) prepared the National Action Plan for the Environment (ENAE), which encompasses environmental issues in all sectors. The Ministry of Environment is primarily responsible for environmental protection. The Ministry of Environment has three departments: i) Department of National Parks, ii) Department of Environment and Establishment and iii) Department of Water, Forest, Hunting and Soil Protection. These three departments are responsible for implementing and enforcing National legislation concerned with environmental issues in Senegal.

The following laws and regulations pertaining to conservation and restoration in Senegal are enforced by CONSERE (JICA, 1999):

- *Forest Code*. This Code provides regulations for forest use to promote community participation and private initiative in forest resource management.
- *Hunting and Fauna Protection Code*. This code provides regulations on hunting and protection of fauna in parks and other protected areas.
- *Environmental Code*. This code regulates the protection of the environment.
- *Pasture Management Code*. This code defines areas to be reserved for pasture and water for livestock.

5.4.2 South and East African (SEA) region

The target areas of the DMP program are located in the arid- and semi-arid parts of southern Africa, i.e. in Namibia, Botswana and South Africa. Local land users in these countries rely almost entirely on livestock for their livelihoods, while those in Zimbabwe and in the south of Kenya engage in mixed agricultural systems, i.e. cropping and livestock production systems (Van Rooyen, 2004). Increasing population numbers result in significant increases in (i) the number of livestock kept and (ii) the area ploughed for crop production. This increased demand on the natural resources in southern and east Africa results in severe degradation of soils in crop fields and changes in vegetation composition, density and cover in natural rangelands. It severely impacts on biodiversity and sustainability of the natural resources in the region, leading to widespread poverty and food insecurity (Van Rooyen, 2004). Various initiatives and activities have been implemented in these countries to combat the effect of land degradation and improve livelihoods. The following sections will give more detailed descriptions about approaches and technologies applied in the South and East African DMP Regions.

5.4.2.1 Kenya

Population increase and urban development in Kenya has resulted in a shortage of arable land for agriculture (Barbier, 2000). Deforestation for agriculture and related land uses, and the high human in-migration from high potential areas to marginal lands, has put a heavy burden on the available arable land (De Vrede; 1996; NEMA, 2003; Muthuri, 2005). It is estimated that more than 50% of the natural rangelands in Kenya are degraded due to a loss in herbaceous species as a result of overgrazing. Only 8.2% of the land area of Kenya is formally protected in a system of national parks, reserves and sanctuaries. The following factors were identified as being the most important contributors to land degradation in Kenya: i.e. overgrazing, low/erratic rainfall, bush encroachment, soil erosion, germplasm shortages, destruction of forage trees and wildlife menace.

Kenyan Acts of Parliament, which mention the environment and/or natural resources, are numerous, but some are more direct than others and thus indicate certain critical areas of legal

intervention in the management of natural resources and the environment (Angwenyi, 2004). The Constitution of Kenya does not have direct environmental protection provisions, but the following legislation pertains to natural resource management in Kenya:

- *Forest Act*. The Minister of Environment and Natural Resources may from time to time declare Government land to be a forest or a nature reserve.
- *Wildlife (Conservation and Management) Act*. Wildlife in Kenya is classified as a national heritage, held in trust for the benefit of the public. This act states that the Minister can declare any given area a national park, nature reserve or a sanctuary.
- *Environmental Management and Co-ordination Act (EMCA)*. This Act provides for the establishment of an appropriate legal and institutional framework for the management of the environment. EMCA also establishes the National Environment Restoration Fund. The object of the Restoration Fund is to act as supplementary insurance for the mitigation of environmental degradation.

Land users in the rural areas of Kenya are combining water harvesting technologies and integrated nutrient management to sustain food production. Land users who are actively farming are usually affiliated to structured farmers' groups and are often involved in research activities. On-farm demonstrations are used by research institutions in an attempt to introduce and implement restoration activities to communities. Usually the researchers select land users to act as 'mentor farmers', but in most cases these 'mentor farmers' are chosen by their peers. One of the main restoration activities in Kenya focuses on the planting of multi-purpose trees as part of the agricultural farming system (Gebauer *et al.*, 2006). Products from these trees are used for food, shelter, forage and cultural activities. Tree seedlings are usually provided by research institutions, but local farmers' groups are also actively involved in the multiplication of tree seedlings (Kamando, 2006).

In addition to the planting of multi-purpose trees, the following restoration, conservation and alternative livelihood technologies have been applied by government, research organizations and land users in Kenya (see Appendix C for detailed description of each technology):

Restoration

- Half moons for increased water retention (Figure 5.6 (a)).

- Stone walls to prevent soil and water run-off.
- Tied ridging and contour ploughing to decrease water run-off and increase water infiltration.
- Over-sowing with grass species.
- Eradication of invader and alien plant species.
- Large-scale soil loosening activities by using the Vallerani system (Figure 5.6 (b)).

Conservation

- Fencing to allow degraded areas to rest by excluding grazing.
- The establishment of protected areas.
- Sahelian Eco-farms to incorporate multi-purpose plants with soil-water-conservation systems.

Alternative livelihoods

- African Market Gardens (AMG) and community food gardens for increased vegetable and fruit production.
- Bee-keeping and the planting of date palms (*Phoenix dactylifera*) as alternative livelihood options (Figure 5.6 (c)).



Figure 5.6 Examples of technologies used in Kenya: (a) Half moons for increased water retention, (b) soil loosening by means of the Vallerani system and (c) bee-keeping.

The Kenya Agricultural Research Institute (KARI), in collaboration with the DMP, is actively involved in training programs for all stakeholders pertaining to improving sustainable livelihoods. These training programs include aspects such as poultry production, bee-keeping and honey production, as well as the establishment of fruit orchids. Most of the training courses have been developed after inputs and collaboration with researchers, as well as land users, which makes technologies more accessible to all stakeholders.

5.4.2.2 Botswana

The most widely perceived perception of degradation in Botswana is the loss of productivity due to soil degradation and vegetation (biomass) loss (Stringer & Reed, 2006). This is caused by severe and frequent droughts, wind and water erosion, as well as high cattle numbers in the communal grazing areas. High cattle numbers contribute to the opening of the grass sward, which enables woody plants to increase and compete for soil moisture. The movement of cattle is constrained by their preference to graze within several kilometers of watering points, which leads to an increase of degradation around watering points (piosphere effect) (Moleele & Perkins, 1998). Poor rangeland management can be contributed to communally managed land which is grazed by privately-owned livestock. In these areas, land users increase their herds because the individual land user gains all the benefits, while sharing the costs with the other land-users (Abel & Blaikie, 1990; Cullis & Watson, 2006).

In Botswana, the Department of Environmental Affairs has the overall responsibility concerning environmental issues, while the Department of Water Affairs deals with issues related to water conservation and development. Both these Departments fall within the Ministry of Environment and Tourism. The Ministry of Agriculture is responsible for the rehabilitation of degraded agricultural land. The government has developed over twenty-five separate laws related to environmental and resource management issues, as well as many national policies, some of which are listed below. The country has also ratified a number of international conventions such as UNCCD, UNCBD and RAMSAR.

- *Agricultural Resources (Conservation) Act*. Provides for the conservation of Botswana's agricultural resources. The Act defines agricultural resources as animals, birds, plants, waters, soils, vegetation and vegetation products, fish, insects, etc.
- *Environmental Impact Assessment Act*. Provides for Environmental Impact Assessments to be used to assess the potential effects of planned developmental activities; to determine and to provide mitigation measures for effects of such activities; to put in place a monitoring process and evaluation of the environmental impacts of implemented activities; and to provide for matters incidental to the foregoing.
- *Forest Act*. The Act gazetted forest reserves, protected trees and the control of forest products. There is provision for the protection of trees that occur on state land within 10 m of a riverbank.

- *Herbage Preservation* (Prevention of Fires). All persons require permission from the Herbage Preservation Committee to set fire to any vegetation on land of which one is not the owner or lawful occupier.
- *Water*. In terms of wetlands, this is an important act as it defines ownership, rights and the use of public water. It also prohibits the pollution, fouling or poisoning of, interference with, or flow alteration of public water.
- *Wildlife Conservation and National Parks Act*. Enables the declaration of national parks, game reserves and Wildlife Management Areas (WMA) in which wildlife conservation and use is the primary land use. Approximately 17% of the land area of Botswana is reserved as National Parks, WMAs and game reserves.

The Department of Environmental Affairs is responsible for awareness raising, capacity building and demonstration activities concerning environmental issues. Some NGOs such as the Kalahari Conservation Society (KCS), Birdlife Botswana, as well as Veld Products Research and Development (VPR&D), are also involved in capacity building and livelihood improvement projects/programs in Botswana dealing with conservation and sustainable utilization of natural resources.

The people in Botswana most affected by land degradation include land users, livestock owners and crop farmers. The overall goal of restoration activities in Botswana is to ensure that natural resources are conserved for future generations. At local level, conservation committees, who mobilize land users for the application of restoration projects, exist in the various villages. In most cases, government departments, in collaboration with local community committees and members, are involved in the restoration of degraded natural resources. Government departments usually provide financial and technical support, while local communities provide labour for restoration activities.

In most of the cases, restoration practices are introduced to a community through demonstrations by a few land users. These technologies then spread to surrounding villages and other land users. Local community members are therefore involved in restoration activities as they see the benefits thereof. As the mobilization of communities is a slow process, the current adoption rate of restoration technologies is low. The latter is, however, improving through good communication between land users and researchers. Results and

other information concerned with restoration are usually communicated to various stakeholders through workshops, seminars and campaigns. The range of restoration and conservation technologies in Botswana includes the following (see Appendix C for detailed description of each technology):

Restoration

- The eradication of invader species.
- The planting of trees to augment the supply of fuel wood from natural woodlands.
- Sand dune stabilization in the drier parts of Botswana.

Conservation

- Fencing to exclude grazing from specific areas and demonstrate the positive effects of resting (Figure 5.7 (a)).
- Implementation of the Forum for Integrated Resource Management (FIRM) and Local Level Monitoring (LLM) as introduced from the Namibian DMP Program (Figure 5.7 (b)).
- The establishment of protected areas.
- The sustainable harvesting of natural veld products, such as truffles and devil's claw (Figure 5.7 (c)). The VPR&D regulates the harvesting of veld products to ensure sustainability over the long term.



Figure 5.7 Examples of activities in Botswana: (a) Fencing to demonstrate the effect of resting on rangelands, (b) the introduction to Forum for Integrated Resource Management (FIRM) to local village committee and (c) the sustainable harvest of truffles.

5.4.2.3 Namibia

Similarly to other DMP countries, land degradation in Namibia is tightly linked to poverty, especially in the communal rangelands. The immediate causes of land degradation in Namibia are ascribed to the large cattle numbers, which exceed the grazing potential of the rangeland (Ward *et al.*, 2000; Klintenberg & Seely, 2004). The repercussion of this is not only the fact that vegetation is lost and soils are eroded, but also that the calving percentage and meat quality decreases. Inappropriate agricultural practices that lead to the loss of nutrients in the soil are additional factors that contribute to land degradation in Namibia (NNF, 2004). Manifestations of land degradation include deforestation, deterioration of rangelands, widespread soil erosion, bush encroachment and localized soil salinization (Wolters, 1994; De Klerk, 2004).

Collaboration between government agencies, local communities and NGOs concerning the conservation of natural resources has improved due to the fact that many sectors adopted the Community Based Natural Resource Management (CBNRM) participatory approach. Namibia was the first country in the world to include protection of the environment and sustainable utilization of wildlife in its constitution (Stefanova, 2005), and as a result of these measures, about 15.5% of the country has been set aside as National Parks (Barnard *et al.*, 1998; Earthtrends, 2003c). The protected areas system in Namibia provides an important core to a greater system of conservation areas that are both ecologically and economically linked. All protected areas are managed and run by the Ministry of Environment and Tourism (MET) (Mendelson *et al.*, 2000; Turpie *et al.*, 2005).

Namibia is characterized by a high aridity index, and the scarcity of water for the country's human and animal population needs to be taken into account prior to policy formulation and during all stages of planning. The following environmental legislation exists in Namibia:

- *The Constitution of the Republic of Namibia.* Article 95 (1) states that “The State shall actively promote and maintain the welfare of the people by adopting policies aimed at the maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilization of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future”.
- *Environmental Management Act.*

- *Parks and Wildlife Management Act.*
- *Pollution Control and Waste Management Act.*
- *Access to Biological Resources and Associated Traditional Knowledge Act.*
- *Environmental Assessment Policy.*

In addition to the National legislation, the country has also initiated Namibia's Program to Combat Desertification (NAPCOD) in 1994 in response to the UNCCD. The overall goal of NAPCOD is to combat the process of desertification by promoting the sustainable and equitable use of natural resources suited to Namibia's variable environment for the benefit of all Namibians, both present and future (Kruger, 2003).

As part of the DMP program in Namibia, the Forum for Integrated Resource Management (FIRM) has been implemented. The Forum for Integrated Resource Management (FIRM) is an approach that puts rural communities in charge of their own development. The community itself identifies needs for technical, planning and financial support for their own development priorities. The overall goal of FIRM is to improve the welfare of rural Namibians by promoting sustainable management of renewable natural resources (Kruger, 2003). Training programs within FIRM addresses livestock issues, integrating wildlife and tourism into community livelihoods, improved water supply management and more efficient information exchange and networking (Appendix C).

Through FIRM and facilitated by NAPCOD, land users have developed simple, easy to follow and repeatable steps on how to monitor rangeland conditions for improved decision making. Local Level Monitoring (LLM) is a tool that can be used directly by land users to collect information on important indicators so that they can make timely management decisions, which leads to better management of the natural resources. The indicators used in LLM in Namibia include livestock condition (Figure 5.8 (a)), rainfall, rangeland condition/bush density and carrying capacity (Appendix C).

In addition to the FIRM and LLM approaches, the following restoration, conservation and alternative livelihood technologies are implemented in Namibia (see Appendix C for detailed description of each technology):

Restoration

- Eradication of alien invader species and the control of bush encroachment.
- The creation of half moons for increased water retention.
- Over-sowing with grass species to increase the grazing capacity.

Conservation

- Fencing to allow natural rangelands to recover through resting.
- The establishment of protected areas and wildlife resorts (Figure 5.8 (b), (c)).
- The establishment of conservancies throughout the country.

Alternative livelihoods

- Food gardens as a source of food and alternative income generation.
- Sustainable Mopane worm harvesting as a source of food and alternative income generation.



Figure 5.8 (a) Livestock condition monitoring as part of the Namibian Local Level Monitoring (LLM) and the Forum for Integrated Resource Management (FIRM), (b) protected area in Namibia – Etosha National Park and (c) the establishments of Namibian Wildlife Resorts.

5.4.2.4 South Africa

The degradation of rangeland areas in South Africa is increasing, mainly due to an increase in population pressure. With an increase in population, the demand for natural resources are higher, and it is evident that the natural resources in South Africa cannot support such a high population for an unlimited time (Van den Berg, 2002). Other factors contributing to land

degradation in South Africa include erratic rainfall patterns, overgrazing, bush encroachment, increase in alien invasive species, soil erosion and deforestation. These factors have been thoroughly discussed in Chapter 2.

South Africa is bound to environmental protection by the Constitution of the Republic of South Africa, a large number of international and national initiatives, such as LandCare, as well as conventions and treaties, such as the UNCCD, UNCBD and UNFCCC. The environmental legislation in South Africa pertaining to degradation and the restoration of natural resources are summarized in Chapter 3 and will therefore not be discussed here. In South Africa the following Departments within the National Government are concerned with a range of environmental issues: the Department of Water Affairs and Forestry (DWAF), the Department of Environmental Affairs and Tourism (DEAT) and the National Department for Agriculture and Land Affairs (DoA). In addition to National Governmental agencies, a large number of NGOs and private organizations are actively involved in the conservation and restoration of natural resources.

A variety of technologies have been implemented in South Africa in an attempt to conserve and restore natural resources (Van der Merwe, 1997, Van den Berg & Kellner, 2005). Most of the technologies have been applied by National Governmental and research institutions, but some activities have been implemented by private land users (small-scale, communal and commercial land users). A paper dealing with the active restoration of areas in the hardeveld of the Kalahari was submitted to the *South African Journal of Range and Forage Science* and is currently under revision (Appendix D). These restoration experiments form part of the DMP activities carried out in the Mier target area, but the results thereof will, however, not be discussed in this thesis.

The restoration of natural resources is approached in different ways by land users implementing different land use systems. Commercial land users usually have the financial and technical resources to implement restoration activities, while small-holders and communal land users very often rely on governmental projects and programs to implement these technologies (See Chapter 4). Land tenure systems in South Africa, as in other parts of the world, play an important role in the adoption rate of introduced conservation and restoration technologies (Parker, 2006).

The most important restoration activities implemented in the DMP target areas in South Africa have been summarized in Chapter 4. In addition to the technologies applied in the DMP target areas, a range of different projects/programs have been implemented in other parts of the country. The following restoration, conservation and alternative livelihood technologies are implemented in South Africa on a small or large-scale (see Appendix C for detailed description of each technology):

Restoration

- Addition of organic materials such as manure to increase soil fertility.
- Brushpacking to protect soil and seedlings from external environmental conditions (Figure 5.9 (a)).
- Dune stabilization (Figure 5.9 (b)).
- Eradication of alien invader species, including bush encroachment and bush thickening.
- The application of erosion control technologies.
- The creation of half moons for increased water retention.
- Over-sowing with grass species to assist with vegetation recovery.
- Soil loosening to increase water infiltration and expose seed in the soil seed bank to favourable conditions (Figure 5.9 (c)).
- The planting of trees in areas which have previously been used as croplands.
- Minimum tillage cultivation projects.

Conservation

- The establishment of protected areas.

Alternative livelihoods

- The establishment of food gardens for fruit and vegetable production.
- The sustainable harvesting of veld products such as Mopane worms.
- The harvesting of wild and cultivated rooibos tea (*Aspalathus linearis*).

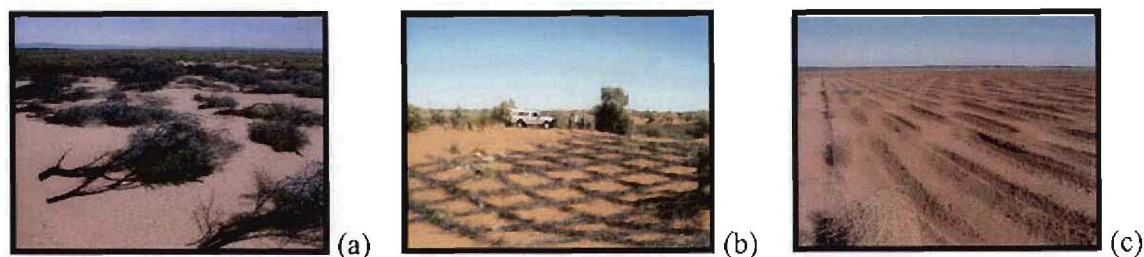


Figure 5.9 Technologies applied in South Africa: (a) Brushpacking to protect the soil and establishing seedlings, (b) dune stabilization and (c) soil loosening to increase water infiltration.

5.4.2.5 Zimbabwe

The post-colonial era in Zimbabwe has been characterized by growing levels of environmental degradation. Since Zimbabwe's economy is agro-based, a greater proportion of the environmental problems are related to agricultural practices in comparison to other land use systems (Chipika & Kowero, 2000; Burt *et al.*, 2001). Factors that are contributing to land degradation in the country include increased human and livestock numbers, increase in gold panning, deforestation, soil erosion and poverty. Some of the interventions implemented by Government Departments to address the above mentioned problems include land redistribution, education and public awareness, land rehabilitation and the provision of alternative livelihood options (Ngoma, 1996; Mutepfa, 2006).

The environmental legislation in Zimbabwe is comprehensive, and covers most of the important environmental areas. Zimbabwe has also ratified a number of international conventions, such as the UNCCD and, in accordance with the convention, developed a NAP. There are nearly 20 Acts and close to 40 statutory laws that are used in the country. The most important environmental legislation includes the following:

- *Natural Resources Act (1941).*
- *Forest Act (1949).*
- *Hazardous Substances and Articles Act (1977).*
- *Atmospheric Pollution Prevention Act (1971).*
- *Water Act (1976).*
- *Communal Land Act (1982).*

A LandCare program has been developed and implemented in the context of the Zimbabwe NAP. In the period from 2001 to 2003, the Department of Natural Resources implemented awareness, education and capacity building programs with the aim to integrate the Zimbabwean NAP with the Environmental Management Act (EMA) at district level. This was carried out in an attempt to promote community led initiatives to combat land degradation, alleviate poverty and improve management of water and land resources for sustainable livelihoods (UNCCD, 2006).

With a few exceptions, such as the establishment of protected areas, most conservation and restoration technologies in Zimbabwe have only been tested and implemented on a small-scale (Figure 5.10 (a)). The following restoration, conservation and alternative livelihood technologies have been observed in Zimbabwe (see Appendix C for detailed description of each technology):

Restoration

- Micro-dosing to improve soil fertility and increase yields.

Conservation

- The establishment of protected areas.

Alternative livelihoods

- The sustainable harvesting of Mopane worms (Figure 5.10 (b)).
- Chicken production as a source of food as well as income generation (Figure 5.10 (c)).



Figure 5.10 Technologies applied in Zimbabwe: (a) Small-scale brushpacking experiments, (b) dried Mopane worms used for food or income generation and (c) chicken production systems.

5.5 Conclusion

As most land users in sub-Saharan rangelands use agro-pastoral farming systems to sustain their livelihoods, land degradation causes an increase in poverty, loss of biodiversity and decrease in soil fertility in these areas. Coupled with this, land degradation causes land users to utilize virgin land for farming activities, as existing agricultural land cannot supply in the increasing livelihood demands of land users living in these areas. From this study, as supported by Reenberg *et al.* (1997) and Wardell *et al.* (2004), the critical determinant of woodland and forest decline in countries in sub-Saharan Africa is agricultural expansion. This problem is exacerbated by climatic variability, as well as considerable increases in population density.

If the demographical statistics of the different DMP countries are compared, it is clear that the total population density is the lowest in Botswana and Namibia (SEA), followed by Mali and Niger (WA). This can be explained by the fact that Namibia, Mali and Niger are all very arid countries, containing or bordering deserts and semi-deserts. Most of the people living in these countries have aggregated in the more humid areas, where a variety of livelihood options are available. This is a universal phenomenon (urbanization) that could result in increased socio-economic problems, specifically with regard to health, employment and education issues. Senegal (WA) and Kenya (SEA) are the two countries with the highest total population densities of all DMP countries. This could be ascribed to the fact that the geographical and environmental conditions in these countries are more favourable to sustain a large variety of livelihood options.

A comparison of the annual growth rate, as estimated in 2006, shows that of all the DMP countries, the SEA region has the lowest growth rate. This can be the result of improved birth control and medical services in these countries. The countries with the highest growth rates include Burkina Faso, Niger and Mali (WA). If the growth rate in these countries continues to rise, the pressure on the natural resources will increase to such an extent that all human livelihoods will be negatively influenced.

To some extent, all of the visited DMP countries in WA and SEA face similar problems concerning the degradation of natural resources. Land degradation in all the visited countries

are characterized by a loss of vegetation cover (rangelands and forests), increased soil erosion, invasion of invader plants species and other. Generally, the land users most affected by land degradation are those living in communally managed areas in the rural areas of the various countries. They have found themselves having to work harder to survive from a diminishing land base of ever-decreasing productivity and environmental integrity, the so called ‘poverty-degradation-cycle’ (Environment Liaison Forum, 2006). Poverty and environmental degradation are closely linked, often in a self-perpetuating negative spiral in which poverty accelerates environmental degradation and degradation results in, or exacerbates poverty. It is very difficult to quantify land degradation and the effect thereof in arid and semi-arid areas, which leads to the fact that most of the estimates concerning land degradation are based on perceptions of land users.

The aims of this study were to document approaches and legislation regarding the restoration of degraded natural resources in the nine DMP countries, to identify, document and characterize technologies used and to communicate these results to the various DMP and other partners in order to enhance the adoption of these technologies. These issues will be discussed individually below.

- **Approaches and legislation regarding the restoration of degraded natural resources**

Formal environmental policy in the sub-Saharan rangelands is largely defined in international conventions, to which individual nations are signatories. All nine countries have signed and ratified the three most important United Nations Conventions regarding factors relating to land degradation and desertification, i.e. United Nations Convention to Combat Desertification (UNCCD), United Nations Convention on Biological Diversity (UNCBD) and United Nations Framework Convention on Climate Change (UNFCCC). Other international treaties that are in accordance with the UNCCD, such as the RAMSAR Convention on Wetlands are also implemented in all of the nine DMP partner countries. All the countries have also developed and implemented National Action Programs (NAPs) for the different United Nations Conventions.

Jointly with these international obligations, each country has its own legislation pertaining to environmental issues such as the conservation and restoration of natural resources. In

addition to general environmental acts and codes, all of the DMP partner countries have legislation pertaining to the following sectors: forestry, water, mining, pastures, wildlife and agriculture (cropping). Even though one of the initial objectives of this study was to document legislation regarding the restoration of degraded natural resources in the DMP countries, it proved to be more challenging than expected. This resulted in the fact that, in most of the cases, only titles and general themes of policy documents of the various countries could be compared with one another. It is recommended that a thorough legal study be made of each piece of legislation to be able to identify similarities and differences between legislative approaches towards the conservation and restoration of natural resources.

Although all of the DMP partner countries have a large array of environmental policies, it is evident that, in most cases, these policies are not optimally implemented and enforced. From the results, it is evident that most environmental action on the ground is driven and implemented by non-governmental organizations (NGOs) (Homewood, 2004). The majority of the NGOs' work is, however, carried out in close collaboration with National Governments and other research and development institutions. Various international and national environmental programs have been implemented in all of the countries, such as LandCare (South Africa), Pagerna – Alleviate poverty and capacitate people (Senegal) and ROSETTE – Monitoring Project (Mali). The Pagerna and ROSETTE projects have not been discussed, as they do not form part of the DMP projects, but they have been mentioned by the DMP National Coordinators in these countries. The majority of these programs are focussed on information transfer, exchange visits and capacity building activities concerning ways to improve livelihoods.

- **Identification, documentation and characterization of observed livelihood improvement technologies**

The identification of various alternative livelihood technologies was carried out by means of visual and photographic observations, interviews with various stakeholders, as well as references to existing literature. The technologies encountered during this study have been divided into three different categories i.e. **restoration** (including rangelands and croplands), **conservation** (including rangelands, croplands, forest areas, wildlife areas and biodiversity areas) and **alternative livelihood technologies** (including improved livelihood technologies).

Restoration technologies include those where active or passive interventions are used to improve the current condition of the natural resource, such as soil loosening, reforestation and the addition of fertilizer, while conservation technologies, such as fencing, the FIRM approach and the establishment of protected areas are mainly those applied to conserve the current condition of the natural resource or to ensure the sustainable use thereof in the future. Alternative livelihood technologies include technologies which are implemented to provide land users with products and services that can be used for livelihood improvement or alternative/increased income generation, such as beekeeping or poultry farming. See Table 5.1 for a summary of the different technologies observed in the DMP partner countries. A total number of 12 restoration, eight conservation and eight alternative livelihood technologies were observed during the study in the nine DMP countries.

It must be noted that, even though some technologies fulfil more than one function, all of the technologies have been categorized according to their primary function, such as the Rural Wood Market technology. Even though the technology contributes to alternative livelihood income generation for land users, the primary function of Rural Wood Markets is the introduction of a system whereby fuel wood is collected sustainably to conserve this resource for long-term use.

From Table 5.1 it is clear that land users from all of the visited countries have implemented conservation, restoration and alternative livelihood technologies, with the exception of Burkina Faso where no alternative livelihood technologies, forming part of the DMP program, were observed. In Botswana, however, some alternative livelihood technologies, such as the Veld Products Research and Development (VPR&D), not implemented by the DMP, have been observed. In the majority of countries, land users have applied more restoration technologies than conservation and alternative livelihood technologies. Most of these restoration technologies have been focussed on the improvement of physical and chemical soil conditions, such as the application of organic material, fertilizers and the Zai technology. In Botswana and Namibia, however, technologies were more focussed on the conservation of natural rangelands, with less agricultural cropping activities, as cropping does not form an important part of the agricultural sector in these countries (Table 5.1). In Zimbabwe, however, land users have applied more alternative livelihood technologies than restoration and conservation technologies. It is possible that various other restoration and conservation

technologies could have been applied in other areas of Zimbabwe, which are not reflected in this study and do not form part of the DMP in the country. Additional technologies and various different approaches would probably have been observed if individuals from other sectors and different parts of the country were also interviewed.

It is clear that all nine countries have established protected areas in the form of National Parks, Conservation Areas and Game Reserves. This could be attributed to the fact that the national environmental legislation in each of the nine DMP countries specifies that the natural resources in the country must be protected. In Senegal and Namibia, however, it was observed that, in addition to national and privately owned protected areas, some of these areas have been established by land user groups living in the DMP target areas in the form of self-managed conservancies, such as the #Khoadi // Hoas Conservancy in Namibia. This reflects the positive attitude of land users towards the protection and sustainable use of natural resources in these areas.

In West Africa, local land users are more dependent on agro-forestry to sustain their livelihoods, as opposed to land users in southern Africa who depend largely on livestock production systems. These differences in farming and land use systems determined the type of livelihood improvement strategies implemented by land users and research projects in the DMP partner countries. Due to the fact that land users in the WA region rely largely on trees and forests to sustain their livelihoods, reforestation and the establishment of tree seedling nurseries were the second and third most widely used technologies in the DMP program (Table 5.1). As a result of the fact that overgrazing and the subsequent encroachment of invader species (bush encroachment/thickening and alien species) is a very big threat to natural rangelands in the SEA region (See Chapter 4 for reference to South Africa), much attention has been focused on the eradication of invader species in these countries (mainly SA and Namibia).

Technologies such as brushpacking and dune stabilization, as implemented in Mali and South Africa, are usually very site specific, which might be the reason why this technology has not been used in other countries. On the other hand, a technology such as the eradication of invader species could be important in most countries as the problem caused is similar and

only the type of invader species differs from country to country, e.g. *R. trichotomum* in South Africa and *T. australis* in Niger.

Wire fencing (using mesh and poles) is a technology commonly applied in the countries where livestock is produced on large commercial farms, such as Botswana and Namibia, while live fencing (using living woody plants planted closely together) is more commonly used in countries where farming takes place on a smaller scale, such as Mali and Niger (Table 5.1). Live fences are usually used to surround small croplands in areas where there is limited financial resources to buy wire fencing. If these two are combined, it is evident that land users in all DMP countries use fencing of some sort in their management system to control the movement of animals.

A technology such as the collection and selling of wood for fuel and construction purposes at Rural Wood Markets, used in Burkina Faso and Niger, would probably be effective in all the other DMP countries, with the exception of Namibia and South Africa. In these two countries the villages are too far apart for such a system to be effective. In some cases, specific technologies have been developed by international research institutions, such as ICRISAT and TSBF, and are restricted to those countries where these institutions are operational. Such technologies include micro-dosing and African Market Gardens (Figure 5.4). The Zai technology, however effective, is only used in countries where cropping is carried out on a small scale. This technology is extremely labour intensive and implies that the financial and labour inputs would increase if the size of the cropping area increases.

Alternative livelihood technologies, such as the harvesting of rooibos tea and mopane worms, are only carried out in the countries where these resources are available. Similarly, date palms for date production are only planted in areas where the environmental conditions are ideal for optimal growth of these palms.

Table 5.1 indicates that the FIRM and LLM technologies (developed in Namibia) have only been applied in Namibia and Botswana. This could be due to the fact that DMP partners from Botswana attended courses and training programs concerning FIRM and LLM in Namibia. Desert Margins Program partners from South Africa have also attended these courses and training programs, but are currently only in the planning phase to implement these

technologies in South Africa. It could be possible that other DMP countries would also implement this technology if it was known and available to them, i.e. in the form of courses and training programs. This could be a valuable technology in other DMP countries as FIRM is focussed on the participation of land users to improve their own development, while simultaneously promoting the sustainable management of natural resources.

Senegal, Mali, Burkina Faso, Botswana, South Africa and Zimbabwe have implemented a large variety of restoration technologies, but in most of the cases only on a very small scale as research trials ‘on-farm’, on-station and in the form of demonstration sites. In Niger, Kenya and Namibia, however, conservation and restoration technologies have been applied on a relatively large-scale, such as reforestation, the Vallerani system, eradication of invader species and the establishment of protected areas (Table 5.1). In most of the cases, the implementation of technologies is correlated to land tenure and the availability of technical and financial resources. In all cases, restoration practices are carried out in a participatory way through good collaboration between a number of stakeholders within each country. Through research, combined with traditional and indigenous knowledge, a large number of new (micro-dosing, FIRM and Sahelian Ecofarms) and improved (dune stabilization, eradication of alien invader species and food gardens) technologies have been developed. The biggest challenge, however, is to convince land users and farmers to adopt these restoration technologies even though it might not be rewarding in the short-term.

Poor adoption and the short-lived use of technologies, among others, are frequently mentioned as the major factors limiting efforts aimed at conservation and restoration. Often financial and technical resources, including labour, are the most limiting factors in the farming system, making investment in new technologies difficult. Even if the applied technologies are very successful, but the costs cannot be afforded by the local communities, the technologies will not be adopted. Most incentives adopted in the above mentioned countries are based on the combination of a number of technologies, to address more than one complex problem and to achieve the best results within the shortest period of time, such as the Sahelian Ecofarm and Zai technologies). Combating land degradation and improving food security for the people living in sub-Saharan Africa require a diversification of production and cropping systems. Farmers seldom adopt fully developed technology packages, but rather look for ‘ingredients’ or ‘building blocks’ which they can put together in different ways that

fit their particular needs and address several problems simultaneously. A very good example of this is the Sahelian Eco-farm system applied in Niger and Kenya, where legumes are used to enrich the soil and improve its fertility, simultaneously acting as wind breaks, mulch and poultry feed. Earth bunds are built in a half moon shape to create water micro-catchments and aid in the control of soil erosion. In most cases, multipurpose trees, which provide fruit and fodder, are also planted in these half moons.

As a result of the fact that most of the mentioned technologies have been developed in response to specific needs and environmental conditions, very little cross-border technology transfer has taken place. This could also be as a result of the financial implications brought about by cross-border visits.

- **Communication of results to DMP partners and other interested parties**

The various technologies for restoration, conservation and alternative livelihood improvement encountered during the visit to the nine DMP partner countries are summarized and categorized in the separate booklet distributed together with this thesis (Appendix C). It should be stressed that this is only an account of the technologies observed during a visit to all nine DMP partner countries and interviews with DMP project coordinators, staff and participating land users. There is no doubt that a large number of other technologies exist in each of the countries that have not been mentioned in this thesis. The main aim, however, was to investigate and assess the technologies used and implemented in the DMP projects in the nine countries. This contributes to the objectives of the DMP program as explained in Chapter 1. During Phase II of the DMP, different restoration, conservation and alternative livelihood technologies were tested within each country to determine which technologies could be applied with the most success. In Phase III, more focus will fall on the dissemination of collected information within and between each of the nine partner countries. This would provide the best opportunity for cross-border technology transfer between the partner countries.

Initially, technologies would only be shared between DMP partners in the various partner countries and therefore the onus would fall on them to introduce and promote these technologies on the local level. Technologies such as soil loosening, micro-dosing, FIRM,

African Market Garden and Sahelian Eco-farms are the best technologies to use in this process as a number of partner countries experience similar environmental, economical and social conditions, and land users could benefit from these technologies. The application of the above mentioned technologies involves low financial and technical investments, which would make these technologies more attractive to land users. This would increase the adoption rate of technologies as resource constraints are the main factors contributing to low adoption rates.

Table 5.1 Summary of the different restoration, conservation and alternative livelihood technologies implemented by each of the nine Desert Margins (DMP) partner countries in West, South and East Africa.

DMP Partner Countries											
		West African Region (W/A)				South and East African Region (SEA)					
Technology		Burkina Faso	Mali	Niger	Senegal	Kenya	Botswana	Namibia	South Africa	Zimbabwe	
Restoration	Brushpacking								X		X
	Dune stabilization		X						X		
	Eradication of alien invader species			X		X	X	X	X		
	Erosion control				X						
	Oversowing of grass species		X			X		X	X		
	Half moons		X			X		X	X		
	Nurseries	X	X	X		X					X
	Micro-dosing	X	X	X							
	Reforestation	X	X	X		X			X		
	Soil loosening	X		X					X		
	Stone walls	X									
	Vallerani	X	X	X	X						
Conservation	Fencing		X				X	X	X		
	FIRM						X		X		
	Live fences	X	X		X						
	LLM							X			
	Protected areas	X	X	X	X	X	X	X	X		X
	Rural Wood Markets	X		X							
	Sahelian Ecofarm			X		X					
	Zai	X		X							
Alternative livelihoods	African Market Garden			X	X	X					
	Bee-keeping				X	X					X
	Chicken production										
	Conservation of tree species		X			X					
	Date palms		X			X					
	Food gardens				X	X		X	X		
	Harvesting of rooibos tea (<i>A. linearis</i>)								X	X	
	Mopane worm harvesting							X	X	X	

CHAPTER 6

The evaluation of the effect of drought stress on the germination, physiological and morphological characteristics of *Cenchrus ciliaris*

(As part of Section 6.4.1.2, a short communication concerning the effect of drought stress on three indigenous South African grass species was accepted by the South African Journal of Botany 72 (2006): 284 – 286. Appendix E.

Although the short communication does not refer to *Cenchrus ciliaris*, the results obtained support the results concerning the effect of drought stress on *C. ciliaris*, as described in this Chapter.)

6.1 Introduction

Rangelands occupy over 70% of the land surface of South Africa (1 219 000 km²), making them the largest single land use (Snyman, 1999). Rangeland degradation is often manifested by decreases in plant species diversity, low grass height and vegetation cover, increases in unpalatable grass species and sharp reductions in plant yields. In addition to grazing by domestic livestock, rainfall patterns are the most important factors influencing rangeland condition (Hoffman & Ashwell, 2001; Sharif-Zadeh & Murdoch, 2001). Drought, extreme temperatures, increased soil salinity and soil crusting all adversely affect the germination and growth of seedlings (Costa Franca *et al.*, 2000). Grasses, with a strong development of underground organs, tend to have efficient adaptive mechanisms to cope with drought, fire and herbivory and provide superior protection against soil erosion to most woody and tree species (Imevbore, 2003).

The dispersal of seeds through over-sowing is an important strategy to actively restore vegetation in degraded areas, as the soil seed banks are usually depleted of viable seed. The sowing of seed is labor-saving when compared to transplanting nursery seedlings (Tobe *et al.*, 2001) and it is extremely important to sow a seed type or cultivar that has the capacity to produce abundant biomass and density in a short period of time (Van den Berg, 2002). Plant growth, distribution and productivity as well as product quality are greatly influenced by environmental stresses and other stimuli to which plants are continuously exposed (Taehtiharju & Palva, 2001).

The two main components of drought resistance in plants are drought avoidance and drought tolerance (Levitt, 1980; Turner, 1991). The mechanisms of drought avoidance principally include the development of an extensive root system and an efficient stomatal closure (Barradas *et al.*, 1994). Mechanisms of drought tolerance involve processes at the cellular level (Mullet & Whitsitt, 1996). At the moment there is too little information available to be able to precisely measure a plant's resistance under drought stress conditions (Blum, 1996).

6.2 Rationale for the use of *Cenchrus ciliaris* L. in restoration technologies in arid and semi-arid regions

Cenchrus ciliaris var *molopo* L. is a C4 bunch grass native to West Asia, India and the whole African continent, mostly in dry areas (Bogdan, 1977). It has been introduced into arid and semi-arid regions of Australia and America (M'Seddi *et al.*, 2002), but in recent years there has been growing concern about its impact on conservation areas and biodiversity in Australia (Desert Knowledge CRC, 2007). Despite this fact, *C. ciliaris* is a popular cultivated pasture in the warm and semi-arid regions of South Africa (Hacker & Ratcliff, 1989; Dickenson *et al.*, 1990; Dannhauser, 2004; Van Oudtshoorn, 2004). This species has found favour with farmers due to the fact that it produces a great bulk of palatable forage under hot and relatively dry conditions (Figure 6.1 (a)). It is able to do this as it has a very deep and vigorous root system (Brits *et al.*, 2003). Secondly, *C. ciliaris* has a long and effective life span. The persistence of *C. ciliaris* is partly explained by the fact that it is strongly stoloniferous; new plants arising from stolons constantly rejuvenate the pasture (Martin, 2000). Seed of this species is carried on spikes (Figure 6.1 (b)).

Cenchrus ciliaris seeds have been tested and used in a large variety of experimental restoration plots and have been found to establish well in arid and semi-arid regions (Singh & Rathod, 2002; Snyman, 2003b; De Wet, 2001; Van den Berg, 2002; Ego & Kibet, 2003; King, 2003). It is best sown just ahead of the expected rainy season at 0.5 – 4 kg/ha (Fair, 1986). The average number of seeds per kilogram is approximately 450 000 to 703 000 (Skerman & Riveros, 1990). Seed of *C. ciliaris* remains viable for two to three years (Figure 6.1 (c)). For good establishment, seed of

C. ciliaris needs to be moist for about five days and for high growth rates, soil moisture must be adequate for 30 consecutive days (Skerman & Riveros, 1990). It is surface sown and lightly harrowed or rolled where possible (Skerman & Riveros, 1990).

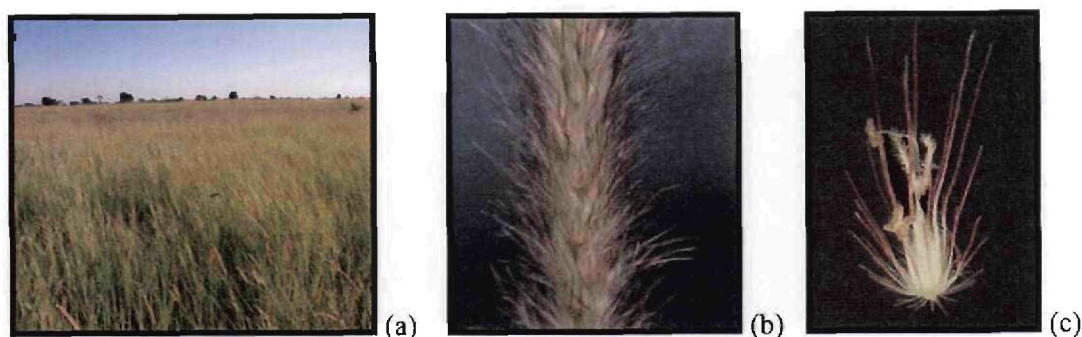


Figure 6.1 (a) Representation of a *Cenchrus ciliaris* field, (b) spike and (c) seed.

The aim of this study was to determine the effect of drought stress on the germination and morphological and physiological processes of *C. ciliaris*. Results from these experiments can be used to explain the response of *C. ciliaris* to drought conditions and how effective this plant can be used in over-sowing active restoration technologies in arid and semi-arid regions.

6.3 Materials and methods

Seed of *C. ciliaris* var *molopo* obtained from Siebert Seed Consultants¹ was used in three different experiments. Dehulled seed was used for laboratory experiments to determine the germination and initial growth response of the species when subjected to drought conditions. Normal seed (non-dehulled) was used in glasshouse experiments to determine the effect of drought stress on the physiological processes (fluorescence, chlorophyll content and relative water content) of mature plants.

¹ Siebert Seed Consultants, Tony Siebert, 26 Kollegelaan, Potchefstroom, 2520. Tel: +27 (0) 83 300 6938. Fax +27 (0) 18 293 2430

6.3.1 Laboratory experiments

Germination of seed in laboratory experiments is the emergence and development of the seedling to a stage where its essential structures indicate whether or not it is able to develop further into a viable plant under favourable conditions (MacKay, 1972). During these experiments, seed of *C. ciliaris* was subjected to normal germination conditions as well as drought stress conditions induced by chemical processes. This section deals with the procedures for normal as well as drought stress induced germination. All seed testing has been done according to the International Seed Testing Association (ISTA) rules.

6.3.1.1 Normal germination tests

Seed testing has been developed to minimize the risk of failure by assessing the quality of seed before it is sown. Overall, the variety, the pure seed percentage and the germination percentage are the best indicators of seed value (Warde, 2001). The factors that play an important role in the accurate analysis of seed for quality determination are:

- the method of sampling of the seed lot,
- purity of the sampled seed, and
- germination capacity of the purified seed.

An example of the purity analysis data sheet, germination analysis data sheet and report sheet is given in Appendix F.

- ***Sampling the seed lot***

The quantity of seed tested in the laboratory is minute compared to the size of the seed lot which it is representing. The term 'seed lot' denotes a nominally uniform consignment of seeds on which representative tests can be made on random samples (Roberts, 1972). To obtain uniform and accurate results, it is essential that samples be taken with care and in accordance with the prescribed methods (ISTA, 1985). Seed is rarely pure, which makes sorting a necessity to obtain

the correct material for the test (MacKay, 1972). The object of sampling is thus to obtain a sample of a smaller size suitable for testing, in which the probability of a particle being present is determined only by its level of occurrence in the sample. A sample is obtained by taking small portions at random from different positions and combining them either by progressive subdivision, or abstracting and combining small amounts of seed (Figure 6.2). The working sample is generally equal to or greater than a weight estimated to contain approximately 2 500 seed units.

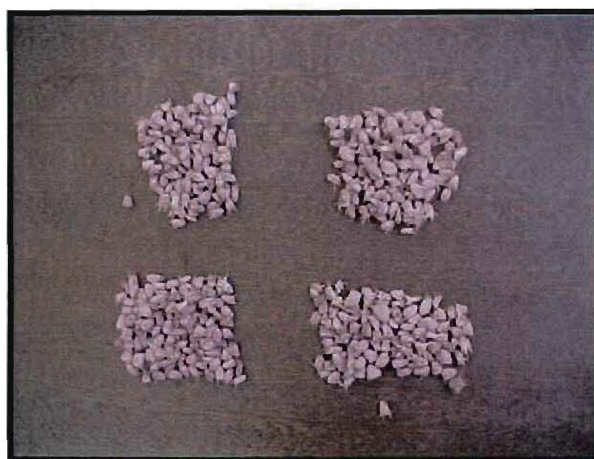


Figure 6.2 An example of the hand halving method to obtain a working sample from the submitted sample.

- ***Purity analysis***

As it is generally not possible to completely remove all impurities during the cleaning process, standards have been set to determine the composition of the seed, including pure seed, impurities and weed seeds. Since the germination test is based on the pure seed component, it can be readily seen that the purity analysis and the germination test complement each other. The object of the purity analysis is to determine:

- 1) The percentage composition by weight of the sample being tested and also the composition of the seed lot, and
- 2) To identify the various species of seeds and inert particles constituting the sample.

- *The germination of seed*

The ultimate objective of testing for germination is to determine the maximum germination capacity of the seed. Laboratory methods in which the external conditions are controlled to give the most regular, rapid and complete germination for a particular species (ISTA, 1985) are used. The result of laboratory germination tests indicates the percentage of pure seeds which have produced seedlings capable of continued development into mature plants. There are different germination methods which include both paper and sand germination. Germination paper is used extensively in seed testing and is particularly suitable for the germination of small seed and for seeds which may require light for germination. For this experiment, only the Top Paper germination method was used. In the Top Paper Method, seeds are placed on a layer of paper and cellulose wadding in petri dishes or other suitable containers (Figure 6.3 (a)). Water or potassium nitrate (KNO_3) (if specified by the ISTA rules) is added to the containers after which the seeds are allowed to germinate (Figure 6.3 (b)). Potassium nitrate (KNO_3) is added to break the dormancy of the seeds and to stimulate germination. The germination rate of the seed is evaluated at various intervals over a total of 15 to 30 days at a temperature of 25°C . Seedlings that have germinated to such an extent that it can be correctly evaluated are removed at intervals during the test to avoid over-crowding and to restrict the spreading of fungi (MacKay, 1972). The assessment of the doubtful and abnormal seedlings, as well as the separation of dead seeds must be left until the test is concluded. Four replicates of 100 dehulled pure seeds were used to determine the normal germination capacity of *C. ciliaris*.

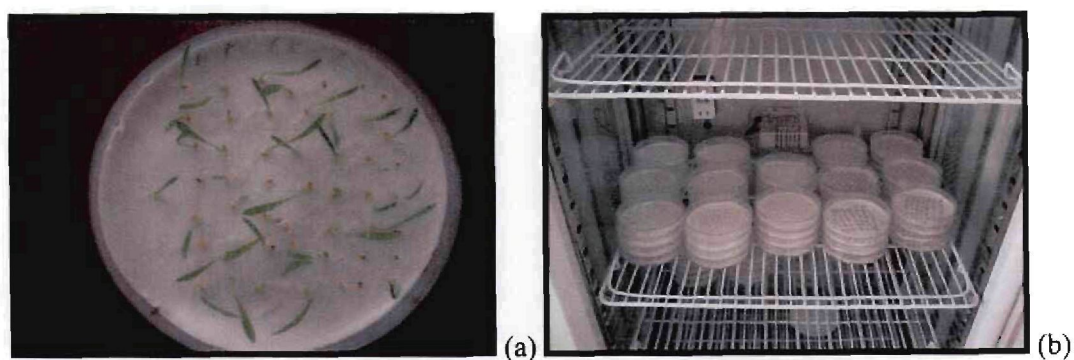


Figure 6.3 (a) Seed of *Cenchrus ciliaris* planted in petri dishes and (b) placed in an incubator to enhance germination.

6.3.1.2 Drought stress induced germination

Osmotic solutions are used to impose water stress reproducibly under in vitro conditions (Pandey & Agarwal, 1998). Polyethylene glycol molecules with a $M_r \geq 6000$ (PEG 6000) are inert, non-ionic and virtually impermeable chains that have frequently been used to induce water stress and maintain a uniform water potential throughout the experimental period (Hohl & Peter, 1991; Lu & Neumann, 1998). Molecules of PEG 6000 are small enough to influence the osmotic potential, but large enough not to be absorbed by plants (Carpita *et al.*, 1979). Because PEG does not enter the apoplast, water is withdrawn from the cell and the cell wall. Therefore, PEG solutions mimic dry soil more closely than solutions of low M_r osmotica, which infiltrate the cell wall with solutes (Verslues *et al.*, 1998).

Four replicates of 100 dehulled seeds each were used to determine germination rates in the absence of osmotic stress. Water stress was applied through incubation in seven different concentrations of PEG 6000 which provided solutions with water potentials ranging from -0.3 to 2.1 MPa (Michel & Kaufmann, 1973). Four replicates of 50 pure dehulled seeds of *C. ciliaris* were used for each of the different osmotic potential experiments. Seeds were germinated at 30°C on filter paper discs moistened with 8 ml of the different solutes. After the addition of the solutes, as well as the seeds, each petri dish was weighed and the weight recorded. On a daily basis the petri dishes were weighed and supplemented with distilled water to the original weight. The seeds were investigated for germination every second day.

In addition to the determination of germination capacity, the seedlings germinated at each water potential were also evaluated to establish the morphological response of *C. ciliaris* to drought stress. Five seedlings of each treatment were selected of which the root and shoot lengths were measured (in cm) on the fifth day of incubation to determine whether a decrease in osmotic potential would have an effect on the physical characteristics of the seedlings of this species (Figure 6.4).

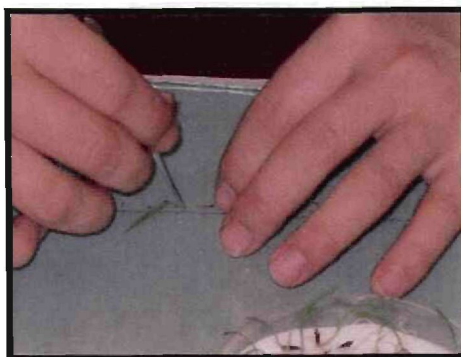


Figure 6.4 Measuring of shoot and root lengths of *Cenchrus ciliaris* to determine the effect of drought stress on the morphology of seedlings.

6.3.2 Glasshouse experiments

The experiments were conducted under controlled conditions in the glasshouse (at 25°C). Seeds of *C. ciliaris* were planted at a high density in containers measuring 20cm x 30cm, containing a growth medium from Hygrotech² (Figure 6.5 (a)). After a period of three weeks when the plants had entered the vegetative phase (Figure 6.5 (b)), individual plants were transplanted into 15cm x 15cm bags containing 800g of growth medium. This resulted in 15 bags containing four individual plants each (Figure 6.5 (c)). Initially the bags were watered to full potential to ensure the successful establishment of transplanted individuals.

The full water capacity of a bag containing 800g of growth medium was determined and ratios were calculated to establish the water capacity of bags receiving 50% and 20% of the full water capacity. The plants were grouped into groups of five bags and watered according to the different ratios. The experimental design was a complete randomized block with five replications of each treatment. Morphological and physiological surveys were conducted on each of the treatments to determine the effect of ratios of drought stress on individual plants.

² Hygrotech, P.O.Box 17220, Pretoria North, Gerard Braak Street, Pyramid, Tel: +27 (0) 12 545 8000

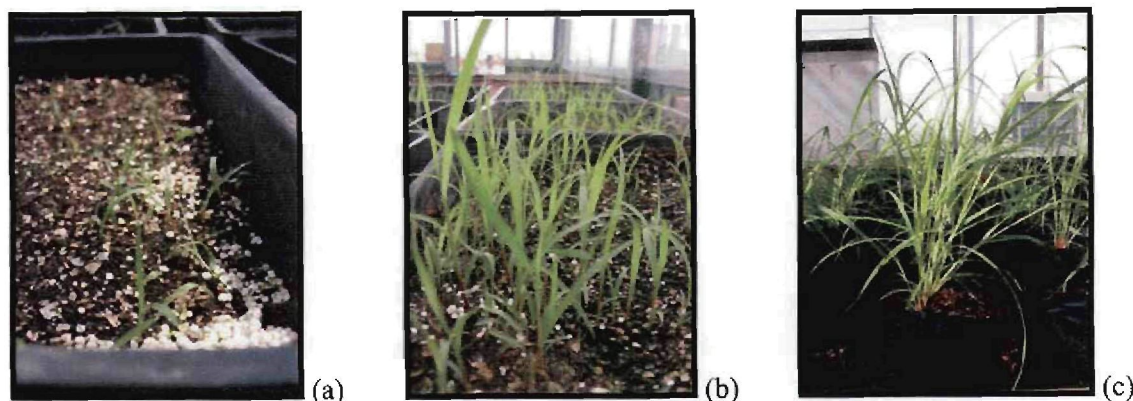


Figure 6.5 (a) The various stages during seed germination in Hygrotech growth medium, (b) seedling growth in the glasshouse under controlled conditions at 25°C, and (c) shows seedlings transplanted into bags.

6.3.2.1 Determination of fluorescence

An important effect of decreasing cellular water content due to exposure to drought stress is that photosynthesis, particularly CO_2 assimilation, is inhibited (Lawlor & Cornic, 2002). Drought tolerance may be exhibited by plants through their ability to maintain a higher water potential under water limiting conditions, or by maintaining physiological processes like photosynthesis at lower water potential (Bhargave & Paranjpe, 2004). Photosystem II (PS II) is highly drought resistant as was found in investigations into the impact of various environmental stresses (drought, heat, high irradiance), applied separately or in combination (Havaux & Davaud, 1994).

Strasser and Strasser (1995) introduced a test that translates the changes observed in the fluorescence transient to quantitative changes in formulated parameters derived from the energy flux theory. This quantitative analysis of the fluorescence transient, called the JIP-test, can be used to explain the stepwise flow of energy through Photosystem II at the reaction centre (Force *et al.*, 2003). The JIP-test is named after the basic steps in the fluorescence transient when plotted on a logarithmic time scale. The fluorescence rise exhibits the steps J and I between the initial O (F_o) and maximum P (F_M) levels. Different environmental conditions cause changes in the shape of the O-J-I-P fluorescence transient, making it suitable for *in vivo* studies of the

behaviour of PS II. A quantified parameter resulting from the JIP-test is the performance index (PI_{ABS}) which has been developed by Strasser *et al.* (2000).

The PI_{ABS} is a multi-parametric expression that combines the three functional steps of photosynthetic activity by a PS II reaction centre complex, i.e. light energy absorption, trapping of excitation energy and the conversion of trapped energy to electron transport. The aim of this investigation was to compare the performance index (PI_{ABS}) of plants subjected to various degrees of drought stress.

Chlorophyll *a* fluorescence transients were recorded with a Plant Efficiency Analyzer³ (Figure 6.6 (a)) under dim green light on attached leaves of *C. ciliaris* plants that have been subjected to various stages of drought stress (Figure 6.6 (b)). The measurements were taken on a four millimeter diameter area of fully dark-adapted leaves over a period of 15 days. The measurements were carried out on five mature leaves of each individual plant. In total fifty measurements were made for each water stress ratio on a particular day (i.e. 100%, 50% and 20% water).

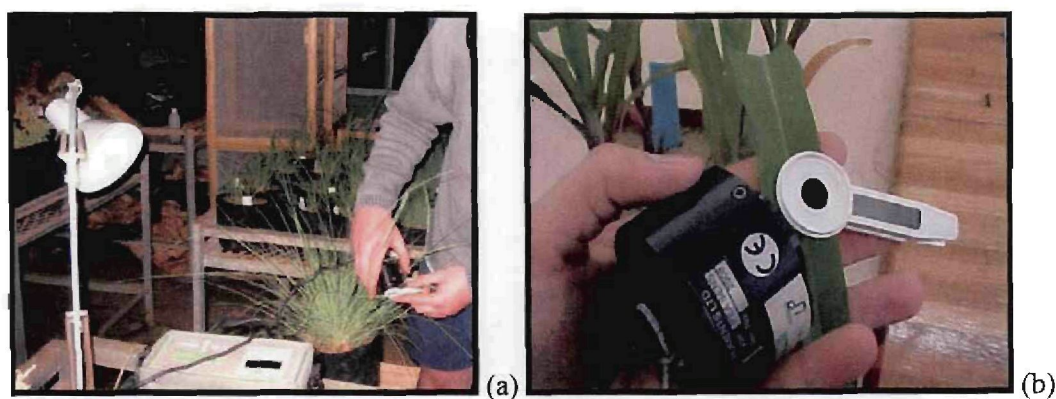


Figure 6.6 Chlorophyll *a* fluorescence measurements taken under dim green light (a) with a Plant Efficiency Analyzer (b).

³ Plant Efficiency Analyzer, Hansatech Instruments Ltd., King's Lynn, Norfolk, PE 30 4NE, UK

6.3.2.2 Chlorophyll Content Index (CCI)

Changes in chlorophyll content can occur as a result of nutrient deficiencies, exposure to environmental stress and differences in light intensity during growth. Chlorophyll has several distinct optical absorbency characteristics that the Chlorophyll Content Meter exploits with non-destructive sampling. Strong absorbency bands are present in the blue and red, but not in the green or infrared bands, hence the green appearance of a leaf. By measuring the amount of energy absorbed in the red band, an estimate of the amount of chlorophyll present in the tissue is possible. Measurements in the infrared band show absorbencies due to cellular structure materials. By using this infrared band to quantify bulk leaf absorbency, factors such as leaf thickness are taken into account in the Chlorophyll Content Index (CCI) value.

The chlorophyll content of a 2.85 cm² area of grass leaves was determined at intervals during the course of the drought stress experiment. The measurements were taken with a Chlorophyll Content Meter⁴ (Figure 6.7) and recorded as a Chlorophyll Content Index (CCI). Twenty-five measurements were taken for each of the three water stress ratios on a particular day. The aim of this investigation was to determine the effect of various degrees of drought stress on the chlorophyll content of individual plants.

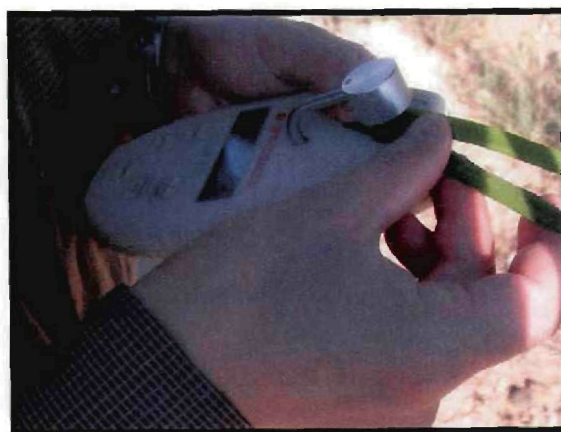


Figure 6.7 Chlorophyll content of leaves measured with a Chlorophyll Content Meter.

⁴ CCM-200, Opti-Sciences, Inc. 164 Westford Road #4, Tyngsboro, MA 01879, USA

6.3.2.3 Relative Water Content (RWC)

Plant and cell water balance is determined by water lost through evaporation (transpiration) to the atmosphere and water absorption from the soil (Lawlor & Cornic, 2002). When transpiration exceeds absorption, cell turgor (P) falls as the Relative Water Content (RWC) and cell volume decrease, whilst the concentration of cellular contents increases, thus causing osmotic potential and water potential to fall (Lawlor & Cornic, 2002). Relative Water Content (RWC) can be used to evaluate the water status in the plants during a stress period (Barrs & Weatherley, 1962). According to Ferreira *et al.* (1979) and O'Regan *et al.* (1993), drought stress causes a decrease in the RWC content of plant leaves and RWC is therefore a satisfactory basis for relating cellular water status to metabolism in plants subjected to drought stress (Lawlor and Cornic, 2002).

The RWC was determined at the end of the experiment by using ten leaves of mature *C. ciliaris* plants from each ratio of drought stress (Figure 6.8). Cut leaves were weighed (fresh weight), then left to saturate in distilled water for 24 hours, after which the turgid weights were calculated. The samples for each drought ratio were then dried in an oven at 75 °C for 24 hours and then weighed (dry weight). The RWC was determined as follows (Henson *et al.*, 1981):

$$RWC (\%) = \frac{\text{fresh weight} - \text{dry weight}}{\text{turgid weight} - \text{dry weight}} \times 100$$

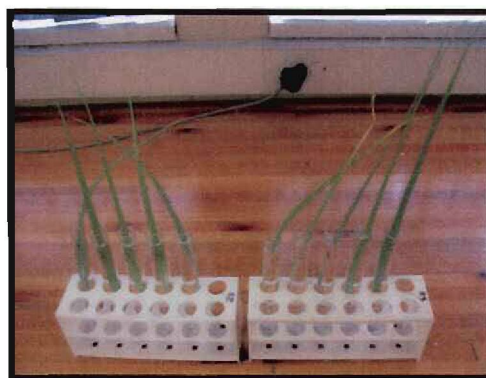


Figure 6.8 Determination of Relative Water Content (RWC) by saturating leaves of *Cenchrus ciliaris* in distilled water.

6.3.2.4 Leaf elongation

In a separate trial, seeds of *C. ciliaris* were planted in Hygrotech growth medium in 20 x 30 cm containers. The 15 containers were divided into three groups and watered according to the different drought stress ratios (100%, 50% and 20% water) from the start of the experiment. After germination of the seedlings, individual plants were used to measure leaf elongation (cm) over a period of twelve days.

6.4 Results and Discussion

In the following section, the results of the germination as well as glasshouse experiments will be discussed. The results will be discussed according to graphs showing the differences between the seven different water potentials used in the laboratory experiments (-0.3, -0.6, -0.9, -1.2, -1.5, -1.8 and -2.1MPa) and the three different water ratios used in the glasshouse experiments (100%, 50% and 20% water).

6.4.1 Laboratory experiments

6.4.1.1 Normal germination

In the following section, the results of the purity and germination tests conducted on *C. ciliaris* will be discussed. The results of the purity tests as well as final germination percentage of *C. ciliaris* will be given in a report format, while normal germination over a time period of 12 days will be represented in a graph.

Seed of *C. ciliaris* was investigated to determine the pure seed component following the guidelines given by the International Seed Testing Association (ISTA). According to ISTA, the pure seed component of *C. ciliaris* includes the following (Box 6.1):

Box 6.1: Definition of the pure seed component of *Cenchrus ciliaris*

Fascicle or burr of 1 – 5 spikelets* with involucre of bristles.

* Spikelet with glumes, lemma and palea enclosing a caryopsis, plus attached sterile lemma.

Floret, with lemma and palea enclosing a caryopsis.

Caryopsis.

Piece of caryopsis larger than one-half the original size.

Table 6.1 represents the purity and germination analysis report for the submitted sample of *Cenchrus ciliaris* used in the drought stress experiment. The percentages of normal seedling germination comply with the standards set by the Plant Improvement Act 53 of 1976, which prescribes purity and germination thresholds that must be obtained before seed may be sold (See Chapter 3.2.3.2). The prescribed purity threshold for *C. ciliaris* is 96%, while the minimum germination threshold is 20%.

From Table 6.1 it is clear that *C. ciliaris* had a pure seed component of 99.4% while the inert component, consisting mostly of chaff and stalks, comprised 0.6% of the sample. In concurrence with the high purity percentage obtained, eighty two percent of the seeds germinated normally in the duration of the test, while 0.8% of the seedlings were deformed (only root development). At the end of the, 16.8% of the seeds were dead and had no further capacity to germinate.

Table 6.1 Purity and germination analysis report for *Cenchrus ciliaris*.

Analysis report			
Code: L4		Date received: 1 August 2003	
Submitted sample weight: 161.7 g		Date concluded: 18 March 2004	
Botanical name: <i>Cenchrus ciliaris</i>			
Purity (% by weight)	Pure seeds	Inert matter	Other seeds
	99.4	0.6	-
Inert matter: Chaff, stalks			
Other seeds: Thereof - % weed seeds			
Germination method: Top paper, KNO ₃ , Light			
Germination (% by number)	Duration of test	Normal seeds	Hard seeds
	28 days	82.0	-
	Fresh seeds	Abnormal seeds	Dead seeds
	-	0.8	16.8
Remarks: Abnormal seeds – Only root development			
Date: 24 August 2004		Sign:	

Normal seed – Seedlings which can develop into normal plants

Fresh seed – Seed still having the ability to germinate into normal seedlings after completion of the test

Abnormal seed – Seedlings which have not developed normally (deformed seedlings)

Dead seed – Unviable seed not being able to germinate within the testing period

In concurrence with the germination results, Figure 6.9 shows the rate of normal germination of *Cenchrus ciliaris* over 12 days. It is evident that *C. ciliaris* shows a high germination percentage (71.5%) within the first four days after which germination seems to level off to reach a plateau of 82%. The results shows that, if provided with optimal germination conditions (moisture and temperature), seed from *C. ciliaris* showed a high germination capacity within the first few days after it was planted. This could serve as an important determining factor when planning any over-sowing treatment with this specific species for restoration purposes.

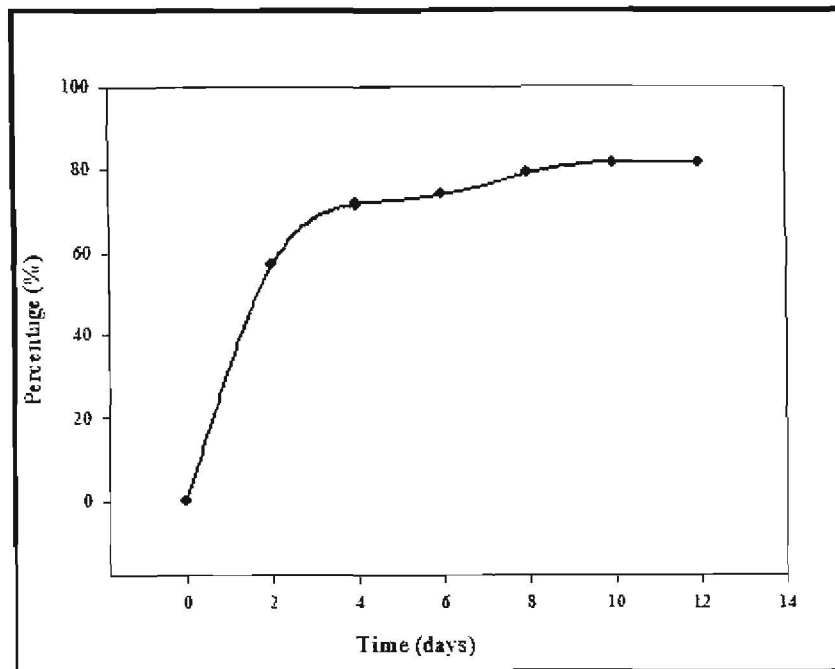


Figure 6.9 Normal germination curve of seeds of *Cenchrus ciliaris* over a period of 12 days.

6.4.1.2 Drought stress induced germination

Figure 6.10 indicates a normal (control) germination of 40.2%. The normal germination (control) during the drought stress experiment is almost half of the germination obtained during the normal experiment (Section 6.4.1.1). This is explained by the fact that no KNO_3 was added during the drought stress experiment. It is important to note that the dynamics of the seed has to be taken into consideration before seed is used in over-sowing restoration treatments. In some instances, seed should be kept under low temperatures for a year or two to allow the dormancy to be broken (Warde, 2001). Some seeds may require light to avoid germination when buried in the soil or under the canopies of existing vegetation, while other species only germinate in the dark to avoid germination on the soil surface (Bellairs & Davidson, 1999).

From Figure 6.10 it is evident that germination capacity decreases for *C. ciliaris* with a decrease in osmotic potential. Only a slight decrease in germination capacity is noted from the control treatment (40.2%) to the -0.3 MPa treatment (38%), after which the germination decreases

considerably (0% at the -2.1 MPa treatment). Although seed germination occurred at all of the different osmotic potentials, with the exception of -2.1 MPa, seed of *Cenchrus ciliaris* does not show a very high tolerance to water stress. The fact that the seeds did not germinate at an osmotic potential of less than -1.8 MPa could be an important survival mechanism that ensures dormancy within the soil seed bank until sufficient moisture is available for optimal seed germination and seedling establishment.

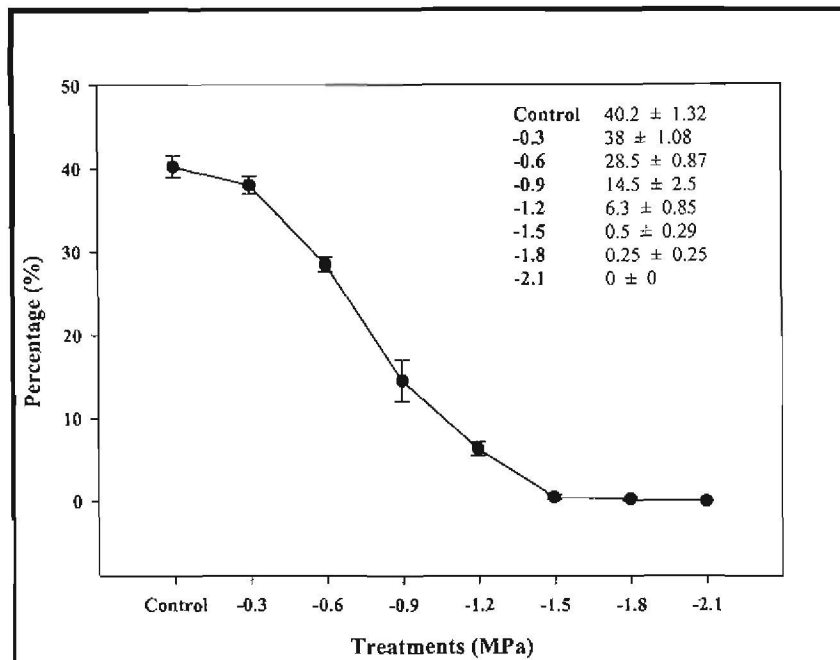


Figure 6.10 Response of germination capacity (%) of *Cenchrus ciliaris* with a decrease in osmotic potential (MPa).

Drought plays an important role in determining germination rates, and also influences seedling development of sown species (Figure 6.11). Even when enough moisture is available to promote germination, in the absence of subsequent rain, growth of newly germinated seedlings will be compromised with potentially fatal consequences.

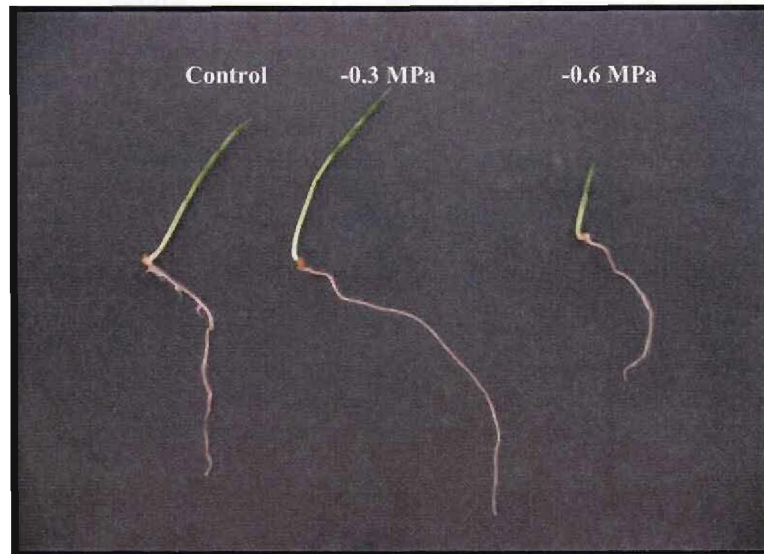


Figure 6.11 Comparative photograph of root and shoot morphology of seedlings of *Cenchrus ciliaris*, five days after subjection to different osmotic potentials (Control, -0.3 MPa and -0.6 MPa).

The shoot lengths of seedlings decreased with an increase in water stress from 2 cm at -0.3 MPa to 0.1 cm at -1.5 MPa (Figure 6.12). Root lengths of *C. ciliaris* were greater under osmotic potentials of -0.3 MPa (3.5 cm) than under the control conditions (2.8 cm) (Figure 6.12), but with a further decrease in osmotic potential, the root lengths of *C. ciliaris* declined progressively, reaching 0 cm at -1.5 MPa.

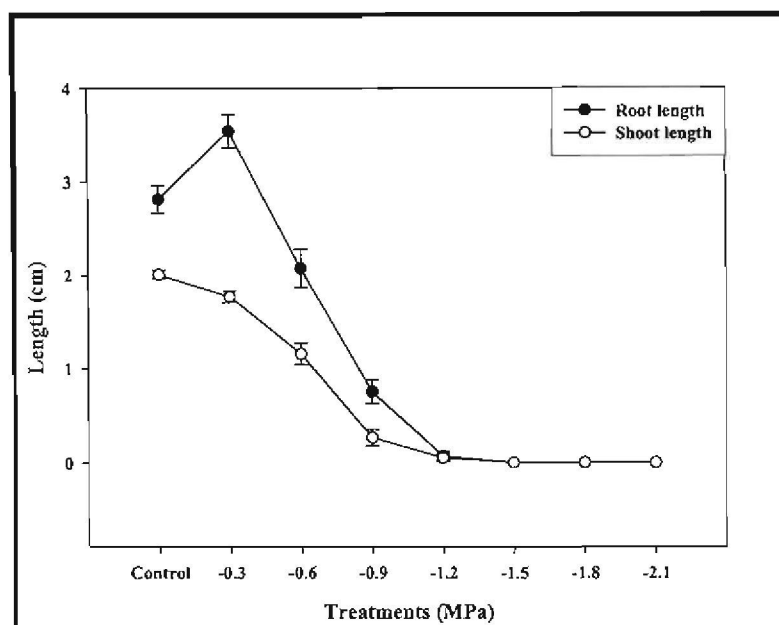


Figure 6.12 Growth rates of emerging root and shoot lengths (cm) of *Cenchrus ciliaris* seedlings exposed to various treatments of decreasing osmotic potentials (MPa).

6.4.2 Glasshouse experiments

In the following section, the results for the physiological as well as morphological measurements carried out during the glasshouse experiments will be discussed.

6.4.2.1 Determination of fluorescence

The ability of a plant to maintain photosynthetic functionality under water stress is of major importance for drought tolerance. Despite the fact that Photosystem II (PSII) is highly drought resistant under water stress (Yordanov *et al.*, 2003), photosynthetic electron transport through PSII is inhibited (Chakir & Jensen, 1999). At the end of the experiment it was evident that the drought treatment induced a stress reaction on day six. Figure 6.13 shows a highly significant ($p < 0.01$) decrease in PI_{ABS} values (23.6%) in the 20% water treatment when compared with the 100% water treatment on day six. From day six to day 15 of the experiment, the 50% and 20%

water treatments showed stabilization in PI_{ABS} values. The stabilization of PI_{ABS} values in all treatments from day six to day 15 can be ascribed to the following:

- The acclimatization of the plants to the drought conditions after initial significant reaction which is linked to the fact that photo-inhibition was reduced during the experiment (Figure 6.14).
- Favourable light intensity conditions (no photo-inhibition) during the experiment, caused by a high amount of cloud cover and rain during the experimental period. This allowed the metabolic adaptation of individual plants.
- General senescence of individual plants during the experiment, including protein denaturation.
- The *C. ciliaris* variety used during the experiment. Seed of the specific variety used (var *molopo*) was collected in the lower rainfall area of South Africa implying a genetic adaptation to moderate water stress conditions.

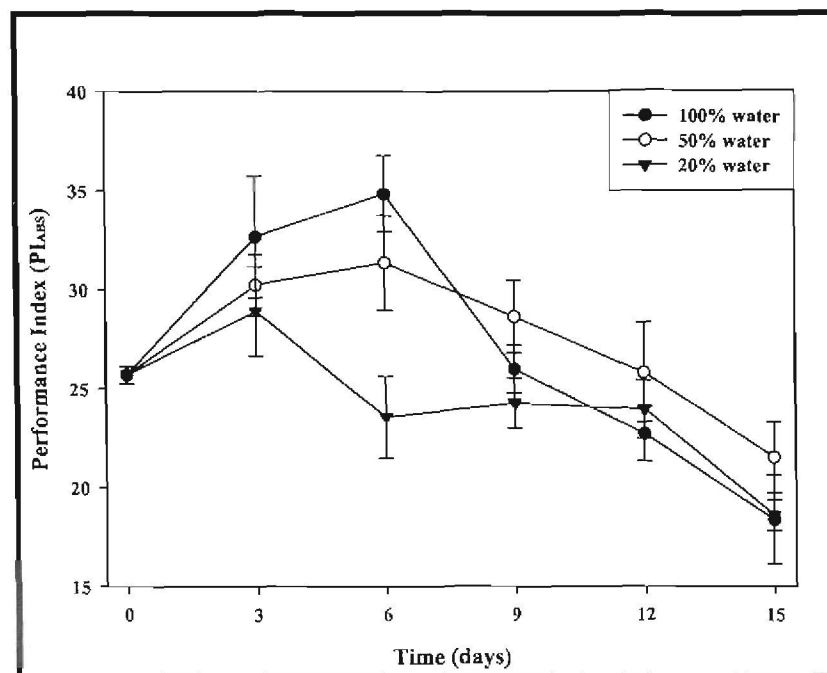


Figure 6.13 Change in Performance index (PI_{ABS}) of *Cenchrus ciliaris* as a result of exposure to three different drought stress ratios (100% water, 50% water and 20% water).

If the change in PI_{ABS} of the treatments (50% and 20% water) are standardized against the control treatment, it is clear that the 20% water treatment showed a highly significant ($p < 0.01$) reaction to drought stress on day six, while the 50% water showed a smaller, yet significant ($p < 0.05$), reaction on the same day (Figure 6.14). At the end of the experiment the control and 20% water treatment showed similar PI_{ABS} values, while the 50% water treatment was significantly higher ($p < 0.05$) than the other treatments. Prevailing low light intensity conditions during the experiment (average $425 \mu\text{Mol}$) facilitated the increased acclimatization of drought stressed plants over a period of nine days (Figure 6.14).

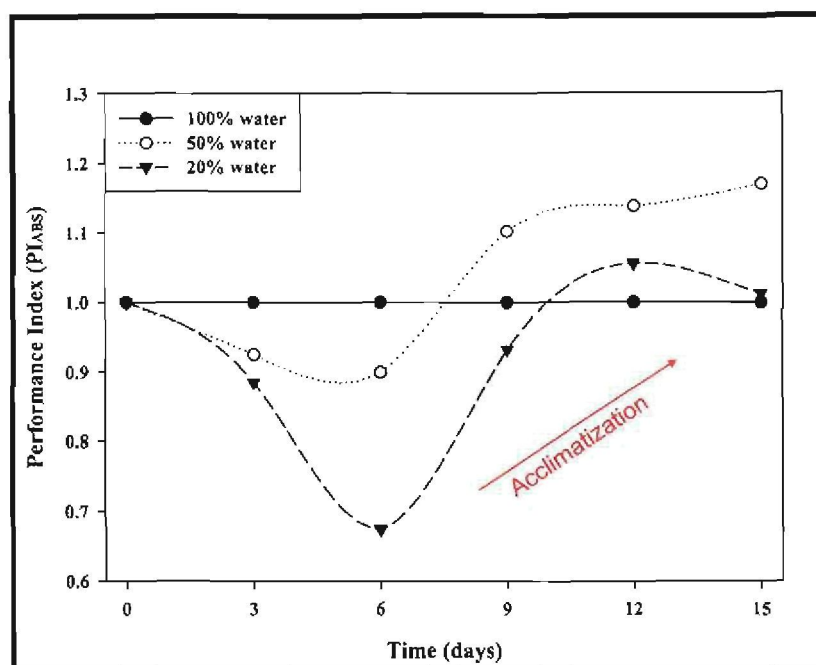


Figure 6.14 Change in Performance Index (PI_{ABS}) of drought subjected plants of *Cenchrus ciliaris*, standardized against the control plants (●) on every third day of the experiment (20% water - ▼ and 50% water - ○).

6.4.2.2 Chlorophyll Content Index (CCI)

Lower Chlorophyll Content Index (CCI) values on day six of the experiment (especially the 20% water treatment) correlates with the lower fluorescence values measured on the same day (Section 6.4.2.1). Even though the CCI values for all treatments on day six were approximately 30% lower than on day zero and day 15, this change in CCI values were not significant (Figure 6.15). The decrease in CCI values on day six of the experiment could be attributed to leaf ageing which cannot be detected with the naked eye. The increase in CCI on day 15 of the experiment could be ascribed to the fact that different aged leaves were used than on day zero and day six.

The higher value of the 20 % water treatment measured on day 15 (Figure 6.15) was caused by a concentration of chlorophyll in the leaves as a buffering mechanism against water stress. In concurrence with the higher CCI value of the 20% water treatment on day 15, and as a result of the low prevailing light intensity, no colouring of leaves (from green to yellow), took place after 15 days.

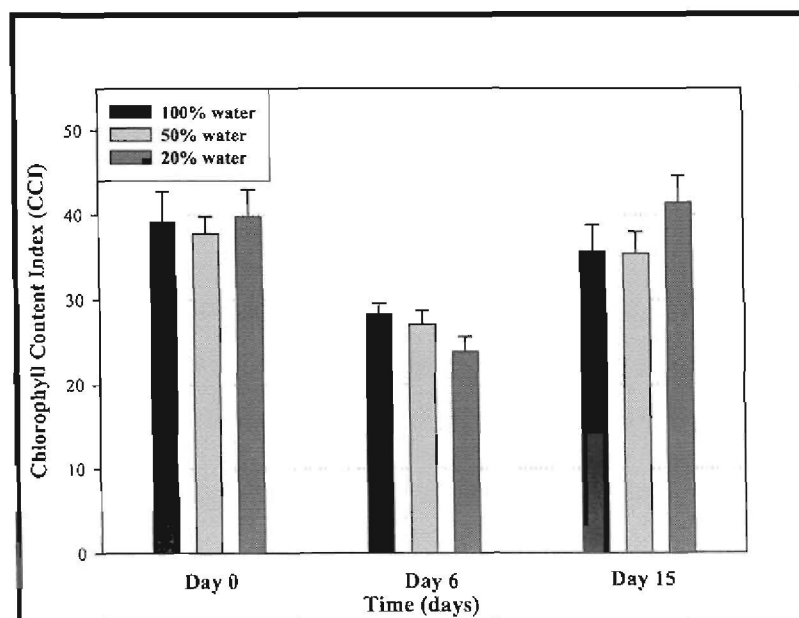


Figure 6.15 Chlorophyll content values of *Cenchrus ciliaris* subjected to different ratios of drought stress.

6.4.2.3 Relative Water Content (RWC)

Water stress has exerted a negative effect on the Relative Water Content (RWC) of the treated plants, thus, in the presence of water stress (50% and 20% water), the plants lost significantly more water than under control water conditions ($p < 0.01$). This result supports work previously carried out on other grass species (Larbi & Mekliche, 2004). The high RWC of the control treatment (90%) indicates that plants from the control treatment were kept at full water capacity (field capacity) for the duration of the experiment. Figure 6.16 shows that the 50% water treatment had a RWC of 72% while the 20% water stress ratio treatment had the lowest value (58%) at the end of the experiment. According to studies done by Van Heerden (1995), the results obtained from the treated plants were still high and could be ascribed to the low light intensity coupled with high humidity levels during the time of the experiment. The high humidity levels caused decreased desiccation in the treated plants, resulting in a higher water content in the all the plants.

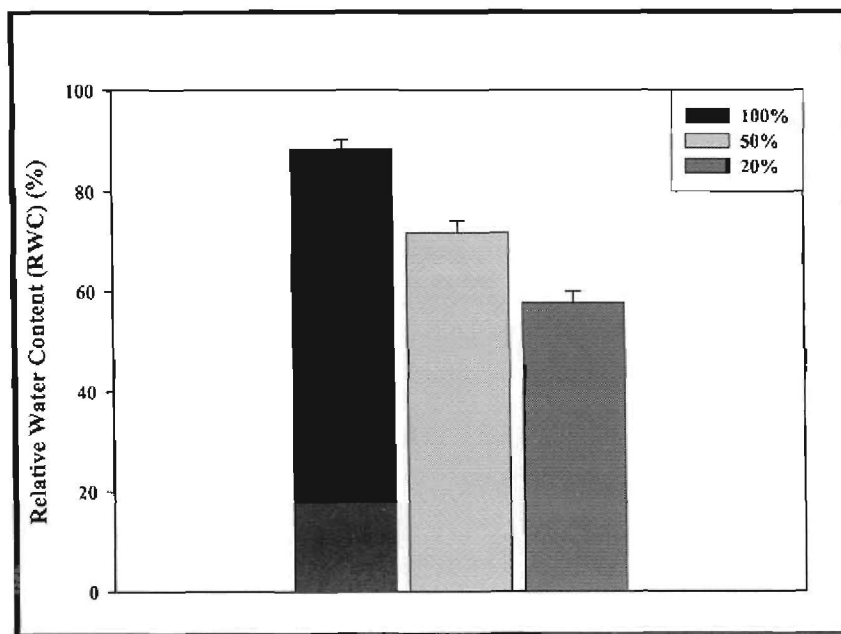


Figure 6.16 Relative Water Content (RWC) (%) of *Cenchrus ciliaris* at three different drought stress ratios.

6.4.2.4 Leaf elongation

Figure 6.17 represents the percentage change in leaf elongation for plants of *C. ciliaris* subjected to three different water stress ratios. From Figure 6.17 it is clear that the 100% water treatment showed a gradual increase in leaf length over a twelve day period. All individual plants of the different treatments showed relatively similar leaf elongation over the first eight days, after which the three treatments responded differently to the water deficiencies. Even though the 50% water treatment developed slower than the 20% treatment over the first ten days, it increased during the last two days of the experiment. The visual change in leaf elongation of the treated plants over the 15 day period is shown in Figure 6.18.

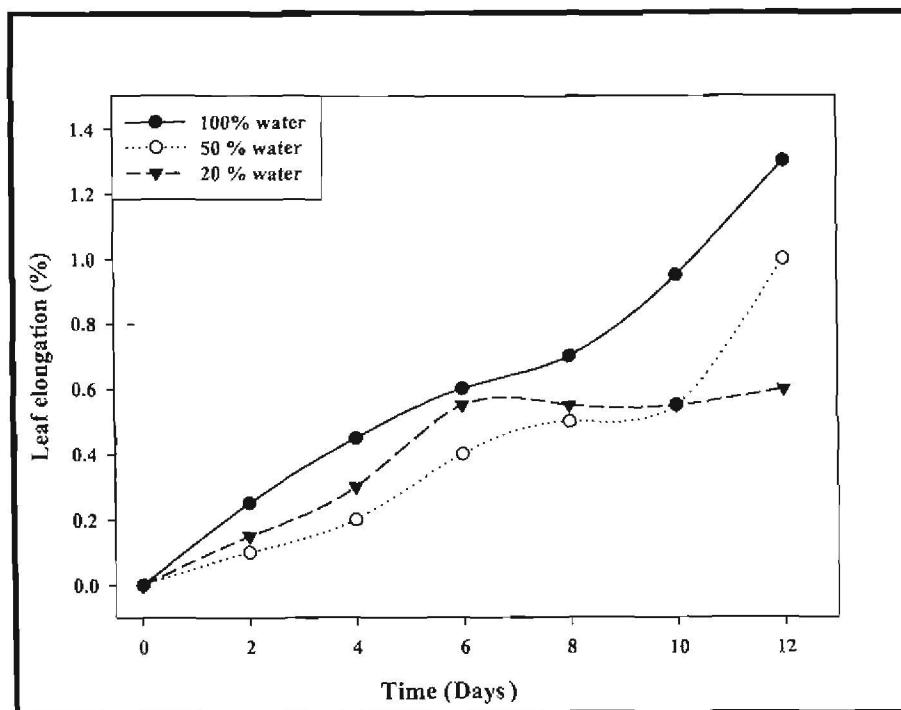


Figure 6.17 Change in leaf elongation (%) of *Cenchrus ciliaris* subjected to different water stress treatments over a 12 day period.

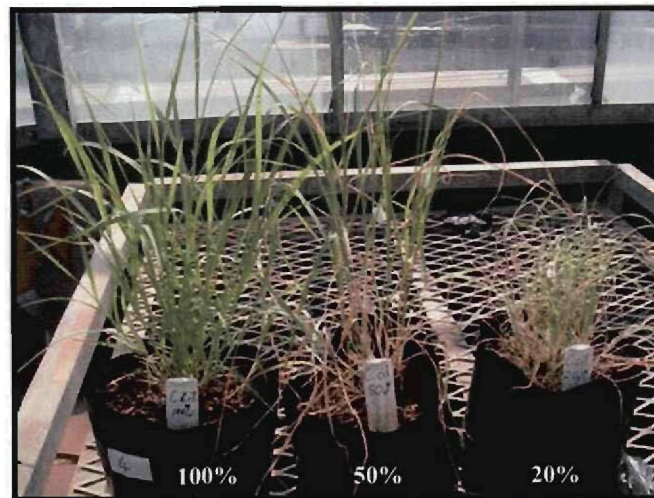


Figure 6.18 Morphological comparison between plants of *Cenchrus ciliaris* subjected to various ratios of water stress (100%, 50% and 20% water).

6.5 Conclusion and recommendations

The identification of drought tolerant subspecies and cultivars of *C. ciliaris* is of great importance to land users when planning farming and restoration activities. The effect of drought periods (i.e. drought stress) on the germination and establishment of *C. ciliaris* plays an important role in the success of the planned activity. Genetic differences caused by drought stress can only be determined through extensive field experiments, while using physiological parameters is a quick and efficient way to determine drought tolerance in plant species. In this study, the germination, morphological and physiological processes were used to determine the effect of drought stress on individuals of *C. ciliaris* var *molopo*.

Results from the normal germination tests conducted in the laboratory showed a correlation between the high pure seed component and the germination capacity. Seed germination under favourable conditions was high within the first four days, implying that, when sowing seed from this batch of *C. ciliaris*, a good result can be expected.

During the laboratory experiments, the germination capacity of *C. ciliaris* decreased with increasing water stress. This provides an essential survival mechanism to the species – if the environmental conditions are unfavourable for germination e.g. drought periods, seeds will remain dormant in the soil until the conditions change. Even though some seeds germinated during drought periods, they suffered a decreased morphological development of organs. Although shoot growth decreased, there was a slight increase in the root length associated with the -0.3 MPa treatment. Most likely, this reflects an adaptive response involving an increase in root length to reach water deeper in the soil.

The results obtained from the fluorescence measurements showed that, even though individuals of *C. ciliaris* showed sensitivity to water stress conditions in the first six days after initiation, no significant changes occurred during the experimental period. It is evident that a reduction in photo-inhibition (low light intensity) favoured the response of individuals of *C. ciliaris* to drought stress.

It is recommended to repeat this study, using various subspecies and varieties of *C. ciliaris* (i.e. subspecies and varieties occurring in higher and lower rainfall areas), to determine the effect of drought stress on a range of accessions of *C. ciliaris*. This would serve as a comparative baseline for choosing a specific *C. ciliaris* subspecies or variety for farming, restoration or re-vegetation activities.

Results obtained from Chlorophyll Content measurements showed no significant difference between day zero and day 15 indicating that drought stress has no effect on chlorophyll content (as a function of light condition) in *C. ciliaris* plants.

Although no significant fluorescence and chlorophyll differences were noted between the various water stress treatments, the RWC parameter showed highly significant differences. Due to these significant differences, Relative Water Content can be used as a standard for other parameters when measuring drought stress.

It can be concluded that drought stress influenced seed germination, seedling establishment and morphology of *C. ciliaris*, while having little effect on the physiological processes of mature plants.

Chapter 7

General conclusions and recommendations

7.1 Introduction

Land degradation and desertification are currently of the most important environmental threats in the world, especially in sub-Saharan Africa, where approximately 90% of the land surface is classified as arid, semi-arid or dry sub-humid. These areas are suffering from a high demand on the natural resources as a result of factors such as an increase in population densities and unsustainable resource utilization, including injudicious management practices. Food insecurity and poverty are two of the most important causes and consequences of degradation and desertification in the world and especially in Africa. Hunger is a major consequence of poverty, which leads to the overuse of every resource available for survival. Most people live off the land and due to erratic climatic conditions and already overstressed natural resources, the development of alternative livelihood strategies has become an important strategy to increase the livelihoods of the people. In addition, poor people often lack sufficient income to purchase appropriate tools, materials and technologies to practice environmentally sustainable agriculture, protect natural resources against degradation or rehabilitate degraded resources. There are, however, many examples of poor people who co-exist in harmony with their marginal environments, and through this study some of the technologies used to conserve and/or restore the natural resources are highlighted.

Throughout the world it is estimated that overgrazing is the main factor contributing to land degradation, while arable farming and deforestation are the second and third most important factors, respectively. Fragile soils in agricultural croplands are increasingly becoming degraded through nutrient depletion and erosion, while natural rangelands suffer as a result of over-utilization.

Through this project, the available resources, innovative solutions and the input of locally affected communities to combat and address land degradation issues, including conservation, restoration technologies and alternative livelihood options are being discussed. As a result of increased concern over the depletion and degradation of natural resources, the conservation of

these resources has become a focus point for environmental activities and legislation worldwide.

This study has mainly followed a theme of restoration ecology, focusing on a variety of aspects including legislation, approaches and specific technologies for improving people's livelihoods. The study was carried out in selected countries in Africa with special reference to South Africa. The Desert Margins Program (DMP) provided the framework for the different components of this study (Chapter 1) and according to the global DMP log frame the following objectives were identified:

- The documentation of existing policies and legislation regarding restoration and rehabilitation of biodiversity and the degradation of natural resources in South Africa, especially in arid and semi-arid rangeland regions.
- To identify and document the best restoration practices, including traditional methods, to conserve and restore biodiversity in the identified study areas.
- To evaluate and characterize the best approaches and practices of restoration technologies in the DMP partner countries.
- To set up pilot plots as demonstration for the restoration of biodiversity in the DMP target areas.
- The evaluation of *Cenchrus ciliaris* (Blue Buffalo Grass) as drought tolerant species to be used in restoration practices.
- To strengthen the knowledge base of all stakeholders with regard to restoration through training and capacity building, as well as farmer to farmer sharing activities, to enhance the adoption of restoration applications.

Chapter 2 of this thesis contains a thorough overview of land degradation and desertification in South Africa. The Chapter deals with the extent of land degradation and desertification in the country, processes and activities that contribute to this problem, as well as technologies that have been applied in South Africa to combat land degradation and restore areas that have been subjected to degradation and desertification. In South Africa it is accepted that restoration technologies are divided into active and passive technologies (Chapter 2.2.1). It appears as if the restoration of natural ecosystems to improve the ecological structure and functional integrity is generally difficult and costly to obtain. This implies that restoration

technologies which do not require huge technical and financial inputs are more readily adopted and implemented by land users.

As mentioned previously, the increased focus on land degradation and desertification has led to the implementation of new and reviewed environmental policies worldwide. The emphasis of Chapter 3 is on policies and legislation concerning degradation and restoration in South Africa, while Chapter 5 gives an overview of similar policies and legislation of the 9 DMP partner countries in Africa.

7.2 Policies and legislation concerning degradation and restoration in South Africa (Chapter 3)

South Africa has a comprehensive environmental legislative system that includes a range of international and national legislation. The summary of environmental legislation in South Africa was made after an in-depth literature survey using various sources, such as Acts and other policy documents, the internet and various knowledgeable individuals. The most important environmental legislation in South Africa has been included on the accompanying CD. This CD can be used as reference to various Acts used for guiding the use, management and protection of natural resources in South Africa.

South Africa is a signatory to an array of international conventions, such as the UNCCD, UNCBD, UNFCCC and RAMSAR, and in accordance with these conventions various National Action Programs (NAPs) have been developed. According to the South African UNCCD-NAP (Combating land degradation to alleviate rural poverty), desertification is not only about the spread of deserts, but it is about the impoverishment of the land in many ways. It is both a cause and effect of human poverty. The NAP drives the integrated approach of sustainability, with the objective of improving land management while alleviating poverty, promoting local development, and sustaining the flow of ecosystem goods and services from the land. Achieving these objectives will involve long-term integrated strategies that simultaneously focus on improved productivity of land and on the rehabilitation, conservation and sustainable management of land and water resources, leading to improved living conditions.

Jointly with the conventions, the NAPs and Constitution of South Africa, a huge number of environmental acts form the baseline for environmental activities in the country, such as the National Environmental Management Act (NEMA) and the Conservation of Agricultural Resources Act (CARA). The origin, objectives and content of the constitution and the various conventions, acts and environmental agencies are described in detail in Chapter 3 and will therefore not be mentioned again.

Various international and national incentives, such as the Millennium Ecosystem Assessment (MA) and the Land Degradation Assessment Program (LADA) deal with the assessment of the causes, status and impact of land degradation, but very few incentives deal directly with the implementation and monitoring of alternative livelihood, conservation and restoration technologies. It is therefore emphasized that there is a need to develop a system that facilitates collaboration between various environmental organizations and agricultural departments in South Africa with regard to the implementation and monitoring of the mentioned technologies.

Environmental legislation positively influences the implementation of conservation and restoration activities as it provides guidelines and regulations to which technologies and activities must adhere, such as the control measures prescribed by the CARA Act. Most of the environmental acts deal only with components of the environment, such as the National Forest Act (84 of 1998), and generally a combination of legislation is used for the planning and implementation of activities. The national government is accountable for creating environmental policy and enforcing it and various government departments, such as the Department of Agriculture (DoA) and the Department of Water Affairs and Forestry (DWAF) join forces to ensure the effectiveness of policy enforcement. Unfortunately, however, land users are often not aware of the legislation controlling the implementation of conservation and restoration activities. Environmental policy interventions should therefore be focused on knowledge transfer and capacity building on all levels of stakeholder involvement, including the grassroots level.

7.3 Land users' views on land degradation and restoration (Chapter 4)

It is commonly accepted that land users' perception of degradation and desertification will differ from that of researchers and scientists. Land users, in general, tend to be more aware of threats to the natural resources as it has a direct influence on their livelihoods. It is, however, unclear what the difference in perceptions concerning land degradation is between land users from different land tenure and land use systems. Chapter 4 aimed to determine the difference in perceptions of degradation, as well as the implementation of conservation and restoration activities between land users in different land use systems, i.e. conservation areas, commercial farming and communal or small-holder farming. It must be stressed however that the results of this study relied solely on the subjective perceptions of land users.

One of the most important questions arising from this study was whether land users' perceptions of degradation and restoration contributes to their adoption of introduced technologies. In general, it has been found that a lack of ownership, as well as an insufficient availability of financial resources is the most important factors limiting the adoption and implementation of conservation and restoration technologies.

Although the DMP program has been implemented in nine countries in Africa the main part of this study forms part of the DMP program in South Africa. The surveys were carried out in the four DMP target areas in the Northern Cape and North West Provinces of South Africa, i.e. Molopo (Molopo study site), Kalahari (Mier study site), Namaqualand (Paulshoek study site) and Suid Bokkeveld (Suid Bokkeveld study site). The research material was collected through a questionnaire used in semi-structured interviews with land users. Five categories were included dealing with general information, land use type, livestock information, erosion information, factors leading to land degradation and the application of possible restoration activities. The questions in each of the categories were compiled in such a way as to provide a clear overview of the perceptions land users from different land use systems have with regard to land degradation in their farming system. In addition, the results from the questionnaire were also used to identify best-bet approaches towards alternative livelihood strategies, conservation and restoration technologies implemented by land users in South Africa, as discussed in Chapter 5.

In the course of this study a total of two individuals from conservation areas, 25 commercial land users and 37 small-holder and communal farmers were interviewed. The larger number of small-holder and communal farmers interviewed is explained by the fact that respondents from this land use type were more accessible than respondents from other land use types. The low number of conservation areas and commercial farms within each study site was one of the limiting factors contributing to the lower number of respondents from these land use types.

The results obtained from the questionnaires were analyzed separately for each study site and comparisons were made in the Conclusion section of Chapter 4. Due to the fact that the four study sites varied in climatic and vegetation conditions, some information, such as livestock numbers and the sizes of farming areas, could not be compared.

Even though no direct comparison was made, it appears that conservation areas were the largest and small-holder farms the smallest. The large area covered by conservation areas is explained by the fact that large areas are needed to optimally conserve the plant and animal diversity within their natural habitats, especially in game protected areas. The small size of small-holder farming areas can mainly be ascribed to the former apartheid regime's discriminatory policies, which contributed to the dualistic structure of South Africa's agricultural sector, i.e. a modern, highly capitalized commercial sector co-existing with a traditional, low technology small-holder and communal sector.

The majority of land users have been farming for more than 10 years and most of their farming knowledge has been passed on from their parents. This contributed to the fact that most of the respondents had a clear understanding of the prevailing environmental conditions and have devised ways in which to deal with these conditions, especially in critical conditions, such as drought periods. Some land users indicated that they have adapted technologies conveyed to them by their parents to adapt to changing environmental and resource conditions. A total of 12.5% of the land users interviewed gained their knowledge of farming by attending tertiary institutions, such as education training colleges and universities. All of the latter respondents were from the commercial farming sector, where financial resources are available to provide for further education. This is, however, scarce for the small holder farmers, who often suffers as a result of poverty.

Eighty percent (80%) of all interviewed land users indicated that they collect and use materials from the environment on a regular basis. The majority of land users who collect and use these materials are from the small-holder and communal sector. These land users also indicated that, as a result of over-utilization, it is becoming increasingly difficult to obtain these materials. In the Paulshoek study site, natural materials are still extensively used for constructing homes and shelters, while most land users from the small-holder and communal sector still use natural materials for cooking and heating. This results in an increased pressure on the natural resources surrounding homesteads and villages.

In the Mier, Paulshoek and Molopo study sites, livestock production is the main farming activity, while a mixture of rooibos tea (*Aspalathus linearis*) cultivation and livestock production is the primary farming activity in the Suid Bokkeveld study site. A large number of animal species were recorded during the survey, including various game and livestock species. Only game species occurred within the conservation areas and their numbers varied according to the size of the conservation area, as well as the current management plan. It is evident that land users from the Paulshoek and Suid Bokkeveld study sites use game, sheep and goats in their farming systems, while land users from the Molopo study site use mainly cattle. Land users from the Mier study site use a combination of game, cattle, goats and sheep in their farming systems. The number of animals and the management of the livestock and game species varied according to land use system. In addition, the grazing systems used in the study sites varied according to land use and included systems such as continuous grazing and rotational grazing using camp systems and herding.

Respondents in all the study sites indicated that ground water is the main source of water, but that surface water is also available during the rainy season. In some cases in the communal sector, however, land users indicated that, even though there are boreholes and pumps, only a few are in working condition. This is a result of minimum or low maintenance and can mainly be ascribed to financial constraints, but also to a lack of ownership in these communal areas. The reduction in water available for livestock contributes to increased grazing and trampling effects in the areas surrounding available water sources. In some areas in the Suid Bokkeveld and Mier study sites, initiatives such as the LandCare program have provided financial and technical assistance to erect water tanks (reservoirs), build dams and erect

paddocks with fencing for rotational grazing to decrease the pressures around existing water sources.

During this study, it became evident that land users are aware of land degradation in the areas where they are farming. Quite a number, however, felt that land degradation is only a result of prolonged droughts and that the situation will improve after an average or above average rainfall season. Another general feeling concerning land degradation was that this phenomenon is only evident due to the fact that the size of the grazing is inadequate for livestock grazing. Most of the interviewed land users felt that land degradation is characterized by a change in species composition, with an increase of poor quality, unwanted and poisonous species. Individuals from all land use sectors pointed out that the presence of bare areas is an indication of degradation. The responses indicated that, in some study sites, especially the Mier study site, land users do not understand that there is a connection between the causes (e.g. overgrazing) and effects (e.g. bare dune crests and wind erosion) of land degradation. Communal land users, who depend on natural resources for sustaining their daily livelihoods, have slightly different perceptions about degradation than commercial farmers. Communal land users felt that the condition of their livestock gives an accurate indication of the condition of the land. Livestock in a poor condition indicates poor grazing conditions or even a lack of available fodder altogether. On the other hand, if livestock is in a good condition, the impression is that the animals have access to enough good quality grazing.

The majority of land users from the commercial sector indicated that erosion is not a major problem on their farms, while land users from the communal and small-holder sectors felt that erosion is a big problem, often seen as gullies and sheet erosion. The perceptions, however, differed according to the different study sites. The respondents from the Suid Bokkeveld and Mier study sites felt that wind erosion has a bigger influence on the condition of the land than water erosion. The land users from the Suid Bokkeveld study sites have, nevertheless, devised ways in which to protect the vegetation from the threats of wind erosion, such as the planting of wind breaks to protect their tea plantations. Respondents from the Paulshoek study site felt that water erosion contributes greatly to land degradation in the area. Water erosion in this area causes large gullies, threatening the safety of their livestock. Some land

users also indicated that, without proper maintenance, water erosion also negatively impacts on the roads in the area, making the grazing area less accessible for vehicles.

Even though the majority of land users from all study sites indicated that land degradation and erosion cause problems, fewer than half have implemented any conservation and restoration technologies to address these problems. The largest percentage of land users who have actively applied conservation and restoration technologies are from the commercial sector, as they have access to the necessary financial resources to apply these technologies. Most of the land users from the communal and small-holder sector indicated that, even if they wanted to apply technologies, they do not have the necessary financial resources. This concurs with previous studies which indicated that technologies with low technical and financial input are more readily adopted by land users. Technologies which involve less labour and financial inputs, such as soil loosening, are more readily adopted than technologies involving higher labour and financial inputs, such as the half moon and Zai technology (Chapter 5). The technology most commonly used by land users from all sectors is resting from grazing impacts. This technology is implemented in various farming strategies, such as herding and rotational grazing systems. Other active restoration technologies implemented by respondents included the eradication of invader woody and alien plant species, the sowing of perennial herbaceous species into natural rangelands, as well as the establishment of planted pastures.

Fewer than half (42%) of all respondents have applied active erosion control technologies, such as the packing of stone walls in gullies and contour ploughing. The majority of respondents who have applied erosion control technologies were from the Suid Bokkeveld study site, where wind erosion threatens the sustainable cultivation of rooibos tea. Land users in this study site have implemented site- and case specific erosion control technologies to decrease or halt the effects of wind erosion, such as the establishment of wind breaks and the use of mulching to ensure the stabilization of surrounding vegetation.

Even though land users from the communal sector indicated that there are quite a number of old lands within the commons, no action has been taken to restore these old lands and they have been left to recover through natural successional processes. In contrast, the majority of respondents from the small-holder and commercial sectors have converted old lands to planted pastures. This contributes to the respondents' livelihoods in that the yields from the

planted pastures are generally used as additional fodder for the livestock during the dry months or the fodder is sold for extra income.

From the results of this study, it is evident that land users have adapted to the environmental conditions at the respective study sites, and have implemented various coping strategies to overcome harsh environmental conditions. It is further clear that individual land users, as well as land users from the different land use groups, perceive land degradation very differently. It can be concluded that land tenure, ownership and the availability of technical and financial resources determine land users' approach towards conservation and restoration activities, as well as the adoption and implementation of technologies.

7.4 Technologies for conservation, restoration and livelihood improvement in DMP partner countries (Chapter 5)

Land degradation, exacerbated by human activities, is an important environmental issue not only in South Africa, but all around the world. Throughout Africa, land degradation causes an increase in poverty, loss of biodiversity and decreased soil fertility. Most of Africa's communities live in rural areas, and the majority of people in these areas rely largely on natural resources for their livelihoods. Various coping strategies have been developed by people in Africa to mitigate land degradation and desertification problems. The question of which technologies are most successful in mitigating the problems and how readily these technologies are accepted and implemented, however, remains. The objectives of this part of the study were to document approaches and legislation regarding restoration, to identify, document and characterize the best-bet technologies for alternative livelihood options and the restoration and conservation of natural resources in DMP partner countries in Africa. An information booklet containing a description of most of the technologies observed during this study has been compiled.

The information for this part of the study was collected through literature studies, questionnaires and interviews with relevant parties in each DMP partner country. The various categories in the questionnaire dealt with legislation and policy pertaining to environmental conservation, approaches to restoration, as well as technologies to restore degraded areas.

Results from these questionnaires and interviews contributed to an overall understanding of the degradation processes and severity in each DMP partner country, as well as the ways in which governments, NGOs, other organizations and individual land users cope with land degradation problems. One or more DMP target area in each country was visited and a written and photographic record was made at each of the visited sites.

All nine DMP partner countries have signed and ratified the three most important United Nations Convention regarding factors relating to land degradation and desertification, i.e. UNCCD, UNCBD and UNFCCC. This puts all of the countries under an international obligation to develop and implement long-term strategies to combat land degradation and desertification, especially with regard to the development of National Action Programs (NAPs) and Namibia's Program to Combat Desertification (NAPCOD).

In addition to the international obligations, all the visited countries have policies and legislation covering all aspects of environmental conservation and the sustainable use of natural resources. This included policies and legislation relating to environmental management in the forestry, water, pastoral, wildlife, agricultural and mining sectors. Despite policies and legislation covering land degradation, sustainable land management and the restoration of natural resource practices, most of the restoration projects are funded and driven by international funders, environmental agencies and NGOs.

The observed technologies in each of the DMP partner countries have been divided into three categories, i.e. conservation, restoration and alternative livelihood technologies. The documentation of the technologies has been done according to these categories. A description of the majority of technologies has been included in a booklet which accompanies this thesis. The booklet can be used by individuals to obtain a basic understanding of the following aspects of each technology: (1) in which DMP partner country the specific technology is applied, (2) the main purpose and benefits of the technology, (3) a simple description of the technology, and (4) the reasons why the technology has been adopted and implemented by land users. Table 5.1 (provided at the end of Chapter 5) gives a summary of all the observed technologies and the categories that they have been grouped into. Technologies implemented to provide land users with products and services to improve their livelihood conditions were classified as alternative livelihood technologies. Conservation technologies entailed those

technologies which have been applied to conserve the current condition of the resource or the sustainable use thereof in the future. Restoration technologies included those active and passive technologies which have been applied to improve the current condition of the natural resource.

From the results, it is evident that all of the DMP countries have implemented various technologies that can be classified into the above mentioned categories. It must be stressed again that the technologies mentioned in this thesis are only those that were observed during visits to the DMP target sites in each country and it is possible that various other technologies could have been applied that are not reflected in this study.

In the Southern and East African DMP partner countries, where livestock production is the main agricultural activity, the majority of technologies implemented included conservation and restoration technologies to conserve and improve the condition of natural rangelands in these countries. Alternative livelihood technologies have been applied to a lesser extent, with the exception of Zimbabwe, where huge efforts have been made towards alternative livelihood options and additional income generation. As previously mentioned only technologies that were observed in each of the countries and form part of the DMP program were documented. According to literature surveys and other knowledge obtained, there are many other technologies implemented in each of the DMP countries. These technologies were however not implemented at the DMP study areas and are therefore not discussed here.

Land users in West African DMP countries such as Senegal, Mali, Burkina Faso and Niger are more dependent on agro-forestry to sustain their livelihoods. Technologies in these countries are therefore more focussed on the restoration of soil fertility to increase crop production, re-forestation, as well as the sustainable use of natural products to ensure their availability over the long-term. In the majority of cases, restoration and alternative livelihood technologies are used in combination to increase the productivity of the natural resources, thereby leading to increased income generation for the land user.

It is important to mention that most of the land users in the different countries use a combination of technologies to address the complex problems of land degradation and desertification. A combination of technologies also ensures that the best possible results will

be achieved in the shortest possible time. As in the case of conservation and restoration technologies applied in South Africa (Chapter 4), the limiting factors contributing to the low adoption and implementation rate of technologies in DMP countries include appropriate knowledge, as well as technical and financial resources.

7.5 The evaluation of the effects of drought stress on the germination, physiological and morphological characteristics of *Cenchrus ciliaris* (Chapter 6)

As mentioned previously, a large number of technologies in South Africa focus on the improvement of natural rangelands through active restoration technologies. One of the most used technologies is the over-sowing of palatable herbaceous species in degraded areas (Chapter 4). This technology is very important in areas where there are bare patches with little or no seed remaining in the soil seed bank. The over-sowing of herbaceous species in semi-arid and arid areas, however, is often unsuccessful as a result of unfavourable environmental conditions such as drought, extreme temperatures, increased soil salinity and soil crusting. These conditions negatively affect the germination and growth of seedlings after over-sowing applications. An ongoing constraint in restoring natural semi-arid and arid areas through over-sowing is the unavailability of seed of species that are adapted to unfavourable conditions. In most cases, seed of herbaceous species that are available in huge quantities are generally species used for planted pastures in higher rainfall areas. *Cenchrus ciliaris*, however, has found favour with land users in South Africa and many other arid and semi-arid countries in Africa and elsewhere, as seed of this species is readily available and it produces a bulk of palatable forage under relatively dry conditions.

Even though this species is used by land users for planted pastures in semi-arid and arid areas, it is uncertain how low water availability in these areas would influence the internal and external germination and growth processes of this species. In an effort to gain an understanding of how this species would react to low water availability and drought conditions with regard to germination, morphology and physiology, *C. ciliaris* was subjected to a number of drought induced experiments (Chapter 6).

Seed, seedlings and mature plants of *C. ciliaris* were subjected to three different experiments, as explained in Chapter 6. Laboratory experiments were used to determine germination capacity of *C. ciliaris* under normal, as well as drought conditions. The seedlings that germinated under these conditions were evaluated to determine their initial growth response to different levels of water stress. Glasshouse experiments were used to establish the effect of drought stress on various physiological aspects of mature plants, such as fluorescence, chlorophyll content and Relative Water Content.

If provided with optimal germination conditions, i.e. light, temperature and moisture, seed of *C. ciliaris* show a high germination rate within the first four days. This implies that, if it is used in restoration activities, a relatively good germination rate could be expected under optimal rainfall conditions. When exposed to drought conditions, however, the germination capacity of *C. ciliaris* decreases with an increase in water stress. The fact that fewer seeds germinated at high water stress conditions can be an important survival mechanism for plants during drought conditions, as these seeds stay dormant in the soil until the conditions are optimal for germination and seedling establishment.

In addition, the small percentage of seeds that germinated under drought conditions showed reduced morphological development of all organs, indicating that these seedlings would be more vulnerable to extreme environmental conditions than seedlings that germinated and established under optimal conditions. The reduced morphological development would also have a direct impact on the amount of forage this species will provide during dry periods.

Results obtained from the fluorescence measurements on mature plants which have been subjected to varying drought conditions indicated that, even though individuals of *C. ciliaris* showed initial sensitivity to drought stress conditions, no significant changes occurred during the experimental period. In addition to the fluorescence results, the results obtained from chlorophyll content measurements also showed no significant differences. From these results it is evident that drought conditions did not have any significant effect on the photosynthesis ability of the plant, implying that the quality of the available forage would not be lower during drought conditions.

The Relative Water Content results however, showed highly significant differences between the various drought stress conditions. The Relative Water Content values decreased with an increase in drought stress conditions, which might result in the wilting of these plants. Plants with low Relative Water Content values suffer from water stress and need water to function optimally. Due to these significant changes, Relative Water Content can be used in future experiments as a standard for other parameters when measuring drought stress.

In conclusion it could be said that, even though drought stress influenced *C. ciliaris* seed germination, seedling establishment and morphology, it had little effect on the physiological processes of mature plants. These results could contribute greatly to the planning and implementation of restoration activities involving the use of this species in active over-sowing technologies. More accurate planning can be made with regards to the time of over-sowing, seedbed preparation and aftercare.

7.6 Value of this study

Taking all of the above mentioned results and statements into consideration, it could be concluded that the threat of degradation and desertification in semi-arid and arid areas in Africa, with special reference to the DMP partner countries, is increasingly becoming an important concept, not only to scientists and land users, but also on government level through policy interventions. Various technologies, focusing on different aspects of livelihood improvement, have been tested and implemented in the mentioned countries. The aim was to implement these technologies according to the needs of land users and to increase the livelihood options for land users in the different land use systems. If this has been successful remains a question.

The first four objectives set out at the beginning of this study were adequately achieved with certain limitations. These limitations included the lack of resources and information concerning environmental legislation in all the DMP partner countries, time constraints and the language barrier during interviews with stakeholders in certain countries, as well as the different interpretations of information and answers by the different persons interviewed. In addition, language constraints in DMP partner countries sometimes led to misunderstandings

and misinterpretation of information and answers. Even with these limitations the results obtained during the study proved to give valuable insight into the views and perceptions of stakeholders with regard to land degradation and restoration.

This study contributes to new information concerning various components regarding the different restoration, conservation and livelihood technologies implemented in the different DMP partner countries. The aim was to learn from each other, contribute to knowledge sharing and exchange activities, as well as to improve collaboration between the sub-Saharan African countries involved in the study with regards to the challenges of land degradation and desertification. The last objective however, has not been adequately achieved in this study. Although a huge amount of information has been gained, very little training and capacity building activities resulted from it. As mentioned in Chapter 1 however, this study forms part of the Desert Margins Program (DMP) and various farmersdays, information packages and other capacity building activities are organized as part of this program. The results of this study will be incorporated in future training and capacity building activities in the DMP.

This thesis provides a baseline document which summarized information concerning legislation and technologies used for conservation and restoration in selected countries and can be used as reference document by DMP partners, stakeholders and other interested parties.

7.7 Recommendations for policy makers, managers and land users

- From this study it is clear that the majority of land users are not aware of specific environmental legislation. Policies pertaining to environmental issues should be transferred to land users in a more effective manner to facilitate the understanding of the legislation. The benefits and disadvantages accompanying the enforcement of environmental legislation should also be explained in a way that is easily understood by all land users. This could be achieved through improved agricultural extension services, effective Governmental initiatives such as LandCare, as well as written and spoken media sources such as television.

- From a legislative perspective, it is evident that even though South Africa has developed the NAPs in accordance with the objectives and guidelines of the UNCCD, UNCBD and UNFCCC, the effects have not yet been felt on the ‘ground’ by the rural land user and communities. It is recommended that the NAPs should be used effectively to integrate natural and socio-economic aspects of the processes of land degradation and drought, as well as to integrate strategies for poverty eradication in efforts to combat land degradation and mitigate the effects of drought.
- Environmental projects can only be successful through strong, long-term government commitment backed up by effective policies, organizational structures and funding mechanisms. In the case of the Mier study site it is clear that restoration activities stopped when funding was no longer provided (See Chapter 4.5.1). This emphasizes the fact that to effectively achieve change, funds and resources need to target the capacity building and appropriate institutional frameworks.
- Results from this study should be included in the World Overview of Conservation Approaches and Technologies (WOCAT) database (Chapter 3), as this will contribute to the network of successful SWC technologies implemented all over the world.
- As the primary needs of people in rural areas are not focused on natural resources, but rather on social and economic resources, it is essential to make land users more aware of how their immediate needs are linked to the environment and the protection thereof.
- As part of projects implemented by National initiatives in South Africa, such as Working for Water and LandCare, land users should not only be capacitated in skills training concerned with the combating of the problem of land degradation and desertification, but also in the actual cause and effect of the problem. From the response to the questionnaire used in South Africa, it is clear that some land users are not aware of the underlying relationship between the causes and effects of land degradation. This problem can be rectified through improved environmental education and increased awareness raising concerning these issues.
- It is imperative that most environmental legislation, and specifically the Conservation of Agricultural Resources Act (Act 43 of 1983), be revised to make provision for the monitoring of degradation, restoration and other environmental issues.
- The information gained through this study can positively impact on the knowledge base of all stakeholders with regard to effective approaches and technologies used to conserve and restore rangelands. Trends and technologies concerning alternative livelihoods,

conservation and restoration should be included as part of formal and informal packages for land users. This would provide land users with the necessary ‘know-how’ to apply alternative livelihood, conservation and restoration technologies in their specific situations.

- Formal monitoring and scientific evaluation should be applied in the Suid Bokkeveld DMP study site to determine the success of the technologies to prevent soil erosion in the rooibos tea lands.
- Although a number of innovative restoration, conservation and alternative livelihood technologies are implemented throughout the DMP countries in Africa, little scientific data is available to determine the success of these technologies. Technologies are perceived to be successful without the necessary evidence to prove the perceptions. It is therefore recommended that scientific monitoring of individual technologies be included in restoration initiatives to verify the success of the technologies.
- It is imperative that programs such as the DMP are implemented over the long-term as this would facilitate the adoption and implementation of ‘best-bet’ technologies by land users.
- It is recommended that technology transfer is promoted within and between DMP countries as various DMP countries share similar environmental, social and financial conditions. An inventory of technologies should be available in each DMP country to serve as reference for all stakeholders.
- Various subspecies and varieties of *Cenchrus ciliaris* (i.e. subspecies and varieties occurring in higher and lower rainfall areas) should be used in drought stress experiments. This would serve as a comparative baseline for choosing a specific *C. ciliaris* subspecies or variety for farming, restoration or re-vegetation activities. Care should however be taken to ensure that this species is only used in areas where it would not pose a threat of becoming a weed.
- It is recommended that further trials are conducted to compare the effect of drought stress on the germination, seedling establishment and morphology of *C. ciliaris* under laboratory and natural field conditions.

CHAPTER 8

Complete References

- ABEL, N.O.J. AND BLAIKIE, P.M.** 1990. Land degradation, stocking rates and conservation policies in the communal rangelands of Botswana and Zimbabwe. Pastoral Development Network. Nr. 29. John Wiley and Sons Ltd.
- ABL GROUP.** 1997. Future Search Process Design. Toronto: York University.
- ADAMS, W.M.** 2002. Africa. IN: PERROW, M.R. AND DAVY, A.J. 2002. Handbook of Ecological Restoration. Volume 2: Restoration in practice. Cambridge University Press.
- AGUIAR, M.R. AND SALA, O.E.** 1997. Seed distribution constrains the dynamics of the Patagonian steppe. *Ecology* 78(1): 93 – 100.
- AHMAD, F.** 2003. Role of local bodies in implementing the Convention to Combat Desertification in Pakistan. *Proceedings of the VII th International Rangeland Congress*. 26 July – 1 August 2003. International Conference Centre. Durban. South Africa.
- AIACC** See Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors.
- ALLEN, E.B.** 1995. Restoration ecology, Limits and possibilities in arid and semi-arid lands. IN: ROUNDY, B.A., McARTHUR, A.D., HALEY, J.S. AND MANN, D.K. 1995. Proceedings: Wild land shrub and arid land restoration symposium. 19 – 21 October 1993. Las Vegas. NV. General Technical Report. INT-GTR-315.
- ALLSOPP, N., AINSLIEN, A., LAURENT, C. AND DEBEAUDOIN, L.** 2003. What kinds of knowledge will improve the prospects for successful interventions in communal rangeland systems in South Africa? *Proceedings of the VIIth International Rangelands Congress*, July – August 2003. Durban. South Africa. p 1820 – 1823.

- AMARASEKARE, P.** 2003. Competitive coexistence in spatially structured environments: a synthesis. *Ecological Letters*. 6: 1109 – 1122.
- AMSALU, A. AND DE GRAAFF, J.** 2006. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. *Ecological Economics*. Article in Press.
- ANGWENYI, A.N.** 2004. Environmental legislation and domestication of international environmental law in Kenya. The Sesei programme sub-regional. 13 – 17 December 2004. Nairobi. Kenya.
- ANON.** 2004. Sustainable livelihoods: towards a research agenda – full report. Website: <http://www.case.org.za/htm/liveli2.htm>
- ARCHER, F., HOFFMAN, M.T. AND DANCKWERTS, J.E.** 1989. How economic are the farming units of Leliefontein, Namaqualand? *Journal of the Grassland Society of Southern Africa*. 6(4): 211 – 215.
- ARONSON, J., CLEWELL, A.F., BLIGNAUT, J.N. AND MILTON, S.J.** 2006. Ecological restoration: A new approach for nature conservation and economics. *Journal for Nature Conservation*. 14: 135 – 139.
- ARONSON, J., FLORET, C., LE FLOC'H, E., OVALLE, C. AND PONTANIER, R.** 1993a. Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands. I. A view from the south. Society for Ecological Restoration – Restoration Ecology. March. p 8 – 17.
- ARONSON, J., FLORET, C., LE FLOC'H, E., OVALLE, C. AND PONTANIER, R.** 1993b. Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands. II. Case studies in southern Tunisia, central Chile and northern Cameroon. Society for Ecological Restoration – Restoration Ecology. September. p 168 – 187.
- ARONSON, J., LE FLOC'H, E. AND OVALLE, C.** 2002. Semi-arid woodlands and desert fringes. IN: PERROW, M. AND DAVY, A. (eds.). 2002. Handbook of Ecological Restoration. Vol 2. p 466 – 485. Cambridge University Press. Cambridge. UK.

ASHBY, J., CARLOS, A.Q. AND RIVERA, Y.M. 1987. Farmer participation in on-farm varietal trials. Agricultural Administration (Research and Extension) Network. Discussion Paper No. 22. London, UK: Overseas Development Institute.

ASSESSMENTS OF IMPACTS AND ADAPTATIONS TO CLIMATE CHANGE IN MULTIPLE REGIONS (AIACC). 2005. For whom the bell tolls. Vulnerabilities in a changing world. A summary of lessons from AIACC. Brochure. Website: http://www.aiaccproject.org/whats_new/vulnerabilitybroch.pdf

AVOKA, C.A. 2002. Poverty and the environment. IN: DODDS, F. (ed). 2002. Earth Summit: A new deal. Earthscan Publications LTD. p 124 – 133.

AYYAD, M.A. 2003. Case studies in the conservation of biodiversity: degradation and threats. *Journal of Arid Environments*. 54: 165 – 182.

BADEN, J.A. AND NOONAN, D.S. 1998. Managing the commons. Indiana University Press. ISBN 0253211530.

BAIJNATH, R. AND CHARLTON, V. 2005. Kenyan Nobel Peace Prize Winner meets South African Ministers. Media release by the Department of Water Affairs and Forestry. 21 July 2005. Website: <http://www.dwaf.gov.za/Communications/PressReleases/2005/Maathai21Jul05.doc>

BAINBRIDGE, D.A. 2003. New hope for arid lands – restoration can succeed. 2003 Southwest Lands Habitat Restoration Conference. Palm Springs. Proceedings. Website: <http://www.dmg.gov.sessions.html>

BAINBRIDGE, D.A. 2007. A guide for desert and dryland restoration: New hope for arid lands. Island Press. Washington. USA.

BAKKER, J.P. AND BERENDSE, F. 1999. Constraints in the restoration of ecological diversity in grassland and heathland communities. *Tree*. 14(2): 63 – 68.

BARBIER, E.B. 2000. The economic linkages between rural poverty and land degradation: some evidence from Africa. *Agriculture, Ecosystems and Environment*. 82: 355 – 370.

BARKER, P. 2001. A technical manual for vegetation monitoring. Resource management and conservation. Department of Primary Industries. Water and Environment. Hobart.

BARNARD, R. 2002. Farmer's charter for sustainable agricultural development. *Proceedings of the National LandCare Conference*. 7 – 10 May 2002. Kopanong Hotel and Conference Centre. Gauteng.

BARNARD, R. AND NEWBY, T. 1999. State of the Environment – South Africa. April 1999. Website: <http://www.environment.gov.za/soer/nsoer/issues.htm>

BARNARD, P., BROWN, C.J., JARVIS, A.M., ROBERTSON, A. AND ROOYEN, L.V. 1998. Extending the Namibian protected area network to safeguard hotspots of endemism and diversity. *Biodiversity and Conservation*. 7(4): 531 – 547.

BARRACLOUGH, S.L. AND GHIMIRE, K.B. 2000. Agricultural expansion and tropical deforestation. EarthScan. London.

BARRADAS, V.L., JONES, H.G., CLARK, J.A. 1994. Stomatal responses to changing irradiance in *Phaseolus vulgaris* L. *Journal of Experimental Botany*. 45, 931–936.

BARRS, H.D. AND WEATHERLEY, P.E. 1962. A re-examination of the relative turgidity technique for estimating water deficits in leaves. *Australian Journal of Biological Science*. 15: 413 – 428.

BATIANO, A., HARTEMINK, A., LUNGU, O., NAIMI, M., OKOTH, P., SMALING, E. AND THIOMBIANO, L. 2006. African soils: the productivity and profitability of fertilizer use. African Fertilizer Summit. 9 – 13 June 2006. Abuja. Nigeria.

BELLAIRS, S. AND DAVIDSON, P. 1999. Native plant establishment after mining in Australian rangelands. *VIth International Rangeland Congress Proceedings*. Vol 2. p 962 – 968.

BERRY, L., OLSON, J. AND CAMPBELL, D. 2003. Assessing the extent, cost and impact of land degradation at the national level: findings and lessons learned from seven pilot case studies. Global Mechanism. Website: http://www.global-mechanism.org/dynamic/documents/document_file/cost-of-land-degradation-case-studies.pdf

- BESTELMEYER, B.T., BROWN, J.R., HAVSTAD, K.M., ALEXANDER, R., CHAVEZ, G. AND HERRICK, J.E.** 2003. Vegetation dynamics on rangeland: A critique of the current paradigms. *Journal of Applied Ecology*. 40: 601 – 614.
- BHARGAVA, S. AND PARANJPE, S.** 2004. Genotypic variation in the photosynthetic competence of *Sorghum bicolor* seedlings subjected to polyethylene glycol-mediated drought stress. *Journal of Plant Physiology*. 161: 125 – 129.
- BIGGS, R., BOHENSKY, E., DESANKER, P.V., FABRICIUS, C., LYNAM, T., MISSELHOM, A.A., MUSVOTO, C., MUTALE, M., REYERS, B., SCHOLE, R.J. SHIKONGO, S. AND VAN JAARSVELD, A.S.** 2004. Nature supporting people. The Southern African Millennium Ecosystem Assessment – Integrated report. A contribution to the Millennium Ecosystem Assessment, prepared by the Southern African Millennium Ecosystem Assessment team. CSIR. Pretoria.
- BIRNIE, P.** 1992. International Environmental Law: Its adequacy for present and future needs. IN: HURRELL, A. AND KINGSBURY, B. 1992. The international politics of the environment. Clarendon Press. Oxford.
- BLANKENBICKER, A.** 2005. Rain-driven erosion: How to prevent farmland runoff. Website: <http://peacecorps.mtu.edu/AdamB/Rain%20Erosion.html>
- BLUM, A.** 1996. Crop response to drought and the interpretation of adaptation. *Plant Growth Regulation*. 20: 135 – 148.
- BOGDAN, A.V.** 1977. Seed morphology of some cultivated African grasses. *Proceedings International Seed Testing Association*, 31: 789–799.
- BONIFACE, D.R. AND BURCHELL, H.** 2000. Investigation of validity of closed questions in a survey of British South Asian and white populations. *Ethnicity and Health*. 5(1): 59 – 65.
- BOTHA, M.** 2001. Incentives for conservation on private land: options and opportunities. Claremont. South Africa. Cape Conservation Unit. Botanical Society of South Africa.

- BOTHA, J.H. AND FOUCHÉ, P.S.** 2000. An assessment of land degradation in the Northern Province from satellite remote sensing and community perception. *South African Geographical Journal*. 82(2): 70 – 79.
- BOWMAN, G.** 2002. Training in environmental law – Law in action. Website: http://www.bowman.co.za/BG_Publications/Publications/Natural_Training.asp
- BOYD, J. AND BANZHAF, S.** 2006. What are ecosystem services? The need for standardized environmental accounting units. Discussion Paper. Resources for the Future. Website: <http://www.rff.org/Documents/RFF-DP-06-02.pdf>
- BRISKE, D.D., FUHLENDORF, S.D. AND SMEINS, F.E.** 2003. Development and use of state and transition models for rangelands. *Journal of Range Management*. 56: 114 – 126.
- BRITS, G., TRYTSMAN, M., SMITH, A., NDLOVU, S., MOGALE, E., MAKHAFULA, R. AND MOLIFI, R.** 2003. Screenings of subtropical grass species for drought tolerance. Proceedings of the VIIth International Rangelands Congress. 26 July – 1 August 2003. Durban. South Africa. p 1348 – 1350.
- BROOKS, R.O., JONES, R. AND VIRGINIA, R.A.** 2002. Law and ecology, the rise of the ecosystem regime. Ashgate. England.
- BUNNING, S. AND LANE, A.** 2003. Proposed framework for indicators of biodiversity, land and socio-economic condition. Extract of a paper on selection and use of indicators and methods for assessing biodiversity and land condition conducted as part of a stock taking of biodiversity issues in the context of the Land Degradation Assessment of Drylands (LADA). Rome. July 2003.
- BURT, R., WILSON, M.A., KANYANDA, C.W., SPURWAY, J.K.R., METZLER, J.D.** 2001. Properties and effects of management on selected granite soils in Zimbabwe. *Geoderma*. 101: 119 – 141.
- CAO, X.** 2006. Regulating mine land reclamation in developing countries: the case of China. *Land Use Policy*. In press.

- CARPENTER, S., WALKER, B., ANDERIES, J.M. AND ABEL, N.** 2001. From metaphor to measurement: Resilience of what to what? *Ecosystems*. 4: 765 – 781.
- CARPITA, N., SABULARSE, D., MONFEZINOS, D. AND DELMER, D.P.** 1979. Determination of the pore size of cell walls of living plant cells. *Science* 205, 1144– 1147.
- CATLEY, A., LEYLAND, T., ADMASSU, B., THOMSON, G., OTIENA, M. AND AKLILU, Y.** 2005. Communities, commodities and crazy ideas: changing livestock policies in Africa. *IDS Bulletin*. June 2005. 36 (2).
- CHAKIR, S. AND JENSEN, M.** 1999. How does *Lobaria pulmoria* regulate Photosystem II during progressive desiccation and osmotic water stress? A chlorophyll fluorescence study at room temperature and at 77 K. *Physiological plant*. 105: 257 – 265.
- CHAMBERS, R., PACEY, A. AND THRUPP, L.A.** 1989. Farmer first: Farmer innovation and agricultural research. London, UK: Intermediate Technology Publications.
- CHARNEY, J., STONE, P.H. AND QUIRK, W.J.** 1975. Drought in the Sahara: a biogeophysical feedback mechanism. *Science*. 187: 434 – 435.
- CHASEK, P.** 1997. The Convention to Combat Desertification: Lessons learned for sustainable development. *Journal of Environmental Development*. 6(2): 147 – 169.
- CHASEK, P.S. AND CORELL, E.** 2002. Addressing desertification at international level: The institutional system. IN: REYNOLDS, J.F. AND STAFFORD SMITH, D.M. 2002. Global Desertification, Do humans cause deserts? Dahlem University Press. Berlin.
- CHILIDES, S.L. AND WALKER, B.H.** 1987. Ecology and dynamics of the woody vegetation on the Kalahari sands in Hwange National Park, Zimbabwe. *Vegetatio* 72:111-128.
- CHINOMBO, D.O.** 2006. The African experience in livestock services (Malawi experience). Enhancing rural development. International Conference on Livestock Services. 16 – 22 April 2006. Beijing. China.
- CHIPIKA, J.T. AND KOWERO, G.** 2000. Deforestation of woodlands in communal areas of Zimbabwe: is it due to agricultural policies? *Agriculture, Ecosystems and Environment*. 79: 175 – 185.

- CAO, M. AND PRINCE, S.D.** 2005. Climate-induced regional and interannual variations in terrestrial carbon uptake. *Tellus*. 57: 210 – 217.
- CARNICELLI, L.** 2003. Weathering. Regents Prep: Earth Science. Website: <http://regentsprep.org/Regents/earthsci/units/weathering/index.cfm>
- COCK, J. AND KOCK, E.** 1991. Going Green, People, politics and the environment in South Africa. Oxford University Press. Cape Town.
- COETZEE, K.** 2005. Caring for natural rangelands. University of KwaZulu-Natal Press. South Africa. ISBN: 1869140710.
- COLLINS, J.** 2001. Desertification . Website: <http://botany.uwc.ac.za/Envfacts/facts/desertification.htm>
- CONNOR, S.** 2006. Ecosystems under threat: Invasion of the alien species. Forest.org News Archive. Website: <http://forests.org/shared/reader/welcome.aspx?linkid=63590&keybold=Ecological%20Internet>
- COSTA FRANCA, M.G., PHAM THI, A.T., PIMENTEL, C., PEREYRA ROSSIELLO, R.O., ZUILY-FODIL, Y. AND LAFFRAY, D.** 2000. Differences in growth and water relations among *Phaseolus vulgaris* cultivars in response to induced drought stress. *Environmental & Experimental Botany*. 43: 227 – 237.
- COULTER, J.** 2006. New tools on trial. *Spore*. Vol 124. August.
- COWLING, R.M. AND PIERCE, S.M.** 1999. Namaqualand: A Succulent Desert. Fernwood Press, Cape Town, pp. 135–138.
- COWLING, R.M., ROUX, P.W. AND PIETERSE, A.J.H.** 1986. The Karoo biome: a preliminary synthesis. Part 1 – Physical environment. *South African National Scientific Programmes Report*. Report Nr. 124.
- CULLIS, A. AND WATSON, C.** 2006. Privatizing common land in Botswana. Institute of Development Studies. Id21 Natural resources highlights #2.

- DAILY, G.C.** 1997. Introduction: What are ecosystem services? In: DAILY G.C. (ed.). 1997. *Nature's Services: Societal Dependence on Natural Ecosystems*, Island Press, Washington, DC. p 1–10.
- DANNHAUSER, C.S.** 2004. The influence of tillage and mulch application on the production of *Cenchrus ciliaris*. *African Journal of Range and Forage Science*. Vol 21(3): 201 – 203.
- DEAN, W.R.J., HOFFMAN, M.T., MEADOWS, M.E. AND MILTON, S.J.** 1995. Desertification in the semi-arid Karoo. South Africa: Review and reassessment. *Journal of Arid Environments*. 30: 247 – 264.
- DEAT** See Department of Environmental Affairs and Tourism.
- DE BEER, G.C.O.** 2000. Rangeland condition and management models for parts of the savanna in the Northern Province. South Africa. Ph.D. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom.
- DE GROOT, P., FIELD-JUMA, A. AND HALL, D.** 1992. Taking root. Revegetation in semi-arid Kenya. Drylands Research Series No. 5. Acts Press.
- DEJENE, A., SHISHIRA, E.K., YANDA, P.Z. AND JOHNSEN, F.H.** 1997. Land degradation in Tanzania: Perception from the village. The World Bank. ISBN 082139931.
- DE KLERK, J.N.** 2004. Bush encroachment in Namibia. Report on Phase I of the Bush Encroachment Research, Monitoring and Management Project of the Ministry of Environment and Tourism (MET). DV8 Publishers. Windhoek. Namibia.
- DENT, J.B.** 1989. Education and training in agriculture. IN: SPEDDING, C.R.W. 1989. *The human food chain*. London. Elsevier. p 77 – 92.
- DEPARTMENT OF AGRICULTURE (DoA).** 2003. First draft – National Action Programme. Combating land degradation to alleviate rural poverty: SA's response to the UNCCD and the effects of drought particularly in Africa.

DEPARTMENT OF AGRICULTURE (DoA). 2003a. CARA Legislation made easy. The Conservation of Agricultural Resources Act, 1983 (Act No 43 of 1983) (CARA). Information leaflet.

DEPARTMENT OF AGRICULTURE (DoA). 2006. Range and forage (veld) policy for South Africa. *Government Gazette*. July 2006. Nr. 28994.

DEPARTMENT OF AGRICULTURE (DoA). 2006a. Strategic plan: Economic performance of the sector. Website: <http://www.nda.agric.za/docs/sectoroverview06.pdf>

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 1999. Sustainability of terrestrial ecosystems. Website: www.environment.gov.za/soer/nsoer/issues/land/response.htm#conventions

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 1999a. White Paper on Environmental Management Policy. Cape and Transvaal Printers (PTY) Ltd. Cape Town.

DERRY, J.F. 2004. Piospheres in semi-arid rangeland: consequences of spacially constrained plant-herbivore interactions. Unpublished Ph.D. Thesis. University of Edinburgh. Website: <http://hdl.handle.net/1842/600>

DESERT KNOWLEDGE CRC. 2007. The dispersal, impact and management of buffel grass in desert Australia. Website: <http://www.desertknowledgecrc.com.au/publications/downloads/63-1702-Buffel-grass-final-web-HR.pdf>

DESERT MARGINS PROGRAM (DMP). 2004. Preliminary site characterization report. Report. Potchefstroom. South Africa.

DE VREDE, M. 1996. Identification of land degradation levels at the grassroots. IN: HAMBLY, H. AND ANGURA, T.O. 1996. Grassroots indicators for desertification. Experience and perspectives from Eastern and Southern Africa. IDRC. Canada.

DE WET, S. 2001. The dynamics of certain grass species used during the restoration of degraded semi-arid rangelands. M.Sc. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom.

- DE WET, T.** 2005. The era of the environmental law bounty-hunter? Improved Law Enforcement. News Centre. Deneys-Reitz Attorneys. Website: http://www.deneysreitz.co.za/news/item/improved_environmental_law_enforcement,676.html
- DICKENSON, E.B., HYAM, G.F.S. AND BREYTENBACH, W.A.S.** 1990. Die Kynoch Weidings-handleiding. Keyser Versveld. Johannesburg. South Africa.
- DIRECTORATE: AGRICULTURAL STATISTICS.** 2005. Abstract of Agricultural Statistics. Website: http://www.nda.agric.za/docs/Abstract_2006.pdf
- DMP** See Desert Margins Program.
- DoA** See Department of Agriculture.
- DODD, J.L.** 1994. Desertification and degradation in Sub-Saharan Africa: the role of livestock. *Bioscience*. 44(1): 28 – 34.
- DONALDSON, C.H.** 1980. The extend of bush encroachment in the bushveld areas of the Transvaal region. IN: Proceedings worksession: bush encroachment and thickening. Department of Agriculture and Fisheries. Pretoria. South Africa.
- DOVIE, D.B.K., SHACKLETON, C.M. AND WITKOWSKI, E.T.F.** 2002. Direct-use values of woodland resources consumed and traded in a South African village. *International Journal of Sustainable Development and World Ecology*. 9: 269 – 283.
- DRECHSEL, P., OLALEYE, A., ADEOTI, A., THIOMBIANO, L., BARRY, B. AND VOHLAND, K.** 2005. Adoption driver and constraints of resource conservation technologies in sub-Saharan Africa. Website: http://www.iwni.cgiar.org/africa/west_africa/projects/AdoptionTechnology/Adoption_Constraints.Overview.pdf
- DREGNE, H.E.** 1986. Desertification of arid lands. IN: EL-BAZ, F. AND HASSAN, M.H.A. 1986. Physics of desertification. Dordrecht, The Netherlands: Martinus, Nijhoff.
- DUBE, O.P. AND PICKUP, G.** 2001. Effects of rainfall variability and communal and semi-commercial grazing on land cover in southern African rangelands. *Climate Research*. 17: 195 – 208.

- DU PLESSIS, W.** 2004. Legislation on energy. Course: Environmental Law for Environmental Managers. 8 – 13 March 2004. Centre for Environmental Management. Potchefstroom. South Africa.
- DU PLESSIS, W. AND BOSMAN, C.** 2004. Minerals Legislation. Course: Environmental Law for Environmental Managers. 8 – 13 March 2004. Centre for Environmental Management. Potchefstroom. South Africa.
- DU TOIT, P.C.V.** 2002. Reclaiming degraded veld in the Kalahari. *Grootfontein Agric.* 5:13 -16.
- EARTHTRENDS.** 2003a. Forests, grasslands and drylands – Burkina Faso. Website: http://earthtrends.wri.org/pdf_library/country_profiles/for_cou_854.pdf
- EARTHTRENDS.** 2003b. Biodiversity and protected areas – Senegal. Website: http://earthtrends.wri.org/pdf_library/country_profiles/bio_cou_686.pdf
- EARTHTRENDS.** 2003c. Biodiversity and protected areas – Namibia. Website: http://earthtrends.wri.org/pdf_library/country_profiles/bio_cou_516.pdf
- EEION** See European Environment Information and Observation Network.
- EGO, W. AND KIBET, P.F.K.** 2003. Evaluation of the potential productivity of *Cenchrus ciliaris* in the semi-arid rangelands of Kenya. *Proceedings of the VII th International Rangeland Congress*. 26 July – 1 August 2003. International Conference Centre. Durban. South Africa.
- EINSTEIN, G. AND ABERNETHY, K.** 2000. Statistical Package for the Social Sciences, Furman University. Website: <http://cs.furman.edu/rushing/mellonj/spss1.htm>
- ELLIOT, L.** 1998. The global politics of the environment. New York University Press. New York.
- ELLIS, J. AND GALVIN, K.A.** 1994. Climate patterns and land use practices in the dry zones of Africa. *Bioscience* 44:340-349.

ELLIS, R.P. 2002. *Rhigozum trichotomum* Burch. The Consilience Engine. EcoPort RSA Country Programme. Website: http://ecoport.org/ep?Plant=33121&entityType=PL****&entityDisplayCategory=full&menuStyle=text

ENVIRONMENT LIAISON FORUM. 2006. ELF Network: What is our analysis of the problem. Website: http://www.zeroregional.com/networks/elf_network.htm

ESLER, K.J., JONES, F.E., BURKE, A., SAMWAYS, M., BARNARD, P., GILBERT, F. AND WISSEL, C. 2002. Guidelines for sustainable rangeland management: recommendations on ecological restoration of rangelands in the semi-arid Nama Karoo biome. Magenta media. Cape Town.

ESLER, K.J., LAROS, M.T., JONES, F.E., BURKE, A. AND BARNARD, P. 2003. Views on policy from a joint European – Southern African funded project: The role of isolated mountains in the sustainable rangeland management of the Nama Karoo. *Proceedings of the VII th International Rangeland Congress*. 26 July – 1 August 2003. International Conference Centre. Durban. South Africa.

EUROPEAN ENVIRONMENT AGENCY. 2006. Arid Land: Concept definition. Website: <http://www.eionet.europa.eu/gemet/concept?cp=552&langcode=en>

EUROPEAN ENVIRONMENT INFORMATION AND OBSERVATION NETWORK. 2006. Land reclamation: Concept definition. Website: <http://www.eionet.europa.eu/gemet/concept?langcode=en&cp=4641>

FABRICIUS, C. AND KOCH, E. 2004. Rights, resources and rural development: Community-based natural resources management in southern Africa. Earthscan. United Kingdom.

FAIR, J. 1986. Guide to profitable pastures. M & J Publications. p 121.

FAKIR, S., KRUGER, F. AND PRETORIUS, J.R. 1999. State of the environment – South Africa. April 1999. Website: <http://www.environment.gov.za/soer/nsoer/issues.htm>

FAO See Food and Agriculture Organization.

FERIS, L.A. 2006. Compliance notices – a new tool in environmental enforcement. Potchefstroom Electronic Journal. Volume 3. ISBN 1727-3781. Website: http://www.puk.ac.za/opencms/export/PUK/html/fakulteite/regte/per/issues/2006_3_feris_art.pdf

FERNANDEZ, R.J., ARCHER, E.R.M., ASH, A.J., DOWLATABADI, H., HIERNAUX, P.H.Y., REYNOLDS, J.F., VOGEL, C.H., WALKER, B.H. AND WIEGAND, T. 2002. Degradation and recovery in socio-ecological systems. IN: REYNOLDS, J.F. AND STAFFORD SMITH, D.M. 2002. Global Desertification, Do humans cause deserts? Dahlem University Press. Berlin.

FERREIRA, L.G.R., DE SOUZA, J.G. AND PRISCO, J.T. 1979. Effects of water deficit on proline accumulation and growth of two cotton genotypes of different drought resistances. *Zeitschrift für Pflanzenphysiologie*. 93: 189 – 199.

FFOLIOTT, P.F., FISHER, J.T., SACHS, M., DEBOER, D.W., DAWSON, J.O. AND FULLBRIGHT, T.E. 1998. Role of demonstration projects in combating desertification. *Journal of Arid Environments*. 39: 155 – 163.

FIELD, A. 2005. Discovering statistics using SPSS. 2nd Edition. SAGE Publications. London.

FINLAYSON, J.D., BETTERIDGE, K., MACKAY, A., THORROLD, B., SINGLETON, P. AND COSTALL, D.A. 2002. A simulation model of the effects of cattle treading on pasture on North Island, New Zealand, hill land. *New Zealand Journal of Agricultural Research*. 45: 255 – 272.

FOLKE, K., BERKES, F. AND COLDING, J. 1998. Ecological practices and social mechanisms for building resilience and sustainability. IN: BERKES, F. AND FOLDKE, K. (eds). 1998. Linking social and ecological systems. Cambridge University Press. Cambridge. p 414 – 436.

FOOD AND AGRICULTURE ORGANIZATION (FAO). 2002. Land degradation assessment in drylands: LADA. Website: <ftp://ftp.fao.org/agl/agll/docs/lada.pdf>

FOOD AND AGRICULTURE ORGANIZATION (FAO). 2002a. Catching the rain and stopping land degradation in Burkina Faso. Website: <http://www.fao.org/english/newsroom/news/2002/7860-en.html>

FOOD AND AGRICULTURE ORGANIZATION (FAO). 2003. Food and Agriculture Organization of the United Nations. The state of the world's forests. Rome. ISBN 92-5-104865-7. Website: www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/Y7581e00.htm

FOOD AND AGRICULTURE ORGANIZATION (FAO). 2004. Food and Agriculture Organization of the United Nations: helping to build a world without hunger. Website: www.fao.org

FOOD AND TREES FOR AFRICA. 2006. Food and trees for Africa. Website: <http://www.trees.co.za>

FORCE, L., CRITCHLEY, C. AND VAN RENSEN, J.J.S. 2003. New fluorescence parameters for monitoring photosynthesis in plants. 1. The effect of illumination on the fluorescence parameters of the JIP-test. *Photosynthesis Research*. 78: 17 – 33.

FRANCIS, E. 2001. Making a living: Changing livelihoods in rural Africa. Routledge. London.

FREEMAN, I. AND MYRICK, A. 2003. The measurement of environmental and resource values. Resources for the Future. Washington, DC.

FTFA See Food and Trees for Africa.

FUGGLE, R.F. AND RABIE, M.A. 1983. Environmental concerns in South Africa. Juta & Co, Ltd. Cape Town. South Africa.

GAMBIZA, J. 1996. Rangeland management. IN: SMITH, T. AND WANGARI, E.O. 1996. Desertification control and natural resources management: Case studies from SADC Countries. UNESCO. Dakar.

GEBAUER, J., EL-SIDDIG, K. AND EBERT, G. 2006. Boabab (*Adansonia digitata* L.): A review on a multi-purpose tree with promising future in the Sudan. *Gartenbauwissenschaft*. 64(4): 155 – 160.

GEERKEN, R. AND ILLAIWI, M. 2004. Assessment of rangeland degradation and development of a strategy for rehabilitation. *Remote sensing of Environment*. 90 (4).

GEIST, H.J. AND LAMBIN, E.F. 2004. Dynamic causal patterns of desertification. *BioScience*. September. 54(9): 817 – 829.

GEIST, H. AND LOHNERT, B. 1999. Changing environments: social dimensions of endangered ecosystems in the developing world. Aldershot. Brookfield USA: Ashgate.

GEO See Global Environment Outlook.

GIBSON, R.S. AND BOSCH, O.J.H. 1996. Indicators species for the interpretation of vegetation condition in the St. Bathans area. Central Otago. New Zealand. *New Zealand Journal of Ecology*. 20(2): 163 – 172.

GILES, J. 2005. Millennium group nails down the financial value of ecosystems. *Nature*. 434: 547.

GIRMAY, A.G. AND SHUICHI, H. 2005. The effect of raindrop impact and initial soil conditions on surface crust formation. *Journal of the Japanese Society of Soil Physics*. 100: 65 – 75.

GLOBAL ENVIRONMENT OUTLOOK (GEO). 2006. Food security. United Nations Environment Program. GEO Yearbook. Website: <http://www.unep.org/geo/yearbook/yb2006/015.asp>

GLOSSARY OF ENVIRONMENT STATISTICS. 1997. Land degradation. Studies in Methods. Series F. No. 67. United Nations. New York.

GLOWKA, L. 1998. A guide to undertaking biodiversity Legal and Institutional profiles. IUCN (The World Conservation Union). Germany.

- GONZALEZ, P.** 2001. Desertification and a shift in forest species in the West African Sahel. *Climate Research*. 17: 217 – 228.
- GORGENS, A.H.M. AND VAN WILGEN, B.W.** 2004. Invasive alien plants and water resources in South Africa: current understanding, predictive ability and research challenges. *South African Journal of Science*. 100: 27 – 32.
- GRAEF, F. AND STAHR, K.** 2000. Incidence of soil surface crust types in semi-arid Niger. *Soil Tillage Research*. 55: 213 – 218.
- GRAY, L.C.** 1999. Is land being degraded? A multi-scale investigation of landscape change in southwestern Burkina Faso. *Land Degradation and Development*. 10: 329 – 344.
- GRIMSHAW, R.G.** 1992. The establishment of *Vetiveria zizanioides* in low rainfall areas. IN: Desertified Grasslands: Their Biology and Management. Academic Press. London.
- HACKER, J.B. AND RATCLIF, D.** 1989. Seed dormancy and factors controlling dormancy breakdown in Buffel Grass accessions from contrasting provenances. *Journal of Applied Ecology*. 26: 201-212.
- HAGMANN, J., CHUMA, E., CONNOLLY, M. AND MURWIRA, K.** 1998. Propelling change from the bottom up: Institutional Reform in Zimbabwe. Gatekeeper Series No. 71. IIED. London. UK.
- HAHN, B.D., RICHARDSON, F.D., HOFFMAN, M.T., ROBERTS, R., TODD, S.W. AND CARRICK, P.J.** 2005. A simulation model of long-term climate, livestock and vegetation interactions on communal rangelands in the semi-arid Succulent Karoo, Namaqualand, South Africa. *Ecological Monitoring*. (Article in Press).
- HAROU, P.A.** 2002. What is the role of markets in altering the sensitivity of arid land systems to perturbation? IN: REYNOLDS, J.F. AND STAFFORD SMITH, D.M. 2002. Global Desertification, Do humans cause deserts? Dahlem University Press. Berlin.
- HARRIS, J.A., BIRCH, P. AND PALMER, J.** 1996. Landscape restoration and reclamation: principles and practice. Essex: Longman.

- HARRISON, P.** 1987. The greening of Africa. International Institute for Environment and Development. Earthscan. Paladin. London. UK.
- HARRISON, P. AND PEARCE, F.** 2000. AAAS – Atlas of population and environment. American Association of the Advancement of Science and the University of California Press.
- HASSAN, R.M.** 2000. Accounting for stock and flow values of woody land resources. Pretoria: CEEPA. University of Pretoria.
- HASSAN, R.M., SCHOLE, R. AND ASH, N.** 2005. Ecosystems and human well-being: Current state and trends. Volume 1. Island Press. Washington. USA.
- HAVAUX, M. AND DAVAUD, A.** 1994. Photoinhibition of photosynthesis in chilled potato leaves is not correlated with a loss of Photosystem II activity: preferential inactivation of Photosystem I. *Photosynthesis Research*. 40: 75 – 92.
- HAVSTAD, K.M., HERRICK, J.E. AND SCHLESINGER, W.H.** 2000. Desert rangelands, degradation and nutrients. IN: ARNALDS, O. AND ARCHER, S. 2000. Rangeland desertification. Kluwer Academic Publishers. Dordrecht.
- HEBDEN, S.** 2006. Researchers find Africa's land degradation can be reversed. Science Development. Website: http://www.solution-site.org/artman/publish/article_284.shtml
- HELLDÉN, U.** 1988. Desertification monitoring: Is the desert encroaching? *Desertification Control Bulletin*. 17: 8 – 12.
- HENNIG, R.** 2006. Forests and deforestation in Africa – the wasting of an immense resource. AfrolNews. Website: www.afrol.com
- HENSON, I.E., MAHALAKSHMI, V., BIDINGER, F.R. AND ALAGARSWAMY, G.** 1981. Genotypic variation in pearl millet (*Pennisetum americanum* (L.) Leeke) in the ability to accumulate abscisic acid in response to water stress. *Journal of Experimental Botany*. 32: 899 – 910.
- HERRICK, J.E., VAN ZEE, J.W., HAVSTAD, K.M., BURKETT, L.M. AND WHITFORD, W.G.** 2005. Monitoring manual for grassland, shrubland and savanna

ecosystems. Volume II: Design, supplementary methods and interpretation. USDA-ARS Jornada Experimental Range. Las Cruces. New Mexico. ISBN 0-9755552-0-0.

HILHORST, T. AND TOULMIN, C. 2000. Integrated Soil Fertility Management. *Policy and Best Practice Document 7*. The Hague: Ministry of Foreign Affairs.

HOBBS, R.J. AND NORTON, D.A. 1996. Towards a conceptual framework for restoration ecology. *Restoration Ecology*. 4: 93 – 110.

HOFFMAN, M.T. AND TODD, S. 2000. A national review of land degradation in South Africa: the influence of biophysical and socio-economic factors. *Journal of southern African Studies*. 26: 743 – 758.

HOFFMAN, T. AND ASHWELL, A. 2001. Nature divided, Land degradation in South Africa. University of Cape Town Press. Cape Town.

HOFFMAN, T. AND ASHWELL, A. 2002a. Provincial Fact Sheet. Land degradation: North West. Website: <http://www.nbi.ac.za/landdeg>

HOFFMAN, T. AND ASHWELL, A. 2002b. Provincial Fact Sheet. Land degradation: Northern Cape Province. Website: <http://www.nbi.ac.za/landdeg>

HOFFMAN, M.T., TODD, S.W., NTSHONA, Z.M. AND TURNER, S.D. 1999. Land degradation in South Africa. Pretoria: Department of Environmental Affairs and Tourism. p 245.

HOMEWOOD, K.M. 2004. Policy, environment and development in African rangelands. *Environmental Science and Policy*. 7: 125 – 143.

HOHL, M. AND PETER, S. 1991. Water relations of growing maize coleoptiles. Comparison between mannitol and polyethylene glycol 6000 as external osmotica for adjusting turgor pressure. *Plant Physiology* 95, 716– 722.

HORNE, P.M. AND STÜR, W.W. 2004. Developing agricultural solutions with smallholder farmers: How to get started with participatory approaches. IN: GONSALVES, J., BECKER, T., BRAUN, A., CAMPILAN, D., DE CHAVEZ, H., FAJBER, E., KAPIRIRI, M., RIVACA-CAMINADE, J. AND VERNOOY, R. 2005. Participatory research and

development for sustainable agriculture and natural resource management: A source book. CIP-UPWARD/IDRC. ISBN 1-55250-181-7. Website: http://www.idrc.ca/en/ev-73443-201-1-DO_TOPIC.html#beginning

HOWELL, J. 1998. Holding up the Himalayas – Nepal. UNDP – Equator Initiative. Website: <http://www.tve.org/ho/doc.cfm?aid=200&lang=English>

HU, W. 1997. Household land tenure reform in China: its impact on farming land use and agro-environment. *Land Use Policy*. 14(3): 175 – 186.

HULME, M., DOHERTY, R., NGARA, T. AND NEW, N. 2005. Global warming and African climate change: a reassessment in Pak Sum Low. *Climate Change and Africa*. Cambridge University Press. Cambridge.

IFAD See International Fund for Agricultural Development.

IFPRI See International Food Policy Research Institute.

IMEVBORE, A.M. 2003. Desertification and desiccation as a threat to the conservation and utilization of biodiversity. United Nations Convention to Combat Desertification. Website: <http://www.unccd.int/knowledge/INCDInfoSeg/parti.php>

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE (IFPRI). 2003. Cropland degradation. Website: <http://www.ifpri.org>

INTERNATIONAL FUND FOR AGRICULTURAL DEVELOPMENT (IFAD). 2006. Rural poverty and desertification. Rural poverty portal. Website: <http://www.ruralpovertyportal.org/english/topics/desertification/index.htm>

INTERNATIONAL SEED TESTING ASSOCIATION (ISTA). 1985. International rules for seed testing. Rules 1985. *Seed Science and Technology*. 13: 299 - 355.

INTERNATIONAL TROPICAL TIMBER ORGANIZATION (ITTO). 2002. ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests. ITTO Policy Development Series No. 13. ISBN 4 902045 01.

ISSA, O. 2004. From wood to coal in an effort to stop deforestation. Inter Press Service News Agency. Website: <http://ipsnews.net/interna.asp?idnews=25947>

ISTA See International Seed Testing Association.

ITTO See International Tropical Timber Organization.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA). 1999. Country profile on environment. Website: <http://www.jica.go.jp/english/global/env/profiles/e99sen.pdf>

JICA See Japan International Cooperation Agency.

JORDAAN, F.P. 1997. Implementation of a computerized system for assessing rangeland condition and monitoring of key species of the Western Grassland Biome. Ph.D. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom.

KAMANDO, B. 2006. Empowering local communities in plant and seed conservation through training: the Kenyan experience. *Samara* (The International Newsletter of the Partners of the Millennium Seed Bank Project). 11: 1 – 8.

KAWANABE, S., NAN, Y., OSHIDA, T., KOU, Z., JIANG, D., TAKEDA-OIKAWA, N. AND MUKAIYAMA, S. 1998. Degradation of grassland in Keerqin sandland, Inner Mongolia. *China Grassland Science*. 44: 109 – 114.

KELLNER, K. 2000. Desert Margins Program. Proceedings of a National Workshop: Appropriate Restoration Technologies in South Africa. 13 – 26 March 1998. Potchefstroom. South Africa.

KELLNER, K. AND BOSCH, O.J.H. 1992. Influence of patch formation in determining the stocking rate for southern African grasslands. *Journal of Arid Environments*. 22: 99 – 105.

KELLNER, K., DE WET, S. AND BUYS, L. 1999. How to make restoration ecology work in the degraded rangelands of southern Africa. Proceedings of the VI International Rangeland Congress. People and Rangelands. Building the future. 1: 370 – 372.

- KER, A.** 1995. Farming systems of the African savanna: A continent in crises. IDRC. Kenya.
- KIDD, M.** 1997. Environmental Law: A South African Guide. Juta & Co. Ltd. Kenwyn.
- KIDD, M.** 2003. International Conventions on the Environment: A South African Perspective. Website: <http://www.globesa.org/lecture1.htm>
- KING, E.** 2003. *Aloe secundiflora* shrubs facilitate a native perennial grass in degraded Kenyan rangelands: Implications for restoration. ESA Annual Meeting. 3 – 8 August 2003. Savannah. Georgia.
- KING, J.** 1996. The importance of ground water awareness and education in the rural areas of Namaqualand. Unpublished *Namaqualand Conference Proceedings*, Kirstenbosch, February 1996.
- KING, E.G. AND HOBBS, R.J.** 2006. Identifying linkages among conceptual models of ecosystem degradation and restoration: Towards an integrative framework. *Restoration Ecology*. 14(3): 369.
- KIUNSI, R. AND MEADOWS, M.E.** 2006. A new and comprehensive land degradation assessment method: a case study of application to the Monduli District, Tanzania. *Land degradation and development*. 17: 1 – 7.
- KLINTENBERG, P. AND SEELY, M.** 2004. Land degradation monitoring in Namibia: A first approximation. *Environmental Monitoring and Assessment*. 99(1-3): 5 – 21.
- KOALA, S. AND VAN DUIVENBOODEN, N.** 1999. ICRISAT report to COP3: Joining hands to implement the CCD Convention in the desert margins of sub-Saharan Africa. Website: <http://www.unccd.int/cop/reports/igo/1999/icrisat-eng.pdf>
- KOALA, S. AND TABO, R.** 2004. Turning adversity into opportunity: The Desert Margins Program. Towards sustainable management of the desert margins of sub-Saharan Africa. Project Document 2002 – 2008. Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. pp. 140.

KOOHAFKAN, A.P. 1996. Desertification, drought and their consequences. SD dimensions Webpage. Website: <http://www.fao.org/waicent/faoinfo/sustdev/Epdirect/Epan0005.htm>

KOOPMAN, J., LOUW, L. AND LOUW, R. 2005. Climate change adaptation and rooibos. Paper presented at the Climate Change Conference. 19 October 2005. Johannesburg. South Africa. Website: http://www.environment.gov.za/HotIssues/2005/climateChange/presentations/19October_consultive/15H00/DEAT%20Climate%20Change%20Conference_Johannesburg_2005.pdf

KOUNDOURI, P. 2006. Water management in arid and semi-arid regions: Interdisciplinary. Edward Elgar Publishing. ISBN: 1845424239.

KRIEL, J. 2006. Kgalagadi Transfrontier Park. Natural and cultural history. South African National Parks. Website: <http://www.sanparks.co.za/parks/kgalagadi/tourism/history.php>

KRÖHNE, H. AND STEYN, L. 1991. Land Use in Namaqualand: Towards a community-based management strategy for agricultural land use in the Namaqualand reserves; Leliefontein, Steinkopf and the Richtersveld. Athlone: Surplus People Project.

KRUGER, B. 2003. FIRM: The Forum for Integrated Resource Management. Desert Research Foundation of Namibia (DRFN). Windhoek. Namibia.

KUNENE, N., WILSON, R.A.C. AND MYENI, N.P. 2003. The use of trees, shrubs and herbs in livestock production by communal farmers in northern KwaZulu-Natal, South Africa. *African Journal of Range and Forage Science*. 20(3): 271 – 274.

LADA See Land Degradation Assessment Program in Drylands.

LAND DEGRADATION ASSESSMENT PROGRAM IN DRYLANDS (LADA). 2002. What is LADA? Website: <ftp://ftp.fao.org/agl/agll/docs/lada.pdf>

LANG, S.S. 2006. ‘Slow, insidious’ soil erosion threatens human health and welfare as well as the environment, Cornell study asserts. Chronicle online. Cornell University. Website: <http://www.news.cornell.edu/stories/March06/soil.erosion.threat.ssl.html>

- LARBI, A., AND MEKLCHE, A.** 2004. Relative water content (RWC) and leaf senescence as screening tools for drought tolerance in wheat . IN: CANTERO-MARTINEZ, C. AND GABIÑA, D. 2004. Mediterranean rainfed agriculture: Strategies for sustainability = Agriculture pluviale méditerranéenne : stratégies de durabilité . Zaragoza (Spain) : CIHEAM-IAMZ. p 193-196.
- LAWLOR, D.W. AND CORNIC, G.** 2002. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant Cell and Environment*. 25: 275 – 294.
- LEISTNER, O.A.** 1967. The plant ecology of the southern Kalahari. Botanical survey memoir No. 38. Government Printer, Pretoria.
- LEMON, M. AND SEATON, R.** 1999. Policy relevant research: the nature of the problem. IN: LEMON, M. (ed). 1999. Exploring environmental change using an integrative method. Gordon and Breach. Reading. p 1- 16.
- LE HOUÉROU, H.N. AND GILLET, H.** 1986. Conservation versus desertification in African arid lands. IN: CONSERVATION BIOLOGY: The Science of Scarcity and Diversity. The Regents of the University of Michigan.
- LEVITT, J.** 1980. Responses of Plants to Environmental Stresses. Vol. II. Water, Radiation, Salt and Others Stresses. Academic Press, New York, pp. 395–434.
- LINIGER, H.** 2000. WOCAT: World Overview of Conservation Approaches and Technologies. Knowledge for sustainable soil and water management. Brochure.
- LIVINGSTONE, I. AND BELSHAW, D.G.R.** 2001. Renewing Development in Sub-Saharan Africa: Policy, Performance and Prospects. Routledge. ISBN: 0415252172.
- LOW, A.B. AND REBELO, A.G.** 1996. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism. Pretoria.
- LU, Z. AND NEUMANN, P.M.** 1998. Water-stressed maize, barley and rice seedlings 254 show species diversity in mechanisms of leaf growth inhibition. *Journal of Experimental Botany* 49, 1945–1952.

LUDWIG, J.A. AND TONGWAY, D.J. 1995. Desertification in Australia: An eye to grass roots and landscapes. IN: Environmental Monitoring and Assessment. 37: 231 – 237.

MA See Millennium Ecosystem Assessment.

MACDONALD, I.A.W. AND RICHARDSON, D.M. 1989. Man's role in changing the face of southern Africa. IN: HUNTLEY, B.J. (eds). Biotic diversity in southern Africa: Concept and conservation. Oxford University Press. Cape Town. P 51 – 77.

MACKAY, D.B. 1972. The Measurement of Viability. IN: Roberts, E.H. 1972. Viability of seeds. Chapman and Hall Ltd Publishers. London.

MAINGUET, M. 1991. Desertification, Natural background and human mismanagement. Berlin: Springer.

MANGOLD, S., KALULE-SABITI, M. AND WALMSLEY, J. 2002. State of the environment report, 2002. North-West Province, South Africa. North-West Province Department of Agriculture, Conservation and Environment. Directorate Environment and Conservation Management. Mafikeng. South Africa.

MANNING, J. AND GOLDBLATT, P. 1997. Niewoudtville – Bokkeveld Plateau & Hantam. South African Wild Flower Guide 9. Botanical Society of South Africa. Claremont.

MARINUS, W.M. 1998. Understanding local institutions and organisations relating to natural resource use and management in the Leliefontein Reserve (Namaqualand). MA Dissertation. Department of Anthropology, University of the Western Cape.

MARGULES, C.R. AND PRESSEY, R.L. 2000. Review article: systematic conservation planning. *Nature*. 405: 243 – 253.

MARTIN, T. 2000. Weed Alert. Wildlife Invasive Species Team Report. Website: <http://tncweeds.ucdavis.edu/alert/alrtcenc.html>

MATTHEWS, S. AND BRAND, K. 2004. Africa invaded. The growing danger of invasive alien species. GISP – The Global Invasive Species Programme.

- MAY, H., ALLSOPP, N., BRADLEY, P.N., CAVE, L., CINDERBY, S., HOFFMAN, T., MARINUS, T., PIETERSEN, K., TITUS, R. AND WILLIAMS, M.** 1997. Rural livelihoods and sustainable natural resource management – Final Project Report (Draft). Athlone: Surplus People Project.
- MAZZUCATO, V. AND NIEMEIJER, D.** 2001. Overestimating land degradation, underestimating farmers in the Sahel. International Institute for Environment and Development (IIED). EarthPrint. London. UK.
- MCDONALD, M. AND BROWN, K.** 2000. Soil and water conservation projects and rural livelihoods: options for design and research to enhance adoption and adaptation. *Land Degradation Development*. 11: 343 – 361.
- MCDONALD, A.W., BAKKER, J.P. AND VEGELIN, K.** 1996. Seed bank classification and its importance for the restoration of species – rich flood meadows. *Journal of Vegetation Science*. 7: 157 – 164.
- MENDELSON, J., EL OBEID, S. AND ROBERTS, C.** 2000. A profile of north central Namibia. Windhoek: Gamsberg Macmillan Publishers.
- MICHEL, B.E. AND KAUFMANN, K.** 1973. The osmotic potential of polyethylene glycol 6000. *Plant Physiology* 51, 914– 916.
- MILLENNIUM ECOSYSTEM ASSESSMENT (MA).** 2003. Ecosystems and human well-being: A framework for assessment. A report of the Conceptual Framework Working Group. World Resources Institute. Website: www.millenniumassessment.org
- MILLENNIUM ECOSYSTEM ASSESSMENT (MA).** 2005. Ecosystems and human well-being: Desertification synthesis. World Resource Institute. Washington. DC.
- MILLENNIUM ECOSYSTEM ASSESSMENT BOARD (MA BOARD).** 2005. Ecosystem Assessment: Living beyond our means. Natural assets and human well-being (Statement from the board). Website: http://www.wri.org/biodiv/pubs_description.cfm?PubID=4115

MILLER, D. 1997. Rangelands and range management. International Center for Integrated Mountain Development Newsletter. 27: 1 – 3.

MILLER, M., MARIOLA, M. AND HANSEN, D. 2007. EARTH to farmers: Extension and the adoption of environmental technologies in the Parismina Watershed, Costa Rica. Paper presented at the annual meeting of the Rural Sociological Society. Website: http://www.allacademic.com/meta/p187210_index.html

MILTON, S.J. AND DEAN, W.R.J. 1995. South Africa's arid and semi-arid rangelands: Why are they changing and can they be restored? *Environmental Monitoring and Assessment*. 37: 245 – 264.

MOIKANGOA, N. 2003. Providing decision, planning and policy support to Government. CSIR. Website: http://www.csir.co.za/plsql/pTI0002/PTL0002_PGE038_ARTICLE?ARTICLE_NO=7122654

MOLEELE, N.M. AND PERKINS, J.S. 1998. Encroaching woody plant species and boreholes: is cattle density the main driving factor in the Olifants Drift communal grazing lands, south eastern Botswana. *Journal of Arid Environments*. 40: 245 – 253.

MONTALVO, A.M., MCMILLAN, P.A. AND ALLEN, E.B. 2002. The relative importance of seeding method, soil ripping, and soil variables on seeding success. *Restoration Ecology*. 10(1): 52 – 67.

MOORE, A. A. 1989. Die ekologie en ekofisiologie van *Rhigozum trichotomum* (Driedoring). Unpublished Ph.D thesis, University of Port Elizabeth, South Africa. 163pp.

MORGAN, G. 2008. Environmental laws. Speech by Gareth Morgan. DA Spokesperson on environmental affairs. 28 February 2008. Website: http://www.environment.co.za/topic.asp?TOPIC_ID=1769

MORGENTAL, T.L. 2000. Vegetation dynamics and management models for coalash disposal sites at Hendrina Power Station. Mpumalanga. South Africa. Ph.D. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom.

- MORIN, J. AND VAN WINKEL, J.** 1996. The effect of raindrop impact and sheet erosion on infiltration rate and crust formation. *Soil Science Society of America Journal*. 60: 1223 – 1227.
- MOSLEY-THOMPSON, E.** 2006. Water, soil, food. Geography Lecture. Ohio State University. Website: <http://geog-www.sbs.ohio-state.edu/courses/H410/lecture%2010.pdf>
- M'SEDDI, K., VISSER, M., NEFATTI, M., REHEUL, D. AND CHAIEB, M.** 2002. Seed and spike traits from remnant populations of *Cenchrus ciliaris* L. in South Tunisia: high distinctiveness, no ecotypes. *Journal of Arid Environments*. 50: 309 – 324.
- MULLET, J.E. AND WHITSITT, M.S.** 1996. Plant cellular responses to water deficit. *Plant Growth Regulation*. 20, 119–124.
- MUTEPFA, F.** 2006. Desertification has a woman's face. *Our Planet Magazine*. Website: <http://www.ourplanet.com/imgversn/171/Fannie%20Mutepfa.pdf>
- MUTSAERS, H.J.W., WEBER, G.K., WALKER, P. AND FISHER, N.M.** 1997. A field guide for on-farm experimentation. IITA / CTA / ISNAR.
- MUTHURI, C.W.** 2005. Dryland agroforestry management systems: The Mt. Kenya region experience. *The Prunis Tribune*. April. p 5.
- NAMIBIA NATURE FOUNDATION (NNF).** 2004. Challenges facing Namibia in achieving sustainable land use. Website: <http://www.cppnam.net/CPP-ISMLnewsletter.pdf>
- NAP** See National Action Program.
- NATIONAL ACTION PROGRAM (NAP).** 2004. Combating land degradation to alleviate rural poverty. Department: Environmental Affairs and Tourism. South Africa.
- NATIONAL ENVIRONMENT MANAGEMENT AUTHORITY (NEMA).** 2003. State of the environment report for Kenya. Nairobi. Kenya. Website: <http://www.nema.go.ke/downloads/SOE03summary.pdf>
- NDULI, N.** 2000. Implementation framework for the LandCare program. National Department of Agriculture, South Africa (revised – First edition 1998).

NEMA See National Environment Management Authority.

NGOMA, L. 1996. Hwange villagers adopt holistic management. *Zimbabwe Herald*. October.

NICHOLSON, S. 2000. Land surface processes and Sahel climate. *Reviews of Geophysics*. 38: 117 – 139.

NICHOLSON, S.E. 2002. What are the key components of climate as a driver of desertification? IN: REYNOLDS, J.F. AND STAFFORD SMITH, D.M. 2002. Global Desertification, Do humans cause deserts? Dahlem University Press. Berlin.

NNF See Namibia Nature Foundation.

NUNES, P.A.L.D., VAN DEN BERG, J.C.J. AND NIJKAMP, P. 2003. The ecological economics of biodiversity. Cheltenham: Edward Elgar.

O'BRIEN, D. 2007. Questionnaire design. Website: http://www-static.cc.gatech.edu/classes/cs6751_97_winter/quest-design

O'CONNOR, T.G. AND PICKETT, G.A. 1992. The influence of grazing on seed production and seed banks of some African Savanna Grasslands. *Journal of Applied Ecology*. 29: 247 – 260.

OJIMA, D.S., TIESZEN, L., CHULUUN, T., BELNAP, J., DODD, J. AND CHEN, Z. 1999. Factors influencing production systems and soil carbon of the Mongolian Steppe. Natural Resource Ecology Laboratory. USA. Website: http://www.nrel.colostate.edu/projects/lutea/dennis_poster.htm

OKIN, G.S. 2002. Toward a unified view of biophysical land degradation processes in arid and semi-arid lands. IN: REYNOLDS, J.F. AND STAFFORD SMITH, D.M. 2002. Global Desertification, Do humans cause deserts? Dahlem University Press. Berlin.

OKOBA, B.O. AND STERK, G. 2006. Farmers' identification of erosion indicators and related erosion damage in the Central Highlands of Kenya. *Catena*. 65: 292 – 301.

O'REGAN, B.P., CRESS, W.A. AND VAN STADEN, J. 1993. Root growth, water relations, abscisic acid and proline levels of drought-resistant and drought-sensitive maize cultivars in response to water stress. *South African Journal of Botany*. 59(1): 98 – 104.

ORGANIZATION OF AFRICAN UNITY. 1968. African Convention on the Conservation of Nature and Natural Resources. Website: http://www.africa-union.org/root/au/Documents/Treaties/Text/Convention_Nature%20&%20Natural_Resources.pdf

O'SULLIVAN, D.B. AND LITHGOW, K.B. 1999. Landholders monitoring rangeland health: a new approach. *VIth International Rangeland Congress Proceedings*. Vol 2. p 741 – 742.

PALMER, A.R. AND AINSLIE, A. 2002. South Africa: FAO Country Profile. Rangeland resources. FAO. Rome. Italy.

PALMER, A.R. AND VAN ROOYEN, A.F. 1998. Detecting vegetation change in the southern Kalahari using Landsat TM data. *Journal of Arid Environments*. 39: 143 – 153.

PAMO, E.T. AND PAMO, C.T. 1991. An evaluation of the problems of open range use system in northern Cameroon. *Tropicultura*. 9 (3): 125 – 128.

PANDEY, R. AND AGARWAL, R.M. 1998. Water stress-induced changes in proline contents and nitrate reductase activity in rice under light and dark conditions. *Physiological and Molecular Biology of Plants* 4, 53– 57.

PARKER, J.S. 2006. Land tenure in the Sugar Creek Watershed: A contextual analysis of land tenure and social networks, intergenerational farm succession, and conservation use among farmers of Wayne County, Ohio. Ph.D. Dissertation. Department of Anthropology. The Ohio State University.

PEET, R. AND WATTS, M. 1993. Introduction: Development theory and environment in an age of market triumphalism. *Economic Geography*. 69 (3): 227 – 253.

PENDER, J., ABDOULAYE, T., NDJEUNGA, J., GERARD, B. AND EDWARD, K. 2006. Impacts of inventory credit, input supply shops and fertilizer micro-dosing in the

drylands of Niger. International Association of Agricultural Economists Conference. 12 – 18 August 2006. Gold Coast. Australia.

PEREZ, P., ALBERGEL, J., DIATTA, M., GROUZIS, M. AND SENE, M. 1998. Rehabilitation of a semi-arid ecosystem in Senegal. 2. Farm-plot experiments. *Agriculture, Ecosystems and Environment*. 70: 19 – 29.

PRESSEY, R.L. AND TAFFS, K.H. 2001. Scheduling conservation action in production landscapes: priority areas in western New South Wales defined by irreplaceability and vulnerability to vegetation loss. *Biological conservation*. 100: 355 – 376.

PIETOLA, L., HORN, R. AND YLI-HALLA, M. 2005. Effects of trampling by cattle on the hydraulic and mechanical properties of soil. *Soil and Tillage Research*. 82: 99 – 108.

PRINCE, S.D. 2002. Spatial and temporal scales for detection of desertification. IN: REYNOLDS, J.F. AND STAFFORD SMITH, D.M. 2002. Global Desertification, Do humans cause deserts? Dahlem University Press. Berlin.

PRINGLE, H. 2000. Grazing impacts in rangelands: Assessment of two contrasting landscape types in arid western Australia from different land management perspectives. Ph.D. Thesis. Australian National University. Canberra.

PROFFITT, A.P.B., BENDOTTI, S., MCGARRY, D. 1995. A comparison between continuous and controlled grazing on a red duplex soil. I. Effects on soil physical characteristics. *Soil and Tillage Research*. 35: 199 – 210.

RADATZ, C. 2005. Can we restore highly grazed land in the Kalahari Desert? Restoration and Reclamation Review. Student On-line Journal. University of Minnesota. St. Paul. Maine. USA. Website: www.hort.agri.umn.edu/h5015/rrr.htm

RADDAD, E.Y. AND LUUKKANEN, O. 2007. The influence of different *Acacia senegal* agroforestry systems on soil water and crop yields in clay soils of the Blue Nile region, Sudan. *Agricultural Water Management*. 87: 61 – 72.

RAO, A.V. AND TARAFDAR, J.C. 1998. Selection of plant species for rehabilitation of gypsum mine spoil in aridzone. *Journal of Arid Environments*. 39: 559 – 567.

- RAVERA, O.** 1989. Ecological assessment of environmental degradation, pollution and recovery. Elsevier Science Publishers. New York.
- REED, M.** 2004. Participatory Rangeland Monitoring and Management. Website: <http://www.env.leeds.ac.uk/~mreed/IVP/>
- REED, M.S. AND DOUGILL, A.J.** 2003. Integrating community and scientific sustainability indicators to facilitate participatory desertification monitoring and sustainable rangeland management in Botswana. *Proceedings of the VII th International Rangeland Congress*. 26 July – 1 August 2003. International Conference Centre. Durban. South Africa.
- REIGH, P.F., NUMBEM, S.T., ALMARAZ, R.H. AND ESWARAN, H.** 2001. Land resource stresses and desertification in Africa. IN: BRIDGES, E.M., HANNAN, I.D., OLDEMAN, L.R., PENING DE VRIES, F.W.T., SCHERR, S.J. AND SOMPATPANIT, S. 2001. Responses to land degradation. *Proceedings of the 2nd International Conference on Land Degradation and Desertification*. Khon Kaen. Thailand. Oxford Press. New Dehli. India.
- REYNOLDS, J.F. AND STAFFORD SMITH, D.M.** 2002. Do humans cause deserts? IN: REYNOLDS, J.F. AND STAFFORD SMITH, D.M. 2002. Global Desertification, Do humans cause deserts? Dahlem University Press. Berlin.
- ROBERTS, E.H.** 1972. Viability of seeds. Chapman and Hall Ltd Publishers. London.
- ROBINS, S.** 1997. Transgressing the borderlands of tradition and modernity: identity, cultural hybridity and land struggles in Namaqualand (1980 - 94). *Journal of Contemporary African Studies* 159(1): 23-43.
- ROETS, M. AND KIRSTEN, J.F.** 2005. Commercialization of goat production in South Africa. *Small Ruminant Research*. 60: 187 – 196.
- ROGERS, M.C.** 1996. Restoration Ecology (Report as part of the course Conservation Management 4 at the School for Forestry at the P.E. Technikon. Port Elizabeth. p 16. (Unpublished).

- ROHDE, R.F., MOLEELE, N.M, MPHALE, M., ALLSOPP, N., CHANDA, R., HOFFMAN, M.T., MAGOLE, L. AND YOUNG, E.** 2006. Dynamics of grazing policy and practice: environmental and social impacts in three communal areas of southern Africa. *Environmental Science and Policy*. 9: 302 – 316.
- ROUX, P.W. AND OPPERMAN, D.P.J.** 1986. Soil erosion. IN: COWLING, R.M., ROUX, P.W. AND PIETERSE, A.J.H. 1986. The Karoo biome, a preliminary synthesis. Part 1. CSIR Report Nr. 124. Pretoria.
- RUNNSTROM, M.C.** 2000. Is northern China winning the battle against desertification? *Ambio*. 29 (8): 468 – 476.
- RUSIKE, J., SNAPP, S. AND TWOMLOW, S.J.** 2000. Mother-baby trial approach for developing soil water and fertility management technologies. Participatory research and development for sustainable agriculture and natural resource management. A sourcebook.
- RUSSELL, M.** 2006. Data Acquisition: Closed-Ended Questionnaire Response Format. *EzineArticles*. Website: <http://ezinearticles.com/?DataAcquisition:-Closed-Ended-Questionnaire-Response-Format&id=373764>
- SCHNEIDER, T. AND BARTOSZEK, J.** 2002. Amphibian and macroinvertebrate monitoring to evaluate restoration success. Ohio Environmental Protection Agency. ESA Annual Meeting. 5 August 2002.
- SCHOLES, R.J. AND WALKER, B.H.** 1993. An African Savanna: Synthesis of the Nylsvley Study. Cambridge University Press. UK.
- SCHUTTE, G.** 1999. LandCare: What is it all about? LandCare Symposium, Potchefstroom. South Africa.
- SCOONES, I., REIJ, C. AND TOULMIN, C.** 1996. Sustaining the soil: Indigenous soil and water conservation in Africa. Earthscan Publications. London. ISBN 1-85383-372.
- SCOONES, I., DEVEREUX, S. AND HADDAD, L.** 2005. Introduction: New directions for African agriculture. IN: SCOONES, I., DEGRASSI, A., DEVEREUX, S. AND

HADDAD, L. 2005. New directions for African agriculture. Institute of Development Studies Bulletin. 36(2): 1-12.

SEAGER, T.P. AND GARDNER, K.H. 2005. Barriers to adoption of novel environmental technologies: contaminated sediments. IN: LEVNER, E., LINKOV, I. AND PROTH, J-M. 2005. Strategic Management of Marine Ecosystems. Springer Netherlands. ISBN 978 14020 31571.

SERI See Society for Ecological Restoration International.

SHARIF, F. AND MURDOCH, A.J. 2001. The effects of temperature and moisture on after-ripening of *Cenchrus ciliaris* seeds. *Journal of Arid Environments*. 49: 823 – 831.

SINGH, G. AND RATHOD, T.R. 2002. Plant growth, biomass production and soil water dynamics in a shifting dune of Indian desert. *Forest ecology and management*. 171: 309 – 320.

SKERMAN, P.J. AND RIVEROS, F. 1990. Tropical grasses. Food and Agricultural Organization (FAO). Website: <http://www.fao.org/ag/AGP/AGPC/doc/Gbase/DATA/Pf000196.HTM>

SMITH, O.B. AND KOALA, S. 2003. Desertification: myths and realities. IN: DARKOH, M. AND RWOMIRE, A. 2003. Human impact on environment and sustainable development in Africa. Ashgate Publishing Company. USA.

SMITH, T. AND WANGARI, E.O. 1996. Desertification control and natural resources management: Case studies from SADC Countries. UNESCO. Dakar.

SMIT, G.N., RICHTER, C.G.F. AND AUCAMP, A.J. 1999. Bush encroachment: An approach to understanding and managing the problem. IN: TAINTON, N.M. (ed). 1999. Veld management in South Africa. University of Natal Press. Pietermaritzburg.

SNEATH, D. 2002. State policy and pasture degradation in Inner Asia. *Science* 281: 1147.

SNYMAN, H.A. 1999. Soil erosion and conservation. IN: TAINTON, N.M. (ed). 1999. Veld management in South Africa. University of Natal Press. Pietermaritzburg.

SNYMAN, H.A. 2003a. Restoration of a degraded semi-arid rangeland in South Africa. *Proceedings of the VII th International Rangeland Congress*. 26 July – 1 August 2003. International Conference Centre. Durban. South Africa.

SNYMAN, H.A. 2003b. Revegetation of bare patches in a semi-arid rangeland of South Africa: an evaluation of various techniques, *Journal of Arid Environments*, 55: 417 – 432.

SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL SCIENCE AND POLICY WORKING GROUP (SER). 2002. The SER Primer on Ecological Restoration. Website: www.ser.org/

SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL SCIENCE AND POLICY WORKING GROUP (SER). 2004. The SER primer on ecological restoration, Science and Policy Working Group. Website: www.ser.org

SOMBROED, W.G. AND HADJI, M.S. 2004. Degradation of rainfed agricultural land, irrigated agricultural lands, ranching and traditional pastoral lands and forest lands. UNCCD, Information sharing segment, First substantive session, Inter governmental Negotiating Committee for a Convention to Combat Desertification. Website: <http://www.unccd.int/knowledge/INCDinfoseg/partii.php>

SOUTH AFRICAN GOVERNMENT. 2004. Before the 1994 elections. Webpage: <http://www.northern-cape.gov.za/legislature/chapter1.html>

SOUTH AFRICAN GOVERNMENT. 2004b. Annexures – How a law is made. Webpage: http://www.northern-cape.gov.za/legislature/annexure_a.html

SPARROW, A. 2006. Forest and range ecology. Lecture 24 April 2006. NRES 493/693. Website: <http://www.cabnr.unr.edu/sparrow/1>

STANCIOFF, A.M., STALJANSSENS, M. AND TAPPAN, G. 1986. Mapping and Remote Sensing of the Resources of the Republic of Senegal: A Study of the Geology, Hydrology, Soils, Vegetation, and Land Use Potential. South Dakota State University/Remote Sensing Institute. Brookings.

- STATISTICS SOUTH AFRICA.** 2006. Survey of large scale agriculture. *Business Report*. Website: <http://www.busrep.co.za>
- STEFANOVA, K.** 2005. Protecting Namibia's natural resources. *eJournal USA: Economic Perspectives*. August. Website: <http://usinfo.state.gov/journals/ites/0805/ijee/stefanova.htm>
- STERK, G., HERRMANN, L. AND BATIONO, A.** 1996. Wind-blown nutrient transport and soil productivity changes in southwest Niger. *Land Degradation Rehabilitation*. 7: 325-335.
- STOCKING, M.A. AND MURNAGHAN, N.** 2001. Handbook for the field assessment of land degradation. Earthscan Publications Ltd. London.
- STOKSTAD, E.** 2005. Taking the pulse of Earth's life-support systems. *Science*. 308: 41 – 43.
- STRASSER, B.J. AND STRASSER, R.J.** 1995. Measuring fast fluorescence transients to address environmental questions: The JIP-test. IN: MATHIS, P. (ed). *Photosynthesis: from Light to Biosphere*. Kluwer Academic Publishers. Dordrecht. The Netherlands. p 977 – 980.
- STRASSER, R.J., SRIVASTAV, A. AND TSIMILLI-MICHAEL, M.** 2000. The fluorescence transient as a tool to characterize and screen photosynthetic samples. IN: YUNUS, M., PATHRE, R. AND MOHANTY, P. 2000. *Probing photosynthesis: Mechanism, regulation and adaptation*. pp. 443 – 480. Taylor and Francis. London. UK.
- STREETLAW.** 2006. Streetlaw. Website: <http://www.streetlaw.org.za>
- STRIEBIG, B.A.** 1999. Erosion by water. Sustainable residential design and construction. Website: http://www.courses.psu.edu/c_e/c_e433_bas124/erosion.htm/
- STRINGER, L.C. AND REED, M.S.** 2006. Land degradation assessment in southern Africa: integrating local and scientific knowledge bases. *Land Degradation and Development*. In press.

- SUNDQUIST, B.** 2003. Grazing lands degradation: a global perspective. IN: SUNDQUIST, B. 2003. The earth's carrying capacity. Some literature reviews. 4th Edition. Website: <http://home.alltel.net/bsundquist1/og0.html>
- SWEARINGEN, W.** 2006. Deserts: Desertification. Encyclopedia of Science and Technology. McGraw-Hill. Website: http://books.mcgraw-hill.com/EST10/site/deserts_article.php
- SYNGENTA FOUNDATION FOR SUSTAINABLE AGRICULTURE.** 2007. A background: The semi-arid regions. Website: http://www.syngentafoundation.org/syngenta_foundation_semi_arid_agriculture_sahel.htm
- TABO, R., BATIANO, A, DIALLO MAIMOUNA, K., HASSANE, O. AND KOALA, S.** 2005. Fertilizer micro-dosing for the prosperity of small-scale farmers in the Sahel. International Crops Research Institute for the semi-arid tropics. Niamey.
- TAEHTIHARJU, S. AND PALVA, T.** 2001. Antisense inhibition of protein phosphatase 2C accelerates cold acclimation in *Arabidopsis thaliana*. *The Plant Journal*. 26: 461 – 470.
- TAINTON, N.M.** 1999. Veld management in South Africa. University of Natal Press. Pietermaritzburg. p 472.
- TAINTON, N.M. AND HARDY, M.B.** 1999. Introduction to the concepts of development of vegetation. IN: TAINTON, N.M. (ed). 1999. Veld management in South Africa. University of Natal Press. Pietermaritzburg.
- TANDARICH, J.P., DARMODY, R.G., FOLLMER, L.R. AND JOHNSON, D.L.** 2002. Comments on historical development of soil and weathering profile concepts from Europe to the United States of America. *Soil Science Society of America Journal*. 66: 335 – 346.
- TAPPAN, G., HADJ, A., WOOD, E. AND LIETZOW, R.** 2000. Use of argon, corona and Landsat imagery to assess 30 years of land resource change in west-central Senegal. *Photogrammetric Engineering and Remote Sensing*. 66(6): 727 – 735.
- TEAGUE, R. AND DOWHOWER, S.** 2003. Drought and grazing patch dynamics under different grazing management treatments in southern USA Prairie. *Proceedings of the VII th*

International Rangeland Congress. 26 July – 1 August 2003. International Conference Centre. Durban. South Africa.

THACHER, P.S. 1992. The role of the United Nations. IN: HURRELL, A. AND KINGSBURY, B. 1992. The international politics of the environment. Clarendon Press. Oxford.

THRASH, I. AND DERRY, J.F. 1999. The nature and modeling of piospheres: a review. *Koedoe*. 42: 73 – 94.

THE GLOBAL CHANGE GAME. 2000. Deforestation and overgrazing in Africa. Website: www.mts.net/~gcg/resources/africa/index04.html

THOMAS, D.S. 2002. Sand, grass, thorns, and....cattle: the modern Kalahari. IN: SPORTON, D. AND THOMAS, D.S.G. 2002. Sustainable livelihoods in Kalahari Environments. Oxford University Press, Inc. New York.

THOMAS, D.S.G. AND SHAW, P.A. 1991. The Kalahari Environment. Cambridge University Press. Cambridge. UK.

THRASH, I., THERON, G.K. AND BOTHMA, J. du P. 1993. Impact of water provision on herbaceous plant community composition in the Kruger National Park. *African Journal of Range & Forage Science*, 10: 31–35.

TIFFEN, M. MORTIMORE, M. AND GICHUKI, F. 1994. More people, less erosion: Environmental recovery in Kenya. Wiley. New York.

TILZ. 2005. How to control soil erosion. Tearfund International Learning Zone. Website: <http://tilz.tearfund.org/Publications/Footsteps+11-20/Footsteps+15/How+to+control+soil+erosion.htm>

TOBE, K., ZHANG, L., QIU, G. SHIMIZU, H. AND OMASA, K. 2001. Characteristics of seed germination in five non-halophytic Chinese desert shrub species. *Journal of Arid Environments*. 47: 191 – 201.

- TODD, S.** 1997. The effects of heavy grazing on plant species diversity and community composition in a communally managed, semi-arid shrubland, Namaqualand, South Africa. M.Sc. Thesis. University of Cape Town. Cape Town.
- TODD, S.** 2006. Gradients in vegetation cover, structure and species richness of Nama-Karoo shrublands in relation to distance from livestock watering points. *Journal of Applied Ecology*. 43(2): 293 – 304.
- TODD, S.W. AND HOFFMAN, M.T.** 1999. A fence-line contrast reveals effects of heavy grazing on plant diversity and community composition in Namaqualand, South Africa. *Plant Ecology*. 142 (1-2): 169 – 178.
- TONGWAY, D. AND HINDLEY, N.** 1995. Manual for soil condition assessment manual. Division of Wildlife and Ecology. CSIRO Australia. Canberra.
- TOWNSEND, G.F.** 1998. Multi-purpose trees for honey production. ECHO technical note. Florida. USA.
- TURNER, N.C.** 1991. Measurement and influence of environmental and plant factors on stomatal conductance in the field. *Agric. For. Meteorol.* 54, 137–154.
- TURPIE, J.K.** 2003. An ecological-economic appraisal of conservation on commercial farm land in four areas of South Africa. Conservation farming project. Fitzpatrick Institute. University of Cape Town. South Africa.
- TURPIE, J., LANGE, G., MARTIN, R., DAVIES, R. AND BARNES, J.** 2005. Namibia's protected areas: Their economic worth and the feasibility of their financing. DEA Research Discussion Paper Nr. 73. September. Windhoek. Namibia.
- TWINE, W.C.** 2005. Socio-economic transitions influence vegetation change in the communal rangelands of the South African lowveld. *African Journal of Range and Forage Science*. 22 (2): 93 – 99.
- UNCCD** See United Nations Convention to Combat Desertification.
- UNDP** See United Nations Development Program.

UNEP See United Nations Environment Program.

UNIDO See United Nations Industrial Development Organization.

UNISFÉRA INTERNATIONAL CENTRE. 2003. Governing Global Desertification: The negotiation and implementation of the United Nations Convention to Combat Desertification. Information leaflet. August 2003.

UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION (UNCCD). 1995. United Nations Convention to Combat Desertification in those countries experiencing serious drought and/or desertification particularly in Africa. *United Nations Environment Program*. Geneva.

UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION (UNCCD). 2002. Secretariat of the United Nations Convention to Combat Desertification. Website: <http://www.unccd.int/main.php>

UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION (UNCCD). 2003. Working document. 6th Meeting of the Conference of the Parties (COP). 25 August – 5 September 2003. Havana. Cuba.

UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION (UNCCD). 2003a. United nations convention to combat desertification in those countries experiencing serious drought and/or desertification, particularly in Africa. CD-ROM. Germany.

UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION (UNCCD). 2006. Implementing the United Nations Convention to Combat Desertification in Africa: Ten African Experiences. Secretariat of the United Nations Convention to Combat Desertification. Bonn. Germany.

UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION (UNCCD). 2006a. Desertification. Definition of desertification in the UNCCD. Website: http://www.sdnpsd.org/sdi/international_days/wed/2006/desertification/index.htm

UNITED NATIONS DEVELOPMENT PROGRAM (UNDP). 1998. Human Development Report 1998. United Nations Development Programme, New York, NY.

UNITED NATIONS ENVIRONMENT PROGRAM (UNEP). 1992. World Atlas of Desertification. Edward Arnold. London.

UNITED NATIONS ENVIRONMENT PROGRAM (UNEP). 1997. World Atlas of Desertification. 2d edition. London. Edward Arnold.

UNITED NATIONS ENVIRONMENTAL PROGRAM (UNEP). 1999. Global Environment Outlook, 2000. Earthscan. London. Website: www.unep.org.geo2000

UNITED NATIONS ENVIRONMENT PROGRAM (UNEP). 2002. Post Johannesburg. WSSD Outcomes. Website: <http://www.uneptie.org/Outreach/wssd/postjoburg/wssdoutcomes.htm>

UNITED NATIONS ENVIRONMENT PROGRAM (UNEP). 2005. Protecting the environment from land degradation – UNEP's Action in the Framework of the Global Environment Facility. UNEP.

UNITED NATIONS ENVIRONMENT PROGRAM (UNEP). 2005a. Agenda 21. Website: <http://earthwatch.unep.net/agenda21/contents.php>

UNITED NATIONS ENVIRONMENT PROGRAM (UNEP). 2006. Don't desert drylands! Facts about deserts and desertification. Website: <http://www.unep.org>

UNITED NATIONS ENVIRONMENT PROGRAM (UNEP). 2006a. Ozone Secretariat. Website: <http://ozone.unep.org/index.asp>

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO). 2006. Montreal Protocol. Website: <http://www.unido.org/doc.18265>

VAN ANDEL, J. AND ARONSON, J. 2006. Restoration Ecology. Blackwell Publishing. USA.

VAN DEN BERG, L. 2002. The evaluation of a number of technologies for the restoration of degraded rangelands in selected arid and semi-arid regions of South Africa. M.Sc. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom.

- VAN DEN BERG, L AND KELLNER, K.** 2005. Restoring degraded patches in a semi-arid rangeland of South Africa. *Journal of Arid Environments*. 61: 497 – 511.
- VAN DER MERWE, J.P.A.** 1997. The development of a database and expert system for rangeland reinforcement practices in southern Africa. M.Sc. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom. South Africa.
- VAN DER MERWE, J.P.A. AND KELLNER, K.** 1999. Soil disturbance and increase in species diversity during rehabilitation of degraded arid rangelands. *Journal of Arid Environments*. 41(3): 323 - 333.
- VAN DER MERWE, G.M.E., BARNARD, R.O. AND PRETORIUS, D.J.** 2004. WOCAT (World Overview of Conservation Approaches and Technologies) in South Africa. Department of Agriculture: Directorate Land Use and Soil Management and Agricultural Research Council: Institute for Soil, Climate and Water. Version 1. Report Number GW/A/2004/02.
- VAN DER WAL, R. AND BROOKER, R.W.** 2004. Mosses mediate grazer impacts on grass abundance in arctic ecosystems. *Functional Ecology*. 18: 77 – 86.
- VAN HEERDEN, M.C.** 2002. Changes in grass species composition and production systems: A LandCare Initiative in the North West Province, South Africa. M.Sc. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom, South Africa.
- VAN HEERDEN, P.D.R.** 1995. Evaluering van prolienakkumulering, proteïensamestelling en –sintese, relatiewe waterinhoud en reduksie van Trifenieltetrazoliumchloried as indikatore van droogtetoleransie in Wes-Kaapse lentekoringkultivars. Ph.D. Thesis. University of Stellenbosch. Stellenbosch. South Africa.
- VAN LYNDEN, G., SCHWILCH, G. AND LINIGER, H.** 2006. A standardized method for assessment of soil degradation and soil conservation: the WOCAT mapping technologies. Website: <http://www.wocat.net/MATERIALS/ISCOmap.pdf>
- VAN OUDTSHOORN, F.** 2004. Guide to the grasses of southern Africa. Briza Publications. Pretoria. p 88.

- VAN ROOYEN, A.F.** 1998. Combating desertification in the southern Kalahari: connecting science with community action in South Africa. *Journal of Arid Environments*. 39: 285 – 297.
- VAN ROOYEN, A.F.** 2004. The Desert Margins Program in eastern and southern Africa: Synthesis report for phase I. Report submitted to DMP Global Coordinating Unit. Niamey.
- VAN ROOYEN, N.** 2001. Flowering plants of the Kalahari dunes. Ekotrust cc. Lynnwood. South Africa.
- VAN ROOYEN, N. AND VAN ROOYEN, M.W.** 2000. Vegetation of the south-western arid Kalahari: an overview. *Transactions of the Royal Society of South Africa*. 52(2): 113 – 140.
- VARIS, O. AND KAJANDER, T.** 2006. An exploration into an urbanizing world – Interconnections on water, poverty, food and urbanization. United Nations Centre for Human Settlements and Helsinki University of Technology: Nairobi and Finland.
- VENTER, J.** 1988. Soil loss and runoff in Umfolozi Game Reserve and the implications for game reserve management. Ph.D. Thesis. University of Natal. Pietermaritzburg. South Africa.
- VERITY, G.E. AND ANDERSON, D.W.** 1990. Soil erosion effects on soil quality and yield. *Canadian Journal of Soil Science*. 70: 471 – 484.
- VERSLUES, P.E., OBER, E.S. AND SHARP, R.E.** 1998. Root growth and oxygen relations 270 at low water potentials. Impact of oxygen availability in polyethylene glycol solutions. *Plant Physiology* 116, 1403– 1412.
- WALKER, B.H., ABEL, N., STAFFORD SMITH, D.M. AND LANGRIDGE, J.L.** 2002. A framework for the determinants of degradation in arid ecosystems. IN: REYNOLDS, J.F. AND STAFFORD SMITH, D.M. 2002. *Global Desertification, Do humans cause deserts?* Dahlem University Press. Berlin.

- WANG, Y. AND GUO, Y.** 1993. Establishment of artificial grasslands on the degraded *Stipa* Steppe in the Alpine area high latitude zone of China. *Journal of Japanese Grassland Science*. 89: 343 – 348.
- WANG, Y., SHIYOMI, M., TSUIKI, M., TSUTSUMI, M., YU. X, AND YI, R.** 2002. Spatial heterogeneity vegetation under different grazing intensities in the northwest Heilongjinag steppe of China. *Agriculture, Ecosystems and Environment*. 90: 217 – 229.
- WARD, D.** 2005. Do we understand the causes of bush encroachment in African savannas? *African Journal of Range and Forage Science*. 22(2): 101 – 105.
- WARD, D., NGAIRORUE, B.T., APOLLUS, A. AND TJIVEZE, H.** 2000. Perceptions and realities of land degradation in arid Otjimbingwe, Namibia. *Journal of Arid Environments*. 45: 337 – 356.
- WARDE, S.** 2001. Seeding for success. *Erosion Control*. March. p.28 - 34.
- WATERS, C.M. AND SHAW, N.L.** 2003. Developing native grass seed industries for revegetation in Australia and the Western United States: A contrast in production and adoption. *Proceedings of the VII th International Rangeland Congress*. 26 July – 1 August 2003. International Conference Centre. Durban. South Africa.
- WESTOBY, M., WALKER, B. AND NOY-MEIR, I.** 1989. Opportunistic management for rangelands not at equilibrium. *Journal of Range Management*. 42(4): 266 – 274. Jul.
- WHISENANT, S.G.** 1995. Landscape dynamics and arid land restoration. IN: ROUNDY, B.A., McARTHUR, A.D., HALEY, J.S. AND MANN, D.K. 1995. Proceedings: Wild land shrub and arid land restoration symposium. 19 – 21 October 1993. Las Vegas. NV. General Technical Report. INT-GTR-315.
- WHITESIDE, M.** 1998. Living farms: Encouraging sustainable smallholders in southern Africa. Earthscan. London.
- WIEGAND, T., CAMARERO, J.J., RÜGER, N. AND GUTIÉRREZ, E.** 2006. Abrupt population changes in treeline ecotones along smooth gradients. *Journal of Ecology*. In press.

- WILSON, R.T.** 2006. Current status and possibilities for improvement of traditional apiculture in sub-Saharan Africa. *Livestock Research for Rural Development*. 18(8). Website: <http://www.cipav.org.co/lrrd18/8/wils/18111.htm>
- WINKEL, V.K., ROUNDY, B.A. AND COX, J.R. JR** 1991. Influence of seedbed microsite characteristics on seedling emergence. *Journal of Range Management* 44 (3): 210 – 214.
- WOLTERS, S.** 1994. Proceedings of Namibia's National Workshop to Combat Desertification. Napcod. Desert Research Foundation of Namibia. Windhoek. Namibia.
- WOOMER, P.L., TIESZEN, L.L., TAPPAN, G., TOURÉ, A. AND SALL, M.** 2004. Land use change and terrestrial carbon stocks in Senegal. *Journal of Arid environments*. 59: 625 – 642.
- WORLD BANK.** 2005. Burkina Faso: the Zai technique and enhanced agricultural productivity. *IK Notes*. Vol. 80. Website: <http://www.worldbank.org/afr/ik/iknt80.htm>
- XUE, Y. AND FENNESSY, M.J.** 2002. Under what conditions does land-cover change impact regional climate? IN: REYNOLDS, J.F. AND STAFFORD SMITH, D.M. 2002. Global Desertification, Do humans cause deserts? Dahlem University Press. Berlin.
- YORDANOV, I., VELIKOVA, V. AND TSONEV, T.** 2003. Plant responses to drought and stress tolerance. *Bulgarian Journal of Plant Physiology*. Special Issue. p 187 – 206.
- ZHOU, W.J., DODSON, J., HEAD, M.J., LI, B.S., HOU, Y.J., LU X.F., DONAHUE D.J. AND JULL, A.J.T.** 2002. Environmental variability within the Chinese desert-loess transition zone over the last 20 000 years. *Holocene*. 12: 107 – 112.

APPENDIX A

Perceptions about land degradation: Best restoration and conservation practice questionnaire – South Africa DMP target areas

**PERCEPTIONS ABOUT LAND DEGRADATION: BEST RESTORATION AND
CONSERVATION PRACTICES QUESTIONNAIRE – SOUTH AFRICA TARGET
AREAS**

GENERAL QUESTIONS

1. Name of sampler

2. Date

3. Name of farmer/community/extension officer

.....

4. Name of farm/region

5. Size of farm/area

6. Type of enterprise, farming system, management and other income

.....

7. Contact details

.....

8. How did you obtain knowledge concerning the management and farming with livestock on arable land?

Parents	School	Experienced people from the community	Other people outside the community	Courses at college / university	Other

9. How long have you been farming? Have you always farmed this land?

.....

.....

10. Type of management practice

Morafe Ranch	Communal grazing	Commercial grazing	Rotational system	Other

**11. Do you use materials from the natural environment to sustain your livelihoods
(fuelwood, medicinal plants, building material etc.)**

..... Yes

..... No

If yes, explain

.....
.....

If yes, how often do you harvest it?

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

If yes, which species?

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

12. Do you keep rainfall record?

..... Yes

..... No

If yes, why?

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

LAND USE QUESTIONS

13. Do you have watering points on your farm/land?

..... Yes

..... No

If yes, how many?

.....
.....

If yes, who owns the water source?

.....
.....

LIVESTOCK QUESTIONS (AMOUNT AND CONDITION)

14. Do you own livestock?

..... Yes

..... No

If yes, which, how many and what are they used for or what products do you get from them?

Animals	Which	Number	What are they used for or products do you get from them?
Cattle			
Sheep			
Donkeys			
Goats			
Other			

15. How big is your herd/s (head of cattle/sheep/goats)?

..... 10 – 20 animals

..... 21 – 50 animals

..... 51 – 100 animals

..... 100 - 500 animals

..... > 500 animals

16. Do the animals you own graze only on natural areas or do you feed them?

..... Natural grazing

..... Feed

If you feed the animals, do you use crops from your own croplands or do you buy or receive feed?

..... Own crops

..... Buy/receive feed

17. How many head of livestock can graze on one hectare of grazing land?

- 1 – 5 animals/ha
- 6 – 10 animals/ha
- 11 -20 animal/ha
- 21 – 50 animals/ha
- > 51 animals/ha

EROSION

18. Do you have wind or water erosion problems on your farms/land?

- Yes
- No

If yes, specify the degree of the problem

1	2	3	4	5	6	7	8	9	10
Low									High

19. Have you done anything to prevent soil loss caused by erosion?

- Yes
- No

If yes, what measures of erosion control have you implemented?

.....

.....

.....

RESTORATION QUESTIONS

20. What is your perception of degraded veld for livestock grazing?

.....

.....

.....

21. Do you think the grazing land on your farm/area is degraded?

- Yes
- No

If yes, why do you think this has happened?

.....

.....

.....

If yes, what species increases in degraded veld?

.....

.....

.....

22. Do you have old croplands on your farm?

..... Yes
..... No

If yes, have you done anything to restore these old lands?

..... Yes
..... No

If yes, what measures have you taken to restore old lands?

.....

.....

.....

23. Have you done anything to restore degraded natural resources on your farm/land?

..... Yes
..... No

If yes, explain

.....

.....

.....

If yes, how long ago have you implemented restoration treatments?

.....

.....

.....

If yes, how have you managed the area after restoration (e.g. rotational grazing)?

.....

.....

24. How would you rate the current condition of the veld?

- Very poor
- Poor
- Average
- Good
- Very good

25. What management practice is currently in place?

.....

.....

.....

26. Do you think the restoration measures were a success?

- Yes
- No

If yes, why do you think it was a success?

.....

.....

.....

APPENDIX B

Best restoration and conservation practices questionnaire (Africa)

Country (Pays).....
Questionnaire number (Numéro de questionnaire).....

Best restoration and conservation practices questionnaire
Questionnaire sur les meilleures pratiques de restauration et conservation

Policy makers, coordinators and organizers
Décideurs politiques, coordinateurs et organisateurs

1. Interviewee name (*Nom de l'interviewé*).....

2. Contact details (*Numéro de contact*)
.....
.....

3. Occupation (*Profession*).....

4. Date (*Date*).....

Legislation and policy (*legislation et politique agricole*)

5. Are there any legislation and policies in the country on international, national and provincial level concerned with degradation, restoration and conservation in the country? *Y a-t-il des législations et politique agricole dans le pays au niveau international, national et provincial concernant la dégradation, restauration et conservation ?*

..... Yes (.....Oui)

..... No (.....Non)

If yes, explain. *Si oui, expliquez*
.....
.....

6. Can anyone make use of the natural resources in the country? *Est ce tout le monde peut utiliser les ressources naturelles dans le pays?*

..... Yes (.....Oui)

..... No (.....Non)

If no, why not? *Si non, pourquoi pas?*

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

7. Is there any collaboration with international conventions? *Y a t-il collaboration avec les conventions internationales?*

..... Yes (.....Oui)

..... No (.....Non)

If yes, which. *Si oui, laquelle*

.....
.....

8. Who are governing conservation and restoration projects and processes in the country? *Qui est responsable des projets de conservation et restauration dans le pays ?*

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

9. Is the Government or any other partner busy with awareness, capacity building, demonstration, community upliftment, poverty relief or livelihood improvement? *Est ce que le gouvernement ou les autres partenaires sont concernés par le renforcement des capacités, démonstration, réduction de la pauvreté, amélioration du bien être ?*

..... Yes (.....Oui)

..... No (.....Non)

If yes, explain. *Si oui, expliquez*

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

10. Is there any collaboration or projects with other enterprises such as private, NGO's etc. *Y a t-il collaboration entre les projets et autres entreprises du secteur privé, ONG, etc.*

..... Yes (.....Oui)

..... No (.....Non)

If yes, name them. *Si oui, nommez les*

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

If yes, explain *Si oui, expliquez*

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

Degradation (*Dégradation*)

11. Do you think the natural environmental system has changed over the last 10 years?

Pensez-vous que l'environnement naturel a changé au cours des 10 dernières années?

..... Yes (*.....Oui*)

..... No (*.....Non*)

If yes, why do you think this has happened? *Si oui, pourquoi cela s'est produit?*

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

12. What is your perception of degradation? *Quelle perception faites vous de dégradation*

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

13. Do you think degradation of natural resources is a problem in the country? *Pensez-vous que la dégradation des ressources naturelles est un problème dans le pays?*

..... Yes (*.....Oui*)

..... No (*.....Non*)

If yes, to what extent. *Si oui, quelle ampleur*

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

14. In your opinion, what are the major causes of degradation in the country (population growth etc)? *Selon vous, quelles sont les majeures causes de dégradation dans le pays (croissance de la population, etc?)*

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

15. In your opinion, what types of degradation occur in the country (vegetation decrease etc)? *Selon vous, quels sont les types de dégradation dans le pays (réduction de la végétation, etc?)*

.....
.....
.....
16. Who is most affected by the degradation of natural resources? *Qui sont les plus affecte par la dégradation des ressources naturelles ?*

..... Land users (people who only use products from the land) (*....exploitants agricoles*)

..... Livestock owners (*.....*)

..... Farmers (*....paysans*)

..... Other (*....autres*)
.....
.....

17. What is the cost of degradation to the country (\$ and other)? *Quel est le coût de la dégradation dans le pays (dollar et autres)*
.....
.....
.....

Restoration (*Restauration*)

18. Are there any national, local or regional programs in the country to promote the restoration of degraded natural resources? *Y a t-il au niveau national, local ou régional des programmes de restauration des ressources naturelles dégradées?*

..... Yes (*....Oui*)

..... No (*....Non*)

If yes, explain. *Si oui, expliquez*
.....
.....
.....

If yes, who contributes, how do they contribute and at what stage do they contribute? *Si oui, qui contribue, comment contribue t-il et à quelle étape s'effectue cette contribution?*
.....
.....
.....

19. What is the overall goal of restoration? *Quel est l'objectif global de la restauration?*

.....

.....

.....

20. How does the country approach restoration projects and processes? *Comment le pays conçoit-il les projets de restauration et procédés?*

.....

.....

.....

21. What factors are taken into consideration when looking at restoration projects? *Quels facteurs sont pris en compte dans les projets de restauration ?*

.....

.....

.....

22. To what extent are social, economic and natural factors taken into consideration when planning and executing restoration projects? *Quelle considération est accordée aux facteurs sociaux, économiques et naturels dans la planification et l'exécution des projets de restauration?*

Social *(Sociale)*

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

Economic *(Economique)*

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

Natural *(Naturelle)*

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

23. What links exist between government (policy makers, coordinators and organizers), researchers and land users concerning degradation and restoration? *Quels liens existent entre le gouvernement (décideurs politiques, coordinateurs et organisateurs), chercheurs et vous même à propos de dégradation et restauration?*

.....

.....

.....

24. Are there any other stakeholders involved in restoration? *Y a t-il d'autres partenaires impliqués dans la restauration?*

..... Yes (.....Oui)

..... No (....Non)

If yes, who? *Si oui, lesquels?*

.....
.....
.....
25. How much financial support is there from each sector? *Quelle est leur contribution financière?*

.....
.....
.....
26. How much technical support (research, extension, monitoring etc) is there from each sector? *Quel type assistance technique (recherche, vulgarisation, suivi, etc.) est fournie par chacun des partenaires*

Participation (*Participation*)

27. Who is involved in approaches to combat degradation? *Qui acteurs sont impliqués dans la lutte contre la dégradation*

- Government agencies (.....*Agence gouvernementale*)
..... International incentives (.....*Motivations internationales*)
..... Scientists (.....*Scientifiques*)
..... National Agricultural Research Institutes (NARS) (.....*Système national de recherche agricole*)
..... Advanced Research Institutes (ARI) (.....*Institut de recherche*)
..... International Agricultural Research Centre (IARC) (.....*Centre internationaux de recherche*)
..... Other (...*Autres*)

.....
.....
28. Are land users involved in restoration projects and processes? *Est ce que les exploitants agricoles sont impliqués dans les projets de restauration*

- Yes (...*Oui*)
..... No (...*Non*)

If yes, to what extent. *Si oui, quelle étendue*

.....
.....
29. In your opinion, why are land users involved in restoration projects and processes (incentives, natural resources, economic, social, cultural, traditional)? *Selon vous, pourquoi les*

exploitants agricoles sont-ils impliqués dans les projets de restauration (prime, ressources naturelles, raisons économiques, sociales, culturelles, traditionnelles)

.....

.....

.....

30. Who pays for restoration? *Qui paie la restauration?*

.....

.....

.....

31. What is the adoption rate of restoration treatments by land users? *Quel est le taux d'adoption des techniques de restauration par les exploitants agricoles?*

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

If low, why? *Si faible, pourquoi?*

.....

.....

.....

If high, why? *Si fort, pourquoi?*

.....

.....

.....

32. What are the benefits of restoration to people (markets and credits)? *Quels sont les bénéfices de la restauration (marchés, crédits)*

.....

.....

.....

33. How are the results of research and other information concerned with restoration communicated and made public to each sector (awareness, upliftment, demonstration)? *Comment les résultats de recherche et autres information concernant la restauration sont communiqués au public (renforcement capacités, démonstration, prise de conscience) ?*

.....

.....

.....

34. How is restoration introduced to land users, farmers and other interested parties? *Par quel procédé la restauration est-elle introduite aux exploitants agricoles, paysans et autres parties intéressées?*

.....

.....

.....

35. How are land users capacitated in conservation and restoration projects and processes? *Comment les exploitants agricoles sont-ils formés en conservation et restauration?*

.....

.....

.....

Methodologies (méthodologies)

36. How is restoration being carried out in the country? *Comment la restauration des terres est-elle conduite dans le pays?*

.....

.....

.....

37. What is the success rate of restoration? *Quel est le niveau de succès de restauration?*

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

38. In your view, is the idea of success of restoration different for researchers, extension services, farmers and donors? *Selon vous l'idée de succès de restauration diffère t-elle entre les chercheurs, la vulgarisation les paysans et les bailleurs de fonds*

..... Yes (....Oui)

..... No (....Non)

If yes, explain. *Si oui, expliquez*

.....

.....

.....

39. Are restoration efforts monitored? *Est ce la restauration est mesurée/suivie*

..... Yes (....Oui)

..... No (....Non)

If yes, how is it being conducted? *Si oui, comment est-elle conduite?*

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

If yes, why is it being conducted? *Si oui, pourquoi est-elle conduite?*

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

If yes, who is monitoring restoration success? *Si oui, qui fait le suivi du succès de la restauration ?*

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

If yes, when is restoration success monitored? *Si oui, quand est ce le suivi est effectué?*

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

40. If re-seeding (revegetation) is used in restoration projects and processes - are native species used?

..... Yes
..... No

If yes, are seed production systems used to propagate these species?

..... Yes
..... No

41. Are big engineering structures e.g. gabions used for erosion control? *Est ce les structures lourdes (gabions) sont utilisées pour lutter contre l'érosion?*

..... Yes (....Oui)
..... No (....Non)

If yes, who is responsible for the building of these structures. *Si oui, qui est responsable pour la confection de ces structures?*

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

APPENDIX E

Restoring degraded areas in the hardveld of the Kalahari, South Africa.
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Restoring degraded areas in the hardveld of the Kalahari, South Africa

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Abstract

The hardveld of the Kalahari is degrading as a response to increased demand and exploitation of the natural resources in these areas. This degradation is characterized by a change in the ratio between palatable and unpalatable species, as well as a loss in the cover and density of herbaceous species, leading to large bare patches. Depending on the degree of degradation, it is well known that these severely degraded areas cannot recover only by means of natural succession processes, but that active intervention in the form of restoration treatments have to be applied. Combinations of different restoration treatments were evaluated in a study site in the hardveld of the Kalahari, South Africa. Quantitative vegetation sampling procedures were carried out over a period of six years (2001 – 2006) to describe the establishment and dynamics of the over-sown species in the different restoration treatments. The germination capacity and viability of the over-sown species were also tested in the laboratory, using methods prescribed by the International Seed Testing Association (ISTA). The results of the seed purity analysis indicated that commercial seed obtained from a registered seed merchant showed a higher purity percentage than seed harvested and obtained locally. Seed from species obtained locally showed low germination percentages when compared to commercial seed harvested in other arid regions. The results from the multivariate analysis carried out for the different restoration treatments showed that the over-sown species were positively correlated with the over-sowing treatments, while local pioneer species mostly correlated with the control and cultivation only restoration treatments. The results of the frequency surveys indicated that it is essential to apply a cultivation (ripping) treatment to ensure the success of any restoration treatment in similar areas.

Keywords: Kalahari, degradation, restoration, over-sowing, ripping

1. Introduction

Characteristic of South Africa is the fact that more than 80% of the land area is used for grazing and livestock production (Hoffman and Ashwell 2001). Due to the fact that large portions of these rangelands are threatened by the higher demand on the resources, it is important to conserve and maintain the natural vegetation. It is estimated that approximately 99% of South Africa falls within the United Nations Convention to Combat Desertification (UNCCD) definition of drylands (Hoffman and Ashwell 2001). The term drylands, as used by the UNCCD, encompasses the arid, semi-arid and sub-humid zones of the world. The UNCCD was initiated to address problems associated with the condition of land resources in dryland ecosystems and to promote sustainable development in these areas (Chasek and Corell 2002). As a full member of the Convention, South Africa had an international obligation to develop a National Action Program (NAP) to combat desertification. The South African NAP follows an integrated approach addressing simultaneously the natural and socio-economic aspects of the processes of land degradation and drought.

The arid rangelands of the Kalahari are changing in response to human usage and exploitation and due to population increases the impacts on the natural resources are greater than ever before (Thomas and Shaw 1991, Collins 2001). Gordonia, the district which covers most of the southern Kalahari in South Africa, has been rated as having both soil and vegetation degradation values much higher than the country wide average (Hoffman *et al.* 1999). The local people highly depend on agriculture for a living as the area holds no other livelihood options from natural resources (Van Rooyen 1998); therefore the degradation of the arid and semi-arid areas of the Kalahari through overgrazing contributes to a reduction in the natural production potential of the area. When there is heavy grazing pressure on rangelands, the animals consume palatable vegetation faster than it can regenerate and eventually only unpalatable or no vegetation remains (Kawanabe *et al.* 1998, Todd and Hoffman 1999, Wang *et al.* 2002, Sombroed and Hadji 2004). Increased pressures on natural resources, together with low and erratic rainfall patterns occurring frequently, adversely affect the livelihoods of local people who experience their effects first hand.

The sands of the Kalahari were blown into linear dunes which were subsequently fixed by savanna vegetation. The north-north-west to south-south-east trending parallel dunes east of the Namibian highlands and north of the Orange River are 5 – 15 meters high with spacing of 200 – 400 meters (Van Rooyen 2000). Although most of the Kalahari is covered by sand at varying depths, there is a flat, stony part in the south which is generally referred to as the hardveld. The hardveld habitat is dominated by dwarf shrubs and the grass layer is poorly developed (Van Rooyen 2001). Even though the hardveld covers only a small part of the southern Kalahari, a large number of people rely on the commons around Rietfontein, the largest town in the Mier region, to raise livestock. In the hardveld, degradation generally starts with the formation of smaller bare areas or patches which expand or join together to form large bare and denuded areas (Kellner and Bosch 1992). The loss of herbaceous cover results in factors, such as increased soil erosion, formation of soil crusts and loss of favourable micro-habitats necessary for germination and establishment of seedlings (Winkel *et al.* 1991, Dean *et al.* 1995). The degradation of natural resources is viewed as a gradual process rather than a simple switch from one condition (state) to another. This implies a potential for reversibility, so that removing or lessening the human impact, mostly through overgrazing, can result in the restoration of soil and vegetation quality. In some instances leaving a degraded area to rest shows a drastic improvement in the condition of the resource, but in arid and semi-arid areas natural succession tends to be slow and stochastic as water frequently limits or prevents plant establishment and growth.

According to the Society for Ecological Restoration (SER) ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER 2002). The application of treatments based on ecological principles and processes are essential for successful restoration of degraded rangelands (Visser *et al.* 2004). According to De Beer (2000), recognizing the role of climatic factors and management practices during restoration activities hold important practical implications for species composition and restoration success. Generally restoration procedures include active interventions, such as burning, clearing, re-seeding and/or cultivation (Allen 1995, Van den Berg 2002) and passive treatments (withdrawal of livestock) (Milton and Dean 1995). Restoration of arid rangelands, where annual precipitation is less than 450 mm, is constrained and complicated by the nature of land disturbances and widely divergent climatic conditions (Call and Roundy 1991). It is therefore important to take

factors such as species composition and selection into consideration when planning any restoration treatment.

Restoration of an ecosystem is always difficult and costly to be obtained, and a complete recovery may often be impossible because some components of the ecosystem may have been altered irreversibly during the degradation process (Fitzgerald 1982, Ravera 1989). The type of restoration practice will depend on the degree of degradation and resources available for restoration. In most cases the local farmers do not have the time or the financial capacity to leave an area for longer resting periods, which leads to the implementation of active restoration treatments (Snyman 2003). The application of restoration treatments must be carried out in conjunction with other land management practices, such as decreasing or removing grazing pressures on the restored area for at least one or two seasons to give plants the time to recover or establish.

The objective of this paper is to evaluate the success of certain restoration treatments with regard to the increase of vegetation cover and density for better grazing in bare and degraded areas in the hardveld of the Kalahari. An understanding of the environmental changes that are taking place in the hardveld due to degradation, over-exploitation and restoration is of fundamental importance for devising sound management and conservation strategies in this arid region.

2. Materials and methods

2.1 Study site

The study was conducted in the Mier rural area, in the southern Kalahari, Northern Cape Province, South Africa. The Mier rural area lies between the Namibian and Botswana borders (26°45'00''S and 20°05'00''E) (Figure 1), and the area consists of three land use types: towns and villages, communal grazing areas and commercialized stock farming by individual land users (Van Rooyen 1998). The study site is situated in the hardveld of the Karroid Kalahari Bushveld (Low and Rebelo 1996). If not degraded or disturbed, the Karroid Kalahari Bushveld is characterized by an almost non-existent and very sparsely scattered tree layer with herbaceous

cover. The shrub layer is moderately developed while the grass layer is poorly developed with dominant species such as *Stipagrostis obtusa* Nees and *Stipagrostis ciliata* De Winter. The restoration demonstration plot is situated on the commons, five kilometers south-east of Rietfontein (the largest village in the area). The area receives a long-term average rainfall (1960 – 2005) of approximately 167.3 mm per annum with the most significant rains falling in the summer months from November to April with peaks in March (South African Weather Service 2006). The location of the site used for this study was chosen through a consultative process with the local municipal council, farmers and extension officers. Consulting land users during decision making processes generally enhance the adoption of management applications (O'Sullivan and Lithgow 1999).

This project forms part of a larger LandCare project, implemented in the Mier rural area. The LandCare project is a community based National Government supported natural resource use management program. The LandCare project near Rietfontein has the objectives of training farmers on restoration techniques, stabilize shifting sand dunes and eradicate alien plants. As part of this project, a large area on the hardveld, within the Rietfontein commons have been selected and fenced off to exclude grazing by livestock. Grazing has been excluded from the large enclosure until 2004. The experimental site of 2 ha is situated within the larger enclosed area and fenced separately (2000). Grazing has been excluded from this smaller enclosure until 2006. Various restoration treatments and surveys have been applied in the 2 ha experimental site.

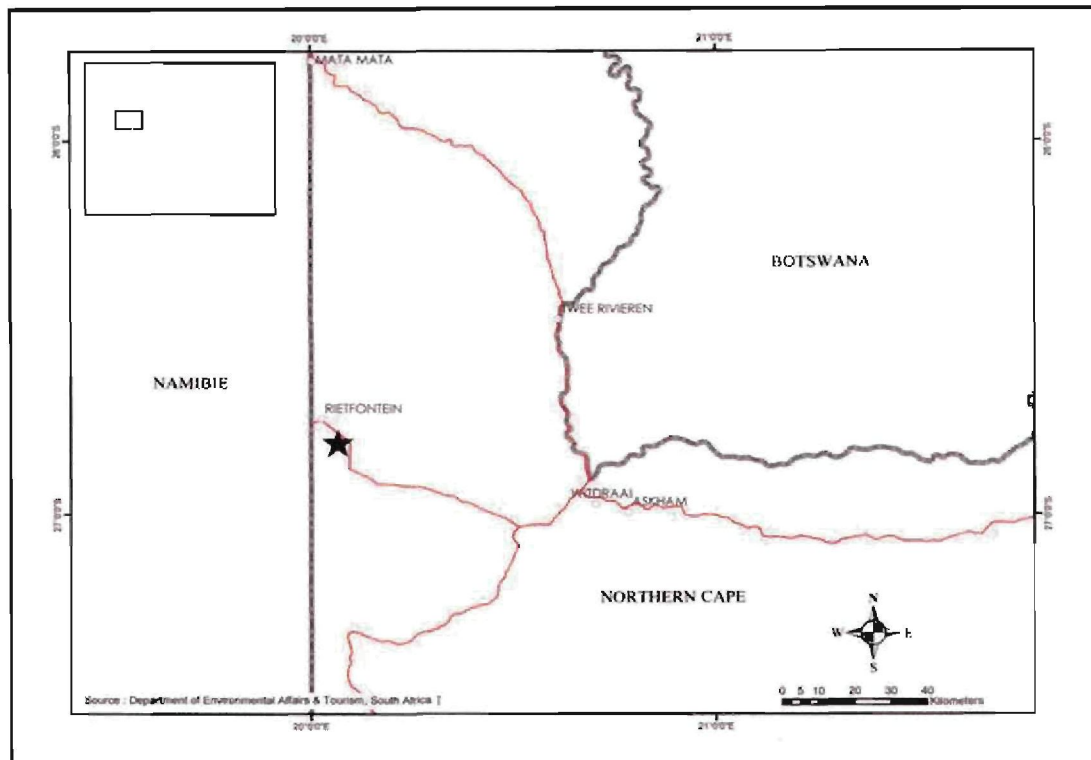


Figure 1 Map showing the location of the restoration demonstration site in the Mier rural area in the southern Kalahari near Rietfontein, between the Namibian and Botswana borders.

2.2 Establishment of restoration experimental site

A site of 2 ha in a bare, denuded area was selected and fenced to exclude large herbivores. The selected area was subdivided into 26 m x 26 m (676 m²) sub-plots and restoration treatments were randomly applied in each sub-plot (Figure 2). The restoration plot was established in March 2000. The restoration treatments included cultivation (ripping) and over-sowing with grass species. The sub-plots were cultivated with a tractor and a one-tine sub-soiler implement (ripper) to break the hard, compacted soil crust and create furrows of 200 mm deep and 100 mm wide for increased water infiltration. The furrows were spaced approximately one meter apart to maximize the area for water catchment. Ripping adds the additional advantage of enhancing the establishment of natural and over-sown species by exposing the dormant seeds in the seed bank to favourable light and moisture conditions (Bakker and Berendse 1999).

Grasses are suitable for restoration purposes due to their extensive root system which binds the soil for increased water infiltration and protection against erosion. A combination of grass species were selected to be used in the over-sowing treatment sub-plots. All of the seed used for the restoration treatments were obtained from a registered seed merchant. Two different seed mixtures consisting of perennial, palatable grass species were used in the over-sowing treatments. The first mixture (A) contained commercial grass species (generally used for planted pastures), not originating from the specific area and the second mixture (B) containing grass species native to the study area. The rationale for using these two different seed mixtures was to determine which type of species would show higher germination and establishment rates.

The first seed mixture (Mixture A) included following species, *Antheophora pubescens* Schreb., *Cenchrus ciliaris* L. and *Chloris gayana* Swartz. Seeds of these species were hand-sown at a rate of 600g/spp/676 m². The second seed mixture (Mixture B) included seed of the following grass species, *Eragrostis lehmanniana* Nees, *Eragrostis echinochloidea* Stapf, *Schmidtia pappophoroides* Steud. and *Fingerhuthia africana* Lehm. The rate of sowing for the second mixture was 400g/spp/676 m² and was carried out by hand. Even though the selected species for the second mixture occur naturally in the region, the seeds were obtained from a seed merchant in a different rainfall zone (Potchefstroom – 600 mm annually). Due to the fact that a limited amount of seed from the second seed mixture was available from the seed merchant, two different sowing densities were used for the over-sowing treatments. Although it is advised to make use of indigenous, locally adapted species, seeds of these species are often not available in large quantities and therefore commercial seed, often used for cultivated pastures, are regularly used in over-sowing restoration practices.

Seed samples of each species (N = 1 000) were taken to the laboratory to assess the purity percentage and germination rate according to the International Seed Testing Association (ISTA) regulations (Wellington 1969, ISTA 1985).

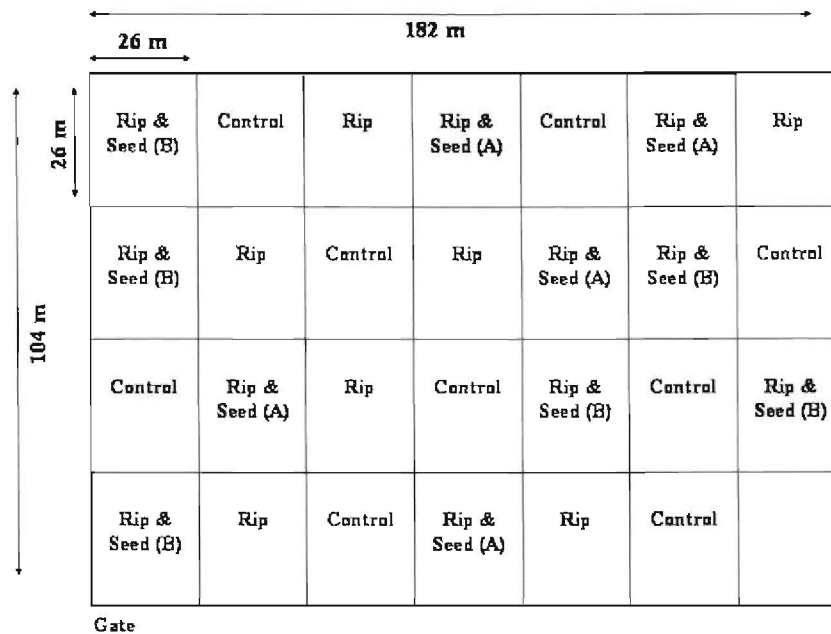


Figure 2 Layout of the restoration demonstration plot as established in March 2000. (A) indicates the *Antheophora pubescens*, *Cenchrus ciliaris* and *Chloris gayana* seed mixture, while (B) indicates the seed mixture containing *Eragrostis lehmanniana*, *Eragrostis echinochloidea*, *Schmidtia pappophoroides* and *Fingerhuthia africana*.

2.3 Seed quality assessment and vegetation sampling

2.3.1 Laboratory experiment

One of the greatest challenges in restoration treatments is sowing a seed type that has the capacity to produce abundant biomass and density to control erosion and cover bare areas that could have formed during the degradation process (Van den Berg 2002). Seed testing has been developed to minimize the risk of failure, by assessing the quality of seed before it is sown. Submitted seed (N = 400 for each species) was exposed to the conditions of the germination test for the prescribed period. During this time, the normal seedlings were counted and removed at regular intervals. The assessment of the doubtful and abnormal seedlings was done at the end of the germination

test. The determination of purity and germination percentages were carried out once at the onset of the long-term restoration experiment. The results from the germination tests were compared to the results of the field data to evaluate the establishment of the over-sown species in the experimental field plots under natural conditions.

2.3.2 Field experiment

The descending point method along on a transect was used to evaluate the abundance of mainly the over-sown, as well as other dominant species in all the sub-plots (676 m²) (Figure 2). A point was lowered at one meter intervals and rooted plants within a radius of 300 mm were recorded (Brown 1954, Sutherland 1996). If no plant occurred within a radius of 300 mm, it was noted as bare ground. A total number of 200 points per sub-plot were surveyed. The plant nomenclature for all species followed Arnold and De Wet (1993). The frequency surveys were carried out on three occasions, near the end of the growing seasons in March/April of 2003, 2005 and 2006.

2.4 Data processing

The result of the germination tests were calculated as the average of four 100 seed replicates for normal, abnormal, fresh and dead seed. These results were summarized in tabular format (Table 1).

General analysis of the frequency surveys were carried out according to results summarized in graphs drawn with the Windows Excel and Sigma Plot programs. The PCA ordination (Principal Component Analysis), from the CANOCO computer program (Ter Braak 1987 – 1992) was used to determine the correlations between species abundance and restoration treatments after vegetation sampling. A scatter graph was used to explain the degree of correlation of certain species to treatments, mainly on the first and the second ordination axes.

3. Results and Discussion

Enhancing vegetation cover and density at restoration sites with over-sown species, rely on effective germination and establishment of the seed at favourable conditions (Bellairs and Davidson 1999). The germination and establishment potential of the over-sown species are dependent on the viability of the seed under optimal conditions. From Table 1, it is evident that all the species from seed mixture (A) i.e. *Antheophora pubescens*, *Cenchrus ciliaris* and *Chloris gayana* showed a high purity percentage of more than 98% and 85% respectively. This is explained by the fact that the commercial seed bought from a registered seed merchant goes through a preliminary separation phase before it is sold, thus limiting the impurities found in the purity analysis. Even though the seed from these three species had been cleaned after harvesting and contained very few impurities, only *A. pubescens* shows a very high germination capacity (82%). In addition to having a high germination rate, 1.3% of the seed was identified as being fresh at the end of the recommended testing period of four weeks. This implies that a portion of the seed still had the ability to germinate after the completion of the test. *Antheophora pubescens* also contained the highest portion of abnormal seedlings (8.8%), which were mainly characterized by seedlings having primary root dysfunction (roots absent or deformed).

Species from seed mixture (B) i.e. *Eragrostis lehmanniana*, *Eragrostis echinochloidea*, *Schmidtia pappophoroides* and *Fingerhuthia africana* showed relatively high purity percentages of above 60%, with the exception of *E. echinochloidea* (6.8%). This is explained by the fact that seed of *E. echinochloidea* are made up of a large number of lemmas, which are shed after seed ripening. This also accounted for the very high portion of impurities found in the sample of *E. echinochloidea* (84%). Even though the purity component of the submitted samples of all the species, except for *E. echinochloidea*, had a value of more than 50%, only *E. lehmanniana* and *F. africana* showed germination rates of more than 20%. None of the species tested showed any abnormal seedling development and only *S. pappophoroides* contained fresh seeds during the germination assessment period of four weeks (1%). For most of the species tested there is a poor correlation between the purity percentages and the germination capacity. This can be attributed to the fact that little is known about the germination requirements of some of the species. In addition, the ISTA rules only provide instructions about the germination requirements of grass

species that are commercially available, and not for most of the indigenous grasses of local ecotypes.

If the results of the laboratory germination results are compared with the frequency results obtained from the field surveys, it is evident that even though *C. gayana* showed a germination capacity of 22 %, it did not establish in the field experiment until 2006 (Figure 5). This is explained by the fact that even though it usually forms part of a restoration seed mixture in other regions, the prevailing climatic conditions at the experimental study site limited the germination and establishment of this species. Natural populations of this species normally grow in higher rainfall zones of South Africa (Van Oudtshoorn 1999). *Eragrostis echinochloidea*, which had the lowest germination capacity in the laboratory experiments, showed the highest abundance of establishment in the field trials after six years (Figure 5). This can be ascribed to the fact that incorrect laboratory germination methods could have been used for this species or that the seed was still dormant when the germination tests were carried out. It is found that seed harvested before full maturity is reached, have a low viability after storage, if compared with seed harvested at maturity (Mackay 1972). It was not known when the seed of *E. echinochloidea* was harvested before it was used in the experiment, nor are dormancy breaking procedures for this species available.

Table 1 Seed purity and germination percentages of the sown-in species obtained from laboratory experiments carried out according to ISTA rules (Mixtures A and B).

Species	Sample weight (g)	Purity (% by weight)			Germination (% by number)		
		Pure seed	Inert matter	Normal seedlings	Fresh seed	Abnormal seedlings	Dead seed
<i>Anthephora pubescens</i> (A)	52.14	98.9	1.1	82	1.3	8.8	8
<i>Cenchrus ciliaris</i> (A)	43.86	98.4	1.6	51.8	0	1.8	46.4
<i>Chloris gayana</i> (A)	28.67	85	12.5	22	0	0	88
<i>Eragrostis lehmanniana</i> (B)	35.16	91	9	24.3	0	0	75.7
<i>Eragrostis echinochloidea</i> (B)	23.99	6.8	86.4	0	1	0	99
<i>Schmidtia pappophoroides</i> (B)	9.404	60	38.6	1	0	0	99
<i>Fingerhuthia africana</i> (B)	14.78	65.4	28.7	38.5	0	0	61.5

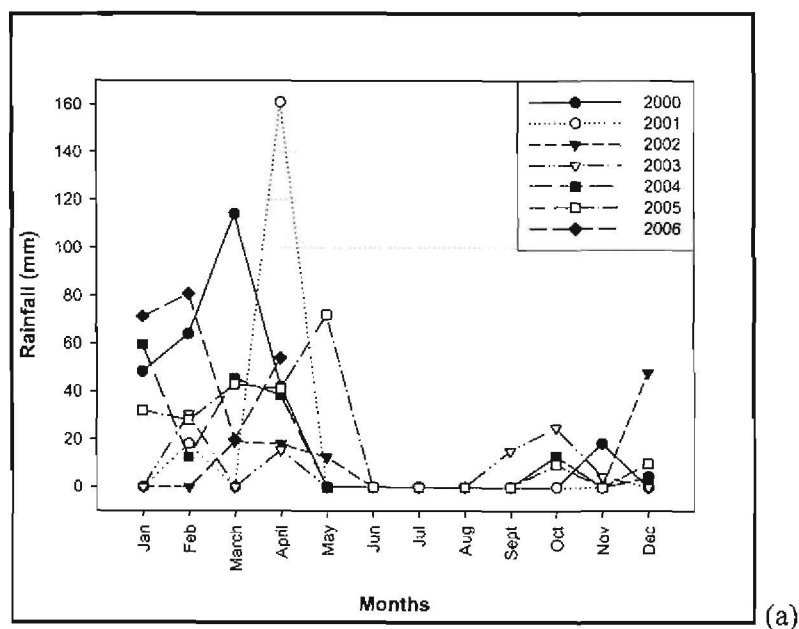
Normal seed – Seedlings which can develop into normal plants.

Fresh seed – Seed still having the ability to germinate into normal seedlings after completion of the test.

Abnormal seed – Seedlings which have not developed normally (deformed seedlings).

Dead seed – Unviable seed not being able to germinate within the testing period.

Even though there was a very good rainfall event in the month during which the plot was established (March 2000) (Figure 3a), the over-sowing was carried out at the end of the growing season. This implies that some seedlings that might have germinated after the good rainfall was probably killed by frost during the winter months from May to August 2000. Although the rainfall in 2002 and 2003 followed the long-term average pattern, the annual rainfall was 60 – 80 mm less than the long-term average rainfall (Figure 3b). A subjective vegetation assessment was carried out in 2001 and 2002 to assess the vegetation cover occurring in the experimental plot during those years. The results showed that the dominant species in the experimental plot in 2001 and 2002 was an annual succulent herb (*Trianthema parvifolia*). No quantitative abundance surveys were however conducted in these two years due to the poor establishment of any of the sown-in species.



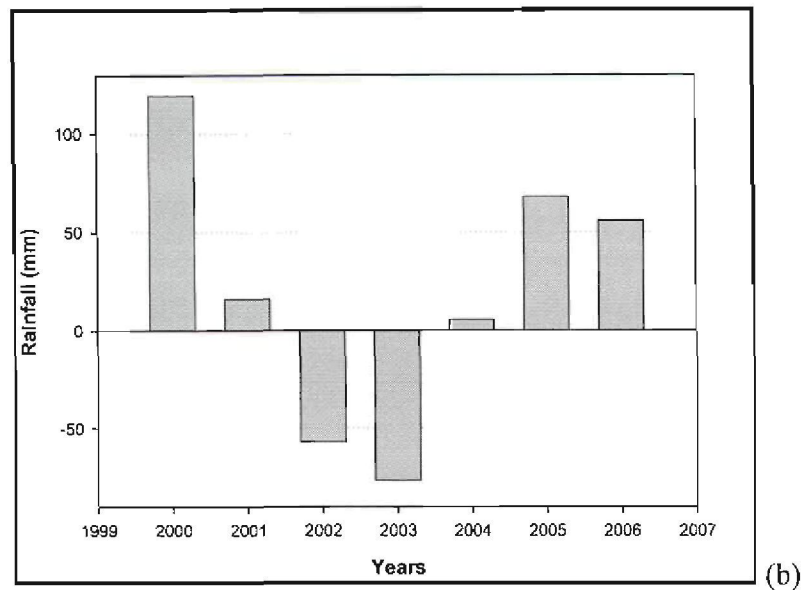


Figure 3 (a) Short-term annual rainfall (mm) of the years following the implementation of restoration treatments and (b) deviation in average rainfall (represented by 0 mm) in the six years following implementation of restoration treatments.

Even though no surveys were conducted in 2001 and 2002, Figure 4 (b) shows a very slight increased vegetation cover if the photos of the experimental site between 2000 and 2001 are compared. The vegetation consisted mainly of annual pioneer species which might have facilitated the germination and establishment of perennial species in the following years. O'Connor (1997) found that if a protective microclimate is provided, it can result in seedling germination and increased vegetation cover of other species over the long-term. Even though the rainfall in 2003 was 80mm lower than the long-term average, a small number of over-sown and natural species established in the treated sub-plots (Figure 4 (c)). The above average rainfall in 2004 and especially 2005 resulted in good vegetation establishment and frequency in the restored sub-plots (Figure 4 (d)).

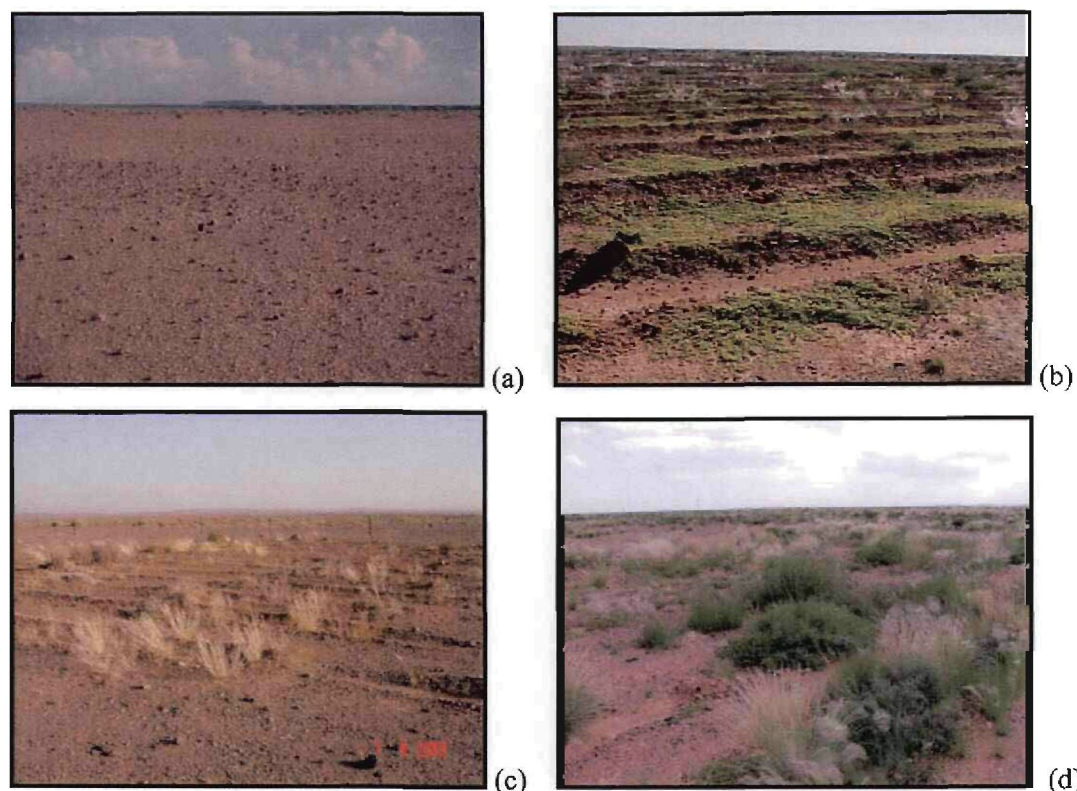


Figure 4 Photographic comparison of the restored site from 2000 to 2006. Figure 4 (a) shows the site prior to the implementation of restoration treatments (March 2000), (b) shows the increase in pioneer cover especially *Trianthema parvifolia* in May 2001, (c) shows the increase in perennial grass cover in August 2003 and (d) indicates the condition inside the exclosure of the restoration site in March 2006.

After the good rainfall season in January to May 2005 and 2006, all of the sown-in species with the exception of *C. gayana* established in the restored plot (Figure 5). When the germination capacity of the seed in the laboratory is compared to the establishment of the species under natural conditions in the field it is evident that even though most of the species showed relatively high germination percentages in the laboratory, only *E. echinochloidea* shows a relatively high establishment in the field trials (Figure 5). None of the species from seed mixture (A) established in the experimental site during 2003. Figure 5 shows that all the species of mixture (B), except for *S. pappophoroides*, established in 2003 and 2005. It is evident that seed mixture (B), containing the species native to the study area, showed a higher increase in frequency than the

commercial seed mixture (A) over the six year period (2000 – 2006) when the restoration site was established. This increase in abundance over the years could also be explained by the fact that established individuals from these species have produced seed during the previous growing seasons which has resided in the seed bank and germinated during favourable climatic conditions. Unfortunately no seed bank analysis has been conducted over the experimental period to confirm this.

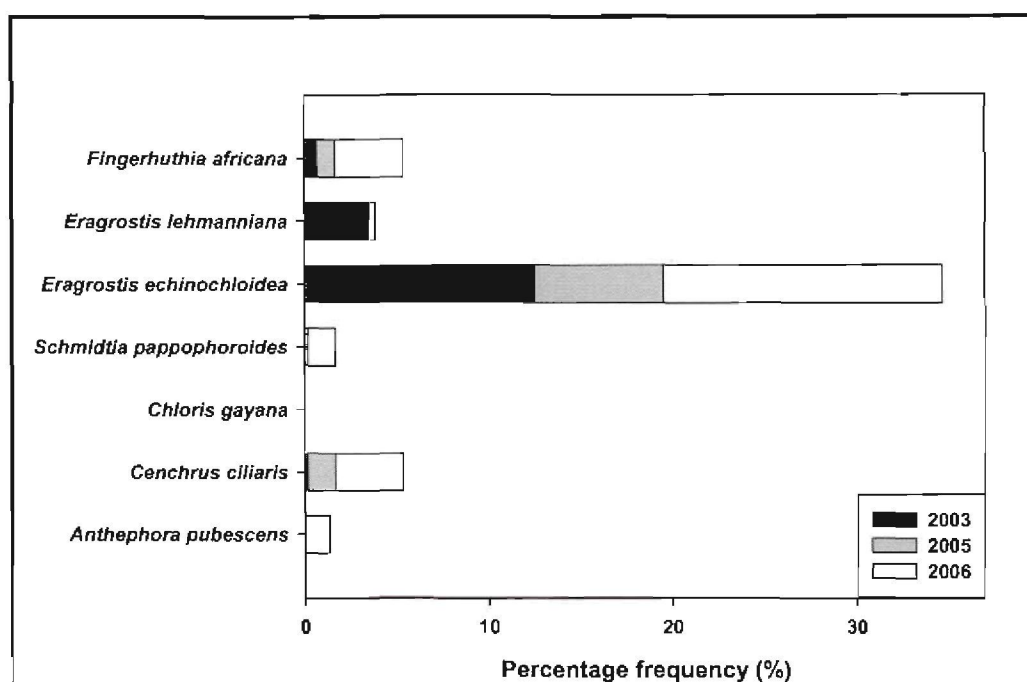


Figure 5 Total abundance (percentage frequency) of over-sown species for 2003, 2005 and 2006 in all the different restoration treatments over-sown with mixtures A and B.

All the treatments, including the control treatment, show a decrease in bare ground from 2003 – 2006 (Figure 6). The decrease in bare ground in the control treatment (from 93% to 57%) is ascribed to the fact that the restoration plot has been fenced off to exclude grazing by livestock. This implies that any species, including grasses, shrubs and succulent creepers which have germinated in the control treatments, had the opportunity to establish and produce seed with no grazing impact. In addition, the above average rainfall contributed to the establishment of vegetation in the control treatment. It is clear that both the rip and rip and seed treatments caused a decrease in bare ground, if compared to the control treatment. A definite increase in the

abundance of especially annual pioneer species occurred in the rip alone treatment in all three years, indicating that the soil seed bank was still viable in the degraded area (Figure 4). The over-sowing treatment contributed to a drastic decrease of bare ground (3%) in the rip and seed treatment after the above normal rainfall season of 2005.

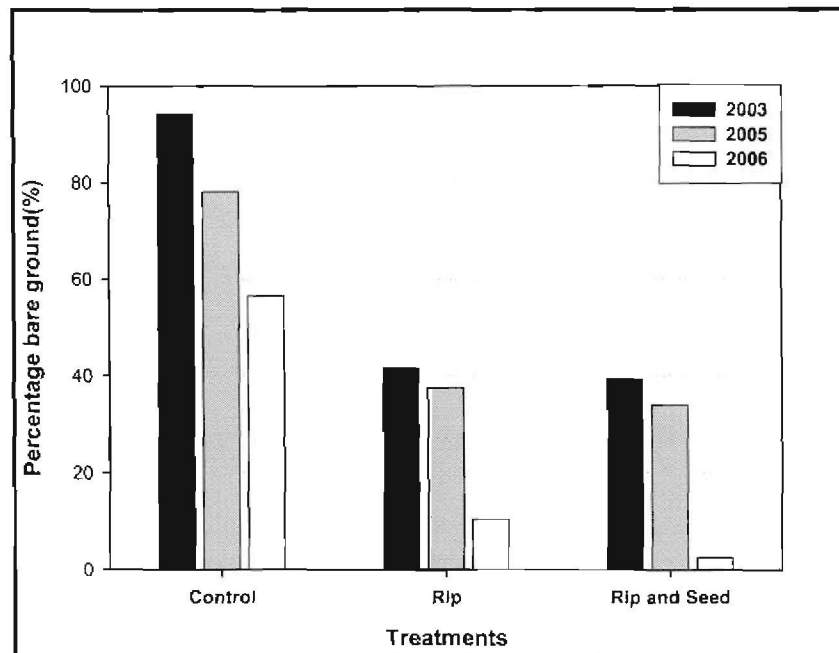


Figure 6 Comparison between the amount of bare ground (%) present in the three treatments from 2003 to 2006. Rip and seed treatments includes both grass seed mixtures (A and B).

From the Principal Component Analysis (PCA) analysis (Figure 7) it is evident that there was a clear distinction in species composition regarding the various treatments applied. According to the first PCA ordination axis (X-axis) there was a clear difference between the control treatment and the rip and rip and seed treatments (Eigenvalue X-axis: 0.704). The second PCA ordination axis (Y-axis) shows a variation between the rip and the rip and seed treatments (Eigenvalue Y-axis: 0.296). The control treatment is mainly correlated with bare ground, while the rip treatment is positively correlated with mainly annual grass species, such as *A. adscensionis* L. Local annual species such as *Enneapogon desvauxii* Beauv. occurred in all the treatments but species such as *S. dealata*, *Stipagrostis obtusa* Nees and *Aristida adscensionis* L. only occurred in the treatments where the hard soil surface was disturbed by the active mechanical treatments. The

majority of species correlated with the rip and seed treatment, were the sown-in species, such as *E. lehmanniana*, *E. echinochloidea*, *S. pappophoroides* and *F. africana* (Figure 7). Shrub and forb species such as *Salsola dealata* Botsch and *Mesembryanthemum* species were correlated with the rip treatment. It seems that these species occurred in the soil seed bank, and were exposed to favourable germination conditions, such as an increase in soil moisture after the soil was disturbed (rip treatment).

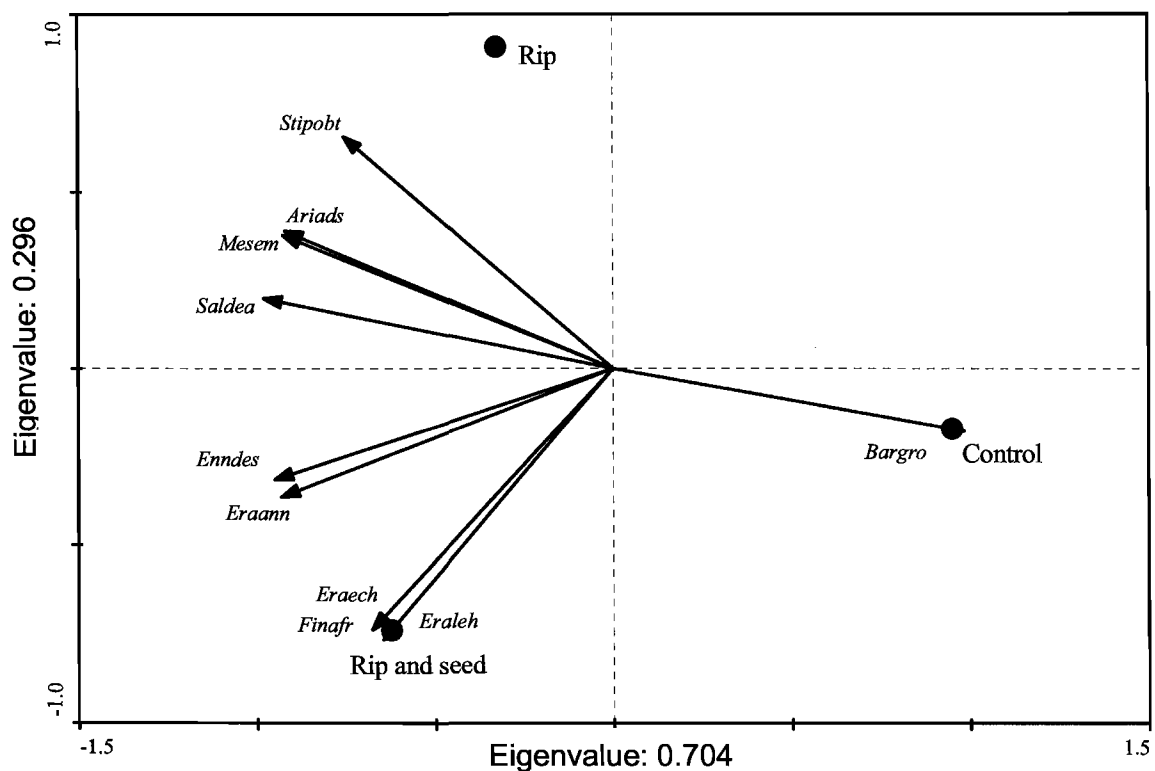


Figure 7 Combined PCA ordination to show the correlation of species abundance (% frequency) in the different treatments (Control, Rip and Rip and Seed – both seed mixtures A and B) on PCA axis 1 (Eigenvalue: 0.704) and axis 2 (Eigenvalue: 0.296) for the 2003, 2005 and 2006 surveys. (Abbreviations: *Stipobt* – *Stipagrostis obtusa*, *Ariads* – *Aristida adscensionis*, *Mesem* – *Mesembryanthemum*, *Saldea* – *Salsola dealata*, *Enndes* – *Enneapogon desvauxii*, *Eraann* – *Eragrostis annulata*, *Eraech* – *Eragrostis echinochloidea*, *Finafr* – *Fingerhuthia africana*, *Eraleh* – *Eragrostis lehmanniana* and *Bargro* – Bare ground).

Conclusions

The purity and germination tests indicated that commercial species showed high purity and germination capacities when compared to species native to the study area. In addition, there seems to be differences in the germination capacity of the over-sown species in the laboratory, if compared with the germination and establishment rates in the field trial. This implies that the germination requirements of these species might not have been met in the laboratory as opposed to the field trial.

The total germination and establishment of vegetation in the field trial at the beginning of the trial was relatively low due to the below average rainfall received in 2002 and 2003, while the above average rainfall in 2004 and 2005 contributed to the increase in vegetation cover in the growing seasons following the good rainfall. From this study it can be concluded that by mere loosening of the compacted soil crust, an increase in vegetation cover and density can be obtained if the soil seed bank is still viable. The type and density of species will depend on the composition of the soil seed bank. Although not measured, disturbing the soil most probably resulted in a higher soil moisture content, which has lead to the increase in species abundance, even in the treatments where no over-sowing was carried out. Only a small number of individual plants of the sown-in species established in the restoration plot, but a large number of annual and pioneer species germinated and established over the long-term as a result of the rip treatment. These results indicate the importance of determining the composition of the soil seed bank before any restoration treatment is applied. This would indicate whether over-sowing treatments are necessary or if the soil seed bank is rich enough that only a cultivation treatment is needed to stimulate the dormant seed in the soil seed bank. Although good results were obtained in the rip treatments, over-sowing perennial forage-producing grass species is necessary to increase the functional value of the area for better grazing production. It must however be emphasized that only species adapted to the specific environmental conditions should be used in over-sowing restoration treatments.

From these results it is evident that similar areas could be improved (or even restored) by using treatments such as soil loosening in conjunction with periods of rest. In conclusion, a better

understanding is however needed of species that are suitable for over-sowing restoration treatments in arid areas.

Acknowledgements

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References

- Allen EB 1995. Restoration ecology: limits and possibilities in arid and semi-arid lands. In: Round, B.A., McArthur, E.D., Haley, J.S., Man, D.K. (Comps.). Proceedings: Wildland Shrub and Arid Land Restoration Symposium. 19 – 21 October 1993. Las Vegas. NV. Gen.Tech. Rep. INT-GTR-315. Ogden. UT: US Department of Agriculture, Forest Services, Intermountain Research Station. pp. 7 – 13.
- Arnold TH, De Wet BC 1993. Plants of Southern Africa: names and distribution. Memoirs of the Botanical Survey of South Africa no 62. National Botanical Institute. Pretoria. South Africa.
- Bakker JP, Berendse F 1999. Constraints in the restoration of ecological diversity in grassland and heathland communities. *Tree* 14 (2), 63 – 68.
- Bellairs S, Davidson P 1999. Native plant establishment after mining in Australian rangelands. VIth International Rangeland Congress Proceedings 2, 962 – 968.
- Brown D 1954. Methods of surveying and measuring vegetation. Bulletin 42: Commonwealth Bureau of Pastures and Field Crops. Commonwealth Agricultural Bureaux Farnham Royal. Bucks. UK.
- Call CA, Roundy BA 1991. Perspectives and processes in revegetation of arid and semi-arid rangelands. *Journal of Range Management* 44 (6), 543 – 549.

- Chasek PS, Corell E 2002. Addressing desertification at international level: The institutional system. IN: Reynolds JF and Stafford Smith DM 2002. Global Desertification, Do humans cause deserts? Dahlem University Press. Berlin.
- Collins C 2001. Desertification. Website: <http://www.uwc.ac.za/Envfacts/facts/desertification.htm>
- Dean WRJ, Hoffman MT, Meadows ME, Milton SJ 1995. Desertification in the semi-arid Karoo. South Africa: Review and reassessment. *Journal of Arid Environments* 30, 247 – 264.
- De Beer GCO 2000. Rangeland condition and management models for parts of the savanna in the Northern Province. South Africa. Ph.D. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom. South Africa.
- Fitzgerald K 1982. Restoring degraded rangelands. *Journal of Agriculture* 2, 46 – 50.
- Hoffman MT, Todd SW, Ntshona ZM, Turner SD 1999. Land degradation in South Africa. Pretoria: Department of Environmental Affairs and Tourism. p 245.
- Hoffman T, Ashwell A 2001. Nature divided, Land degradation in South Africa. University of Cape Town Press. Cape Town. South Africa.
- International Seed Testing Association (ISTA) 1985. International rules for seed testing. *Rules 1985. Seed Science and Technology* 13, 299 – 355.
- Kawanabe S, Nan Y, Oshida T, Kou Z, Jiang D, Takeda-Oikawa N, Mukaiyama S 1998. Degradation of grassland in Keerqin sandland, Inner Mongolia. *China Grassland Science* 44, 109 – 114.
- Kellner K, Bosch OJH 1992. Influence of patch formation in determining the stocking rate for southern African grasslands. *Journal of Arid Environments* 22, 99 – 105.
- Low AB, Rebelo AG 1996. Vegetation of South Africa, Lesotho, Swaziland. Department of Environmental Affairs and Tourism. Pretoria. South Africa.
- Mackay DB 1972. The measurement of viability. IN: Roberts EH 1972. Viability of seeds. Chapman and Hall Ltd Publishers. London. UK.
- Milton SJ, Dean WRJ 1995. South Africa's arid and semi-arid rangelands: why are they changing and can they be restored? *Environmental Monitoring and Assessment* 37, 245 – 264.
- O'Connor TG 1997. Micro-site influence on seed longevity and seedling emergence of a bunchgrass (*Themeda triandra*) in a semi-arid savanna. *African Journal of Range and Forage Science* 14, 7 – 11.

- O'Sullivan DB, Lithgow KB 1999. Landholders monitoring rangeland health: a new approach. VIth International Rangeland Congress Proceedings 2, 984 – 985.
- Ravera O 1989. Ecological assessment of environmental degradation, pollution and recovery. Elsevier Science Publishers. New York. USA.
- Snyman HA 2003. Revegetation of bare patches in a semi-arid rangeland of South Africa: an evaluation of various techniques. *Journal of Arid Environments* 55, 417 – 432.
- Society for Ecological Restoration & Policy Working Group (SER) 2002. The SER primer on Ecological restoration. Website: www.ser.org
- Sombroed WG, Hadji MS 2004. Degradation of rainfed agricultural land, irrigated agricultural lands, ranching and traditional pastoral lands and forest lands. UNCCD, Information sharing segment, First substantive session, Inter governmental Negotiating Committee for a Convention to Combat Desertification 2006. Website: <http://www.unccd.int/knowledge/INCDinfoseg/partii.php>
- South African Weather Service 2006. Rainfall measured at the Rietfontein Police Station. <http://www.weathersa.co.za>
- Sutherland WJ 1996. Ecological census techniques, a handbook. Cambridge University Press. Cambridge. UK.
- Thomas DSG, Shaw PA 1991. The Kalahari Environment. Cambridge University Press. Cambridge. UK.
- Todd SW, Hoffman MT 1999. A fence-line contrast reveals effects of heavy grazing on plant diversity and community composition in Namaqualand, South Africa. *Plant Ecology* 142 (1-2), 169 – 178.
- Van den Berg L 2002. The evaluation of a number of technologies for the restoration of degraded rangelands in selected arid and semi-arid regions of South Africa. M.Sc. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom. South Africa.
- Van Rooyen AF 1998. Combating desertification in the southern Kalahari: connecting science with community action in South Africa. *Journal of Arid Environments* 39, 285 – 297.
- Van Rooyen AF 2000. Rangeland degradation in the southern Kalahari. Ph.D. Thesis. University of Natal. Pietermaritzburg, South Africa.
- Van Rooyen N 2001. Flowering plants of the Kalahari dunes. Ekotrust cc. Lynwood. South Africa.

- Van Oudtshoorn F 1999. Guide to the grasses of southern Africa. Briza Publications. Pretoria. South Africa.
- Visser N, Botha JC, Hardy MB 2004. Re-establishing vegetation on bare patches in the Nama Karoo, South Africa. *Journal of Arid Environments* 57, 155 – 177.
- Wang Y, Shiyomi M, Tsuiki M, Tsutsumi M, Yu X, Yi R 2002. Spatial heterogeneity vegetation under different grazing intensities in the northwest Heilongjinag steppe of China. *Agriculture, Ecosystems and Environment* 90, 217 – 229.
- Wellington PS 1969. Handbook for seedling evaluation. The International Seed Testing Association. Zurich. Switzerland.
- Winkel VK, Roundy BA, Cox JR 1991. Influence of seedbed microsite characteristics on seedling emergence. *Journal of Range Management* 44 (3), 210 – 214.

APPENDIX F

Response of South African indigenous grass species to drought stress induced by polyethylene glycol (PEG) 6000. Article published in the South African Journal of Botany, 2006, 72: 284 – 286.

Response of South African indigenous grass species to drought stress induced by polyethylene glycol (PEG) 6000

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Degradation in arid and semi-arid regions can be ascribed primarily to environmental conditions such as extreme changes in temperature and erratic rainfall patterns. Seed germination and seedling growth of three grass species (*Antheophora pubescens*, *Heteropogon contortus* and *Themeda triandra*) indigenous to arid and semi-arid regions of southern Africa were assessed under controlled conditions that simulated drought stress using polyethylene glycol (PEG) 6000. Exposure to water potentials below -0.3 MPa significantly decreased germination rates and shoot lengths for all three species, despite slight differences in their sensitivities to osmotic stress. More dramatic differences between the species were evident when the effects of water stress on root growth were evaluated. These findings form the basis for future trials involving the use of indigenous grasses in the restoration of rangelands.

It has been estimated that about nine million square kilometers of the world's arid rangelands have been turned into man-made deserts over the past half century (Le Houérou and Gillet 1986). Rangelands are areas unsuitable for cultivation, but provide forage for animals (Miller 1997). Rangeland degradation is often manifested by decreases in plant species diversity, low grass

height and vegetation cover, an increase in unpalatable grass species and sharp reductions in plant yields. The dispersal of seeds through oversowing is an important strategy to actively restore vegetation in degraded areas as their seed banks are usually depleted of viable seed. One of the greatest challenges in restoration ecology is to sow a seed type or cultivar that has the capacity to produce abundant biomass and cover in a short period of time (Van den Berg 2002).

In addition to grazing by domestic livestock, rainfall patterns are the most important factors influencing rangeland condition (Hoffman and Ashwell 2001). Drought, extreme temperatures, increased soil salinity, soil crusting or sand covering, as well as pathogens and herbivores all adversely affect the germination and growth of seedlings. Grasses, with strong development of underground organs tend to have efficient adaptive mechanisms to cope with drought, fire and herbivory and provide superior protection against soil erosion than most woody shrub and tree species (Imevbore 2003). Grasses with network root systems bind soil better than woody species with taproot systems (Cowling *et al.* 1986).

Osmotic solutions are used to impose water stress reproducibly under *in vitro* conditions (Pandey and Agarwal 1998). Polyethylene glycol molecules with a $M_r \geq 6000$ (PEG 6000) are inert, non-ionic and virtually impermeable chains that have frequently been used to induce water stress and maintain a uniform water potential throughout the experimental period (Hohl and Peter 1991, Lu and Neumann 1998). Molecules of PEG 6000 are small enough to influence the osmotic potential, but large enough to not be absorbed by plants (Carpita *et al.* 1979). Because PEG does not enter the apoplast, water is withdrawn from the cell and the cell wall. Therefore, PEG solutions mimic dry soil more closely than solutions of low M_r osmotica, which infiltrate the cell wall with solutes (Verslues *et al.* 1998).

The objective of this study was to determine the germination and morphological responses of *Antheophora pubescens* Nees, *Heteropogon contortus* L. and *Themeda triandra* Forssk. (Gibbs Russel *et al.* 1990) to drought stress induced by PEG 6000. Results from initial germination capacity tests conducted according to the rules of the International Seed Testing Association (ISTA, 1976) indicated that 30°C is the optimal temperature for seed germination of *A. pubescens*, *H. contortus* and *T. triandra*. Four replicates of 100 seeds per species were used to

determine germination rates in the absence of osmotic stress (Figure 1). Both *A. pubescens* and *H. contortus* show a high germination percentage (75% and 48%) within the first two days, after which germination seems to reach a plateau. *Themeda triandra* germinates poorly during the first two days, but after the fourth day, germination rates increased to 67% and reached a plateau of 77%. Therefore, at 30°C and in the absence of osmotic stress, seed from all three species tested showed a high germination capacity within the first four days. This could be of significance when planning oversowing treatments with the specific species for restoration purposes.

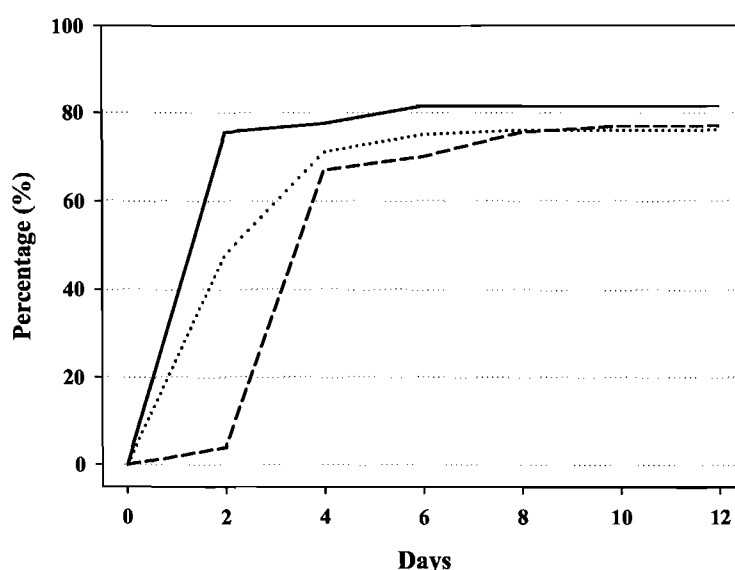


Figure 1 Germination rate of *Anthephora pubescens* (—), *Heteropogon contortus* (····) and *Themeda triandra* (---) at 30°C over a period of 12 days

Water stress was applied through incubation in seven different concentrations of PEG 6000 that provide solutions with water potentials ranging from -0.3 MPa to -2.1 MPa (Michel and Kaufmann 1973). PEG 6000 was dissolved in water and placed in a shaker bed (25°C) for 16 hours. Four replicates of 50 pure seeds per species were used for each of the different osmotic potential experiments. Seeds of the different species were germinated at 30°C on filter paper discs moistened with 8 ml of the different solutions. After the addition of the solution, as well as the seeds, each petri dish was weighed and the weight recorded. Petri dishes were weighed daily and supplemented with distilled water to the original weight. The seeds were investigated for

germination every second day. Germination data were analysed using the statistical program GenStat (2000). The experiment was designed as a completely randomised design with two factors. The first factor was the species and the second the drought stress treatments. Differences in germination between species and between treatments, as well as the interaction between these variables were tested for an analysis of variance. The arcsin transformation was used to stabilise variances. After the transformation, the data was acceptably normal with homogeneous treatment variances. Treatment means were separated using Fishers' protected t-test least significant difference (LSD) at the 5% level of significance (Snedecor and Cochran, 1980).

Germination capacity decreases for all three of the species with a decrease in osmotic potential (Table 1). The final germination capacity for the control treatment differed significantly for all three species. There is also a significant difference in the germination of the three species when comparing the total germination percentage of all treatments (species mean). Both *A. pubescens* and *H. contortus* show better germination in response to the -0.3 MPa osmotic treatment than the control treatment. Although seed germination occurred at all of the different osmotic potentials tested, with the exception of -2.1 MPa, none of the three species tested showed a very high tolerance of water stress.

Table 1 Germination capacity (%) of *Antheophora pubescens*, *Heteropogon contortus* and *Themeda triandra* after incubation with different osmotic potentials

Treatment (MPa)	<i>Antheophora pubescens</i>	<i>Heteropogon contortus</i>	<i>Themeda triandra</i>
Control	40.75 ± 2.06 ^a	38.00 ± 1.15 ^b	38.50 ± 3.11 ^c
-0.3	41.00 ± 2.16 ^a	38.75 ± 4.99 ^a	31.00 ± 4.16 ^a
-0.6	39.25 ± 1.50 ^a	24.00 ± 3.83 ^a	16.75 ± 1.71 ^a
-0.9	25.25 ± 2.99 ^a	17.00 ± 5.72 ^a	13.50 ± 3.00 ^a
-1.2	9.50 ± 3.11 ^a	10.00 ± 5.48 ^a	9.25 ± 3.30 ^a
-1.5	7.50 ± 1.73 ^a	3.50 ± 0.57 ^a	7.00 ± 3.56 ^a
-1.8	3.25 ± 2.63 ^a	5.25 ± 2.99 ^a	3.75 ± 4.19 ^a
-2.1	0 ^a	0 ^a	0 ^a
Species mean (treatments)	20.81 ± 17.00 ^a	17.16 ± 14.72 ^b	15.06 ± 12.95 ^c

Different letters indicate statistically significant differences for germination capacity (P<0.05)

Although the germination capacity decreased with a decrease in osmotic potential, seeds from all species germinated at an osmotic potential of -1.8 MPa. Although the seeds did not germinate at an osmotic potential less than -1.8 MPa, this might indicate an important survival mechanism that ensures dormancy within the soil seed bank until sufficient moisture is available for optimal seed germination and seedling establishment.

Drought plays an important role not only in determining germination rates, but also influences seedling development. Even when enough moisture is available to promote germination, in the absence of subsequent rain, growth of newly germinated seedlings will be compromised with potentially fatal consequences. Five seedlings of each treatment were selected and root and shoot lengths were measured on the fifth day of incubation to determine whether a decrease in osmotic potential would affect seedling growth. Analysis of variance (ANOVA) was used to test for differences between the three species. The data was acceptably normal but with some heterogeneous treatment variances. Glass *et al.* (1972) indicated that the consequences on inference after ANOVA are not serious, as no transformation could be found to rectify the problem. Species means were separated using Fisher's protected t-test least significant difference (LSD) at the 1% level of significance (Snedecor and Cochran, 1980).

For all three the species, the shoot lengths of seedlings decreased with an increase in water stress (Figure 3a). Root lengths of *A. pubescens* and *H. contortus* were greater under osmotic potentials of -0.3 MPa than under control conditions and *A. pubescens* seedlings displayed even more dramatic root elongation at -0.6 MPa (Figure 3b). In contrast, root elongation of *T. triandra* decreased progressively with any decrease in osmotic potential (Figure 3b). All three species displayed decreases in root length as osmotic potential was decreased from -0.6 MPa to -2.1 MPa (Figure 3b).

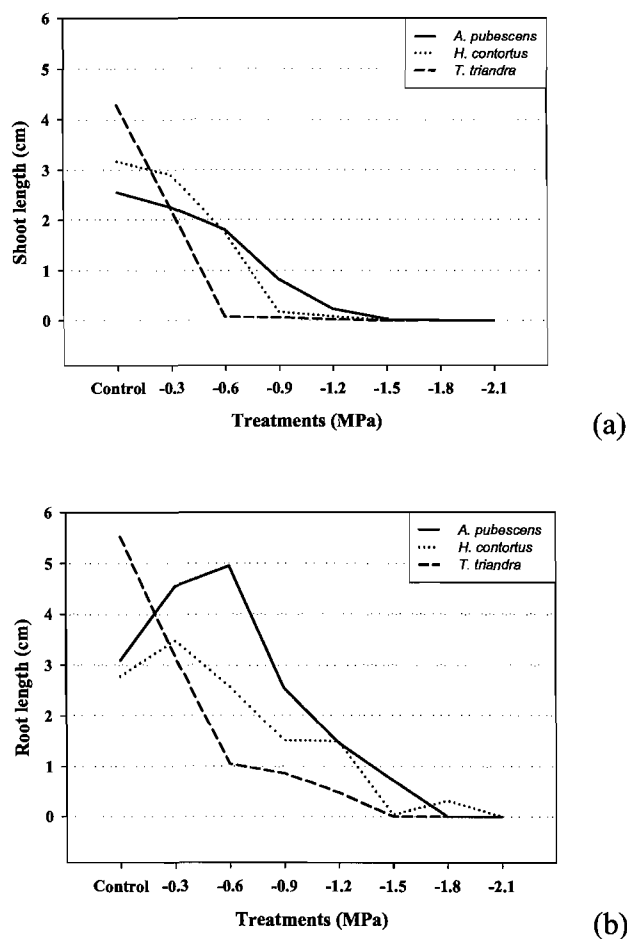


Figure 3 Growth rates of emerging shoots (a) and roots (b) of *Anthephora pubescens*, *Heteropogon contortus* and *Themeda triandra* seedlings exposed to various treatments of decreasing osmotic potentials

Decreases in the external osmotic potential generally caused decreased morphological development of organs from the young grass seedlings of the three species tested. Whereas shoot growth was always decreased by exposure to all of the stress levels tested, there was a slight increase in root length associated with the -0.3 MPa treatments for *A. pubescens* and *H. contortus*. Most likely, this reflects an adaptive response involving an increase in root length to reach water deeper in the soil.

This study has shown that specific environmental conditions are needed for optimal seed germination of *A. pubescens*, *H. contortus* as well as *T. triandra* and that water stress differentially affects germination capacity as well as root and shoots lengths in these three species. All three species seem suitable for restoration trials in areas that are not subjected to short periods of drought, but field studies are needed to determine their suitability for areas with specific environmental conditions.

References

- Carpita N, Sabulase D, Monfezinos D, Delmer DP (1979) Determination of the pore size of cell walls of living plant cells. *Science* **205**: 1144–1147
- Cowling RM, Roux PW, Pieterse AJH (1986) The Karoo biome: a preliminary synthesis. Part 1 – Physical environment. South African National Scientific Programmes Report **124**. pp 1-100
- GenStat for Windows (2000) Release 4.2. Fifth Edition. Oxford: VSN International
- Gibbs Russell GE, Watson L, Koekemoer M, Smook L, Barker NP, Anderson HM, Dallwitz MJ (1990) Grasses of southern Africa. *Memoirs of the Botanical Survey of South Africa* **58**: 1–437
- Glass GV, Peckham PD, Sanders JR (1972) Consequences of failure to meet assumptions underlying the fixed effects analyses of variance and covariance. *Review of Educational Research* **42**: 237–288
- Hoffman T, Ashwell A (2001) Nature divided, Land degradation in South Africa. University of Cape Town Press, Cape Town, pp 99–100. ISBN 1-9197-1354-9
- Hohl M, Peter S (1991) Water relations of growing maize coleoptiles. Comparison between mannitol and polyethylene glycol 6000 as external osmotica for adjusting turgor pressure. *Plant Physiology* **95**: 716–722
- Imevbore AM (2003) Desertification and dessication as a threat to the conservation and utilization of biodiversity. United Nations Convention to Combat Desertification. <http://www.unccd.int/knowledge/INCDinfoSeg/parti.php>
- International Seed Testing Association (ISTA) (1976) International rules for seed testing. *Seed Science and Technology* **4**: 5 - 177

- Le Houérou HN, Gillet H (1986) Conservation versus desertification in African arid lands. IN: Soule ME (1986) Conservation biology: The Science of Scarcity and Diversity. Sinauer, Sunderland, Massachusetts, pp 1 – 20. ISBN 0-8789-3795-1
- Lu Z, Neumann PM (1998) Water-stressed maize, barley and rice seedlings show species diversity in mechanisms of leaf growth inhibition. *Journal of Experimental Botany* **49**: 1945 – 1952
- Michel BE, Kaufmann K (1973) The osmotic potential of polyethylene glycol 6000. *Plant Physiology* **51**: 914 – 916
- Miller D (1997) Rangelands and range management. International Center for Integrated Mountain Development Newsletter **27**: 1 – 3
- Pandey R, Agarwal RM (1998) Water stress-induced changes in praline contents and nitrate reductase activity in rice under light and dark conditions. *Physiological and Molecular Biology of Plants* **4**: 53 – 57
- Snedecor GW, Cochran WG (1980) Statistical methods (7th Ed.). Ames, Iowa State University Press p 507
- Van den Berg L (2002) The evaluation of a number of technologies for the restoration of degraded rangelands in selected arid and semi-arid regions of South Africa. M.Sc. Thesis, Potchefstroom University for Christian Higher Education, Potchefstroom, South Africa
- Verslues PE, Ober ES, Sharp RE (1998) Root growth and oxygen relations at low water potentials. Impact of oxygen availability in Polyethylene glycol solutions. *Plant Physiology* **116**: 1403 – 1412

APPENDIX G

An example of the working sample weight, purity analysis, germination analysis and report sheet

Purity Analysis

No:	% Pure seed	% Inert matter	% Other seed	% Other weed
Seedkind:		Botanical name:		
Submitted sample weight (gram):				
Working sample weight (gram):				
Weight gain/loss (%)				
	Mass in gram		%	
Pure seed				
Inert matter (1)				
Other seeds (2)				
Weed seeds (3)				
Total				
1)				
2)				
3)				
Date:			Sign:	
Remarks:				

Germination test

No:	Days:	% Normal	% Hard	% Fresh	% Abnormal	% Dead																		
Seedkind:				Botanical name:																				
Germination method	Substratum:	Temperature:	Container:	Number of replicates:	Seeds per replicate:																			
Additional recommendations:																								
Evaluation intervals:				Date planted:																				
Evaluation dates:	A					B					C					D								
	N	H	F	A	D	L	N	H	F	A	D	L	N	H	F	A	D	L	N	H	F	A	D	L
Total																								
Abnormal seedlings (describe):																								
Remarks:																								
Planted by:												Evaluated by:												

Seed Analysis Report

Information about sender:		Information supplied by applicant Seedkind: Variety: Code:	
Analysis results			
Code:		Date received:	
Submitted sample weight:			
Date test concluded:			
Botanical name:			
Purity (% by weight)	Pure seeds	Inert matter	Other seeds*
Inert matter:			
Other seeds:* Thereof % weed seeds			
Germination method:			
Germination (% by number)	Duration of test	Normal seeds	Hard seeds
	Fresh seeds	Abnormal seeds	Dead seeds
Remarks:			
Date:		Sign:	

THE DESERT MARGINS PROGRAM

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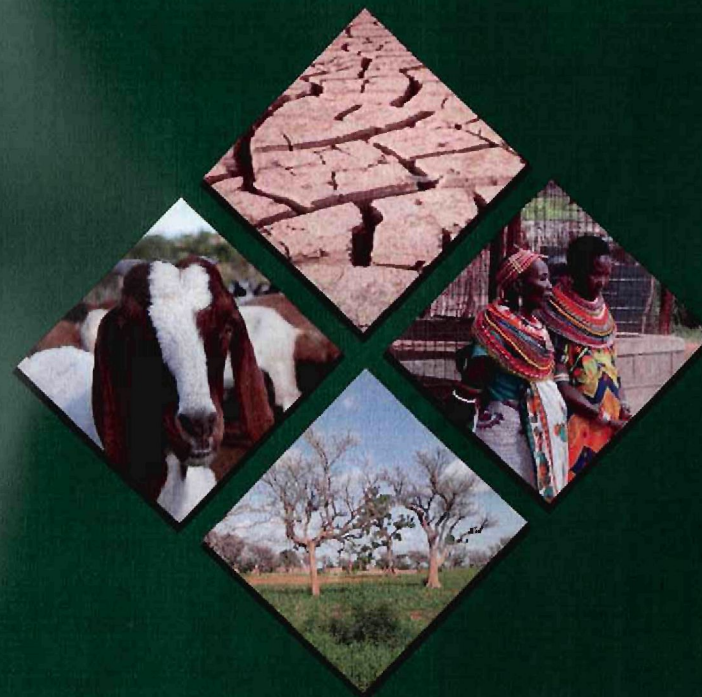
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Restoration Conservation Alternative livelihoods

Technologies in selected countries in Africa



Desert Margins Program



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CITATION

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Restoration Conservation Alternative livelihoods Technologies in selected countries in Africa

Lorraine van den Berg

2006



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INTRODUCTION

The United Nations Convention to Combat Desertification (UNCCD) recognizes land degradation and desertification as a loss of economic and environmental potential. Degradation and desertification is a major worldwide problem, but it is most extensive and severe in the arid and semi-arid areas of sub-Saharan Africa.

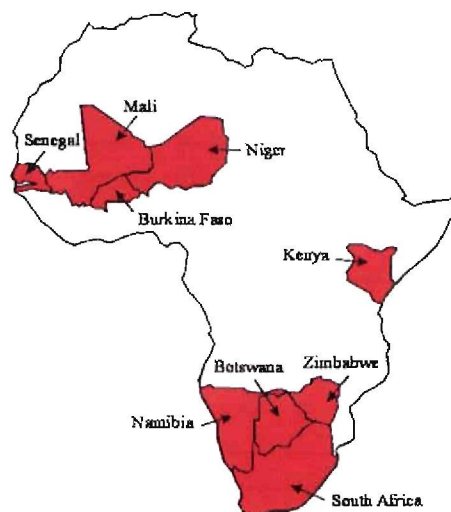
The Desert Margins Program (DMP) is a collaborative initiative among nine African countries - Botswana, Burkina Faso, Kenya, Mali, Namibia, Niger, Senegal, South Africa and Zimbabwe. The overall objective of the DMP is to arrest land degradation in Africa's desert margins through demonstration and capacity building activities.

One of the broader objectives of the DMP includes the documentation and evaluation of current indigenous soil, water, nutrient, vegetation and livestock management practices for arresting land degradation. This booklet aims to summarize current restoration and conservation activities in the nine countries participating in the Desert Margins Program (DMP).

OUTPUTS OF THE DMP

- Improve the understanding of ecosystem status and dynamics with regard to the loss of biodiversity.
- Develop and implement strategies for conservation, restoration and sustainable use of degraded agro-ecosystems.
- Enhance the capacity of stakeholders and target populations.
- Test and promote alternative livelihood systems (including poverty reduction strategies in arid systems).
- Formulate, adopt and implement sound policy intervention/guidelines for sustainable resources.
- Implement participatory natural resource management methods.
- Ensure that target populations are involved at all stages of the project cycle.
- Identify linkages between poverty and land degradation.

COLLABORATIVE COUNTRIES IN AFRICA



Restoration



Technologies in Africa



BRUSHPACKING

Geographic distribution

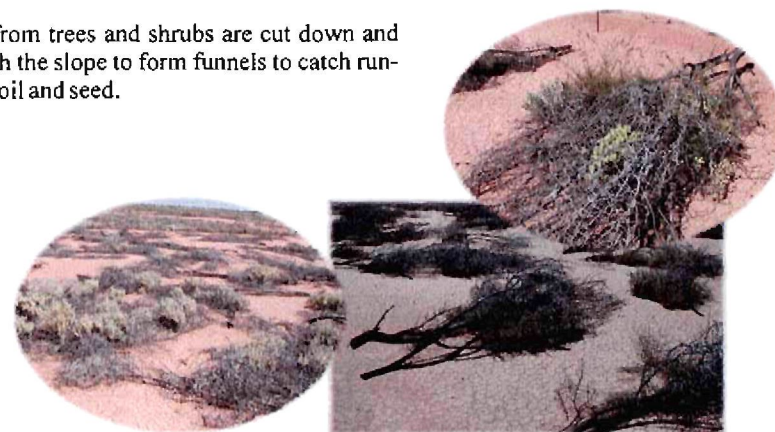
South Africa and Zimbabwe

Main purpose and benefits

Brushpacking is a technology where branches of trees and shrubs are packed on bare patches in an attempt to restore the vegetation. It is effective in protecting newly established seedlings from grazing and environmental conditions as well as providing shade and additional moisture. The leaves and stems of branches contribute to the replacing of organic material in the soil as well as trapping seed blown in by wind.

Description of practice

Branches from trees and shrubs are cut down and packed with the slope to form funnels to catch run-off water, soil and seed.



Reasons for successful adoption by farmers

- Brushpacking helps in forming micro-sites for seedling establishment.
- The technology is not readily adopted by farmers as it is labour and cost intensive.

Restoration



Technologies in Africa



DUNE STABILIZATION

Geographic distribution

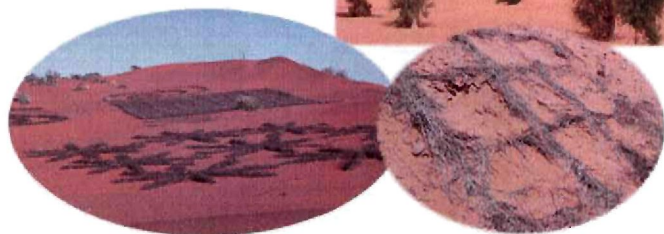
Mali and South Africa

Main purpose and benefits

When degraded, dunes become mobile and tend to be vulnerable to wind erosion. Dunes are stabilized to prevent the movement of soil and in some cases to trap fine sand, organic material and seed. This aids in vegetation establishment on degraded sand dunes.

Description of practice

In some areas trees such as *Prosopis* sp. are planted on dunes in an attempt to stabilize them. Stabilization of dunes are also carried out by manually packing brush or straw on the slopes of the dunes. The dunes are then left to recover through succession.



Reasons for successful adoption by farmers

- Dune stabilization is not carried out readily by farmers as this is a cost and labour intensive technology.
- In South Africa the dune stabilization formed part of a National Initiative (LandCare) and contributed to job creation and poverty alleviation

Restoration



Technologies in Africa



ERADICATION OF INVADER/ALIEN PLANTS

Geographic distribution

Niger, Kenya, South Africa and Namibia

Main purpose and benefits

The eradication of invader species contributes to an increase in productivity of an area by increasing natural vegetation. In most cases clearing alien vegetation leads to an increase in water availability and quality. Invader tree species can be used for charcoal or fuel wood once eradicated. In addition eradication is carried out to restore indigenous biodiversity.

Description of practice

Various methods exist to eradicate alien vegetation i.e. biological, mechanical, manual and chemical methods. Mechanical methods, where vegetation is manually removed by hand and biologically through fire and goats, are most widely used. Where invasions covers large areas, chemicals are more frequently used.



Reasons for successful adoption by farmers

- The short-term cost-benefit ratio of this technology is very high and it is only adopted in extreme cases.
- Eradication of alien invaders could contribute to income generation and poverty alleviation through job creation.
- Chemical methods (which is less labour intensive) is the most frequently used method of eradication of invader/alien plants.

Restoration



Technologies in Africa



EROSION CONTROL

Geographic distribution

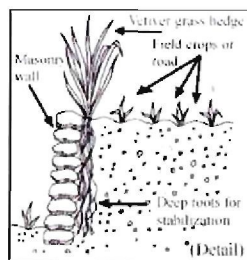
Senegal and South Africa

Main purpose and benefits

Soil erosion through wind and water is responsible for the removal of fertile topsoil. Erosion control contributes to an increase in productivity of the area by retaining or capturing fertile topsoil and organic matter, ultimately improving the nutritional status of the soil. In addition erosion control reduces raindrop splash effects, increases the rate of water infiltration and reduces the speed of run-off water.

Description of practice

Erosion control are carried out by placing rocks, stones or bags filled with sand in erosion gullies in an attempt to slow the run-off water. Usually, in addition to making barriers, vegetation species such as grasses are planted to stabilize the areas.



Reasons for successful adoption by farmers

- Controls the erosion problem from increasing in size.
- Increase in soil fertility adding to the productivity of the area.
- Grasses used can be cut down for additional fodder for livestock.
- Sometimes rejected due to huge labour inputs.

Restoration



Technologies in Africa



HALF MOONS

Geographic distribution

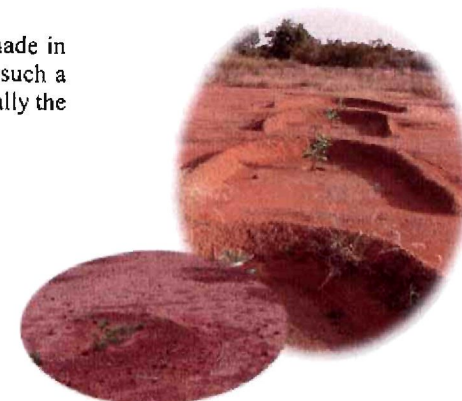
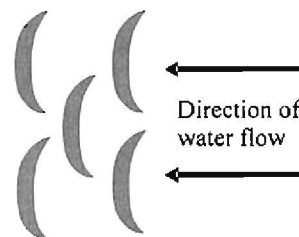
Niger, Burkina Faso and Kenya

Main purpose and benefits

Half moons are used to rehabilitate degraded land for crop cultivation and fodder production. The technology also assists in conserving water and capturing organic material and seed for increased soil fertility. Half moons provides suitable micro-sites for seed germination and establishment.

Description of practice

Half moon shaped micro-catchments are made in degraded areas along the slope of land, in such a way as to capture and retain rainwater. Usually the half moons are made by hand.



Reasons for successful adoption by farmers

- Half moons provide fertile islands for improved crop or fodder production.
- Half moons assist in natural recovery of rangelands.
- The use of half moons increases water accumulation and water retention.



MICRO-DOSING

Geographic distribution

Burkina Faso, Niger, Mali and Zimbabwe

Main purpose and benefits

Micro-dosing helps crops mature more rapidly and escape the worst effects of drought. The warrantage system was developed with the micro-dosing technology. This allows farmers to mortgage their cereals at harvest time to secure a loan in order to carry out their income-generating activities during the off-season, without selling their grains at a lower price.

Description of practice

Micro-dosing involves the application of small quantities of fertilizers in the hole where seed is sown to increase yields while minimizing input costs. The technology is usually combined with other natural resource management technologies as part of a sustainable system.



Reasons for successful adoption by farmers

- Micro-dosing leads to an increase in crop production and income generation.
- The technology requires low labour inputs.
- The technology leads to an increase in soil fertility.



NURSERIES

Geographic distribution

Senegal, Mali, Niger, Burkina Faso and Kenya

Main purpose and benefits

Seedlings of multipurpose trees such as *Melia volkensii* (Melia) and *Adansonia digitata* (Boabab) are propagated in tree nurseries. These trees provide timber and fodder and are usually used for honey production. From the nurseries seedlings are distributed to farmers, or farmers use seedlings from their own group nurseries. The nurseries are also used for farmer training (tree planting, aftercare, micro-financing etc.)

Description of practice

Seeds are collected in natural environments and germinated at the nurseries. Optimal germination methods and conditions are used to ensure good results. Seedlings are transplanted from seedling trays to individual containers. The seedlings are then distributed to farmers according to demand and usage.



Reasons for successful adoption by farmers

- In group nurseries, farmers can grow seedlings of preferred species.
- The seedlings from group nurseries can be sold to other interested farmers.
- This technology is successfully adopted by farmers due to close collaboration between scientists, extension services and farmers via training and education.

Restoration



Technologies in Africa



OVER-SOWING OF GRASS SPECIES

Geographic distribution

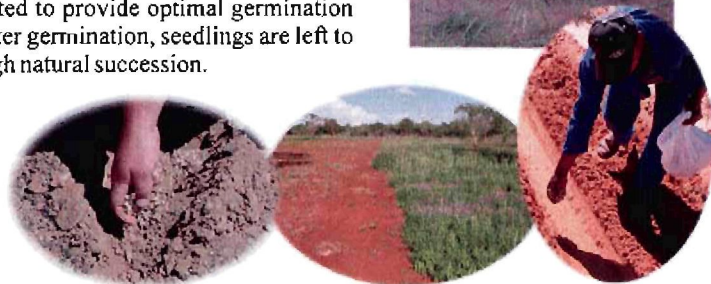
Mali, Kenya, South Africa and Namibia

Main purpose and benefits

Where an area is bare with no or little seed in the soil seed bank, over-sowing is important. The restoration of the original natural herbaceous vegetation may be enhanced by the introduction of species occurring naturally in the area. Over-sowing of herbaceous species will lead to an increase in fodder available for livestock.

Description of practice

Seed for over-sowing is either collected from natural stands or bought from seed merchants. The seed is then sown by hand or through mechanical implements such as a plastic pipe fitted to a tractor. The sown seed should preferably be covered and lightly compacted to provide optimal germination conditions. After germination, seedlings are left to establish through natural succession.



Reasons for successful adoption by farmers

- The technology is simple and easy to apply.
- The sowing of seed leads to an increase in fodder for livestock.

Restoration



Technologies in Africa



REFORESTATION

Geographic distribution

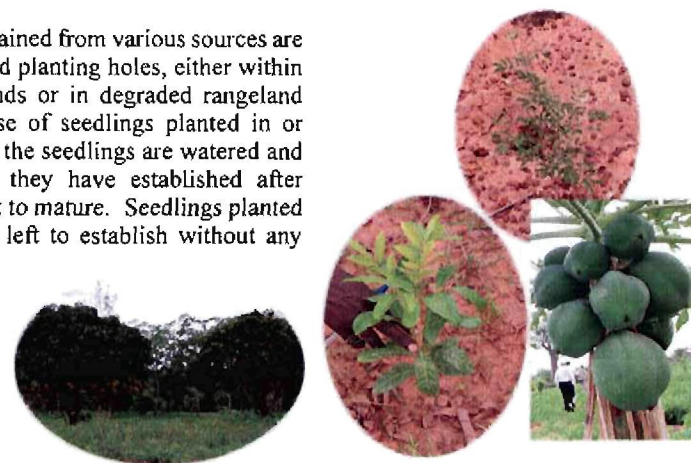
Senegal, Mali, Niger, Burkina Faso and Kenya

Main purpose and benefits

The planting of multipurpose trees are promoted as this adds to livelihood options. In addition to multipurpose trees (which provide fuel wood, timber, fodder and medicine), fruit trees e.g. mango trees are planted. The planted trees could play an important role in income generation activities.

Description of practice

Tree seedlings obtained from various sources are planted in prepared planting holes, either within or around croplands or in degraded rangeland areas. In the case of seedlings planted in or around croplands, the seedlings are watered and attended to until they have established after which they are left to mature. Seedlings planted in rangelands are left to establish without any aftercare.



Reasons for successful adoption by farmers

- Trees provide economical, cultural and aesthetical value to farmers and contribute to products for housing, shading and animals, etc.

Restoration



Technologies in Africa



SOIL LOOSENING

Geographic distribution

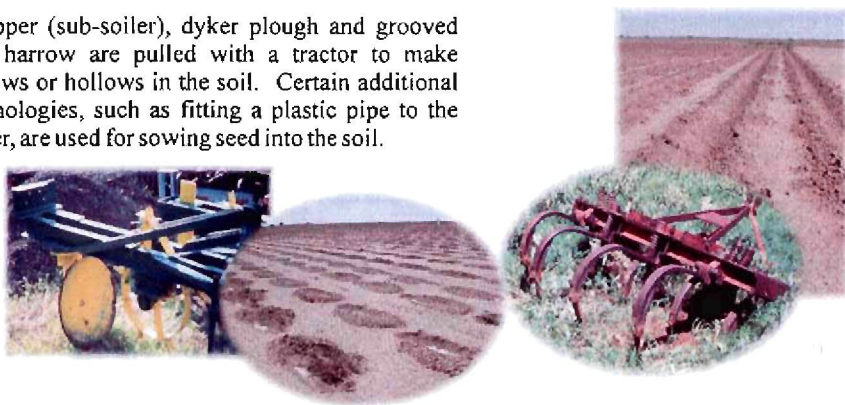
South Africa

Main purpose and benefits

Soil loosening is used to break the soil crust and form shallow or deep furrows for better water infiltration. This allows water to be freely available to the roots of germinating plants. Soil loosening are used frequently with the over-sowing of natural grass species in an attempt to restore degraded areas. The type of soil loosening technology is soil specific - sand, loam or clay.

Description of practice

A ripper (sub-soiler), dyker plough and grooved disc harrow are pulled with a tractor to make furrows or hollows in the soil. Certain additional technologies, such as fitting a plastic pipe to the ripper, are used for sowing seed into the soil.



Reasons for successful adoption by farmers

- This technology is adopted by farmers if they have the necessary equipment available.
- Loosening the soil facilitates the re-establishment of vegetation in bare areas.

Restoration



Technologies in Africa



STONE WALLS

Geographic distribution

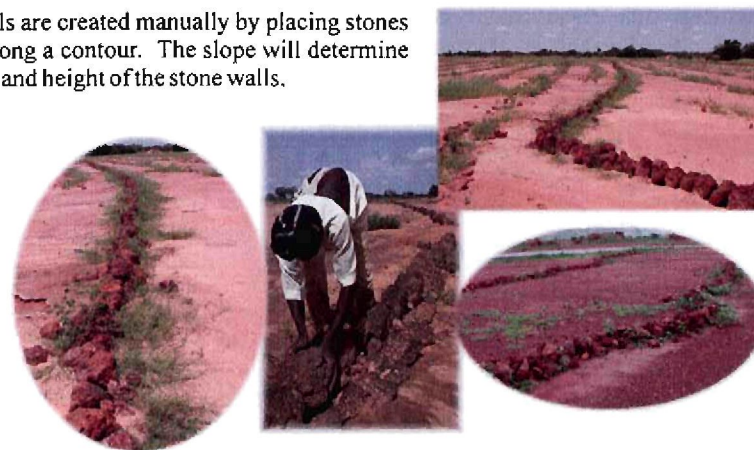
Senegal, Burkina Faso and South Africa

Main purpose and benefits

Stone walls is a continuous line of layer of stones placed along a contour line not too far apart. Stone walls reduce the force of run-off water, trap soil, organic matter and seed and provide a micro-climate that favours the establishment of natural vegetation after the rainy season. Stone walls are used to break the speed of water flow on eroded areas.

Description of practice

Stone walls are created manually by placing stones in rows along a contour. The slope will determine the length and height of the stone walls.



Reasons for successful adoption by farmers

- The making of stone walls is not readily adopted by small-scale farmers as it is labour and cost intensive and in most cases, stones are not readily available. This technology is usually applied where stones are readily available.

Restoration



Technologies in Africa



VALLERANI SYSTEM

Geographic distribution

Senegal, Mali, Niger, and Kenya

Main purpose and benefits

The Vallerani system is used on a large scale to loosen soil that has been compacted as a result of degradation. Loosening the soil improves water infiltration and provides a suitable micro-climate for seed germination. The main benefit of this technology is that large areas can be treated within a small amount of time.

Description of practice

The micro-basins are constructed by two different ploughs (dolphin plough and treno plough), pulled by a tractor. The number of micro-basins varies according to the size of the area and the annual rainfall. The Vallerani system is sometimes used in combination with over-sowing treatments or the planting of trees.



Reasons for successful adoption by farmers

- The technology is not easily adopted by individual farmers as it is cost intensive and the equipment is not always available.

Conservation



Technologies in Africa



CONSERVATION OF TREES

Geographic distribution

Senegal, South Africa and Mali

Main purpose and benefits

In some countries tree species such as *Adansonia digitata* (Boabab) are protected. These species are planted for aesthetic and cultural value but mostly contribute to sustainable livelihoods e.g. fruit and fodder production and in some cases to increase the soil fertility.

Description of practice

Individual trees of the following species are protected and are not allowed to be cut down*. Fines are issued if these trees are cut down or products from these trees used in a non-sustainable way.

- *Adansonia digitata*
- *Parkia biglobosa*
- *Vittelaria pradoxa*
- *Acacia albida*
- *Sclerocarya birrea*
- *Tamarundus indica*
- *Cassia siberiana*

* Depend on legislation by each country.



Reasons for successful adoption by farmers

- Trees increase the aesthetic and cultural value of village areas.
- Protected trees contribute to food security and sustainable livelihood options.

Conservation



Technologies in Africa



FENCING

Geographic distribution

Mali, Kenya, South Africa and Namibia

Main purpose and benefits

Fencing are used in management systems to protect croplands and rangeland from utilization by herbivores. Fences can be constructed from a large variety of materials depending on the resources available and the need of the farmer. Fencing of degraded areas can control grazing and assist in the restoration process.

Description of practice

Fences are mostly constructed on the boundaries of croplands and grazing area, but in some cases fencing are used to divide a large piece of land in smaller paddocks. A large amount of labour and financial inputs are needed when constructing fences, and are mostly substituted by Governmental subsidy schemes.



Reasons for successful adoption by farmers

- Fences protect croplands from herbivores.
- Better control of grazing and management systems.

Conservation



Technologies in Africa



FORUM FOR INTEGRATED RESOURCE MANAGEMENT (FIRM) AND LOCAL LEVEL MONITORING (LLM)

Geographic distribution

Namibia, Botswana and South Africa

Main purpose and benefits

FIRM (Forum for Integrated Resource Management) is an approach that puts rural communities in charge of their own development. FIRM uses simple, easy to follow and repeatable steps on how to monitor rangeland condition (Local Level Monitoring) for improved decision making.

Description of practice

Local Level Monitoring (LLM) uses the following indicators for improved decision making: livestock condition, rainfall, rangeland condition/ bush density and carrying capacity. A field guide, on how to conduct regular monitoring with colour photos, graphics and information sheets are used.



Reasons for successful adoption by farmers

- Through FIRM farmers take control and contribute to the decision making process.
- FIRM enhances collaboration between multiple stakeholders (farmers, teachers, pastors, etc.)
- LLM uses easy identifiable indicators to assist in improved decision making.

Conservation



Technologies in Africa



LIVE FENCES

Geographic distribution

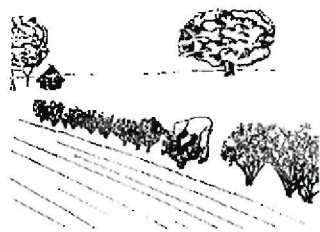
Senegal, Burkina Faso and Kenya

Main purpose and benefits

The primary purpose of live fences is to control the movement of animals and people. Besides their main function, live fences can provide fuel wood, fodder and food, act as wind breaks or enrich the soil, depending on the species used.

Description of practice

The best way to establish a live fence is to plant developed seedlings at suitable intervals and to weave branches from one individual into another. Once the plants begin to increase in diameter they should grow together firmly. Live fences act as a barrier against animal and human movement, while simultaneously providing fodder and other materials for humans and animals.



Reasons for successful adoption by farmers

- Provides protection from people and grazing animals.
- Food, fodder and fuel wood can be obtained if a multipurpose species is used.
- After initial establishment limited labour inputs are needed to maintain the hedge.

Conservation



Technologies in Africa



PROTECTED AREAS

Geographic distribution

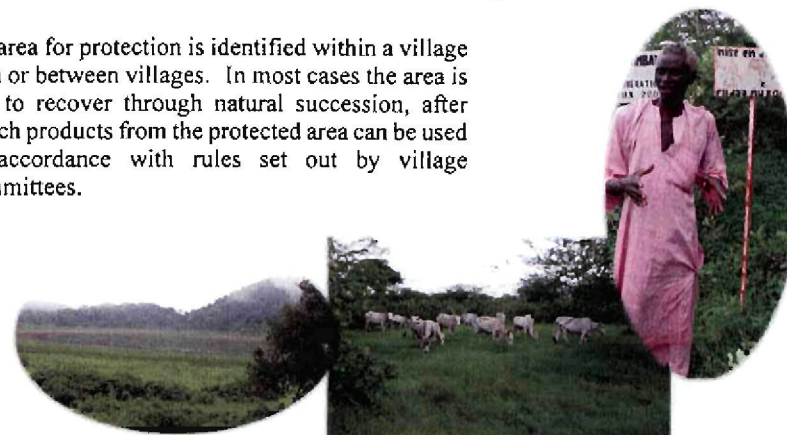
Senegal, Mali, Burkina Faso, Kenya and South Africa

Main purpose and benefits

Usually protected areas are formed between more than one village and are the areas not suitable for cropping. These areas are open to grazing and the sustainable harvesting of products are permitted e.g. dry wood and fruit collection.

Description of practice

An area for protection is identified within a village area or between villages. In most cases the area is left to recover through natural succession, after which products from the protected area can be used in accordance with rules set out by village committees.



Reasons for successful adoption by farmers

- Forming a protected area involves limited labour and monetary inputs.
- Protected areas provides areas for livestock grazing.
- An improvement in livelihoods can be obtained through sustainable utilization of products from protected areas.
- Protected areas contributes to biodiversity conservation.

Conservation



Technologies in Africa



RURAL WOOD MARKETS

Geographic distribution

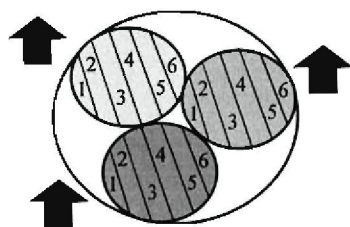
Niger and Burkina Faso

Main purpose and benefits

Rural Wood Markets are registered and contributes to the sustainable collection of fuel wood. Tax money collected after wood is sold at the Rural Wood Markets is used to improve livelihoods e.g. the planting of trees or the building of schools and clinics.

Description of practice

In a Rural Wood Market every village has a big area of land which is divided into six smaller blocks. Wood is cut down in one block and sold in one cubic metre bundles. A different block is used every year to ensure wood is only cut in each block every sixth year.



Reasons for successful adoption by farmers

- Farmers adopt this technology as it provides in their fuel wood needs.
- Farmers adopt this technology as it ensures the sustainable use of fuel wood sources.
- Rural wood markets could contribute to an improvement in livelihoods.

Conservation



Technologies in Africa



SAHELIAN ECO-FARM

Geographic distribution

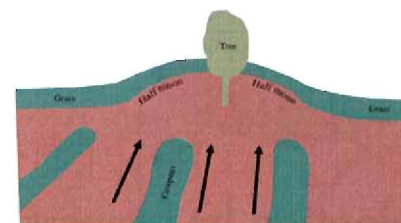
Niger and Kenya

Main purpose and benefits

The Sahelian Ecofarm is an integrated system that incorporates high value multi-purpose plants with soil and water conservation structures. It brings benefits in the form of fuel wood, forage, cash and protection from wind erosion.

Description of practice

The Sahelian Ecofarm features strategic choices in the placement of trees, grass and annual crops. Multipurpose trees are planted at 2m intervals within beds shaped like half moons. Grass are planted on the edges of the half moons to stabilize the soil. Crops such as cowpeas are planted in front of the half moons to utilize the run-off water.



Reasons for successful adoption by farmers

- Farmers are adopting this technology as it provides a large number of products and benefits, such as increased crop production, fodder, fuel wood and fruits.

Conservation



Technologies in Africa



ZAI

Geographic distribution

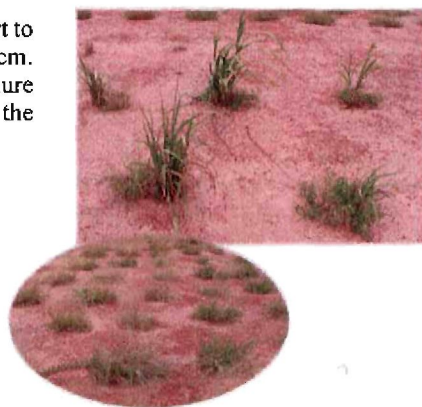
Mali, Niger and Burkina Faso

Main purpose and benefits

The Zai are holes dug during the dry season and filled with compost or manure. During the rainy season the holes are filled with run-off water and extend favourable conditions for infiltration for as long as possible. The holes causes an increase in crop yields on farms if correctly managed.

Description of practice

The Zai are holes dug approximately 80cm apart to a depth of 5-15cm, with a diameter of 15-50cm. The holes are filled with organic material or manure and improvements can be made through the addition of fertilizer.



Reasons for successful adoption by farmers

- This is a simple technology which needs only hand held equipment.
- The technology causes an increase in crop yields and can assist in the restoration of degraded areas due to higher vegetation cover and density.

Alternative livelihoods



Technologies in Africa



AFRICAN MARKET GARDEN (AMG)

Geographic distribution

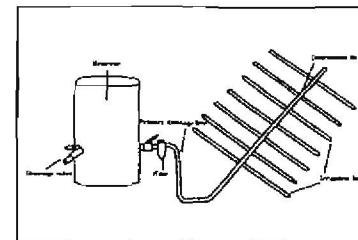
Senegal, Niger and Kenya

Main purpose and benefits

The benefits of using the AMG system include higher yields of improved quality vegetables and fruits as well as the ability to produce crop year round. In addition the AMG ensures the most efficient utilization of water resources and decreased labour requirements for irrigation and weeding. The likelihood of maintaining the productive capacity of the soil increases when using the AMG technology.

Description of practice

The African Market Garden (AMC) is a small-scale horticultural system based on low pressure drip-irrigation, a mix of annual crops and trees, and an 'operation system'. The basic low pressure drip irrigation kit is composed of a reservoir, taps, a filter, the main distribution line and 500 - 1000 meters of laterals (in which the drippers are embedded).



Reasons for successful adoption by farmers

- Reduction in labour and costs.
- Higher yields are produced with a variety of crops.
- Efficient utilization of water resources.



BEE-KEEPING

Geographic distribution

Senegal and Kenya

Main purpose and benefits

The main purpose of bee-keeping in Africa is to improve livelihoods by providing products such as honey and wax to markets. This could lead to an increase in income generation for individuals, families or community based organizations e.g. Woman groups. Bee-keeping gives local people an economic incentive for the retention of natural habitats such as forests.

Description of practice

Traditional log, grass and mud hives or newly adapted hives are constructed in suitable places. Bee-keepers usually hang their hives from trees to minimize damage by honey badgers. The bees build their nest inside the containers. Eventually the bee-keeper harvests the nest to obtain honey and beeswax.



Reasons for successful adoption by farmers

- Bee-keeping is easy and cheap to start.
- Bee-keeping can provide valuable food/medicine for the family and honey and beeswax for cash crops.



CHICKEN PRODUCTION

Geographic distribution

Zimbabwe

Main purpose and benefits

Village chicken production systems are based on scavenging indigenous domestic fowl. Chicken meat and eggs are reported to complement staple diets of people in Africa due to the high nutrient concentration. Poultry production improves household food security and increase household welfare through increased protein intake.

Description of practice

Three chicken breeding types have been identified (Spotted, Koekoek and Rednecks). Currently the chickens are bred and feeding experiments are conducted. Improved housing structures are also tested and introduced in local communities.



Reasons for successful adoption by farmers

- Integral part of the farming system of rural communities with short life cycles and quick turnovers.
- A means of converting low quality feed into high quality protein.

CULTIVATION OF ROOIBOS TEA (*Aspalathus linearis*)

Geographic distribution

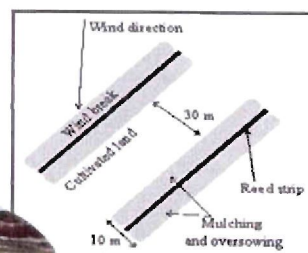
South Africa

Main purpose and benefits

Rooibos tea production holds an economic benefit for small-scale farmers. The Heiveld Co-operative Limited, owned by local small-scale farmers, provides a processing service to its members, purchasing raw rooibos from them, processing and packaging the product for overseas markets. Local farmers are increasingly applying conservation cultivation to ensure the sustainable production of rooibos tea.

Description of practice

Two separate types of rooibos tea are harvested, i.e. wild rooibos (natural environment) and cultivated rooibos (croplands). The soil in croplands is protected from wind erosion by creating wind breaks in the lands. Wind breaks, combined with mulching and over-sowing of natural species, are created at 30m intervals in such a way to ensure that the wind is guided away from the cultivated strips.



Reasons for successful adoption by farmers

- Both wild rooibos tea collection and cultivation holds economic benefits for small-scale farmers.
- If conservation practices are applied effectively, rooibos tea production can be improved and increased.

DATE PALMS (*Phoenix dactylifera*)

Geographic distribution

Niger, Mali, Kenya and Namibia

Main purpose and benefits

Date palms are planted in arid and sub-tropical areas as they provide a range of products varying from fruits to fibre. The products are either kept for personal use or marketed and sold as part of an income generating activity.

Description of practice

Date palm seedlings are propagated in nurseries and transplanted to suitable areas. The cultivated date palms are adapted to specific areas and distributed to land users as needed. The trees are attended to during their whole life to ensure optimal production (leaf and bunch management, fertilization and pest control).



Reasons for successful adoption by farmers

- Date palms are used as multi-purpose tree, adding to the value of livelihoods and income generation.
- Date palms provide fibre, food and construction material to land users.



FOOD GARDENS

Geographic distribution

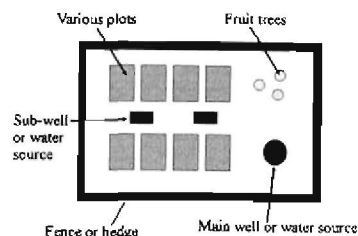
Senegal, Kenya and South Africa

Main purpose and benefits

Food gardens serve as source of food for people living in rural areas. Food gardens add value and nutrients to produce and could serve as a source of alternative income generation if excessive vegetables are sold. One food garden can support crop production for a number of families. Food gardens can contribute to increased health of land users by providing products with high nutritional value.

Description of practice

The area identified for the food garden should be fenced (man-made or natural fencing). The area is sub-divided into smaller plots and various kinds of vegetables and fruit trees are planted. Irrigation is done by hand from the local water source. Weeding can be carried out if necessary.



Reasons for successful adoption by farmers

- Added nutritional value to everyday livelihoods.
- Source of additional or alternative income generation.



MOPANE WORM HARVESTING

Geographic distribution

Botswana, South Africa and Zimbabwe

Main purpose and benefits

The harvesting of Mopane worms serve as a source of food in rural communities and contributes to the health status of people, as these worms are very nutritional. In addition, the selling of Mopane worms adds to income generation in rural communities.

Description of practice

Mopane worms are generally harvested from communal woodlands. Harvesting lasts for about three weeks and is carried out by shaking the Mopane trees or by cutting infested branches. The caterpillars are then disembowelled, boiled and dried in the sun. The worms are then privately used or sold at markets.



Reasons for successful adoption by farmers

- Added nutritional value to everyday livelihoods.
- Source of alternative income.
- Mopane worms occur in natural woodlands.

Alternative livelihoods Technologies in Africa



SMALL STOCK EXCHANGE PROGRAM

Geographic distribution

South Africa

Main purpose and benefits

Providing land users farming with small stock with an opportunity to improve their breeding stock, by supplying them with a breeding stock of high quality. In addition, providing land users with the knowledge on how to select breeding stock of a higher quality.

Description of practice

After the successful completion of the Dorper Breeding Association Course, land users are provided with a herd of 50 high quality Dorper sheep, which the farmer can use to better the quality of his own stock. Once the land user has a sufficient number of new breeding stock, the original 50 sheep plus additional sheep the farmer wishes to contribute, is assigned to a new farmer. Thereby the original herd grows from one farmer to the next.



Reasons for successful adoption by farmers

- Individuals are capacitated to select breeding and stock animals of higher quality.
- Improved quality of animals results in higher market value and therefore contributes to income generation.

FOR MORE INFORMATION

Desert Margins Program
www.dmpafrica.net

Global Environment Facility
www.gefweb.org

United Nations Environment Program
www.unep.org

North-West University (Potchefstroom Campus)
www.nwu.ac.za

African Market Garden (AMG)
www.ipalac.org/code/projects/AMGlandscape.doc

Bee-keeping
www.biavl.dk/africa

Date palms
www.dipbot.unict.it/Palms/descr02.html

Dune stabilization
Van Rooyen, A.F. 2000. Rangeland degradation in the souther Kalahari. Ph.D Thesis. University of Natal. Pietermaritzburg. South Africa.

To obtain thesis contact A.VanRooyen@cgiar.org

Erosion control
www.africangabions.co.za

FIRM
www.drfn.org.na/publications.htm

Food gardens
Www.cityfarmer.org/s.africa.html

Oversowing, Brushpacking, Eradication of invader plants, Fencing, Soil loosening

Van den Berg, L. 2002. The evaluation of a number of technologies for the restoration of degraded rangelands in selected arid and semi-arid regions of South Africa. M.Sc. Thesis. Potchefstroom University for Christian Higher Education. Potchefstroom.

To obtain thesis consult www.dmpafrica.net

Live fences

www.ppath.cornell.edu/mba_project/livefence.html

Rural wood markets

www.etfrn.org/etfrn/newsletter/news39/nl39_oip_8_.htm

Sahelian ecofarm

www.ipalac.org/code/projects/SEFpamphlet.pdf

Zai

www.zef.de/fileadmin/webfiles/downloads/zefnews/No8-9-2001-engl.pdf