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Challenges and opportunities

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1. Introduction

1.1 Land degradation and desertification

Land degradation and desertification have been on the global agenda for many years, not only since the inception of the United Nations Convention to Combat Desertification (UNCCD) in 1994. It is a vicious cycle where climate change, aridity, land degradation and biodiversity loss are strongly linked. Although there remains a great deal of disagreement about the causes and extent of desertification, it is often argued that the main causes and consequences of land degradation is two-fold: it is firstly caused by a combination of human activities, particularly overgrazing, often triggered or exacerbated by climatic variability, such as drought; and secondly it has a direct impact on the economic status of the human population, which is why desertification and poverty are often linked and why desertification affects the well-being of people. This means that the causes of desertification are not only anthropogenic, but are related to climatic and other environmental drivers, such as the loss in above- and below-ground flora and fauna due to the habitat change and the alteration of soil conditions, especially the carbon cycle. Nearly 6 million hectares are permanently lost to agriculture **each year** through human induced soil degradation.

It is therefore well known that desertification is a global challenge, together with Climate Change and Biodiversity, meaning that land degradation, desertification, the loss in biodiversity and climate change are directly linked (MEA, 2005).

Despite this global care and the many years of effort and investment made for prevention, mitigation or restoration, the problems of desertification and land degradation still persist. People living in **dryland** areas, where desertification mostly occurs, are amongst the world's poorest, most marginalised and politically weak citizens (UNCCD, 2005). Land degradation and desertification threaten the livelihoods of over 1 billion people in more than 110 countries, which is about one third of the world's land area. It is estimated that the economic cost of desertification worldwide exceeds U$ 42 billion, including the output forgone and the damage to the natural resources, while the cost of combating desertification was estimated a few year ago to have been in the range of U$ 10 – 22 billion per year (Toulmin, 1994).

Although there are more than 100 definitions of **desertification**, the one most people agree on and the one that is currently applied by the UNCCD is that "*desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities*"; and the combating of desertification "*includes activities which are part of the integrated development of land in arid, semi-arid and dry sub-humid areas for sustainable development*" (UNCCD, 2005).

Land degradation and desertification are phenomena which can be similar in appearance but are different in scope and time scales. The concept of scale, both in temporal and spatial dimensions, determines the severity of desertification (Prince, 2002). Desertification is often restricted to drylands, whereas land degradation can affect any environment. Desertification implies longer time scales, whereas land degradation is a more short-term process. Taking all definitions and descriptions into consideration, there is no doubt that land degradation, drought and desertification have emerged as one of the major problems affecting dryland environments globally (Johnson *et al.*, 2006).

1.2 Causes of land degradation

The word "desertification", as explained above, does not mean that deserts will "move" across landscapes, engulfing fertile lands and leaving people starving. The terms "degradation", "damage", "destruction" and "transformation" all refer to deviations from the normal or desired state of an intact ecosystem. As the meanings of these terms overlap, and their application is not always clear, "degradation" pertains to subtle or gradual changes that reduce ecological integrity and health (SER Primer, 2004). Causes of land degradation in the world include **overgrazing,** (680 million ha), **deforestation** (580 million ha), **agricultural mismanagement** (550 million ha), **fuel wood over consumption** (137 million ha), as well as **industry** (with associated pollution) and **urbanisation** (19.5 million ha) (UNEP, 2003). Most land degradation is directly linked to agricultural practices and it occurs while we are sitting here today. Often the question arises, "do humans create deserts?" This mainly depends on the location and the timeframe, as well as the type of land involved (soil types, vegetation, soil fertility, etc.), its historical use and the specific views of the particular stakeholders (Reynolds & Stafford-Smith, 2002).

Large areas in arid and semi-arid regions, where climatic conditions are not favourable for crop production or agricultural cultivation, are often used for livestock husbandry. We commonly refer to these areas as "rangelands". In Southern Africa, 86% of the agricultural land (80%) are rangelands and are used for livestock production. **Rangelands** can be defined as natural grazing lands where the climatic conditions of the natural resource are too dry and not suitable for agricultural crop production. These areas are used for livestock husbandry.

It is estimated that approximately 66% of rangelands in South Africa are moderately to severely degraded (Snyman, 1998). Overgrazing is one of the main causes of land degradation in the rangelands of South Africa. The semi-arid rangelands form the most important live-stock enterprise and therefore also the single most important economic and cultural resource in most biomes in Southern Africa (Beukes & Ellis, 2003; Van der Westhuizen, Snyman & Fouche, 2005). Livestock also provide fuel through manure, they recycle nutrients and they are used for transport. Cattle ownership and management, however, does not follow "normal" (or first-world) economic principles and are often the main capital resource of poor households. Animal numbers are increased during good times and the animals are not sold, as these extra animals are kept as an investment. Animal populations tend to crash during severe droughts and especially after severe overgrazing when the land is most vulnerable. Even where cattle are managed for profit, livestock densities often exceed the carrying capacity of the land, resulting in denuded landscapes with loss in vegetation cover due to severe degradation. To release the pressure on rangelands through livestock farming, especially in drylands, the focus has to be on the creation of alternative livelihoods for financial income.

Factors related to land degradation can be identified as:

1. Reduction or loss, in arid, semi-arid and dry sub-humid areas of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitat patterns, such as (i) soil erosion caused by wind and/or water, (ii) deterioration of the physical, chemical and biological or economic properties of soil, which includes the salinisation, acidification, water-logging and loss of fertility; (iii) loss in biodiversity; and (iv) long-term loss of natural vegetation, which includes:

- Loss of vegetation cover;
- Increase in bush encroachment;
- Alien plant invasion;
- Change in the composition of plant species;
- Deforestation – forests are being cut down for agricultural livestock;
- Clearing of the land – rangelands are being transformed into crop lands; and
- Draining of wetlands.

2. Insecurity of land tenure. Farmers throughout the developing world subsist under complex arrangements of land tenure that do not provide them with the necessary guarantees of future rights that are essential to anchor land restoration and rehabilitation. Women are frequently the primary land managers but all too often have no rights of ownership or inheritance. Without attention to the gender aspects of land governance, we will make little progress.

3. Loss of rural livelihood options which will ultimately lead to increased poverty.

4. Increased social, economic and environmental vulnerability to drought.

Land degradation in rangelands therefore involves complex interactions between bio-physical factors (the meteorological and ecological dimensions of desertification) and socio-economic or anthropogenic (the human dimensions that include overgrazing, deforestation, intensive use of soil and water resources, etc.). One of the main goals, however, is to obtain a better scientific understanding of the processes of land degradation and how to restore them. While the Millennium Ecosystem Assessment has helped us understand the scale and causes of land degradation, much more needs to be done to understand the processes of land degradation over different time and spatial scales in different land tenure systems. Often the problem of degradation in rangelands is experienced when it is too late and when the "thresholds" of recovery have been exceeded. Many farmers and land managers are also not aware or have insufficient knowledge of the ecological processes that lead to the degradation of land, especially when it is manifested in the long term. Biodiversity conservation will depend ultimately on land-use decisions. Land management is also an instrument both for climate-change adaptation and for mitigation. Well-managed and well-restored land will withstand changes in rainfall and temperatures far better than degraded land. Well-managed land with good tree cover will sequester carbon. Local land management and restoration is thus an important element in the fight against global climate change. We must urgently develop better policies for land use and, where necessary, reverse changes that have taken place.

According to Ms Rejoice Mabudafhasi, Deputy Minister of the Department of Environmental Affairs and Tourism, South Africa: "Preventing land degradation is a lot more cost-effective than rehabilitating it. In South Africa, we have taken a practical approach to work as much as impossible with available resources to create opportunities for improving livelihoods. The rural-urban divide also needs to be considered in the context of land degradation … land degradation is obviously not only about land, it is about the people. Millions of people are directly affected by natural resource degradation and many of them live below the poverty line. They depend on natural resources for survival. Yet the capacity of our country's land, water and biological resources to sustain its people is eroding. Tons of productive land are now lost and many once pristine conservation areas are denuded. Desertification is more of a challenge to us than ever before. It poses a huge threat to rural communities who depend on natural resources for their livelihoods. Unfortunately the poorest of the poor, of which most are women, bare the brunt as they are the ones who depend on these natural resources for survival, in a form of wood, water and agricultural produce for subsistence and commercial. The Department of Environmental Affairs and Tourism as the focal point together with other national and provincial departments, have committed themselves to providing support to provincial and national activities aimed at promoting awareness on desertification, land degradation and the effects of drought." (Mabudafhasi, 2006).

Poverty alleviation strategies must involve local actions to combat desertification, including restoration applications, which will favour the development of sustainable land management (SLM) practices and ultimately improve the livelihoods of especially rural poor people. Restoration actions can lead to increased agricultural productivity and biodiversity, thereby raising incomes and contributing to overall food security and minimising the dependence and pressure on the land resources.

1.3 Desertification in Africa

Desertification has its greatest impact in Africa, leading to a multitude of socio-economic problems for vulnerable communities. Most African communities rely on agriculture-based economies, and survive through subsistence farming or on the productivity of marginal lands. Activities that take place in the developed economies can indirectly contribute to the livelihood of these communities due to the global impacts of climate change and desertification. The most vulnerable continent for the desertification process is Africa, with about two thirds of its total area covered by deserts or drylands. The United Nations Environment Programme (UNEP) estimates that desertification costs Africa about US$9 billion a year.

Almost three quarters of the extensive agricultural drylands in Africa are already degraded to some degree and the region is further afflicted by frequent and severe droughts. Many African countries are landlocked, experience widespread poverty, need external assistance, and depend heavily on natural resources for subsistence. They have difficult socio-economic conditions, insufficient institutional and legal frameworks, incomplete infrastructure, and weak scientific, technical, and educational capacities. These difficult circumstances explain why African countries have put so much effort into convincing the international community for the need of support in the framework of the Convention to Combat Desertification.

As Africa's desertification is strongly linked to poverty, migration, and food security, combating desertification and promoting development are virtually one and the same, due to the social and economic importance of natural resources in agriculture. When people live in poverty, they have little choice but to over-exploit the land. When the land eventually becomes uneconomic to farm, these people are often forced into internal and cross-border migrations, which in turn can further strain the environment and cause social and political tensions and conflicts. Food security can ultimately be put at risk when people already living on the edge, face severe droughts and other calamities. Most of the 850 million people that suffer from hunger globally (MEA, 2005), are rural farmers, many of which are in the remote areas where food production is affected most by economic, environmental and climatic shocks. More than 44% of the world's malnourished people are small farmers. Desertification is a major driver of poverty and hunger among these populations, mostly due to declining agricultural yields in crop- and rangelands.

Although the recently published International Assessment of Agricultural Science and Technology for Development (IAASTD, 2008) draws a rather dark picture of the current situation of agriculture, it also highlights that the world – and mainly the land user – has the necessary means, technologies and knowledge to secure the worldwide food production in the future in an ecologically, socially and culturally sustainable way. Examples show that Sustainable Land Management (SLM) practices provide opportunities for combating land degradation, which not only enhance agricultural production, promote nature conservation and increase resilience to climate change in especially extreme events, but also enhance carbon sequestration (Liniger & Critchley, 2007).

What is required is to set the right priorities and create the necessary political framework conditions in an ecosystem approach which provides a widely accepted integrated framework to analyse suitable SLM strategies and to develop integrated technologies and approaches for combating desertification (MEA, 2005).

1.4 Climate change and desertification

There is increasing consensus that global climatic change is occurring and that in the next century, shifts in global weather patterns and the changes in climate regimes are likely to have regional consequences for biota in ecosystems (Harris *et al.*, 2006). Climate change will result in the following:

- Changes in the weather patterns;
- Increases in mean temperatures;
- Changes in the patterns of precipitation;
- Increasing incidence of extreme climatic events; and
- Rising sea levels.

More than ever before, research stresses that the cause-and-effect cycles of climate change include drought, land degradation and biodiversity loss. The continued improved understanding of these links calls for a fresh appraisal of the role of desertification in climate change, in adaptation and mitigation efforts and in biodiversity preservation.

Climate change aggravates drought, which aggravates land degradation. Land degradation, in turn, releases carbon stored in the soil, thus worsening global warming and climate change.

The strategy of combating land degradation by restoration requires quantitative goals, underpinned by scientifically evidence-based facts and a clear assessment methodology. This will attract investment on a regional, national and international scale. We have to work towards a better understanding of the existing links between climate change adaptation and mitigation schemes for drought preparedness and mitigation processes, including issues to do with drought risk management. The restoration of degraded agricultural land is often seen as one of the most important responses to climate change as these activities help in the improvement of production and increases in soil carbon stocks.

According to **Luc Gnacadja, Executive Secretary of the UNCCD (2007)**: "Although Climate change is making desertification one of the greatest challenges of our time, the good news, and we now know this from grass-roots experience, is that drought and desertification are predictable. Land degradation leading to desertification is reversible. To a large extent, therefore, the severe impact of dryland degradation and desertification on the livelihoods of affected populations is the result of public and even global policy failure. Failure to converge from the global to the local through strategic partnerships, failure to mainstream at the national level, failure to diffuse the available information and knowledge, failure to disseminate and upscale the good practices and failure to mobilize the required resources."

1.5 Drylands and land degradation

Drylands are regions that are affected routinely by moisture deficits and are among the earth's most fragile ecosystems. The regions are characterised by low precipitation and extreme interannual rainfall variability and extended drought. The potential evaporative demand exceeds the total rainfall. The amounts of precipitation drive the dynamic processes in dryland ecosystems. Different indicators define them, including vegetation and climate.

Land degradation occurs everywhere, but is most damaging in the drylands that cover approximately 41% of the land surface of the world (hyper-arid areas included), comprise 44% of the worlds cultivated lands, and are home to more than 2 billion people. It is here – where the soils are fragile, vegetation is sparse and the climate is particularly unforgiving – that desertification takes hold (MEA, 2005).

The world's drylands not only make up 34% of the global population, but their soils contain over a quarter of all of the organic carbon stores in the world as well as nearly all the inorganic carbon. Drylands are home to eight of the world's 25 identified biodiversity hotspots. One of the threats is that dryland populations have among the highest population growth rates in the world, with an average of 18.5% in the 1990s (MEA, 2005). According to the Millennium Ecosystem Assessment (2005), up to 20% of the worlds drylands (about 20 million square kilometres) are degraded, including two thirds of productive agricultural land.

Extremely arid regions can only support a few people and due to the acceptance of these people to arid conditions, land degradation is often reported from the semi-arid regions with a higher concentration of people, but where drought often occurs.

Ecologically, arid and semi-arid environments normally function as non-equilibrium systems. Equilibrium systems are more characteristic of more humid areas and are associated with concepts of succession and climax vegetation. Non-equilibrium systems, on the other hand, are governed by variability and unpredictability, where the vegetation dynamics are driven by stochastic events, which often result in discontinuous and possibly non-reversible changes. When ecological **thresholds**, which represent critical points in slow variables (both socio-economic and bio-physical), are crossed, the system moves into new states or conditions with different internal dynamics, which can be in another equilibrial state with a higher resilience. The productivity and resource availability also fluctuates accordingly, which implies that adapted management strategies are required in the long term. Traditional land use systems which have evolved under these circumstances are often adapted to cope with these uncertainties and changes in the functioning of ecosystems. It is therefore important to recognise and understand these indigenous and traditional land use systems as part of the overall SLM strategies and combating land degradation and to incorporate them in future management plans.

The bio-physical system is therefore characterised by the "state of the ecosystem", whereas the socio-economic system is characterised by the "rural livelihood" of the community

(Reynolds and Stafford Smith, 2002). These two systems are closely linked in dryland degradation but are constantly changing, both in the short term (e.g. climatic variability, interest rates, crop yields, changes in markets, population migration) and in the long term (e.g. global change, increased population, land-use changes and climate change). Some of these processes are "fast" and some are "slow" and thus vary over time and space. The causes and consequences of desertification are therefore affected by the "scale" and "purpose" of the integrated systems. Four scales of interest are identified. These include (a) the farm/household, (b) the village/community, (c) national and (d) the international scale. Different systems may be at different risks of desertification, depending on the policy and management applications in each of these systems. There is an immediate need at all levels (local, regional, national and international) for policy measures on how to identify, prevent and/or adapt to desertification and land degradation processes. Studies in combating land degradation and desertification, which includes different types of restoration practices, should span over a wide range of temporal and spatial scales.

Although drylands are extremely fragile with regard to disturbances, the species can respond by offering an increased resilience, making them more widely accepted in these harsh conditions. Dryland systems that are disturbed might therefore have a high potential to recover and may respond better to restoration and rehabilitation efforts. The limit of productivity of dryland ecosystems is often not reached and there is much scope for improvement via efforts in research and development and the dissemination of information (Thomas, 2008).

In terms of the global economy, marginal areas, which include the drylands, are still under-researched. Many uncertainties still exist about the scientific basis of understanding the dynamic processes of dryland ecosystems. The interest in desertification was driven more by politics than science in the past. The institutionalisation of the desertification issues has offered an opportunity for many dryland nations to work together with international agencies to gather support for multidisciplinary programmes regarding the combating of desertification.

1.6 Aridity and drought

Aridity and drought are two natural features of drylands. While similar in appearance and often confused, they operate at different time scales. **Aridity** is a long-term climatic phenomenon and a defining physical characteristic of drylands. It is characterised by a permanent deficit in rainfall often connected to other climatic parameters, such as higher temperatures and higher evaporation rates. In arid areas, the vegetation cover is poor and discontinuous and soils poorly evolved, as soils develop slowly in the absence of water (Hermann & Hutchinson, 2006).

The UNCCD has defined five aridity categories, namely hyper-arid, arid, semi-arid, dry sub-humid and humid. To work out the aridity index, one must compare the annual precipitation with its potential to loose water through evaporation and transpiration. This is known as the MAP:PET ratio. The desert, for example, receives very little precipitation, but the potential to loose water by evapo-transpiration is high, because the area is hot and dry. Hyper-arid zones have a MAP:PET ratio of less than 0.05. On the other hand, Durban has a high rainfall, but because it is very humid, relatively little water is lost by evapo-transpiration. The MAP:PET ration for humid areas is greater than 0.65 (Hoffman & Ashwell, 2001).

Drylands are mostly characterised by arid, semi-arid and dry-subhumid areas. These are the fragile drylands and have the most risk of desertification. More than 91% of South Africa falls in this category and a further 8% of the land, mostly in the Northern and Western Cape Provinces, is hyper-arid. Only 1% is classified as humid, characterised by small pockets of land in the Eastern Cape, KwaZulu-Natal, Mpumalanga and the Western Cape (, UNESCO, 1977; Hoffman & Ashwell, 2001).

Percentage of land area in each aridity zone in South Africa (Hoffman & Ashwell, 2001)

Aridity zone	Hyper-arid	Arid	Semi-arid	Dry sub-humid	Humid
MAP:PET	< 0.05	0.05-0.2	0.2-0.5	0.5-0.65	> 0.65
% of SA	8%	47%	39%	5%	1%

According to UNESCO (1977) the annual rainfall for the main aridity categories are, for arid areas: <500mm/a, for semi-arid areas: 500 – 750mm/a, and for dry sub-humid areas: > 750mm/a.

Drought is an episodic, short-term event that can affect any environment, but it can be a frequent and defining characteristic of drylands. During drought periods, below-average rainfall periods occur, which can be over extended periods of time, but are not restricted to any particular environment. Drought is not only a physical phenomenon, manifesting in vegetation stress and the loss of vegetation cover, but also has an important social component in that its impacts are influenced by drought vulnerability of particular societies or social groups. In most dryland systems, hunger and poverty are closely related to the unpredictable and volatile rainfall events and the recurrent droughts severely affect the resilience of the people's livelihoods. The unpredictability in rainfall leads to food insecurity from one season to the next and contribute to the loss in people's assets and lowering in their livelihood systems. The latter is especially true for the arid and semi-arid regions of Sub-Saharan countries in Africa. Poverty forces people to engage in unsustainable land use practices, such as over-grazing, deforestation, over-cultivation, mining of ground water and unsustainable population growth.

Wilhite and Glantz (1985) distinguish four kinds of drought with increasing severity, resulting in meteorological, hydrological, agricultural and/or socio-economic impacts:

- Meteorological droughts are below-average precipitation events.
- Hydrological droughts are associated with the effects of below-average precipitation events and shortfalls of surface or sub-surface water supply, usually after meteorological droughts.
- Agricultural droughts focus on the lower crop production impacts due to reduced water supply.
- Socio-economic droughts refer to the cumulative impacts of all the other drought types due to the negative impact and functioning of the socio-economic system, for example the supply and demand of some economic goods and services.

Land degradation and drought can also contribute to increased migration patterns of people due to the lowering in agricultural yields, as a result of poor soils and the lack of water. Many areas in Africa, especially the Sahelian region, have experienced increased migration patterns over the last decade. Protecting the land means stemming the factors of forced migrations, reducing the causes of conflicts and alleviating the impact of natural disasters.

2. Sustainable Land Management (SLM)

Effective Sustainable Land Management (SLM) depends on suitable technologies, policies and associated implementation approaches, and on flexibility and responsiveness to changing complex ecological and socio-economic environments. Major emphasis has to be on the prevention and mitigation of land degradation and desertification, to be more proactive and to decrease the vulnerability of the rural poor to environmental stresses driven by climate change and loss in biodiversity. This can be achieved through combating desertification actions, including restoration ecology and sustainable land management (SLM) strategies. SLM addresses the following socio-economic principles, namely to:

- Maintain or enhance production/services (Productivity);
- Reduce the level of production risk (Security);
- Protect the natural resources and prevent soil and water degradation (Protection);
- Become economic viable (Viability); and
- To be socially acceptable (Acceptability).

Reversing land degradation through restoration and improved soil and water conservation strategies often depends on local and indigenous knowledge. However, there is an apparent reluctance among farmers to adopt new SLM practices, especially if these are proposed directly by the scientific community or external agencies that often do not have the experience of the local environmental and management conditions. Another important reason for not applying new technologies and for the reluctance of farmers to invest in land improvement, is the lack of land tenure and property rights, as often the land users do not own or control the land (World Development Report 2008, *Agriculture for development,* World Bank, Washington, D.C. USA, 2007). Other factors include the reluctance to invest in new and unfamiliar equipment that will change the current farming operations and a lack of the short term pay offs when the new applications have a certain risk, such as the cultivation of bare patches in the rangeland and re-vegetation with natural seed with low viability and germination potentials.

The pathways for attaining SLM to address the loss in yield and productivity gaps in drylands mostly focus on improving the land, including soil nutrient and water productivity through integrated land management practices and the adoption of alternative livelihood strategies (Thomas, 2008).

SLM practices also try to deal with the complexity of rural development and integrated natural resource management (INRM). Changing the management of ecosystems will therefore require careful attention to local knowledge building and networking between the different role players. It will also entail the building of strong leadership that span across level of governance, policies and institutional perspectives (Thomas, 2008).

The combination of scientific and local monitoring methods to strengthen the participation, build partnerships – which develops a common vision in the understanding of ecosystem processes and includes both a bottom-up and top-down approach – is needed to address the various scales of interventions. The above-mentioned aims of partnership building are addressed through the collaborative projects between the Department of Agriculture, Conservation and Environment (DACE) on Provincial level, the Department of Agriculture (DoA) and DEAT on National level, and the North-West University (NWU). The NWU provides a good scientific background and helps with the implementation and adoption of strategies to combat land degradation through restoration practices and hetter SLM practices. However, certain obstacles have to be overcome:

1. Lack of awareness of the seriousness and links between land degradation and climate change in the development community.
2. Lack of focus on the main issues to be addressed in poverty reduction and environmental protection.
3. The limited time frames of projects (only 3-5 years) to measure the response of ecosystem change and degradation in drylands, whereas long-term studies are required. Land users often get frustrated if results are not reached quickly, and it influences their participation and commitment.
4. Low cost:benefit ratios for the implementation of strategies to combat land degradation and desertification in the short term.
5. Too many issues are addressed and integrated at the same time, which confuses the land users and other stakeholders, for instance desertification, climate change, human diseases, gender, education and population growth. This could lead to a "mainstream overload".
6. Too many barriers in governments and donor agencies, e.g. expertise in land degradation and climate change is frequently only found in agricultural or environment departments that have limited leverage over sectored guidelines and policies.
7. Insufficient knowledge about the relevance and insufficient data on the accuracy of land degradation and climate change to develop related decisions, especially at policy level.
8. Insufficient knowledge about the ecological processes that lead to land degradation and desertification.
9. Insufficient monitoring of factors related to land degradation in the long term (see above).
10. Limitations on resources (human and financial) for implementation and adoption.

(Thomas, 2008).

SLM can, however, be addressed when the following steps are followed:

(a) Assess the dynamics that lead to the changes in land conditions over time, using remote sensing and ground truthing.
(b) Assess and gain an understanding of the interplay between climatic and socio-economic factors that result in the loss of productivity and land degradation.
(c) Assess how adaptations towards climate variability and long-term changes can be implemented using seasonal and longer-term forecasting linked to agricultural activities and insurance schemes for the rural poor.
(d) Link efforts regarding land degradation and adaptation to climate change to development processes (mainstream legal and policy frameworks and incentives).
(e) Develop low-cost monitoring, evaluation and modelling tools for land degradation and environmental services that can be carried out and used by land users and policy makers for decision making.
(f) Disseminate knowledge and contribute to capacity development on climate risk and land degradation, increasing the collaboration between land users and other agencies such as the national meteorological, hydrological and agricultural services.

Although many of the above-mentioned steps are already in place and are carried out at different institutions and agencies in South Africa within several land degradation and desertification projects, including the School of Environmental Sciences and Development at the NWU, the challenge is to bring all these factors together and to work towards a common goal, without duplication, and to ensure the implementation and adoption of SLM practices in the long term.

3. United Nations Conventions related to desertification

3.1 The United Nations Convention to Combat Desertification (UNCCD)

Agenda 21, which created the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, lead the commitment in the development of global Conventions, of which the UNCCD, United Nations Convention for Biodiversity (UNCBD) and the Framework for the Convention of Climate Change (FCCCC) are the most important regarding the land degradation and desertification challenges. UNCCD is about fighting deserts, it is about reversing trends in land degradation, improving living conditions and alleviating poverty in rural drylands. The UNCCD therefore focuses on the poverty of people as well as on the environment, which makes this convention a "sustainable development convention". It is the first international treaty to recognise the linkages between poverty and environmental degradation and to emphasise the need for an integrated approach to natural resource management and rural development. The principles set by the International Conventions were further developed and strengthened by the Millennium Development Goals (MDGs), as well as during the World Summit on Sustainable Development (WSSD), which was held in Johannesburg in 2002. The WSSD called for good governance of the Conventions with the participation of civil society, the private sector and governments in partnerships to fight poverty and promote sustainable development (Poulsen & Lo, 2006).

The UNCCD's role is therefore to promote a people-centred development, and especially to strengthen the role of women in decision making, planning and implementation.

A total of 193 countries worldwide are currently parties of and have ratified the UNCCD. Country parties often have difficulty positioning the convention in national policy and development programming processes. Consequently, the UNCCD and its implementation are often not viewed as a national priority, particularly in countries where drylands are non-existent or where only small parts of the country fall under the convention's definition of drylands.

The **recently adopted ten-year strategy** for the UNCCD (Decision 3 of the Conference of Parties meeting No 8), by the Intersessional Intergovernmental Working Group (IIWG), addresses the role of the convention in the various geographical and ecological areas and the approach to its implementation, in line with the clear goals and objectives stated in its text, tries "to contribute and achieve sustainable development in affected areas" (Section 2 of the UNCCD).

The UNCCD's contribution to the overall setting of development priorities, to development programming and to achieving global objectives such as the Millennium Development Goals, is determined by its ability to integrate UNCCD implementation into these frameworks at country level. The UNCCD is not considered to be a freestanding convention, since its existence depends upon the identification of the specialised contribution it can make at national level to effective resource mobilisation for rural development and sustainable natural resource management and therefore it acknowledges its contribution in national development programmes. This means that more weight needs to be given to a conducive policy environment, legislative reform, governance issues and institution building, thereby supporting country parties to place UNCCD concerns for the development agenda in the mainstream, thus making the UNCCD a more effective tool (UNCCD, 2005).

3.2 The National Action Programme (NAP) of the UNCCD

National Action Programmes (NAP) is one of the key instruments in the implementation of the convention. They are strengthened by Action Programmes on sub-regional (SRAP) and regional (RAP) level. National Action Programmes are developed in the framework of a participative approach, involving the local communities and they spell out the practical steps and measures to be taken to combat desertification in specific ecosystems.

At a national level, the UNCCD focal points should involve key decision makers in the process of the implementation of the convention. This can be carried out through the NAPs of each country, which highlight the priorities to pave the way for the development and implementation of projects that include the combating of desertification. Through the National Focal Points and the NAPs, financial structure is created to support such projects and programmes.

3.3 The UNCCD-NAP in South Africa

South Africa ratified the United Nations Convention to Combat Desertification (UNCCD) in 30 September 1997 and subsequently adopted a National Action Programme (NAP) in November 2004, with the title "Combating Land Degradation to Alleviate Rural Poverty" (DEAT, 2004). The UNCCD-NAP forms part of the NEPAD (New Partnerships for Africa's Development) initiative in South Africa. NEPAD is a comprehensive, integrated development plan and programme of action for the re-development of the African continent, a commitment that African leaders are making to African people and to the international community, to place Africa on a path of sustainable growth; and it is the key mechanism for Africa-wide projects under the UNCCD.

The Department of Environmental Affairs and Tourism (DEAT) is the focal point for the UNCCD in South Africa. The UNCCD objectives to combat desertification are implemented through the NAP which was approved by the South African cabinet in 2004 (DEAT, 2004). The NAP calls for all South Africans to work together in implementing its objectives through effective actions at all levels, supported by international cooperation and partnership arrangements. The implementation of the NAP relies largely on the coordination, harmonisation and strengthening of these various initiatives. It focuses on forming linkages between sustainable development, to increase the livelihood of the rural people and to identify efforts to combat desertification and to mitigate the effects of drought as a result of the prevalent climatic change. DEAT is currently appointing a new National Coordinating Body (NCB) in the place of the UNCCD Steering Committee in South Africa. The NCB will oversee the implementation of the NAP and will see to it that all stakeholders are represented, form partnerships and inform and support the focal point in desertification activities in the country.

The UNCCD-NAP in South Africa also focuses on the improvement of the productivity of the land, including the rehabilitation/restoration, conservation and sustainable management of land and water resources, which will lead to improved living conditions, in particular at community level. Activities of the UNCCD in South Africa are included in arid, semi-arid and dry subhumid areas of sustainable development, which are aimed at:

- The prevention and/or reduction of land degradation;
- The rehabilitation/restoration of partly degraded land; and
- The reclamation of desertified land.

The vision of the UNCCD-NAP in South Africa is a "prosperous and healthy South Africans living in an environment restored and maintained through universal improvement in land management to its beautiful landscapes and productive ecosystems that sustain livelihoods and ecosystem services, for the benefit of current and future generations" (DEAT, 2004). However, prior to the adoption of NAP, South Africa already had policies, laws, strategies, programmes and projects in support of the UNCCD objectives with respect to the promotion of sustainable land management. The implementation of NAP thus relies largely on the coordination, harmonisation and strengthening of these various initiatives.

4. How to study rangeland degradation

Changes in rangeland condition, or the "health" of a certain area, are compared with the potential or ideal for that area (Jordaan & Kellner, 1997). Wilson and Tupper (1982) regard rangeland condition as a comparison between composition of the rangeland and production with a standard benchmark representing a certain habitat. The condition of the benchmark is mainly measured through three principles, i.e. stability, resilience and resistance, which can be briefly defined as follows:

- **Resistance** is the term describing an ecosystem's ability to maintain its structural and functional attributes in the face of stress and disturbances;
- **Resilience** is the ability of an ecosystem to regain structural and functional attributes that have suffered harm from stress or disturbance; and
- **Ecosystem stability,** which is the ability of an ecosystem to maintain its given trajectory in spite of stress; it denotes dynamic equilibrium rather than stasis. Stability is achieved in part on the basis of an ecosystem's capacity for resistance and resilience.

The degree of ecosystem changes between rangeland condition states that are measured by the three principles above, are often characterised by ecological **thresholds** on so-called "degradation or range condition gradients". These principles are driven by various factors, such as rainfall events (including drought), species diversity and composition, soil type and structure, human interventions and the interaction of management practices (Moussa *et al.*, 2007). Ecological thresholds describe the abrupt changes in the ecological properties of a specific system in time and space (Bestelmeyer, 2006). Thresholds are measured against the benchmarks and are often irreversible, due to the physical and chemical changes in the soil properties, decrease in vegetation cover, density and composition and the depletion of the soil seed bank. The latter leads to a decline in forage productivity and biomass, and ultimately to degradation, which will have a negative impact on animal production. By using range condition or degradation models, the processes of land degradation is better understood and thresholds or the recovery potential depicted, which can help to prioritise the type of management or restoration efforts that have to be applied (Bosch & Kellner, 1991; Bestelmeyer, 2006; King & Hobbs, 2006). If the land has been degraded past a certain threshold on the gradient, often due to long-term overgrazing and drought conditions, the biotic processes have become dysfunctional and the abiotic function has been degraded beyond its resilience. The most severe degradation occurs when both the biotic and abiotic functions are damaged and there is nothing left to control the resource loss (King & Hobbs, 2006). The degree of change is not linear, but includes multidirectional characteristics and multiple states, described in so-called "state and transition models" (Westoby *et al.*, 1989), which are used to describe the degree of resistance, resilience and stability of a certain rangeland condition.

A good understanding of the vegetation, soil properties and climatic impacts that may lead to changes and possible thresholds is therefore necessary before any management or perhaps restoration technologies can be proposed in future. This understanding and knowledge of the ecosystem dynamics can only be obtained through long-term monitoring of the soil, vegetation and climatic conditions, which will tell if changes occur due to seasonal fluctuations or successive changes. In rangeland degradation it is widely accepted that if certain limits of resilience are exceeded (i.e. if the thresholds are crossed) towards the more degraded state or condition on a gradient, the recovery process is virtually impossible without the intervention of the manager or land user, mostly through the implementation of various restoration practices. Researchers have developed a range of monitoring technologies that can evaluate the ecosystem function and evaluate the state of the environment by measuring various indicators, e.g. through the Landscape Function Analysis (LFA) developed by Tongway and Hindley (2002), computerised remote sensing technologies, vegetation and soil surveys using fence line effects and distances from watering points (piopheres) (Bosch & Kellner 1991; Friedel, 1997; Jordaan *et al.*, 1997; de Beer, 2000) or the DPSIR model, which is often used on a national level (DEAT, 2004). The latter analysis measures the state of a given aspect of the environment in terms of the **driving forces** for change (D – inequity of land distribution), the **pressure** that arises from the force (P – population density, poverty social weaknesses, etc), the **state** of the environmental aspect that arises from the pressure (S – loss in topsoil and eroded landscapes), the **indicator** of that state (I – silting of dams and decrease in crop production), and the presence, absence or quality of the institutional or policy **response** to the state (R – support to small-farm development, developing of local markets, restoration of degraded lands).

No matter what type of land degradation assessment system or model is used, good scientific data of several environmental properties, including social and economic factors, must be sampled in the long term in order to interpret the level of ecosystem function, to determine the trajectory of degradation and to identify the thresholds on such gradients. Only an in-depth understanding of these processes can be used to develop better SLM practices which can be applied by the land user and manager.

If the stresses of degradation continue over time, they will contribute to a spiralling affect of land degradation towards desertification affecting all ecosystem processes. Restoration ecologists and ecosystem managers seek to reverse this downward spiral of land degradation. They want to restore the functions and improve the structures of ecosystem components, e.g. to improve water infiltration (abiotic) and to increase vegetation cover (biotic).

5. Restoration ecology

Land restoration has become an increasingly important topic for scientists, extension services and land users. In fact, the restoration of degraded rangelands has only been significantly developed over the past decade and has only been acknowledged as a fully independent discipline within the last 12 odd years (Cairns & Heckman, 1996). **Ecological restoration** is the practice of restoring ecosystems as performed by practitioners at specific project sites, whereas **restoration ecology** is the science upon which the practice is based (SER, 2004). Restoration ecology ideally provides clear concepts, models, methodologies and tools for practitioners in support of their practice. Ecologists, social scientists and land managers are challenged to explore, test and apply the current theories, models and concepts of the academic restoration ecologists. As for land degradation and desertification, restoration ecology is not restricted to environmental conditions alone, but also includes the social and economic components (Van Andel & Aronson, 2006). All three aspects have to be addressed simultaneously to ensure sustainable ecological restoration applications.

Ecological restoration is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability. Frequently, the ecosystem that requires restoration has been degraded, damaged, transformed or entirely destroyed as the direct or indirect result of human activities (SER, 2004).

The definition of Ecological Restoration that is widely accepted and promoted by the Society for Ecological Restoration International (SERI), is: "*Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed*" (SER, 2004).

Although this is a very broad definition, it shows that restoration is not something theoretical without a practical application, but has to do with the active involvement and intervention of social, economic and environmental affairs. Ecological restoration is one of several activities that strive to alter the biota and physical conditions at a site, and are frequently confused with restoration ecology. These activities include reclamation, rehabilitation, mitigation, ecological engineering and various kinds of resource management, including wildlife, fisheries and range management, agro-forestry, and forestry. All of these activities can overlap with and may even qualify as ecological restoration.

The success of a restoration application can be assessed by comparing it to a reference ecosystem or reference. The latter serves as a model for planning a restoration project. In its simplest form, the reference is an actual site, or multiple sites with certain ecosystem attributes. The reference fall within the historic range of variation of that ecosystem (SER, 2004).

Rehabilitation shares with restoration a fundamental focus on historical or pre-existing ecosystems as models or references, but the two activities differ in their goals and strategies. Rehabilitation emphasises the reparation of ecosystem processes, productivity and services, whereas the goals of restoration also include the re-establishment of the pre-existing, historical biotic integrity in terms of species composition and community structure. Nonetheless, restoration, as broadly conceived herein, probably encompasses a large majority of project work that has previously been identified as rehabilitation (SER, 2004). Ecological restoration therefore differs from rehabilitation, reclamation, ecological engineering and landscaping, in that all aspects of ecosystem structure and function are considered and addressed in restoration ecology (Van Andel & Aronson, 2006).

Hobbs and Norton (1996) give a number of reasons why restoration has to be carried out. These include:

- To enhance the conservation values in protected landscapes;
- To enhance conservation values in productive landscapes;
- To improve the productive capability in degraded productive lands; and
- To restore highly degraded but localised sites, such as mining or other industrial disturbed sites.

Restoration is therefore the most ambitious level of all practices, as it includes the reconstruction of previous, historical situations, with former species and community structure and function, having a self-sustaining target. Restoration includes the re-instatement of the maximum biodiversity prior to disturbance or degradation and with maximum ecosystem services. The success of restoration activities are related to long-term commitments and often include high financial inputs. Without proper monitoring, the success of restoration cannot be assessed.

5.1 Restoration of rangelands

One of the challenges we face in achieving sustainability, is to reverse the trends of ecosystem degradation through the restoration of the natural capital of rangeland ecosystems. The magnitude of degraded areas depends on the size of the rangeland unit (e.g. localized bare patches to one or two paddocks) and how the land was previously used and managed (e.g. open rangelands, old cultivated lands or industrial disturbed sites), as well as the climatic conditions, especially rainfall patterns, that prevailed in the long and short term in the area. Restoration ecology can be carried out in different ways, which will depend on the (i) aim of restoration, (ii) degree and (iii) scale of disturbance, as well as the resources available to reverse the negative trends of degradation. Depending on the condition of the soil and vegetation and the temporal and spatial scale, restoration activities can either be carried out through **passive** or **active** interventions (Dregne, 1995; Milton & Dean, 1995; Aronson *et al.*, 2002; Snyman, 2003;).

Passive restoration is introduced where the resilience of the ecosystem is still high, with relatively limited structural and functional damage. These activities entail the removal of stresses that caused the original degradation, such as heavy grazing, and then allowing natural succession to take place (Whisenant, 1995). Restoration activities therefore include the implementation of better management strategies, such as rotational grazing, or the control and reduction of live-stock numbers (Jordaan 1997; Curtin, 2002). A large "self-recovery" process still exists in these ecosystems, mainly due to available seed and propagules in the soil-seed bank, with limited erosion or physical damage to the natural resource. Passive restoration technologies generally require low input costs and can easily be carried out by the land user with appropriate knowledge regarding sustainable management practices. The land user must also have sufficient funds and resources to establish an appropriate fencing or paddock system, which can be used in approved livestock control management systems.

Active restoration technologies, however, are implemented in ecosystems with very low resilience due to high stress factors, such as low water infiltration rates due to compacted soils, low vegetation cover and density which can also result in extreme temperatures on the soil surfaces. Temperatures of high clay soil surfaces of rangelands in poor condition can fluctuate from -7°C to 62°C in summer (Van Rensburg, 2003). To facilitate seed germination and seedling establishment in these extreme soil surface conditions, the restoration practice should also include protection measures such as brush packing or any cover by other organic matter, such as hay (Boateng, 2002). Ecosystems where active restoration practices have to be implemented, have mostly lost their structure and function and have passed a certain level of threshold (Aronson *et al.*, 1993; Reynolds & Stafford-Smith, 2002). This includes the disturbance of the soil surface or removal of undesired species to reduce the competitive effect of the existing vegetation. The plant community is therefore in an alternative state and recovery will only be possible if additional management interventions are applied, such as the tilling or pitting of the scalded soil surfaces by an agricultural implement or the control and removal of indigenous or exotic species that have encroached a certain area. The tilling and pitting of degraded soil surfaces will allow better water infiltration and moisture retention for the vegetation (Montalvo *et al.*, 2002). The soil-seed bank of especially the indigenous and ecotype vegetation in such areas is mostly depleted and requires re-vegetation by re-seeding practices. This will ensure rapid establishment and an increase in vegetation cover, especially in the short term (Milton 1994; Pywell *et al.*, 2002; Van Den Berg, 2002; Van Den Berg & Kellner, 2004). The question now arises: What type of vegetation should be used in these re-seeding (over-sowing) interventions? Restoration management often aims at restoring a certain target community of well-defined local and natural ecotype species. This target may be derived from historical data or from reference communities and ecosystems in the vicinity of the site to be restored. Seed-bank assessments should therefore become an integral part of possible restoration measures in an area. It has been shown that although a complete list of species present in the seed bank cannot be obtained, the most important result of seed-bank studies, which may be applied in management practices, is the knowledge of the ratio between seed numbers of target and other species. This knowledge will help to determine what type of species can be expected to establish first in any restoration site (Bekker, 1998). The above-ground species composition may be different from the composition of the seeds in the below-ground seed bank (Bakker & Berendse, 1999). Depending on the degree of disturbance or degradation, a rich seed bank of the local ecotypes may still exist in the soil, just awaiting favourable conditions, such as certain climate or management processes, including fire occurrences, to germinate and re-sprout. In-depth analyses of the soil seed banks are therefore necessary. Sites with the greatest potential for restoration are those with a short history of agricultural intensification or that have only recently been disturbed (Leck *et al.*, 1989; Bakker & Berendse, 1999).

One of the main goals of restoration in degraded arid and semi-arid rangelands is to increase the grazing capacity for livestock production. It is recommended that the restoration application includes re-seeding or re-vegetation with local ecotype selected species, mainly grass species which are adapted to the specific soil and climatic conditions of the area.

Although any active re-vegetation (re-seeding) effort to restore degraded rangelands should aim to establish local ecotype species, there are, however, some constraints in the selection of these species. These include factors such as the type and availability of the seed, the morphology and dynamics of the seed, method of re-seeding and dormancy requirements of specific ecotype species. Re-seeding of large degraded areas with specific ecotype selected species greatly depends on the availability of seed. This is a major limiting factor and contributes to the fact that seeds which are more readily available in large quantities for the establishment of cultivated pastures and that can be purchased from commercial seed merchants, are usually used. However, to collect large quantities of seed from the specific habitat is very labour intensive and often not cost-effective. Furthermore, if local ecotype selected seed is used, the quality, viability and purity are often not of a high standard, leading to poor restoration results.

Although the economic implications of restoration application are often regarded as the determining factor, the ecological importance and improvement in the range condition should not be underestimated. Restoration applications have to be rooted in ecology and implemented according to a predetermined plan, and should include sound long-term management principles. Designing restoration strategies to optimize short- and long-term restoration outcomes will require a good understanding of both the abiotic/biotic (e.g. erosion or soil types and seed bank or re-seeding) and structure/function (vegetation patterns and dynamic processes) relationships and interactions (King & Hobbs, 2006).

5.2 Why restoration fails

The restoration of degraded rangelands is a long-term process which needs long-term commitments from both the researchers and policy makers. Studies in arid areas where the seed bank was depleted, have shown that no measurable improvement in species composition and recovery could be detected within 15 to 70 years after livestock removal (Fairall & Le Roux, 1991; O'Connor. 1991).

According to Harris *et al.* (1996), the reasons for resistance to restoration ecology includes the multivariate conditions at restoration sites, which seems forbidding to research desiring neat experimental settings, or the division of academic budgets into different departments deterring interdisciplinary collaboration, as well as the fact that restoration demands longer term research efforts than can be afforded by academic budgets and the fact that restoration ecology has been excluded from curricula of training institutions in the past.

As mentioned previously, degradation and the control thereof is a complex interplay of social, economic and technical factors. It is a fairly simple and straightforward procedure technically, but one that commonly is difficult to carry out, because of the variability of climate and other physical factors or because of a lack in management and political commitment. The most important factor for the control of degradation and related resource development is rather a social undertaking than a technical or economic one (Kellner & Shabangu, 1998). Restoration/reclamation ecology therefore requires approaches that integrate ecology and environmental sciences, economics, sociology and politics (Cairns & Heckman, 1996). Other reasons why restoration and the adoption of restoration technologies fail or have been slow, include:

- Inadequate understanding of the principles of ecosystem functioning;
- Ignorance and uncertainty by land users about which is the most appropriate technique or combination of techniques to use;
- The fact that restoration efforts have a negative cost:benefit ratio in the short term and the uncertainty about the comparative costs and benefits of different techniques;
- Uncertainty about the timing and application of a certain technique;
- The absence of proven techniques, that the land user can refer to before applying a specific technology (site surveys/demonstration plots "on farm" research);
- Insufficient collaboration and co-operation between all parties involved in the restoration efforts (scientists, extension & land user) – a lack of a bottom-up, grassroots, community-based, participatory approaches, especially in the under-privileged and underdeveloped communal managed areas of Africa;
- Failure to implement all aspects of the restoration plan;
- A lack of conservation ethic; prestige of owning large herds of live stock and the greater investment of live stock;
- More concern for the day-to-day family survival (sanitation, water, housing. etc.);
- High levels of poverty, especially among the local land users in the rural areas.
- Insecure land tenure policy (many land users do not own the land); and
- Lack of knowledge at higher levels of government about the extent and severity of land degradation. Governments understand food shortages and they believe that they know how to increase agricultural production. However, little is understood about the

relative importance of the degradation process, the timeframe and costs of reversing degradation, the difference between drought and degradation and the magnitude thereof.

Restoration should be part of the conservation of natural and agricultural resources: there should be guidelines and norms for bow to conserve; there should be control measures for this process; and it should be within the socio-economic needs and constraints of the land user. Restoration should also form part of the total conservation and/or production plan of any system. It must, however, be emphasised that restoration is not an instant solution to a major problem.

A vital step forward in land restoration will be to give full attention to agriculture. The farmers of the world are being called upon to feed a growing world population. This makes agriculture the most important driver of land use, land change and degradation. Farmers are the guardians of land and landscape, and can be our most important agents for land management and restoration.

5.3 Planning ecological restoration

Although restoration very seldom occurs according to a certain plan, Cairns (1995) emphasises that many steps are required to conduct a successful restoration project. One of the most important components for success, is understanding that restoration takes time. The following are some basic steps of any restoration project (Adapted from Cairns, 1995):

- **Seek help from experts and use a multi-disciplinary team in planning.** The team should include biologists, ecologists, agronomists, engineers, geological and soil scientists, economists and sociologists.
- **Clearly define the objectives, goals and measurements.** It is important to establish site-specific experiments and goals (short and long term) for each project. Ecological systems are complex and restoration efforts in different systems will evolve through many stages before the end result is achieved. The importance of site-specific demonstration sites and an "on-farm" approach cannot be overemphasised.
- **Conduct site-specific analysis** of hydrological, geological and biological variables at each site. This includes investigation and sampling of present and historic impacts and influences of as much biotic and abiotic parameters (climate, soil, geology, hydrology, plant and animal biota and dynamics. gene pools and seed banks, etc.) as possible at each experimental site.
- **Setting priorities.** Concentrate on land that has the potential to recover in shorter periods of time. Ensure early success, as it generates continued support. After easy success, the more difficult environments can be attacked. Economic benefits of rangeland restoration becomes more speculative as the climate becomes drier (e.g. an annual rainfall of 150-200mm/a is said to be too dry).
- **Develop a detailed site plan.** The plan should include specific information about the characteristics of that site and which areas of a site will be restored to what type of community. Information should be included on a site plan map.
- **Select species for sites carefully.** Using the most applicable and adapted animal and/or plant species for a certain environment, will not only enhance the restoration process, but will also be more cost-effective. Identify the sources for the species to be used and ensure that different species of ecotypes are considered before application.
- **Create a detailed design for each different community including a spatial and temporal planting plan.** By implementing the correct restoration practice concerning

species-specific requirements, e.g. seed types, over-seeding techniques for certain plant species (in rows or broadcast), seeding and planting depths, spacing, etc., the implementation costs and long term maintenance will be minimised.

- **Prepare the site.** This can include physical changes (cultivation) and/or chemical amelioration (fertiliser application), and other soil treatments. It can also involve management decisions concerning existing vegetation on the site.
- **Supervise project implementation.** Any restoration practise needs guidance and must be under supervision of experts to ensure that the work is conducted in the most effective way and according to plan.
- **Control of exotic and undesirable species.** The restoration plan may include the removal of exotic and undesirable species by mechanical and/or chemical techniques. Before any of the latter techniques are implemented, it must be established what are the most efficient and cost-effective ways. The impacts of each technique should also be known and carefully monitored.
- **Economic analysis.** Financial concerns and social priorities are often ruled above ecological principles and functioning. The input costs will depend on the condition of the degraded site and aim of the restoration practice. Assess the short- and long-term benefits. Restoration often implies short-term economic sacrifices for long-term resource conservation. There should, however, be a compromise between short- and long-term objectives in rangeland management for optimisation of the quantity and quality of plant production.
- **Establish a plan for feedback and midcourse corrections.** A contingency plan must be in place. There must be a process for making assessments of conditions of the restoration process and responding at any time. Adjustments and corrections to the initial plan should be made timely to ensure ongoing success.
- **Develop a plan for long-term monitoring, management, and maintenance.** This plan should very specifically address the goals of the project and measure the success of reaching those goals. All persons involved in the restoration process should not only be familiar with the long-term plan, but should also be acquainted with their specific tasks and role within the total programme. The plan must also include aspects such as the total frame of the project, the method and frequency of monitoring, as well as the objectives, management and maintenance of the project in the long term.

5.4 Community participation in rangeland restoration

As degradation has multiple causes, the control of degradation requires site- and community-specific solutions. The combating of degradation by restoration therefore should not only address the physical and biological characteristics of the land, but also the social and economic factors of communities involved (Mouat *et al.*, 1995; Thomas, 1997). The need for bottom-up, grassroots and community-based participatory development projects can be regarded as one of the main objectives for any future plan in combating degradation and desertification. Projects must be planned, implemented and assessed by those who intend to help in making the project work. It cannot be achieved through decree, regardless of social value or scientific merit. Restoration ecology can be used to "bridge" social and natural sciences (Cairns & Heckman, 1996, Barac, *et al., 2004*). Seely (1998) emphasises the need to involve human cultures in restoration projects, as they are the "glue" that keeps these projects together. Restoration efforts must therefore be people centred. This means that the reason for implementing restoration practices must be well understood at grassroots level by the people concerned, and also by the community that is prepared to take ownership and full responsibility for the restoration or conservation programme. They must view such programmes as their own (Scheepers, 1998). The challenge is to not only concentrate on the negative effects of rangeland degradation, but also to emphasise the positive outcomes any restoration efforts may have.

When restoration practices are introduced in communal and underdeveloped areas, it has to be realised that rural people are not necessarily "farmers". Only a minority of rural people are seriously interested in and committed to farming. It is more useful to try to understand rural livelihoods and the role that natural resources and crop and live-stock production systems play in those livelihoods. The sustainable adoption of land restoration technologies is only likely when land users perceive degradation as a significant problem or when the land user considers that the land is worth restoring (Turner, 1998). Very often, extension services or conservation programmes come to rural people with land restoration at the top of their agenda. They are frustrated when their investigations reveal that schools, clinics or water supply are, however, at the top of the people's needs and problems, with land degradation some way down, if at all mentioned. The option would be to tackle those concerns first and come back to restoration later, a matter which is rarely permitted by funding agencies (Turner, 1998). Restoration practices should therefore be production orientated and include agricultural initiatives of more economic interest to the land user, or should be built into broader programmes which address the primary concerns of local people. Economic development should accompany land restoration so that the poverty factor can be minimised.

The implementation of restoration technologies should also be coupled to other community upliftment projects. These projects must include awareness raising, training, job creation and capacity building to ensure the long-term sustainability of any restoration effort. Such an approach will not only enhance the adoption of restoration technologies, but will also have a positive change in attitude towards restoration ecology in the whole. Turner (1998), however, cautions that to pay people to do conservation work is an inappropriate incentive. It gives the impression that land restoration is just another wage paying piece job. Conservation practices built on this basis are rarely maintained without further payment. The knowledge and rights of people that are directly afflicted by the problems of land degradation are also often overlooked. Only recently has considerable weight been placed on recognising indigenous knowledge of local communities in solving environmental problems. Recognition of indigenous knowledge is part of the process of connecting science and community action (Seely, 1998). It is important to recognise the wealth of knowledge and years of experience of land users about resolving the problem of rangeland degradation and the implementation of restoration technologies. The task of knowledge maximisation must be seen as a co-operative venture between the scientists, extension and land users (Bosch *et. al.*, 1997). If research projects are carried out in collaboration with the land user in an "on-farm" approach, taking the resource and socio-economic needs and constraints into consideration, the farmer also becomes a "researcher" (Kellner & Shabangu, 1999). Technologies tested and implemented by this type of approach must be a joint design between the scientist and land user in order to ensure that techniques fit the local environment and specific problems. The land user and his/her knowledge immediately becomes involved in the decision making. It also bridges high cost, facilitates long-term scientific experiments across a wide spectrum of environmental conditions and takes the land user's needs into consideration. The challenge is to bring both the local and scientific knowledge together in a single, accessible database and possible decision support system (DSS).

5.5 Participation by agriculture and conservation in restoration ecology projects

The participation of the scientists, extension worker, technician and manager in agriculture and environmental conservation agencies in any restoration programme cannot be overemphasised. They form one of the most important links in the awareness, teaching, learning and capacity building aspects during the development, process and adoption of restoration projects. If all stakeholders are involved, mutual trust and respect between them are established, which will lead to the benefit of all parties involved Jordaan & Kellner, 1997).

The agriculture and conservation specialists often have a much better understanding of the administrative structures in the rural communities, especially in communal managed land, such as the role of headmen, other leaders, councils and the community structure in total. The latter is often not known or understood by the scientist or consultants who want to carry out research and development projects in the area. It is important to follow the correct procedure for addressing each of the community structures and the role they play, before conducting any research project. Only agricultural extension workers, scientists and conservation officers that are committed to the cause of combating land degradation or the implementation of a sustainable restoration programme should be involved. They only have one chance to get it right. Once the community looses faith in and respect for the project and its leaders, there is no second chance.

As mentioned before, most causes of land degradation are linked to agricultural processes, but although the Potchefstroom Campus of the North-West University does not have a faculty or department of Agriculture and/or Conservation, the School of Environmental Sciences and Development has very close links with the national and provincial Departments of Agriculture, Conservation and Environment. For instance, there is good collaboration, regarding research, development, training and capacity building with the Department of Agriculture (DoA) and Department of Environmental Affairs and Tourism (DEAT) at a national level, as well as with the Department of Agriculture, Conservation and Environment (DACE) at a provincial level.

5.6 Restoration by demonstration

A demonstration plot is a "reference area" or "site" which facilitates the baseline studies and monitoring success, which can be accomplished largely by the use of similar site comparisons and chronosequence studies. As mentioned, restoration research, carried out by the so-called "on-farm" (or "on-site") approach, is important as it gives the stakeholders a feeling of ownership and has a very high demonstration value (Van Rooyen, 1998). The scientific background for the trials are given by the researcher, whereas the execution is performed by the land-user or committed persons in the community. The restoration technique applied must be in accordance with the ability and resources available at that specific site and for that specific community. To promote the adoption of restoration technologies in the long term, will imply the development of techniques that will work and that are endorsed by the local land user.

The purpose of "on-farm" sites is also to demonstrate how acquired research information and technology can be applied to specific management situations (Ffolliott *et al.*, 1998). The importance of combining the restoration treatment with other land management practices can be demonstrated as well (Ludwig & Tongway, 1995). It also links available knowledge to people responsible for decision making and actions at all levels of society and land use practices. Through an awareness, education and training programme, not only restoration technologies are transferred to different levels of land-users, but also the principles of SLM options. Demonstration sites promote the two mottos we would like to achieve, i.e. **"seeing is believing"** and **"learning by doing"** (Kellner & Shabangu, 1998).

6. Challenges

Land degradation and desertification affects the sustainable development through the interrelationships between important social causes and effects, such as poverty, poor health and nutrition and lack of food security, as well as the sustainable management and restoration of the natural resources. For me as a scientist in the Faculty of Science at the NWU, it is a very good thing that our School includes the aspects of "Environmental Sciences" as well as "Development", as the combating of desertification does not only include the application of scientific outputs at a bio-physical level, but also the "upliftment and development" of people at a social and economic level. The challenge is to keep the NWU, with all its partners and activities, the "best" University in Southern Africa to address research in rangeland degradation, desertification and restoration ecology.

Analysis of successes and failures and scientific output of data, facts and trends generated by academic and research institutions, such as the NWU, must also be made available in order to enable policy choices. It is particularly necessary that enhanced scientific information on land degradation, desertification and restoration strategies should motivate policy makers, who often do not have all the knowledge and the necessary materials for addressing longer-term environmental challenges. Robust scientific data generated at research institutions, such as the NWU, can strengthen the evidence base for sound environmental and socio-economic policy on land- and soil-related issues. The latter has to be underpinned by scientific dialogue and studies that investigate concrete needs and activities which create real comparative advantages by addressing them at the regional, national and global level. The NWU has this comparative advantage, as many of the important scientists and expertise that can follow such an integrative and trans-disciplinary approach, are all housed in one institution. Although there is much room for improvement, good partnerships of multidisciplinary teams between scientists of the NWU and researchers, extension and technical staff, including policy makers at national and provincial government level, already exist in a number of collaborative programmes regarding the understanding of land degradation and the implementation of restoration. These partnerships also include partnerships with non-governmental organisations (NGOs), civil society groups or community-based organisations (CBOs), private organisations, farmers and land users, who play a vital role in the development of appropriate SLM options and policies at national, regional and global level.

Better collaboration will also develop more synergism between the three most important conventions for the protection and restoration of our natural resources and the adaptation of land users to local challenges, i.e. the United Nations Convention to Combat Desertification (UNCCD), the United Nations Convention on Biodiversity (CBD) and the UN Framework for the Convention of Climate Change (UNFCCC). Better implementation will be achieved through increased co-ordination between projects and programmes which simultaneously focus on increased land productivity, climate change and biodiversity issues.

7. Opportunities

The Vice–Chancellor of the NWU, Dr Theuns Eloff, expressed the mission of the NWU as to "become a balanced teaching-learning and research University and implement our expertise in an innovative way". Dr Eloff further explains that towards the end of 2007, the Council of the NWU agreed that the mission element dealing with the Universities research could be formulated as to "develop and maintain high-quality, relevant and focused research, supplying innovative solutions to challenges faced by the scholarly community, the country, the continent and the world" (Eloff, 2007). With this vision and mission as background, the terrestrial research group in the School of Environmental Research and Development at the NWU has the opportunity to deliver high quality scientific outputs regarding land degradation, desertification and restoration ecology that will serve the needs and challenges of the community in Southern Africa. This can, however, only be fulfilled if good partnerships exist and collaborative projects between government, non-government, private organisations, land users and managers are implemented.

More than 11 years ago, the current Director of the School of Environmental Sciences and Development, Prof Huib van Hamburg, stressed the following points in his inaugural speech, and these points were re-iterated in the inaugural speech of Prof Sarel Cilliers in 2008. Prof Van Hamburg emphasised that the vision of the School of Environmental Sciences and Development is to:
"Do research, education and training more in an interdisciplinary and transdisciplinary manner, across subject groups, units, centres and faculties, and include aspects of economy, law, communication and social sciences. The curriculum should also include more and better collaboration with consultation firms and the private sector, as well as environmental organisations" (Van Hamburg, 1997; Cilliers, 2008).

Future vision for this research group includes:

- The North-West University, with all its faculties, schools, centres and units, is a perfect institute where an integrated approach can be formed through collaborative work between all the expertise at the different units. There is much expertise available, but it is a pity that such an integrated approach is currently only partly achieved at the NWU. Collaboration between all the different scientists and expertise of the different schools and units at both the campuses in Potchefstroom and Mafikeng is currently not sufficient and requires urgent attention, especially in the development and execution of projects and programmes that address the challenges in land degradation, desertification and restoration ecology. These include, for example, the Centre for Indigenous Knowledge Systems, the Schools of Agricultural and Social Sciences, the Unit for Sustainable Development, the School of Chemistry, the Centre for Environmental Management (CEM) and the remote sensing division in the Unit for Environmental Sciences and Development.
- More co-ordination, also from the management sector of the NWU, is needed to develop better synergies to stimulate multidisciplinary projects between the units within and between the campuses of the NWU.
- More collaboration with the consulting and private sector has been achieved, mainly due to the strong guidance by the Director of Research, Prof Leon van Rensburg, who has promoted this type of interaction, as it brings more research and development funds to our University. This has also contributed to the fact that consulting, private and government

organisations receive better and more rigorous scientific data and results, which have been statistically verified, and on which they can base their decision making and policy development in the long term. The involvement with private organisations are not only financially lucrative, but it also exposes the students to the practical implementation and market-related industrial challenges. It is, however, important not to get sidetracked with consultation projects alone, which could have a negative impact on research outputs and the training of under- and post-graduate students. It is therefore important to keep a good balance between these two approaches.

- Fortunately, the gap regarding the involvement of social sciences in environmental research that previously existed, has recently also been recognised by the director of our Unit in Environmental Research and Management, Prof Leon van Rensburg. Prof van Rensburg has employed Mr Hendri Coetzee on a part-time basis to address the human-environmental and socio-economic interactions so urgently needed in bio-physical research projects. This appointment will increasingly enhance the outputs of the school and although this interaction already takes place and is being used by different research groups, the exposure to principles of community-based natural resource management (CBNRM) and participatory action research (PAR) projects will give students a more holistic training and a better understanding of the cultural, social and economic differences of the populations in a developing country, such as South Africa.
- One of the most important assets of the School of Environmental Sciences and Development at the NWU, is its students and especially its post-graduate students. It is a privilege to have such excellent, positive, hard working and very motivated post-graduate students in present and past research programmes. I will do everything in my power to give them the best possible education and training, based on good ecological science, which addresses the needs and challenges regarding land degradation, desertification and restoration ecology on a national, regional and global scale. It is therefore important that the focus of research projects are carried out in a way to prepare students for their working career after their university training. This preparation, among others, involves the teaching of good and up to date ecological science, so that research results of a high and international standard may be published in accredited scientific journals. Furthermore, students are prepared for research project management. The latter includes the writing of research proposals, applying for research funds to national and international agencies, the logistical and financial management of projects, submitting timely progress reports and the collaboration and exposure to national and international scientists at meetings, workshops and conferences. We believe that projects must be carried out "on-farm" or "on-site", using demonstration sites and promoting the mottos of "seeing is believing" and "learning by doing"; therefore, the collaboration with local land users, managers and communities of different cultures and languages in especially the rural areas of Southern Africa is also very important. The training programme also includes the involvement of post-graduate students in negotiation and decision making processes for research funds and project development, such as the United Nations Environment Program (UNEP), Global Environment Facility (GEF), World Bank, European Commission (EC) etc. The latter also makes students more aware of the national and sub-regional obligations to international treaties and agreements, such as the three United Nations Conventions mentioned above.
- Collaborative action between all the stakeholders also encourages the investigation of alternative livelihood strategies to relieve the pressure of living from the land alone. Such alternative livelihood practices in drylands include aspects such as ecotourism, bird and game watching, identification of scarce fauna and flora that are adapted to harsh environments, alien plant invasions, biodiversity conservation, arts and crafts, cultural

activities, etc. This emphasises the collaboration between the School of Business Management and especially the Institute for Tourism and Leisure studies at the NWU.

- As the NWU provide a good scientific background and help in the implementation and adoption of restoration practices, as well as better SLM practices, research projects are carried out in the monitoring and evaluation of land degradation to get a better understanding of the ecosystem processes that lead to degradation, and to develop ecologically and economically sound management strategies that are sustainable in the long term. Projects that address these strategies will not only increase the production potential of the degraded land for better grazing capacities and livestock keeping, but will also improve the livelihoods of the people living off the land in already poverty stricken areas.
- Research projects are, however, not only carried out in the natural environment, but also include laboratory and greenhouse experiments at the NWU in Potchefstroom. This provides the students with the opportunity to do basic laboratory work, as well as applied research in the natural environment.
- Although land degradation and desertification are mostly studied by the terrestrial plant ecologists at the North-West University, zoologists, microbiologists, air and water ecologists should be involved in the projects. It is applauded that more emphasis is currently placed on the training of soil scientists, as this subject forms an integral part of land degradation and the conservation of our natural resources. The return of research and training regarding soil sciences to the School of Environmental Sciences and Development, will have a great positive impact on the outputs in our school and will not only be of benefit to terrestrial ecologists, but to all research and development actions at the NWU.
- It must be emphasised that research projects regarding land degradation, desertification and restoration ecology have to be carried out over longer periods and over more than one year or season, especially if experiments are done in the natural environment, which is influenced by climatic variations. This means that scientifically sound data and results that can be published in international scientific journals are often only expected after long-term monitoring and data analysis.
- One of the main aims of this terrestrial land research group is to improve the networking between different institutions that will break down departmental and institutional (including academic) barriers between research and development at the decision making and policy levels.

8. Conclusion

The single greatest challenge facing the human population is the management of the natural resources in a manner that will prove to be sustainable in a rapidly changing global environment (Oettle, 2006). Land degradation, desertification, restoration and sustainable land management (SLM) means local action and addressing the needs and challenges of global responsibility.

The vision and challenge of strategies, such as defined by the UNCCD, are to forge national, regional and global partnerships to support poverty reduction and environmental sustainability in an integrated manner.

Therefore, securing the productivity of drylands, restoring degraded land and enhancing better land tenure regimes, are indispensable steps the world must take in the fight to prevent future structural food crises and to enhance our resilience to matters such as carbon sequestration in soils and vegetation and the impacts of climate change. It will be important to improve the conceptual thinking of ecosystem degradation and restoration, with a view to develop an integrated approach that may lead to a better understanding of the causes of land degradation and in particular the restoration measures that have to be applied. A better understanding of the underlying processes of degradation, both bio-physical and socio-economic, will allow the successful implementation of effective technologies that will fulfil the specific needs and demands of the land user, manager and community as a whole. Restoration ecology will be most successful when it is based on available scientifically sound knowledge, good communication and the inclusion of all stakeholders that strive towards sustainable results.

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