Thesis

# Selection and Assessment of Environmental Indicators for an Operational Environmental Monitoring System in Namibia



Licentiate thesis

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**Abstract**

Research presented in this thesis undertook to 1) identify and assess criteria for selection and evaluation of indicators 2) develop a national land degradation monitoring system and 3) assess outputs from national monitoring in close co-operation with local land users. In paper I an analysis of State of the Environment indicators developed for Namibia is presented. The study concluded that a set of well-defined criteria is required to identify, evaluate and select useful indicators. Five core criteria were defined 1) scientific relevance, 2) data accessibility, 3) accessibility of historical data and time series 4) sensitivity and accuracy, and 5) threshold values. In Paper II, the process of developing and implementing a national land degradation monitoring system was presented. A participatory approach based on recommendations from Paper I resulted in identification and selection of four indicators; 1) population pressure, 2) livestock pressure, 3) rainfall variability and 4) soil erosion hazard. Annual land degradation risk maps were calculated by combining these four indicators. Quasi-assessments of accuracy of these indicators are presented in papers II and III. A comparison of results from national level monitoring and local farmer's perceptions was carried out in the Ombuga grasslands, northern Namibia (paper III). The results show some correspondence between national assessments and local conditions. However, it was concluded that a more detailed investigation of farmers perceptions of the state of their local environment and an extensive field based survey of actual land degradation in the Ombuga grasslands is the next step to further evaluate results from national level monitoring and interviews presented here.

## Foreword

Shortly after signing the UN Convention to Combat Desertification in 1994, Namibia initiated its Programme to Combat Desertification (Napcod) (Bethune & Pallett, 2002). The Napcod programme constitutes Namibia's national action plan (NAP) - thus fulfilling convention requirements. Napcod is jointly administered by two government ministries, the Ministry of Environment and Tourism (MET) and the Ministry of Agriculture, Water and Rural Development (MAWRD). A unique feature of Napcod is that government and NGO's jointly implement activities within the project. Presently two NGOs are involved in Napcod, the Desert Research Foundation of Namibia (DFRN) and Namibia Economic Policy Research Unit (Nepru) (Bethune & Pallett, 2002).

One starting point for this thesis is that the author was, between 1999 and 2002, involved in development of Napcod's national level land degradation monitoring system. He led the process of developing, selecting and testing indicators as well as being responsible for implementing an operational GIS based system for land degradation assessment in Namibia. Another starting point is that the output and use of strategic monitoring systems, whether indicator based or not, need to be critically examined in the light of scientific uncertainty, see e.g. (Funtowicz & Ravetz, 1990; Funtowicz & Ravetz, 1994; Funtowicz et al., 2000).

The Licentiate thesis is based on three publications:

I/ Klintenberg, P. 2001: Analysis of the development of indicators in State of the Environment Reports (SoER) for Namibia compiled between 1998-2000. Pages 21-22 and Appendix (34pp.) *in* Nakanuku, L., Iinana, E., Zeidler, J. and Katjiua, M., editors. Environmental Monitoring and Indicators Network (EMIN) for Namibia's state of the environment reporting. Gamsberg Macmillan, Midgard, Namibia.

II/ Klintenberg, P., and Seely, M.K., 2003. Land Degradation Monitoring in Namibia: A First Approximation. *Environmental Monitoring and Assessment.* **In press**.

III/ Klintenberg, P., Seely, M. K. and Christiansson, C. 2003: Local and national perceptions of land degradation in the Ombuga grasslands, northern Namibia. *Journal of Arid Environments* **Submitted**.

## Introduction

Defining desertification and land degradation

This thesis frequently refers to the terms desertification and land degradation; these terms are defined in this text as follows. Land degradation and desertification are commonly perceived to be major threats to ecosystems and livelihoods in semi-arid and arid parts of the world. While some researchers state that the problem of desertification is universal (UN, 1992; Cardy, 1993; Kassas, 1995), others question the assumptions, methodologies, evidence and scale upon which these statements are based e.g. (Binns, 1990; Hellden, 1991; Olsson, 1993; Agnew & Warren, 1996; Swift, 1996; Sullivan, 2000). Swift (1996) even states that desertification has less to do with science than with competing claims of different political and bureaucratic constituencies. Some disagreement is likely to arise from the fact that several different processes and pathways can bring about degradation and desertification. This complexity of the concept has led to the term desertification often being used as a heading under which a wide range of degradation processes are organised, e.g. soil erosion, soil nutrient depletion, deforestation, and disappearance of useful species (Rasmussen et al., 2001). The resulting conflicts and confusions have produced constantly shifting sets of definitions, ranging from definitions that exclude climatic deterioration and emphasise mismanagement, and those that put emphasis the other way around (Agnew & Warren, 1996). A vast number of definitions of desertification has been proposed since the early 1950s, when the word was introduced (Glantz & Orlovsky, 1983; Verstraete, 1986; Dodd, 1994; Mainguet, 1994; Swift, 1996). Aubreville introduced the term desertification in 1949. As a forest expert he observed replacement of tropical and sub-tropical forests in Africa by savannahs. He used the term desertification to describe conditions where extreme cases of deforestation took place, characterised by severe erosion, changed soil properties and invasion of xeric plant species (Verstraete, 1986).

The UN definition of desertification states that desertification is land degradation in arid, semi-arid and dry sub-humid conditions, caused by various factors, including climatic variations and human activities (UN, 1992).
Napcod defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas, resulting mainly from negative human impacts combined with difficult climatic and environmental conditions" (Napcod, 1997). The difference between these two definitions lies with Napcod putting a stronger emphasis on the human component causing desertification, e.g. caused by non-adaptive land management in a highly variable climate. It should be noted that none of these definitions consider any temporal aspects of degradation, i.e. they neglect to address whether land degradation is irreversible or resilient in a human perspective. According to (Rasmussen et al., 2001), the UN (and Napcod) definition of desertification is virtually devoid of meaning and content, unless 'land degradation' is properly defined.

(Swift, 1996) defined dryland degradation as "a persistent decrease in the productivity of vegetation and soils, brought about largely by inappropriate land use leading to physical changes in soil and vegetation structure, irrespective of levels of rainfall or soil moisture". Swift omits the influence of climate completely, but adds a temporal dimension by saying that a decrease in productivity has to be persistent, i.e. conditions of decreased productivity prevail for a long or longer than usual time or continuously. In other words, normal variability, e.g. in rainfall, leading to a short-term decrease in productivity is not defined as dryland degradation. By omitting climate from the equation it is not clear if Swift supports the consideration that prolonged drought can lead to or accelerate land degradation processes if land management is not adapted accordingly.

According to the definitions given above, the difference between land degradation and desertification seems to be the duration and/or irreversibility and the severity of decreased productivity. According to (Binns, 1990) "(land) degradation is a change that is reversible with good weather and a little time", while he associates desertification with irreversible change. (Mainguet, 1994) states that desertification is the ultimate step of land degradation, leading to irreversibly sterile land.

In this thesis the definition of desertification given by Napcod is used, but adding the fact that it represents land degradation so severe that it is irreversible in human terms, i.e. "good weather" will not improve the state of the environment. Land degradation is defined based on Swift's definition, i.e. "a persistent change in productivity of vegetation and soils, brought about largely by inappropriate land use leading to physical changes in soil and vegetation structure", but adding the potential negative influence of prolonged drought in combination with non-adaptive land management on the rate of land degradation.

<u>The controversy of extent and rate of dryland degradation and desertification</u>

The concept of desertification became headline news in the early 1970s, due to a major drought in the Sahelian and Sudanic ecological zones (Swift, 1996). Two researchers, Hugh Lamprey and Fouad N. Ibrahim, carried out research during the 1970s, which had a major impact on forming an international consensus about the extent and rate of desertification. After three weeks of fieldwork and examination of aerial photographs in 1975, Lamprey stated that the desert boundary of Sahara had moved south by 90-110 km since 1958 (Lamprey, 1975) in (Swift, 1996). Based on research in Sudan, Ibrahim concluded "in the past fifty years, Sahara alone has taken over 650,000 square kilometres through desertification of the Sahel". Ibrahim continues by stating that man is the real cause of this desertification (Ibrahim, 1984) in (Swift, 1996). The conclusions of Lamprey's and Ibrahim's research formed the basis for explanation of desertification in the late 1970s and early 1980s. The problem was seen to be mainly the result of populations exceeding the capacity of the land supporting them, and inappropriate land use. Lamprey's estimates of the Sahara desert moving south with a rate of 6 km per annum became the basis for desert movement along the whole southern Sahara edge (Swift, 1996). Lamprey's study also produced the common perception of a southward advancing Sahara desert, i.e. desertification being equal to galloping sand dunes leading to a rapid expansion of deserts. This view has been contested and shown to be wrong by various authors cf. (Hellden, 1991; Scoones, 1995; Swift, 1996; Ward et al., 1998; Rasmussen et al., 2001; Warren, 2002), but pictures of fields and houses covered by encroaching sand dunes still persist in public memory.

Based on a questionnaire UN Environmental Programme (UNEP) sent to 91 countries thought to be affected by desertification 1984, it was concluded that "desertification threatens 35 % of the earth's land surface and 20 % of its population; 75 % of the threatened area and 60 % of the threatened population are already affected through deterioration of the environment". Further, it was stated that annually 6 million ha of land are `dd a`ad to desert-like conditions (UNEP, 1984). These figures given by UNEP became the received wisdom of desertification. The UNEP view was uncritically accepted as a key example of the severity of desertification by public policy makers and was frequently used in popular reports. However, many dryland researchers never accepted the results of the UNEP survey, questioning reliability of the data and the analysis (Swift, 1996). One major reason for the UNEP view to be so persistent is that very little good field research was carried out during the 1970s and 1980s on dryland degradation, and a small number of works( a$a. the research by Lamprey and Ibrahim outlined above, were repeatedly cited. A major flaw of these studies was that dry years often were compared to wetter years, and interpreted as a decline in productivity, instead of an effect of natural rainfall variability (Verstraete, 1986; Swift, 1996).

Another factor that has contributed to confusion about the extent and rate of land degradation and desertification is the limited number of studies linking scientific investigations with local knowledge (Leach & Mearns, 1996; Swift, 1996; Sullivan, 2000). Several authors have drawn attention to the importance of local knowledge and perceptions for improved understanding of often complex systems in arid environments (Swift, 1996; Norton et al., 1998; Verlinden & Dayot, 2000; Rasmussen et al., 2001; Gray & Morant, 2003; Osbahr & Allan, 2003).

Two different schools of thought

From the debate about interpretations of desertification a disagreement around the ecological dynamics and appropriate management of semi-arid rangelands has developed (Sandford, 1983; Ellis & Swift, 1988). This debate led to a challenge of received wisdoms of range management and pastoral development in dryland Africa, resulting in a critical scrutiny of the use of terms and concepts such as 'vegetation succession', carrying capacity' and 'land degradation' (Scoones, 1995). Traditional rangeland science was and still is based on the assumption that rangeland systems are responding to equilibrium dynamics. The theory of equilibrium dynamics has its roots in the Clementian school of plant ecology (Clement, 1916), based on ideas of succession and a climax state of vegetation. The equilibrium model emphasises the importance of biotic feedbacks between herbivores and their resource and with each other. Since the late 70s there has been an increasing recognition in ecology outside rangeland systems that equilibrium dynamics are difficult or impossible to demonstrate conclusively in many ecological systems (Wiens, 1977; DeAngelis & Waterhouse, 1987). There are also several examples of rangeland systems assumed to have been degraded showing a dramatic resilience, recovering as soon as rainfall conditions improve (Hellden, 1991; Olsson, 1993; Agnew & Warren, 1996; Swift, 1996). This contradicts the importance given to livestock as the main controller of rangeland condition, i.e. overgrazing leading to degradation via undesirable vegetation change and loss of cover (Heady & Child, 1994; Tainton, 1999). Limitations of the equilibrium model led to development of a new paradigm, describing non-equilibrium systems (Behnke & Scoones, 1993; Scoones, 1995). Non-equilibrium rangeland systems are thought to be driven primarily by stochastic abiotic factors, e.g. highly variable rainfall, characteristic of semi-arid and arid environments, which results in highly variable and unpredictable primary production (Westoby et al., 1989; Behnke & Scoones, 1993; Scoones, 1995). According to this thinking, risks of environmental degradation in non-equilibrium systems are limited, as livestock populations rarely reach levels likely to cause irreversible damage (Ellis & Swift, 1988; Behnke & Scoones, 1993).

The fundamental difference between predictions of the two models is that the equilibrium model sees drought as focusing the effects of herbivory (Illius & O'Connor, 1999), whereas the non-equilibrium model sees drought as relieving the pressure of high stocking densities, by making grazeable vegetation unavailable (Sullivan & Rohde, 2002), and by inducing livestock mortality, which reduces grazing pressure (Ellis & Swift, 1988; Behnke & Scoones, 1993).

Indicators and state of the environment monitoring

The previous sections showed that there is no consensus towards the extent or rate of dryland degradation or desertification. As was stated above, some disagreement is likely to be owing to the fact that several different processes and pathways can bring about degradation and desertification. Further, two different schools of thought, regarding ecological dynamics and how semi-arid and arid environments are best managed, co-exist. The old model assumes that arid and semi-arid environments follow equilibrium dynamics, while the opposing model assumes that these environments follow non-equilibrium dynamics. In terms of environmental monitoring, the challenge is to develop monitoring systems that, based on the vague definitions of dryland degradation and desertification and implications of the two contrasting ecological models, can provide us with the required information about the state of the environment and that can detect changes over time.

Much of the discussions to follow are about monitoring states and changes in environmental conditions. Here the natural environment is defined as the complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival (Merriam-Webster, 2003). The social environment is here defined as the environment developed by humans as contrasted with the natural environment; society as a whole, especially in its relation to the individual. The state of the environment is then a measure of the present state of physical, chemical and biotic factors, i.e. natural environment. It is also a measure of the present state of organisms and ecological communities depending on these factors for their survival, i.e. social environment. Ideally monitoring the state of the environmental should incorporate both natural and social environments. However, on national level, monitoring of natural environments tends to dominate reporting.

In 1992 the United Nation's Conference on Environment and Development (UNCED) approved Agenda 21 as an international action plan for sustainable development (CIESIN, 2001). Chapter 40 of Agenda 21 calls for improved environmental information as a prerequisite for reporting on progress toward sustainability. Further, it was recommended that each nation develop environmental indicators and environmental monitoring systems to strengthen decision-making. GRID-Arendal in Norway, being part of UNEP, has taken the lead in developing a common framework for national state of the environment reports (Denisov et al., 1998). In response to the lack of information about extent and rate of desertification on national, regional and continental levels, UN recommends that countries involved in UNCCD develop indicator based monitoring and geographic information systems (GIS) for development of policy and National Action Plans (NAPs) (UN, 1994).

There are several methods to evaluate the state of the environment, e.g. direct observations and measurements, mathematical models and parametric equations, remote sensing techniques, and application of indicators. The use of indicators has the advantage of providing simplified, synthetic information on the state and tendency of complex processes. Further, indicators can be easily communicated to the public and policy-makers (Rubio & Bochet, 1998). In response to decision-makers increasing needs for information about environmental conditions on global, regional, national and local levels, the development and use of indicators for environmental monitoring has become a common approach (Bockstaller & Girardin, 2003). Indicators, as a measure of environmental health, should ideally determine the present state of the environment and be able to timely identify changes in measured environmental conditions (Rubio & Bochet, 1998). Indicators must be developed to precisely and unambiguously represent quantifiable properties, symptoms or parameters of a phenomenon relating to a feature of the environment or of society (Mendizabal, 1998).

There are many ambiguities and contradictions regarding the general concept of indicators. Some clarity and consensus is required about the definition of what an indicator is, as well as in the definition of related concepts such as threshold, index, target and standard (Gallopin, 1997). There is currently a variety of different definitions of indicators e.g. "An indicator is a measure that summarizes information relevant to a particular phenomenon, or a reasonable proxy for such a measure" (McQueen & Noak, 1988) and "…a parameter, or a value derived from parameters, which provides information about the state of an environment with a significance extending beyond that directly associated with a parameter value" (OECD, 1993). This means that the indicator not only provides us with a value, but also explains the significance of that value in relation to what is being monitored, e.g. state of the environment or risk of land degradation. A review done by (Gallopin, 1997) concluded that due to the diverse meanings assigned to the concept of indictors there is a need to develop a unified, generic and rigorous definition of indicators. Indicators should, according to Gallopin: assess conditions and trends; be comparable across places and situations; assess conditions and trends in relation to goals and targets (threshold values), provide early warning information and anticipate future conditions and trends. A resent e-mail conference arranged by the Land Degradation Assessment in Drylands (LADA) project concluded that important criteria for selection of land degradation indicators were indicators' causal relationships with land degradation, their availability, and their user-friendliness. Further, the importance of data accessibility and quality was also highlighted. A number of participants stated that any national level monitoring system has to be based on existing data, while other participants expressed that the present poor data quality warrants new data collection (Snel et al., 2003).

Need for a more rigorous definition of indicators became apparent after the World Summit in Rio 1992, when the UN Conference on Environment and Development (UNCED) adopted Agenda 21, which led to a large number of countries initiating preparation of national, indicator-based state of environment reports.

**Aim**

This thesis aims to:

A) Identify and assess criteria for selection and evaluation of indicators for a land degradation monitoring system with national coverage, based on data readily accessible in Namibia as an example of a developing country.

B) Develop and deploy an operational national level land degradation monitoring system

C) To quasi-validate the output of the monitoring system, in a participatory manner based on the opinion of the actual land-users/stake holders i.e. by an "extended peer review" cf: (Funtowicz & Ravetz, 1994; Funtowicz et al., 2000).

## Geographic setting

The research presented in this thesis was carried out at two different levels. Namibian state of the environment indicators and Napcod's national level land degradation monitoring system both have a national scope, while investigations of land degradation and evaluation of national results were done on a local level. In order to give the reader an overview of Namibia and the main local study area Onkani, a brief outline of the geographic settings is given below.

### Namibia

Namibia covers an area of approximately 825 000 $km^2$ (Fig. 1). Much of Namibia consists of a wide, rather flat plateau that continues north, south and east into neighbouring countries. The height of the plateau is about 900 to 1300 m above sea level. There is a great variation in altitude to the west and south, where the escarpment rises from the coast (Mendelsohn et al., 2002). Rainfall is highly seasonal in Namibia, with very well marked dry and wet seasons. In general the dry season extends from April/May to September/October, and the wet season over the rest of the year (Olszewski & Moorsom, 1995). The seasonality (summer rainfall) is consistent throughout much of Namibia but the actual amounts of rainfall received vary widely (Fig. 2). The exceptions to summer rainfall are in the very south west, experiencing winter rainfall, and the coastal areas where the wet season hardly exists (Hutchinson, 1995).Rainfall is naturally low with high inter-annual and intra-seasonal variability (Seely, 1978; Marsh & Seely, 1992). Temperature also shows a marked seasonality with the highest temperatures occurring just before the wet season in wetter areas and during the rain season in drier areas. Lowest temperatures occur in the dry season months of June, July and August (Hutchinson, 1995).

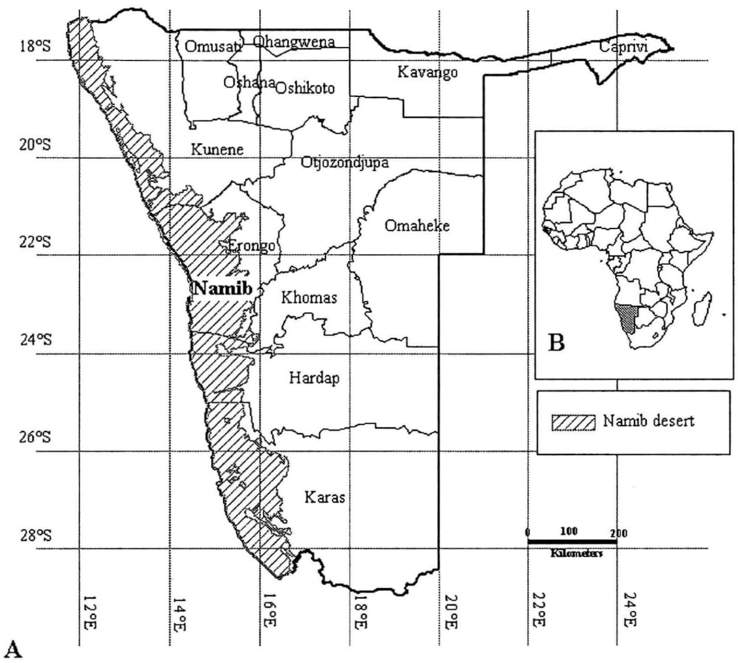


**Figure 1.** The map shows the 13 regions of Namibia and location of the Namib Desert. Regional boundaries from the National Remote Sensing Centre (MET) and boundary of the Namib from the Agro-ecological zoning program (MAWRD).

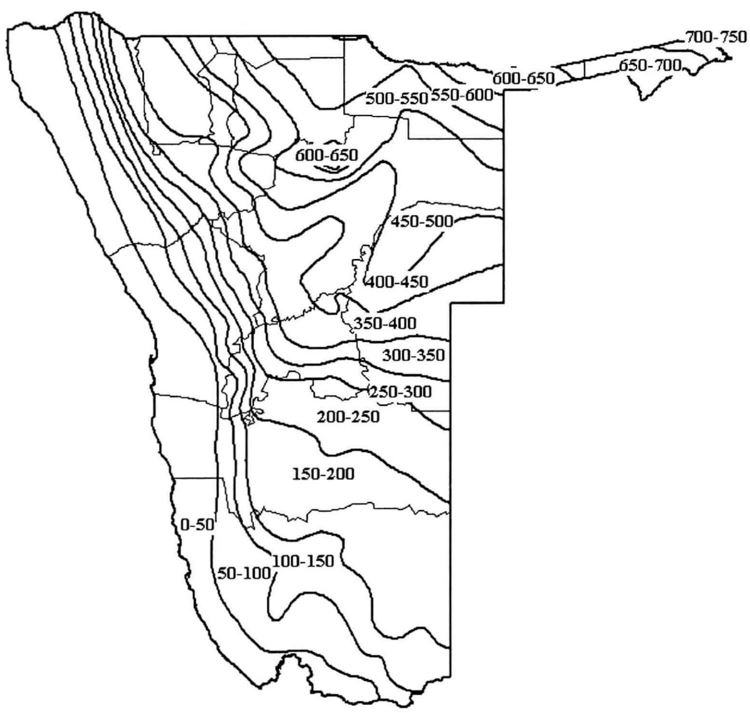


**Figure 2**. Annual mean rainfall. Interpolation of isohyets based on approximately 250 rainfall stations in Namibia

Most soils in Namibia are unsuitable for crop growth. The most fertile soils are cambisols and calcisols, however not rating high on a world scale of soil potential. In the south Kalahari deep sands dominate, north-central Namibia is characterised by clayey and salty soils, and in rocky areas, e.g. the escarpment, shallow, mica-rich soils are found (Mendelsohn et al., 2002). Vegetation in Namibia is strongly influenced by rainfall. Most vegetation in the country consists of shrubland. Dwarf shrubs dominate areas in the southwest and at the eastern edge of the central Namib sand sea. Much of the Namib sand sea is characterised by a combination of dwarf shrubs in the dune valleys and gravel plains and grasses on the dunes. More and more trees replace shrubs from south to north in the eastern zone of the Kalahari sands, first as Kalahari shrubland, then as shrubland-woodland mosaic and, finally, as woodland in northern Namibia. The centre of the country has a moderate to dense cover of shrubs and small trees, particularly acacias (Mendelsohn et al., 2002).

The total population in Namibia is about 1.8 million, of which approximately 50% are settled in the central northern regions (NPC, 2002), which comprise only 18% of Namibia's land surface. As a result of population growth and expanding human settlement during the past century, natural resources of central northern Namibia are presently under high pressure (Quan et al., 1994a). In 1994 an estimated 68% of the Namibian population derived at least part of their livelihood from agriculture (Kruger, 2001).

Due to arid conditions, farmers rely predominantly on livestock for their livelihoods. Cattle dominate in central, north-central and north-east where the rainfall is highest, while sheep and goats are preferred in the western and southern parts of the country. Crop production is only possible in the northern parts of Namibia, except at a few locations in the south with irrigation (Balarrin & New, 1996; UNDP, 1996). The more favourable natural conditions in north-central and north-eastern Namibia have led to high human and animal populations in these rural areas. High pressure on land in these areas has had an adverse impact on natural resources, evident through deforestation, overgrazing and depletion of already scarce water resources (Adams et al., 1990; Fuls, 1992; Quan et al., 1994b).

Onkani area (the Ombuga grasslands)

Two of the papers (Paper II and III) refer to a community named Onkani. This is a rural community in Okahao constituency, Omusati region, but it is also the name given to an area including four rural communities in and around the Ombuga grasslands: Uuvudhiya, Lake Oponono and Omapale in Uuvudhiya constituency in Oshana region and Onkani. The area covers about 1,600 km$^2$ and is situated at approximately 1100 m above sea level (Fig. 3).

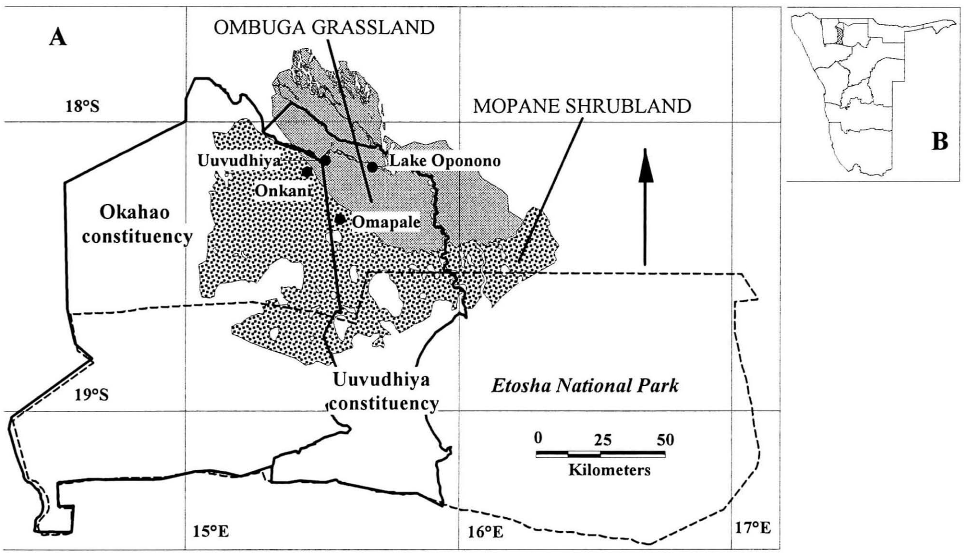


**Figure 3.** Map A shows the location of the Onkani community referred to in paper II and the Ombuga grasslands and surrounding shrubland, the area investigated in paper III. Map B shows the location of Uuvudhiya constituency in Namibia.

The description of the Ombuga grasslands and surrounding shrubland will be brief as an extensive description of both biophysical and socio-economic conditions in the area is given in paper III. The soil is not very fertile, characterised by a high sand fraction (Marsh & Seely, 1992). The area typically has sandy topsoil, about 20 cm thick, underlain by a saline hardpan forming very distinct prismatic structures. The climate is semi-arid and the area receives an average annual precipitation of approximately 350 mm in the southwest and 450 mm in the northeast. Rainfall is patchy and highly variable in time and space.

Two distinct vegetation types occur in the study area, saline Ombuga grassland and mopane shrubland. Perennial grasses dominate undisturbed parts of the grassland as the shallow salty soils prevent growth of woody species (Mendelsohn et al., 2000). The shrubland is dominated by *Colophospermum mopane* Kirk ex Benth., reaching a maximum height of about 2.5 m.

There are no perennial watercourses in the area (Erkkilä, 2001). Due to the flat character of the landscape in central northern Namibia and poor infiltration owing to hardpans, a large number of shallow, ephemeral, poorly defined but interconnected flood channels (oshanas) and pans occur (Christelis & Struckmeier, 2001). During the rain season and early dry season, oshanas serve as fresh water reservoirs providing drinking water for humans and livestock. Later in the season when dried up, they are used for grazing (Marsh & Seely, 1992). Being an inland drainage system, the salt content of soil and water in the Ombuga grasslands tends to increase as salt is continuously added to the system by water flowing into the area and concentrated by evaporation (Marsh & Seely, 1992). A pipeline system was constructed in 1992/93 to supply safe water to within 2.5 km of households in Onkani and Uuvudhiya settlements (Mendelsohn et al., 2000; Christelis & Struckmeier, 2001). The pipeline also extends into the less populated southern parts of the Ombuga grassland and into the shrubland, providing livestock with permanent water supply at evenly spaced water points.

Before the late 1960s the Ombuga grasslands were sparsely populated by San and Ovahimba semi-nomadic pastoralists (Erkkilä, 2001). The first permanent settlements in and around the Ombuga grasslands were established in 1968 (Christelis &

Struckmeier, 2001) centred around hand dug wells. Population numbers were low until the beginning of the 1990s, when a rapid increase led to the present population of approximately 4,400 (NPC, 2002). This rapid population increase coincides with construction of the water pipeline. No information is available about the present population of the four communities Onkani, Uuvudhiya, Omapale and Lake Oponono. According to the national census of 1991 the communities fall within two enumeration areas where a total of 1075 people were living (Central Bureau of Statistics, 1994). The Uuvudhiya and Okahao constituencies are under the communal tenure system, i.e. the land is owned by the Government and is in principle accessible to anyone but with no exclusive rights. The Ombuga grassland is among the rapidly decreasing open access grazing areas in central northern Namibia, which has led to an increased number of cattle from other parts of northern Namibia grazing in the area, and a large number of new cattle posts being established (Low et al., 1997; Denker & Schalken, 1998; Denker & Schalken, 1999)

**Paper I**

In Namibia the process of defining national environmental indicators was initiated in 1998, and has resulted in five sectoral State of the Environment reports, 1) Fresh water resources, 2) Socio-economic environment, 3) Transport, energy, industry and mining, 4) Parks, biodiversity and tourism, and 5) Agriculture and rangeland resources. All together these reports suggested a total of 99 potential environmental indicators (Klintenberg, 2001). The objective of the Namibian state of the environment reporting (SoER) project is to provide pertinent information to policy makers, technicians and the general public on the health and trends in Namibia's environment, and to provide key indicators for an operational long term monitoring of the state of the environment and on environmental policy performance.

An analysis of the 99 indicators was presented in Paper I (Klintenberg, 2001). The aim of the analysis was to determine if the indicators developed actually do provide pertinent information about the health and trends in Namibia's environment. The analysis was based on five criteria, defined as the minimum requirements to be fulfilled by a suitable indicator, i.e. 1) scientific relevance, 2) data accessibility, 3) accessibility of historical data and time series 4) sensitivity and accuracy, and 5) threshold values (Klintenberg, 2001). These criteria were developed by the author based on a wide range of criteria used in the five sectoral reports and others identified in various literature sources, e.g. (OECD, 1993; Denisov et al., 1998; Rubio & Bochet, 1998). It was found that 67% of the indicators fulfilled the criterion of perceived scientific relevance by reflecting what could be argued to represent "current received wisdom", 90% of the indicators had available data and 82% fulfilled the criterion of historic data/time series. Only 33% of the indicators were regarded to be accurate enough to give useful information regarding the state of the environment and even fewer of the indicators, 24%, had defined threshold values. Only 25 of the 99 indicators were considered to be potentially useful for practical environmental monitoring.

**Paper II**

In 1999 Napcod started to develop a monitoring system based on national level indicators for monitoring of land degradation. The aim of the system is to provide information about extent and rate of land degradation as a basis for policy development and strategic decision-making on national level. In Paper II (Klintenberg & Seely, 2003), the process of developing this system is presented together with a time series analysis of results generated by the monitoring system for two communal areas in Namibia.

A process, based on findings and recommendations presented in Paper I, involving representatives from local communities and national experts, led to the definition of four indicators; population pressure, livestock pressure, rainfall variability and soil erosion hazard. Annual land degradation risk maps were generated for the period 1971-1997 by combining these four indicators. A first attempt to evaluate the national level land degradation indicators was presented in Paper II. An analysis of resulting annual land degradation risk maps for the period 1971-1997, generated by the national monitoring system for two rural communities, Onkani in central northern Namibia, and Gibeon in southern Namibia was done (Klintenberg & Seely, 2003). The purpose of this analysis was to identify if there are any trends in the time series and if they correspond to actual local conditions.

The combined land degradation risk maps indicate increased risk of land degradation in both Onkani and Gibeon. The rainfall index shows a decrease in rainfall for both sites over the period considered. According to the population pressure index, the Onkani area has experienced a low population increase from the 1970s to year 1997, while Gibeon shows a much steeper increase. Recent fieldwork in the Onkani area showed that the population has increased more rapidly since 1992 when a fresh water pipeline was installed providing people and livestock with a permanent supply of water (Akawa et al., 2002).

The livestock index shows that livestock numbers in Onkani have increased steadily since 1992 while livestock numbers in Gibeon show a slight decrease over the same period of time. However, it is questionable if it is wise to draw any lengthy conclusions based on these data as livestock data in the northern regions, including Onkani, were only based on estimates until 1998.

These findings indicate that increased land degradation risk in Onkani is mainly caused by increase in livestock pressure and negative rainfall trend. In Gibeon, increase in population pressure and a negative rainfall trend caused the increased land degradation risk there.

The national level results did not contradict local observations made at the two communities. Although other findings indicate a population increase in Onkani, the area still has a very low population density. Based on this analysis it was concluded that in order to evaluate the accuracy of the national level monitoring, and these highly preliminary findings, thorough field evaluations of the state of the environment at local level had to be done.

**Paper III**

In paper II it was shown that the national level monitoring system identifies the Ombuga grasslands in central northern Namibia as experiencing a high risk of land degradation. Paper III presents results from an evaluation of the correspondence between results from national level monitoring and conditions on the ground. The study was based on interviews held with local farmers in the area. The interviews focused on determining farmers' perceptions about the present state of their environment, if they have detected any positive or negative changes in the state of the environment, and if so, had they any ideas about what might have caused these changes.

The findings presented in paper III show that none of the respondents had identified any improvement of the state of the environment, and that changes were generally referred to as land degradation. The interviewed farmers identified an increased rate of land degradation in the study area by using such indicators as grass species composition, rainfall and occurrence of bare ground. Further, they believe the main causes of land degradation to be decreased rainfall and increased number of livestock in the area. This corresponds to results from the national level monitoring system (Paper II). In addition to the verbal responses from interviewees, interviewed farmers drew a state of the environment map (Fig. 4). The map shows that most of the perceived land degradation occurs around permanent water points, confirming one of the main assumptions made for the livestock pressure index developed for the national land degradation risk monitoring system. An analysis of annual rainfall records from four rainfall stations within a radius of 100 km from the area of interest, for the period

1930-2000, shows a decrease in rainfall since the early 1990s, supporting statements made by interviewees. However, it was also shown that the present period of lower rainfall is not unique and that drier periods are part of the normal conditions.

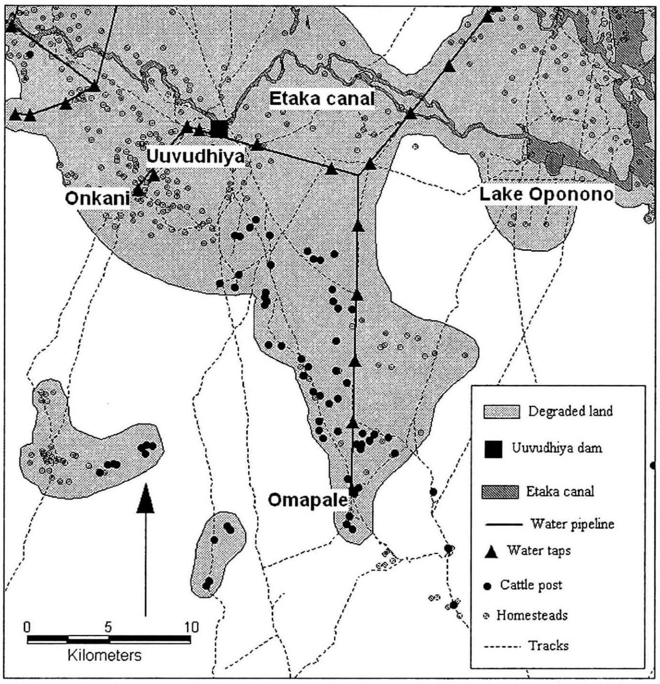


**Figure 4.** The grey areas outline the areas that were identified by the interviewees to be degraded. Source of GIS data: Northern Namibia Environmental Project (NNEP).

A conceptual model was developed based on responses given by the interviewees (Fig. 5). The model indicates that there could be three fundamental factors behind the perceived land degradation: rainfall variability, the introduction of pipelines providing permanent access to water and the slow introduction of regional councils, leaving the traditional authorities with limited control of the resources.

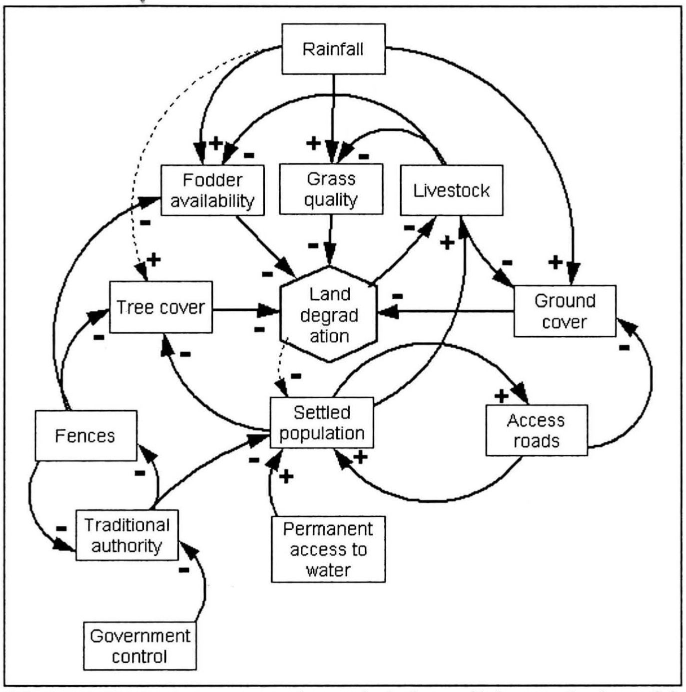


**Figure 5.** A conceptual model describing relationships between manifestations and causes of perceived land degradation in the study area. Thick lines indicate strong relationships between variables, while dashed lines indicate weaker relationships. Variables responding in similar directions are linked with (+) and variables responding in opposite directions are linked with (-).

Some interviewees introduced the concept of reduced resilience, i.e. increased rainfall after a dry period results in grass returning but of both lower quantity and quality than previously, which may imply that land degradation is occurring in the Ombuga grasslands. Still the question of whether long-term degradation, or desertification, occurs in the Ombuga grasslands remains unanswered. A more detailed investigation of farmers' perceptions of the state of their local environment and an extensive field based survey of actual land degradation in the Ombuga grasslands is the next step to further evaluate results from national level monitoring and interviews presented here.

## Discussion

This thesis aimed to identify and assess criteria for selection and evaluation of indicators for a land degradation monitoring system with national coverage, based on data readily accessible in Namibia as an example of a developing country, to develop and deploy an operational national level land degradation monitoring system and to quasi-validate the output of the monitoring system.

The importance of criteria for evaluation of potential indicators was shown in paper I and II. In paper I five criteria were used to evaluate indicators suggested for Namibian state of the environment reporting. It was concluded that even though a lot of fruitful work has been put into developing these reports, the weaknesses presented, e.g. only 25% of suggested indicators considered to be useful for environmental monitoring, have to be overcome before the identified indicators can be implemented. The acceptance of the concept of indicators, as a tool capable of giving the status of complex systems, by Namibia, was one of the positive aspects of the process of developing Namibian SoE reports. Further, the project has resulted in a thorough inventory of accessible data sets, although the qualities of these data sets have to be further evaluated. It was concluded that the number of indicators suggested is too high. In order to make a monitoring system affordable and usable in a developing country the total number of indicators to be included should be decreased from 99 to not more than 30. Even though so few of the suggested indicators fulfilled the criteria it was stated that they should not be disregarded, but rather form the basis for a discussion amongst experts and stakeholders, leading to a refinement and adjustment that hopefully will result in a core set of more useful indicators.

Experiences since Paper I was written has shown that it is difficult, and sometimes even impossible to define threshold values for some indicators, especially if they are aggregates of several variables. Nevertheless, indicators that lack well defined thresholds might still provide useful information, and should therefore not be rejected.

The process of defining land degradation indicators presented in Paper II corresponds to approaches developed and applied in Mediterranean Europe (Rubio & Bochet, 1998; Enne & Zucca, 2000; Brandt et al., 2003). Based on the experiences of developing the Namibian system, it was concluded that a set of criteria should be developed on an international level, to set a globally accepted standard for development of indicators. Further, it was stated that there are no universal desertification indicators as there are no universal causes or effects of desertification. The resent Land Degradation Assessment in Drylands (LADA) project (Oct-Nov 2002) reached the same conclusion, i.e. "...the need to be cautious when interpreting indicators and not to assume a single universal causality relation for a particular indicator." (Warren in (Snel et al., 2003). Instead it was suggested that specific indicators should be developed applicable to a national level. Most countries in the developing world, involved in the UNCCD, are developing progress indicators, i.e. indicators used for monitoring and evaluation of implementation of national action programmes (NAPs). Just a few developing countries have even attempted to quantify extent and rate of desertification or land degradation on a national level, e.g. in South Africa (Hoffman & Todd, 2000) and in Argentina (Viglizzo et al., 2003). The Sahara and Sahel Observatory (OSS) is presently developing a desertification monitoring system to serve countries and sub-regions in northern Africa (Fezzani et al., 2002). The situation is different in Europe, cf. (Enne & Zucca, 2000; Brandt et al., 2003). European Community research into desertification was first initiated in 1989, prioritising desertification in the Mediterranean area. About 55 multi-disciplinary research projects have been supported by the EC from 1991-1998 (Peter & Balabanis, 1998). Desertlinks, established in 2002, is presently developing a desertification indicator system for Mediterranean Europe. The project involves eleven research groups from universities and institutes in Portugal, Spain, Italy, Greece, the Netherlands and the United Kingdom (Brandt et al., 2003; Desertlinks, 2003). However, (Brandt et al., 2003) concluded that there is a lack of quantitative data available to monitor environmental change in Europe, stating that nowhere in Europe are there long-term measurements of indicators comparable to those available in the USA.

In Canada, The Ecological Monitoring and Assessment Network (EMAN) is a national ecological monitoring network composed of approximately 100 sites located throughout Canada. This project has tested and evaluated a wide range of indicators (core monitoring variables) to detect and track ecosystem change at the 100 sites (Tegler et al., 2001). The major difference between the developed world, here represented by Europe and Canada, and the developing world is the institutional resources, e.g. eleven research groups from 6 countries taking part in Desertlinks. A second major difference is financial support. EC supports 55 multi-disciplinary research projects focused on the Mediterranean region, and in Canada, extensive data collection is taking place at over 100 sites. In developing countries, the universities are generally not as resourceful as in Europe. Due to the high costs involved in collecting data with national coverage, and lack of data processing capacity, many countries lack capacity to collect the most basic data, limiting any attempt to do national environmental monitoring. Seen in that perspective the Namibian national monitoring system is unique, being one of very few initiatives towards monitoring land degradation on national level in a developing country, actually providing an assessment of degradation risk.

However, the Napcod national level monitoring system has a number of limitations. Firstly, the indicators developed are based on a large number of assumptions. For instance the population pressure index relies on population figures from only one national census carried out 1991. A constant growth rate of 3.1% per annum was assumed (growth rate 1991), which is an over simplification of the actual situation, as growth rate might be higher or lower in different parts of the country. The livestock index is based on annual livestock counts summarised into 15 state veterinary districts. It was assumed that these animals are located within 10 km from any permanent water source and that they are evenly distributed within these areas. All these assumptions reflect a poor availability of data with high enough resolution. This is also reflected in the fact that annual risk assessment maps have only been produced for the time period 1971-1997 due to lack of data. After 1997 there is not enough rainfall data accessible to calculate the rainfall index. The availability of data from Namibian rainfall stations has decreased drastically since the early 1990s (Fig. 6). It is not clear if the cause of decreased access to rainfall data is due to loss of stations or an enormous backlog in data processing. The number of active rainfall stations decreased from approximately 265 to about 115 just after Independence in 1990. The drastic loss in data accessibility from 1997 onwards is more likely to be related to slow data processing. In other words, over 100 rainfall stations are still producing daily data, but these data have not been processed yet. Whatever the cause, the result is the same; a nationwide rainfall index cannot be calculated after 1997.

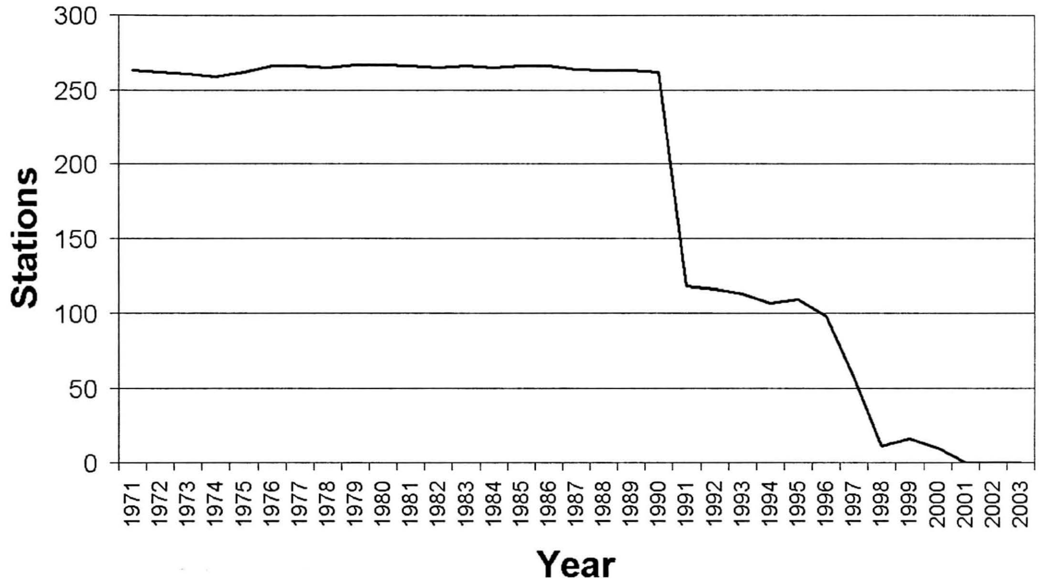


**Figure 6.** The graph shows the number of rainfall stations from 1971 until 2003 for which data is accessible to Napcod.

Another limitation of the national level monitoring system is that it cannot give a value for the actual extent of land degradation in Namibia, but only a risk assessment based on the four indicators, i.e. no direct observations of land degradation are made. According to the requirements of a useful indicator outlined by Gallopin (1997), presented in the introduction of this paper, it can be concluded that the four indicators developed and the combined land degradation risk index fulfil three of these requirements, i.e. assess conditions and trends; be comparable across places and situations; assess conditions and trends in relation to goals and targets (threshold values). However, the system is not able to provide any early warning information due to the backlog in data processing. So far no attempts have been done to predict future conditions and trends.

Even though the process of developing the national level monitoring system was participatory, involving representatives from local communities and national experts, it has become apparent that involvement of local communities was insufficient in the early stages of the programme. If the process of developing a national level monitoring system was started all over again, it would be my recommendation to initially develop indicators on local level, based on local knowledge and information needs. After evaluation and adjustment of these indicators, the second step would be to adapt them for national level monitoring. Recent experiences within Napcod has shown that indicators developed in close co-operation with local natural resource users are far more useful than the set of four very general indicators now being used by the national level monitoring system. The major challenge and limitation to this approach, extrapolating local indicators to national level, would be to gather required data, a common problem in a developing country.

The third aim of this thesis was to quasi-validate the output of the monitoring system. "Quasi" reflects that the validations carried out were not exhaustive but should be seen as preliminary assessments of outputs of the monitoring system and a basis for development of a more rigorous validation methodology. In paper III, the analysis of farmer's perceptions of their local state of the environment in the Ombuga grasslands concluded that interviewed farmers regard land degradation as occurring in the area. Decreasing rainfall and increasing numbers of livestock was said to be main causes. However, results presented are based on a small sample of the populations in the four communities visited, and do therefore only represents the opinions of interviewed farmers. Nevertheless, the consistency in answers between interviewees indicates that results might reflect the actual situation. Further, An independent investigation focused on impact of livestock around permanent water points were conducted in the Onkani area, based on remote sensing and field observations. This study concluded that grazing around permanent water points has had a negative effect on the rangeland, suggesting a negative systematic change in vegetation cover in relation to water points along a 2 km radius. Further, vegetation was shown to gradually decline with 1) vicinity of water points, 2) length of utilisation and, 3) increased grazing intensity (Larsson, 2003).

Seasonally adjusted annual rainfall data (September – August) recorded at four rainfall stations during the period 1930-2000, were analysed in paper III. Results supported statements made by farmers. The validity of these findings might be questioned as they are only based on annual rainfall data. Inter-annual and intra seasonal variability plays a major role in the climate of Namibia, something that might be lost by only analysing annual total rainfall records. Secondly, none of the four rainfall stations is located within the Ombuga grassland, a limiting factor as rainfall in Namibia is extremely localised (Seely, 1978; Sharon, 1981).

## Conclusion

Research presented in this thesis has discussed the importance of criteria for selection and evaluation of environmental indicators. Five core criteria for indicator selection were defined; 1) scientific relevance, 2) data accessibility, 3) accessibility of historical data/time series 4) sensitivity/accuracy, and 5) threshold values. A comparison between developed countries, i.e. Europe and Canada and developing countries, exemplified by Namibia revealed that the criteria of data accessibility and access of historical data/time series are major hurdles in developing countries as institutional and financial resources are limited. Further, it was shown that the criterion of threshold values might, unnecessarily, disqualify potentially useful indicators. However, threshold values are still believed to be essential, e.g. rainfall measurements over time are only meaningful as an indicator when we have some kind of threshold or benchmark value against which to compare these measurements. Therefore, a closer examination of functions and dynamics of thresholds for selected indicators in different environments is an important next step.

The process of developing a national level monitoring system based on four primary indicators was presented and discussed in Paper II. A number of limitations of the Namibian monitoring system were identified and discussed but it was concluded that, given the circumstances of limited institutional and financial capacities characteristic of developing countries, the Namibian national monitoring system is successful as it is one of few national monitoring initiatives associated to UNCCD that actually provides results.

Accuracy of the national system was evaluated by comparing results with independent data and responses given by local farmers in central-northern Namibia. Results showed correspondence between national and local conditions. However, comparisons were only based on information given by a few local farmers and annual rainfall figures. Therefore, a more comprehensive investigation of local farmers perceptions and a survey of the extent of actual land degradation in the study area is the next step to further evaluate results from national level monitoring and interviews presented here.

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