# Historical Consideration of Environmental Dynamics in the Identification of Dryland Degradation in Northern Damaraland

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# Abstract


Dryland degradation is widely viewed as a major environmental issue and in many parts of Namibia is perceived to be significant to severe. In recent years, however, following a world-wide trend, there has been a re-evaluation and questioning of the extent, nature and causes of dryland degradation. Too often it seems pronouncements of degradation are based on limited data and a poor understanding of the context and functioning of dryland ecosystems. The aim of this report, therefore, is to demonstrate why an historical perspective of environmental dynamics is valuable in drylands for the identification of degradation and to evaluate the use of such a perspective using northern Damaraland a case study. In order to achieve this aim, several objectives were addressed, these being:

- to provide a clear and unambiguous definition of the term 'dryland degradation' or 'land degradation'
- to review possible indicators and agents of environmental change and land degradation
- to provide a conceptual framework that emphasises the importance of an historical perspective, and the role of arid rangeland dynamics, in evaluating environmental change
- to analyse environmental dynamics in northern Damaraland from an historical perspective, utilising aerial photography and archival data in the form of stock numbers
- to highlight inherent problems and the utility of an historical perspective

The literature on the topic of degradation is fraught with confusions and contradictions. A clear, unambiguous definition of dryland degradation is necessary, nonetheless, to evaluate the nature of environmental dynamics. In this report, therefore, it was defined as a human-induced irreversible decline in usable primary and secondary productivity. There may, however, be many optimal states in an ecosystem depending on the veiwpoint or aims of particular interested parties, and interpretations of environmental dynamics will differ. Accordingly, degradation was viewed in the context of livestock productivity to avoid confusion. Although degradation may be described as detrimental consequence of people's efforts to use natural resources, the causes are complex and often indirect.

Degradation can be indicated by changes in ecosystem productivity, however, many traditional indicators of degradation may be reinterpreted as natural and reversible traits of a dynamic environment. New ideas have emerged on the functioning of dryland ecosystems as resilient flexible systems that are inherently heterogeneous in both time and space. They are event driven systems where frequent and large fluctuations in productivity occur and vegetation can be more sensitive to rainfall than grazing effects. Productivity reductions may therefore, not be due to human-induced degradation and separating human-induced changes from natural environmental dynamics is difficult. In this respect, an historical perspective may be valuable. Single 'snap shot' assessments will not take into account the full range of variation a system can exhibit. If, however, productivity dynamics are viewed over time, trends and changes in the response time of an ecosystem, or changes in the range of variability that a system exhibits to a smaller range of variation or a lower state can be seen and may be indicative of degradation.

The spatial heterogeneity of drylands is an important consideration in analysis which should encompass the changing objectives of different land uses.

Theoretically, the value of a historical perspective is clear, however, the practical implementation and use may be problematic, and was demonstrated in the case study. Northern Damaraland is an arid, highly heterogenous area with a growing population and there are concerns that widespread dryland degradation is occurring. In an analysis of the environmental dynamics in the study area over time, however, it was not possible to ascertain whether dryland degradation had occurred. The use of a historical perspective was limited by time constraints and data problems. Aerial photography and stock numbers were utilised to investigate environmental dynamics in the area but these data did not cover a long enough time period and their resolution was poor. The spatial resolution of the rainfall record was also insufficient and biased towards the wetter regions of the study area. Stock numbers were, however, highly influenced by rainfall and there was an underlying increasing trend that could be due to the increasing population in the area. No discernible differences were noted on the aerial photographs. The conclusions of the analysis do not exclude the possibility that localised degradation problems exist. The use of longer time series data, of a higher spatial resolution, and the analysis of stock numbers in terms of stocking rates could aid interpretation of environmental dynamics further in the study area.

Identifying dryland degradation is problematic given the nature of dryland ecosystems. It is concluded that although the use of a historical perspective may be limited by available data, such a perspective adds to the knowledge of the environmental dynamics in an area. Long term monitoring rather than short term instantaneous interpretation of degradation indicators is more likely to yield accurate results.

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# List of Abbreviations

| | |
|---|---|
| EEAN | Environmental Evaluation Associates of Namibia |
| GTZ | Deutsche Gesellschaft für Technische Zusammenarbeit |
| km | kilometres |
| LU | large livestock units |
| MET | Ministry of Environment and Tourism |
| NAPCOD | Namibian Programme to Combat Desertification |
| n.d. | no date |
| pers. comm. | personal communication |
| UCT | University of Cape Town |
| UNCED | United Nations Conference on Environment and Development |
| UNCOD | United Nations Conference on Desertification |
| UNEP | United Nations Environmental Programme |

# Preface

# Preface

In Namibia, a significant proportion of both formal and informal economic activity depends on the ecological production and integrity of the environment (National Planning Commission, 1995). Thus, Namibia, as a developing country largely dependent on its own environment and ecological production, has a special imperative to achieve environmentally sound and sustainable land use and economic activities (Namibia's Green Plan, n.d.). Design, planning and implementation of policies, programmes and projects should therefore protect and enhance this sensitive environment (MPhil Baseline Report, 1997).

This is of particular importance in rural and communal areas where communities are vulnerable to the effects of environmental degradation due to their dependence on the natural environment for their livelihood. In many rural areas, boreholes are the sole source of water and form a focal point for settlements and agricultural activities. However, little or no environmental assessment has been undertaken in the planning of borehole provision (Koch, pers. comm. and Tarr, pers. comm.). Boreholes arguably affect a whole range of physical, ecological, social and economic components that interact and determine the nature of the environment and the quality of human life (MPhil Baseline Report, 1997). They have been implicated in processes of desertification and land degradation (Goudie, 1986; Seely and Jacobson, 1994; Jacobson *et al.*, 1995) and concern has been expressed by several government and non-government institutions in Namibia that insufficient knowledge exists regarding the impact of boreholes on the environment (MPhil Baseline Report, 1997).

This lack of knowledge may result in an inadequate assessment of environmental impacts in the planning process for borehole provision. Thus there is a need for focused research into the environmental impact of boreholes so that a scientific basis from which the planning process for emergency water supply and other boreholes may be informed can be established.

Consequently, the Namibian Programme to Combat Desertification (NAPCOD), through the Ministry of Environment and Tourism (MET) in Namibia, commissioned a report from the students of the Environmental Science Masters Course at the Department of Environmental and Geographical Science, University of Cape Town, South Africa. The completion of this project formed part of the academic requirements of the course. In addition, a further academic requirement of the Environmental Science Masters Course is the production of an individual dissertation that develops and extends the findings or an aspect of the project

The initial project report investigated the environmental impacts of emergency water supply in the form of boreholes. The Khorixas region and the Gam area were used as case studies. Boreholes in the Khorixas area were supplied during a drought in 1992/93 and in Gam as part of a resettlement programme. During the progress of this initial project, several issues arose for the author, concerning the identification and nature of the environmental impacts, specifically the ecological impacts, of boreholes. These issues mainly concerned the problem of identifying impacts in the short time period available during the project and whether these could be classed as indicators of degradation or desertification. This has important implications for the assessment of development projects because it is ultimately the explanation and identification of degradation that will provide an effective framework for policy formulation (Blaikie, 1989).

# Chapter 1

# 1. Introduction

## *1.1 Introduction and Problem Statement*

Desertification and land degradation are widely viewed as major environmental issues in scientific, political and even popular circles (Thomas and Middleton, 1994). In many parts of Namibia, desertification is perceived to be significant to severe (MET, 1994). These concerns about desertification have a history since the 1930's. Colonial officials described native reserves as areas that were 'rapidly becoming deserts' and as being 'beyond further redemption' (cited in Werner, 1994). Various scientific reports have also expressed alarm. One describing the former communal area of Damaraland stated that:

> 'abuse of natural resources in the past has aggravated the problems of the livestock industry in the Homeland. Severe deterioration has occurred' (Loxton *et al.*, 1974 cited in Sullivan, 1996a).

More recently it has been stated that land degradation has, and is continuing to take place at an alarming rate in Namibia (Dewdney, 1996).

However, many of the pronouncements of desertification, such as that cited above for Damaraland are being challenged as incorrect (Sullivan, 1996a). This follows a world-wide trend that in recent years has seen a re-evaluation and questioning of many of the issues surrounding desertification and land degradation.

The term desertification has been criticised as too evocative of inaccurate concepts of advancing deserts and that 'dryland degradation' is a better description of the processes involved (Thomas and Middleton, 1994; Dean *et al.*, 1995a). In many cases, the existence of desertification and perceptions and the nature of land degradation have also been questioned (Hoffman and Cowling, 1990; Hellden, 1991; Perkins and Thomas, 1993; Biot *et al.*, 1992 cited in Dahlberg, 1994).

This re-evaluation and questioning of environmental change involves disagreements over what constitutes degradation i.e. over the definition of dryland degradation and the nature of observed environmental changes. New ideas have emerged on the functioning of semi-arid and arid rangelands as resilient flexible systems (Mills, 1995; Behnke *et al.*, 1993). Arid rangelands are inherently heterogenous, both in time and space. Climatic variability is an important characteristic of such regions and a wealth of literature indicates that the productivity of dryland ecosystems is better described by its variability through time and space, than by average values (Westoby *et al.*, 1989). Traditional indicators of degradation can, therefore, often be reinterpreted as natural and reversible traits of a variable environment (Dahlberg, 1994). Too often, it seems, pronouncements of degradation may be based on limited data and poor understanding of the context and functioning of arid systems.

One major weak link in the recognition and study of degradation is the shortage of a temporal perspective. By its very nature, degradation implies change, yet environmental changes are often not looked at within appropriate contexts or time scales. As stated, arid lands are characterised by variability. The time scale of this variability is important to consider in looking for signs of detrimental environmental change. A long term perspective in a variable environment can allow dynamics to be followed to determine if degradation is occurring, can lead to improved interpretation of dynamics where different influencing factors can be identified and isolated, and show the impact of cyclic factors in fluctuations and trends. Thus, land perceived to be in a degraded state might be revealed through historical analysis to be merely in one part of a cycle.

In seeking to identify dryland degradation or desertification, several steps should occur. A clear definition of dryland degradation should be conceptualised, a time scale for investigating change decided upon, environmental dynamics identified and then the nature of this change evaluated in the context of the particular circumstances that prevail in a predefined area.

An evaluation of environmental change from a historical perspective and within an appropriate conceptual framework may lead to a recognition of environmental transformation in many cases rather than the more negative concept of degradation (Beinart, 1996).

## *1.2 Aims and Objectives*

The overall aim of this report is to show why an historical perspective of environmental dynamics is valuable in arid and semi-arid environments for identifying dryland degradation and evaluate the use of such a perspective using the northern Damaraland as a case study.

Several objectives have been identified as important in achieving the stated aim. This report aims to:

- provide a clear and unambiguous definition of the term 'dryland degradation' or 'land degradation'

- review possible indicators and agents of environmental change and land degradation

- provide a conceptual framework that emphasises the importance of an historical perspective and the role of arid rangeland dynamics and time scales in evaluating environmental change

- analyse environmental dynamics in northern Damaraland from an historical perspective utilising aerial photography and archival data in the form of stock numbers

- highlight inherent problems and the utility of an historical perspective

## *1.3 Boundaries of the Case Study Area*

The case study is limited to the Khorixas regional constituency, an area that was formerly the northern part of the 'ethnic' homeland Damaraland. The area is now part of the Kunene Region, which is located along the north-western side of Namibia (Figure 1.1). The region stretches from the Kunene River in the north to the Ugab River in the south, and is bordered by the Atlantic Ocean to the west, the Erongo region to the south, and the Otjozondjupa, Oshikoto, Oshana and Omusuti Regions to the east. The study area itself comprises northern Damaraland which mainly corresponds to the present regional constituency of Khorixas and covers an area of over 15 000km$^2$. The western border of the case study area is formed by the boundary of the Skeleton Coast National Park and the southern border by the Ugab river (Figure 1.2).

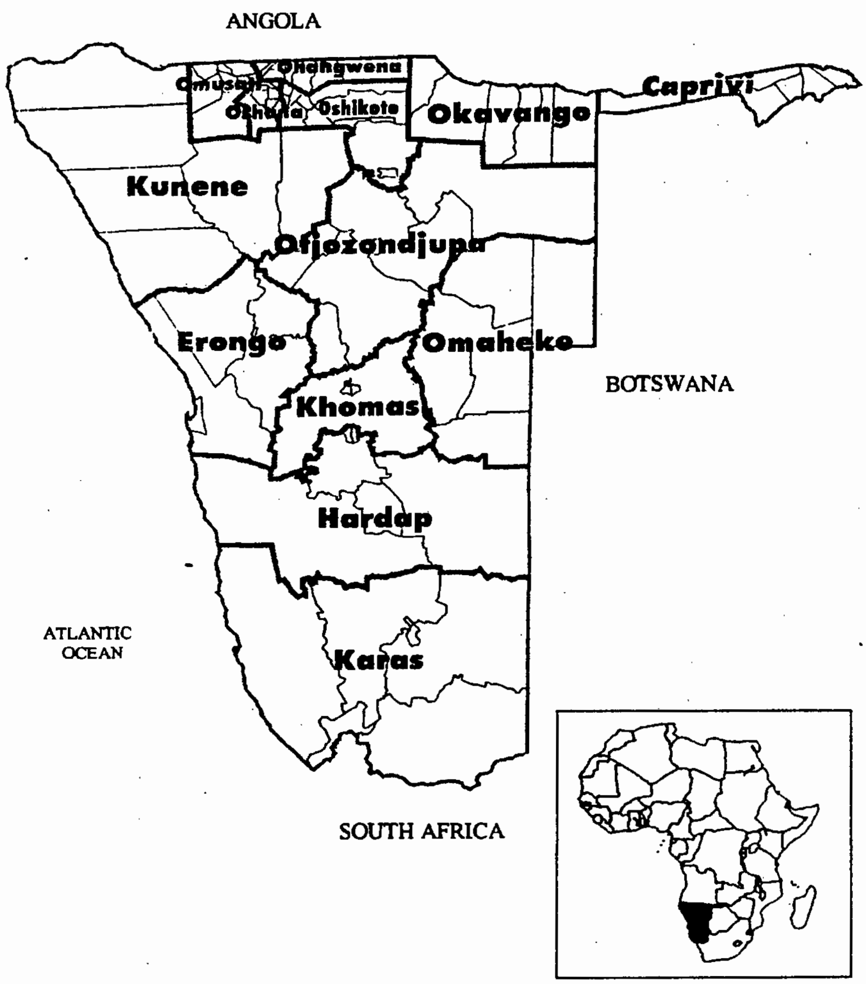



**Figure 1.1.** Location of the Kunene region in Namibia.

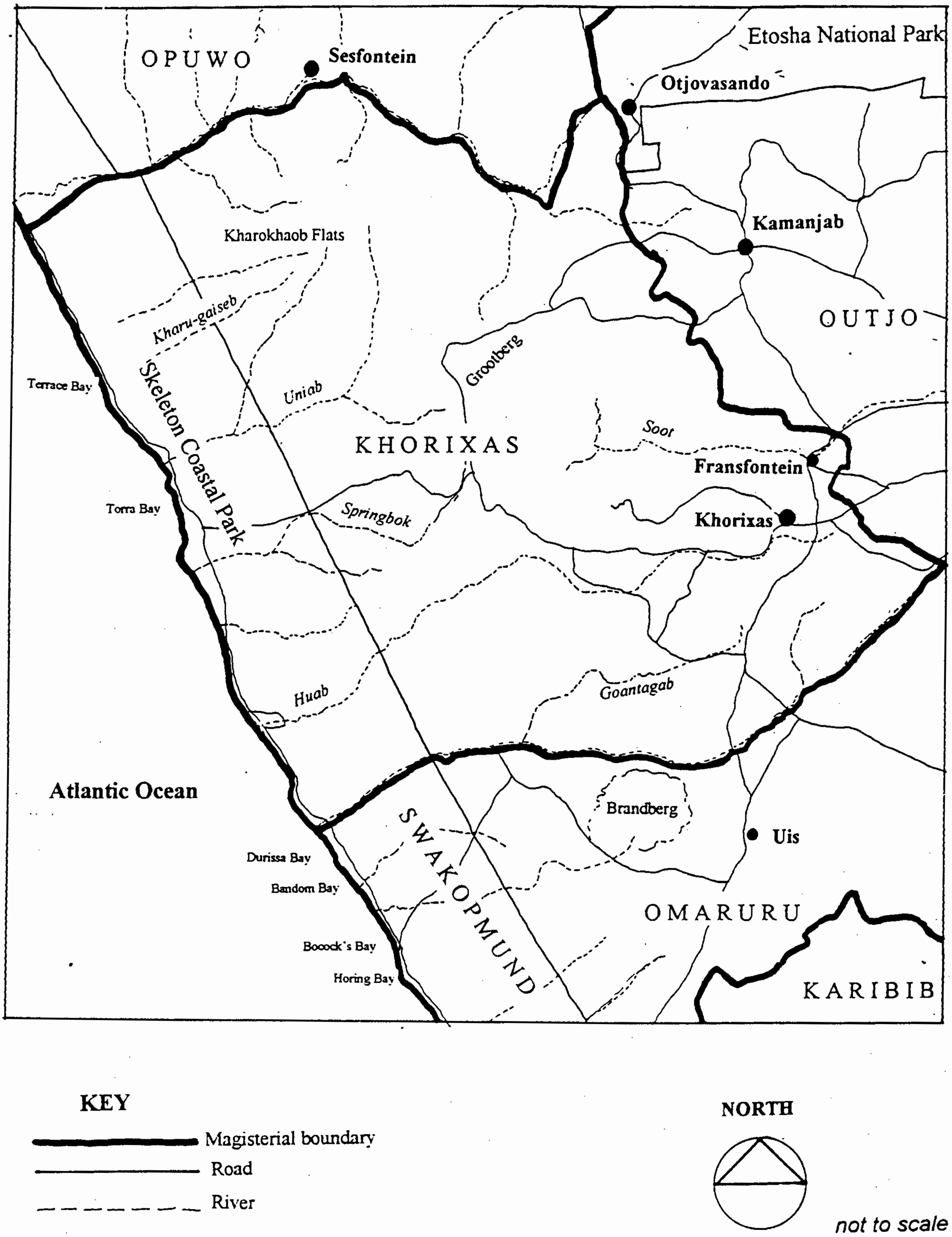



**Figure 1.2.** The Khorixas regional constituency which corresponds to northern Damaraland.

# *1.4 Assumptions and Limitations*

## 1.4.1 Assumptions

Several assumptions were made at the outset and during this study:

- It was assumed that all the literature pertinent to this study reviewed, was complete and correct.
- Dryland degradation was viewed in the context of livestock farming and it was assumed that reductions in stock numbers would reflect degradation in the study area.
- Information gained from the Weather Bureau in Namibia and the Department of Veterinary Services is accurate and reliable

## 1.4.2 Limitations

The limitations of this study are:

- Due to time constraints much archival data that may have been valuable in the case study could not be accessed. This meant that analysis of environmental dynamics in the study area was not as comprehensive as it could have been.
- The spatial resolution of rainfall data was very low and biased towards the wetter regions of the study area. This may have distorted the results of the analysis of stock numbers.
- Inexperience of the author in analysing aerial photographs may have resulted in distortions and inaccuracies in data obtained.

- The historical information utilised in the case study was not extensive enough in time. Aerial photographs were only available up until 1975 and stock numbers were not available for the case study area earlier than 1979. This limited the extent of the temporal analysis that could be done.

- Other limitations encountered in the use of the aerial photographs are discussed further in 5.2.1.

## *1.5 Structure of Report*

This report comprises seven chapters.
Chapter 1 introduces the background and rationale of the report. The aim and objectives are stated, and the boundaries of the case study area and the assumptions and limitations are described. In Chapter 2 a clear definition of the term 'dryland degradation' or 'land degradation' is sought to provide a measure against which to evaluate environmental change. In addition, possible indicators and agents of environmental dynamics in relation to degradation are described. Chapter 3 provides a conceptual framework that looks at the importance of an historical perspective in identifying land degradation. The roles of arid rangeland dynamics, different time scales and spatial factors in such a perspective are discussed. The next two chapters deal with the case study and environmental change in Damaraland is investigated within the conceptual framework provided in the previous chapters.

Chapter 4 provides a description of the biophysical aspects and land use history of the study area as a background within which an analysis of environmental dynamics can be done. In Chapter 5, the methodology used to gather information and analyse data is described and the limitations of the data are diccussed. The results of aerial photographic interpretation and stock rate analysis to identify environmental change are presented and analysed. The use of aerial photography and stock rate analysis are evaluated in the context of northern Damaraland and problems encountered highlighted.

Chapter 6 concludes with a discussion of some pertinent issues on the utility and importance of a historical perspective in identifying land degradation. It concludes by drawing together all the arguments and findings from the various chapters in the report.

# Chapter 2

# 2. Land Degradation - Definitions, Manifestations and Causes

In this chapter, land degradation is defined as a measure against which environmental change can be evaluated. A general review is given of the causes of degradation and possible indicators and agents of environmental change are also discussed. Environmental dynamics are not confined to certain landscapes, however, in the context of this report, only rangelands and the uses associated with them are discussed.

## *2.1 Towards a Definition*

In seeking to evaluate the nature of environmental dynamics, it is necessary to have clear, unambiguous definitions and understanding of the terms desertification and land degradation. The meaning ascribed to these terms will determine the diagnostic criteria used to measure their occurrence (Behnke and Scoones, 1993) and, in addition, influence perceptions of the causes and processes of degradation. Blaikie and Brookfield (1987) see the term land degradation as perceptual, with differing meanings and, therefore, different definitions for different people.

Both the terms desertification and land degradation are used to describe processes of environmental deterioration. Their usage, however, is often unclear and controversial and the literature on this topic is fraught with confusion and contradictions (Thomas and Middleton, 1994). Dahlberg (1994) notes that a review of some of the definitions reveals that differences are more to do with changing perceptions of the relationship between humans and the environment than changing environmental conditions *per se*.

### 2.1.1 Definitions of Desertification

As stated, the term 'desertification' has been criticised as too evocative of the concept of advancing deserts which may be inaccurate and as such that 'dryland degradation' is a better description of the processes involved (Thomas and Middleton, 1994; Dean *et al.*, 1995a). It is, however, a term that is still in general use and one which has undergone many redefinitions (Mainguet, 1994). It thus warrants brief consideration.

In the late twentieth century, with wider recognition of environmental issues and arising from the United Nations Conference (UNCOD) on the topic in 1977, the term desertification has entered into general use (Thomas and Middleton, 1994). The conventional, evocative image of an inexorable advance of the Saharan dunes engulfing farmland is, however, blatantly inaccurate; understanding of desertification has shifted to a more generalised view of progressive land degradation occurring more as a 'sporadic rash' (Verstraete, 1986; Goudie, 1986; Binns, 1990; Dean *et al.*, 1995a). The latest definition of the term by UNEP was adopted after the United Nations Conference on Environment and Development (UNCED) in Rio, 1992 and was agreed on within the context of Agenda 21 as:

> land degradation in arid, semi-arid and dry sub-humid areas resulting from climatic variations and human activities (Toulmin, 1993: 2).

In this definition, the problem of desertification is confined to a specific geographical area of occurrence, the drylands - arid, semi-arid and dry sub-humid areas and is attributable to varying causes. Drylands comprise a complex set of ecosystems in areas with a hydrological limit which may be defined by the 700mm rainfall isohyet (Mainguet, 1994). Another method of delimiting drylands is by using an aridity index, for example the P/PET index used by UNEP, where P is mean annual precipitation and PET is mean annual potential evapotranspiration (Agnew and Anderson, 1992). Drylands, then, are those areas with an aridity index of less than 0.5. In addition, the UNCED definition does not confine the causes solely to anthropogenic factors but includes the possibility that climatic factors may also be causal.

The role of climate in desertification is a contentious issue (Dahlberg, 1994). Drylands are particularly prone to variations in moisture availability (Thomas and Middleton, 1994) and frequently there is confusion over the differences between drought, desertification and desiccation and the role they play in drylands. Definitions of drought and desiccation are provided in Box 1. Desertification should not be used to describe 'normal' processes and states of the environment which result from periods of low rainfall which are integral to dryland climates (Seely, 1991).

**Box 1: Drought and Desiccation**

Drought and desiccation are both distinct from degradation. Both are climate related and are caused by changes in moisture availability.

**Meteorological drought** is a period of 2 or more years where rainfall is substantially below the mean (Warren and Khogali, 1992 cited in Agnew and Warren, 1996). Drylands are susceptible to drought due to very high interannual rainfall variability, frequently in excess of 30% (Thomas and Middleton, 1994).

**Agricultural drought** is a soil moisture deficit during the growing season (Agnew and Anderson, 1992). This measure allows the impact on vegetation productivity to be assessed.

**Desiccation** is the process of longer-term reductions in moisture availability resulting from a dry period on a scale of decades (Thomas and Middleton, 1994).

Both drought and desiccation cannot cause degradation but may result in increased environmental susceptibility to those human actions leading to degradation.

The definition of desertification adopted in Namibia by the Namibia Programme to Combat Desertification (NAPCOD) is slightly, but crucially, different to that of UNEP:

> land degradation in arid, semi-arid and dry sub-humid areas resulting mainly from negative human impacts combined with difficult climatic and environmental conditions (Dewdney, 1996: iii).

Climatic factors are not viewed as a cause of desertification in themselves and rather, a causal interrelationship between climatic, environmental and anthropogenic impacts is emphasised. Desertification is recognised principally as a human problem with human causes i.e. climate predisposes an area to desertification but is not a causal factor in its own right.

Most definitions of desertification embody the concept of land degradation or the loss or reduced productivity of land (Seely and Jacobson, 1994; Thomas and Middleton, 1994). Desertification could, in fact, be argued as merely a special case of land degradation that is confined to certain climatic zones, the drylands. The term dryland degradation is perhaps, a better description of the process.

### 2.1.2 Definitions of Land Degradation

The term land degradation, like that of desertification, has various shades of meaning attached to it. It seems to elude a constantly and universally acceptable definition (Mills, 1995). In its modern usage, degradation refers to decreases in usable primary and secondary productivity or unfavourable changes in species composition (Dodd, 1994; Dean *et al.*, 1995b). Thomas and Middleton (1994) state that degradation implies a reduction in resource potential caused by one or a series of processes acting on the land.

Degradation implies, therefore, an undesirable change in the state of land or rangeland, from productive to unproductive. However, not all processes of environmental change are necessarily processes of land degradation (Biot, 1993). Agnew and Warren (1996) distinguish between environmental problems and environmental changes. They define environmental problems as environmental issues that affect peoples lives and environmental changes as purely physical changes. An environmental change should not, in itself, imply degradation (an environmental problem), land could still be productive and useful i.e. not degraded. One might say that for measured environmental changes to be problems, they must perceived as having an impact on peoples lives.

This view is congruent with that offered by Blaikie and Brookfield (1987), who state that degradation implies social criteria relating land to its actual potential use i.e. degradation is a reduction in the capacity of land to satisfy a particular use. This view is formalised by Abel and Blaikie (1989), who define land degradation in the specific context of rangelands as:

> ...an effectively permanent decline in the rate at which land yields livestock products under a given system of management. "Effectively" means that natural processes will not rehabilitate the land within a time scale relevant to humans, and that capital or labour vested in rehabilitation are not justified...This definition excludes reversible vegetation changes even if these lead to temporary declines in secondary productivity. It includes effectively irreversible changes in both soils and vegetation (Abel and Blaikie, 1989: 113).

Degradation therefore takes into account the utility of resources to the user and invokes an assessment of the capacity of a given management system to maintain those features of the natural environment for its own continued well being (Behnke and Scoones, 1993). Perceptions of degradation will thus vary depending on the management system in place and the aims of the users. For example, conservationists have very different perceptions of what constitutes degraded land as compared to subsistence pastoralists such as those found in the study area. The conservationist may aim to maintain biodiversity of a rangeland, whereas a pastoralist may wish to maximise a rangeland's utility for livestock rearing; a potentially conflicting aim with that of the conservationist if it results in a reduction in biodiversity. There is no attempt in Abel and Blaikie's definition to evaluate which land use system is "best" (Behnke and Scoones, 1993) and it is quite possible there are many optimal states in the system depending on the observers view point (Blaikie, 1997).

An important aspect of land degradation relates is the 'causes'. Biot (1993) states that a distinction between human-induced degradation and natural change is irrelevant from the point of view of the user. Such a distinction is important, however, because it influences the explanations and actions that will occur to combat the problem. Environmental dynamics could be the result of long term readjustments in landscapes due to climatic change (Roberts, 1996). In this case the removal of human land use will not result in processes of environmental change stopping. Degradation will require different interventions from those needed for long term climatic change like desiccation for example (Warren and Khogali, 1992 cited in Dahlberg, 1994).

The role that climate can play should, however, not be disregarded. For example degradation can clearly be worsened by drought (Seely *et al.*, 1994). However, degradation as defined here is that initiated by people through inappropriate land use practices. Thus, herein, an environmental change might be a problem from the point of the user in that it affects peoples lives (Agnew and Warren, 1996), but is not regarded as degradation unless it is human induced.

The reversibility of environmental change is an important consideration in land degradation. Arid and semi-arid environments are event driven systems characterised by fluctuations in primary productivity due to erratic rainfall variations (Sullivan, 1996a). Declines in productivity due to temporary variations in vegetation may therefore be excluded from consideration as degradation, as these changes are usually reversible due to the resilience of vegetation to natural climatic variation. It should be stressed however, that effectively irreversible changes in vegetation can and do occur that are distinct from natural climatically induced change (Westoby *et al.*, 1989). 'Irreversible change' is however too loose a term to include in a definition, as Myers (1988 cited in Dahlberg, 1994) pointed out, that even severely stressed land can revert to a less degraded state, given enough time. 'Enough time' may vary from centuries, or even to thousands of years. A more useful definition thus confines the time of the ability of land to recover to a temporal scale relevant to people. A scale which would be appropriate is that suggested by Driver and Chapman (1996), a 'generational time scale', a basic unit of which is approximately 20 or 30 years.

Abel and Blaikie's definition also refers to natural and human capital or labour failing to rehabilitate degraded land (Abel and Blaikie, 1989). This is a further aspect of reversibility of degradation. Essentially land degradation is about costs to society, which makes use of the land. Indeed definitions may refer to detrimental changes in aspects such as soil, vegetation or species, but it is the costs to society that will result in action.

Based on the above review, in this report the term land degradation or degradation refers to human-induced irreversible reductions in usable primary and secondary productivity.

Degradation is viewed in the context of pastoralists who depend upon the environment in the study area.

## *2.2 Manifestations and Causes of Degradation*

### 2.2.1 Manifestations

Various indicators of degradation have been proposed as valuable in establishing the magnitude of the problem, in identifying impacts of degradation and so that appropriate responses can be taken (Mabbutt, 1986). Degradation manifests itself in observable changes in the biophysical environment. Since degradation involves reductions in usable primary and secondary productivity, indicators are found not only within the biophysical sphere. Productivity losses will have a ripple effect through societies and thus social and economic indicators must also be considered. Many different biophysical indicators of degradation in rangelands have been suggested. These include changes in vegetation, soil and livestock productivity (Table 2.1) (Behnke and Scoones, 1993). Social indicators of degradation include increased poverty and vulnerability, increased conflict over resources, changes in land use, and altered settlement patterns (Mabbutt, 1986; Dahlberg, 1994). Many social indicators are not uniquely related to degradation (Mabbutt, 1986). However, the same can be said of many of the biophysical indicators as will be discussed in Chapter 3.

A more direct indicator of change is livestock production (Behnke and Scoones, 1993). It has been shown that decreases in stocking rates often reflect decreases in secondary productivity of rangelands (Dean and MacDonald, 1994). However, care has to be taken in assessing fluctuations in livestock productivity. For example, measuring declines in meat production is a traditional western standard of productivity (Dahlberg, 1994), but livestock often have other values for pastoralists in Africa, (for example draft power, milk or social status (Scoones, 1995a)) and thus a decline in meat production might not necessarily reflect a change in rangeland productivity. The objectives of the pastoralists or farmers have to be taken into account when measuring reductions in livestock productivity. Another factor to be taken into account in assessing changes in livestock productivity is the influence of external factors other than degradation. Declines may be the result of diseases, changes in land use or shifts in the objectives of farmers. What is important about degradation indicators is that they should viewed within a local context and over a time scale relevant to the ecological functioning of the system (Dahlberg, 1994).

**Table 2.1.** Biophysical indicators of degradation in rangelands (Behnke and Scoones, 1993).

**Soil changes**
- Decreased fertility
- Decreased water holding capacity
- Decreased infiltration
- Soil loss significantly in excess of soil formation

**Vegetation changes**
- Changes in vegetation productivity over time, unrelated to rainfall patterns
- Changes in vegetation cover
- Changes of plant species composition due to the use of animals
- Shifts between vegetation transition states that result in decreased fodder (e.g. severe bush encroachment)

**Livestock production**
- Condition scoring of animals
- Calving rates and death rates (population models)
- Milk yields

## 2.2.2 Causes

The causes of land degradation are complex but can be simply explained as a detrimental consequence of people's efforts to use natural resources (Thomas and Middleton, 1994). There exists, however, a multitude of complex interacting physical processes along with human values and constraints (Johnson and Lewis, 1995).

Although, grazing by domestic livestock is thought to be a major anthropogenic force causing dryland degradation in the arid and semi-arid rangelands of southern Africa (Perkins and Thomas, 1993; Dean and MacDonald, 1994; Mills, 1995), this is only one level of explanation. Explanations related only to land use as a cause ignore questions such as why people cause land degradation. Causes can be interpreted in terms of specific actions and land use practices resulting directly in land degradation or at a structural level where factors that enable, encourage or force these practices to be employed are examined (Thomas and Middleton, 1994). Jacobson and Seely (1994) distinguish these two levels as proximate or direct causes and ultimate or indirect causes. Direct causes relate to inappropriate land use or management strategies and indirect causes relate to political and socio-economic issues such as inappropriate government policies and population growth.

Various models and ways of viewing the complex interrelated causes of degradation have been proposed. Toulmin (1993) envisages causes as a multi-level set of explanations with more immediate cause followed by increasing levels of complexity and removal from the immediate problem. Blaikie (1989) envisages causes in a chain of explanation, which starts at the level of the resource user and ends at a global level. An example of an explanation of some causes of degradation is provided in the form of a conceptual model (Figure 2.1). In the model, the causes are presented at various levels of explanation. Structural causes are at the top leading down to specific land use practices and actions. In addition, some processes of degradation are included such as vegetation destruction. Loss of vegetation cover leads to soil loss or degradation through processes such as trampling. Trampling renders soils more susceptible to wind and water erosion and to desiccation and oxidation. Moreover, persistent over trampling and wind erosion will lead to the reduction and ultimate eradication of the seed bank that sustains the grasses (Seely *et al.,* 1994).

Events such as droughts should not be seen as a cause of degradation. Droughts are a natural part of drylands which these systems can cope with having evolved in conjunction with such disturbances (Seely, 1991; Ellis, 1995). The role of drought in Figure 2.1 is as a factor that can exacerbate degradation already induced by human actions. The role of the complex array of environmental conditions that exist in drylands play, however, in increasing the vulnerability of drylands to degradation should not be ignored (Thomas and Middleton, 1994). For example, climatic change such as desiccation is not in itself a cause of degradation, however it can exacerbate changes already brought about by inappropriate land use (Dahlberg, 1994).

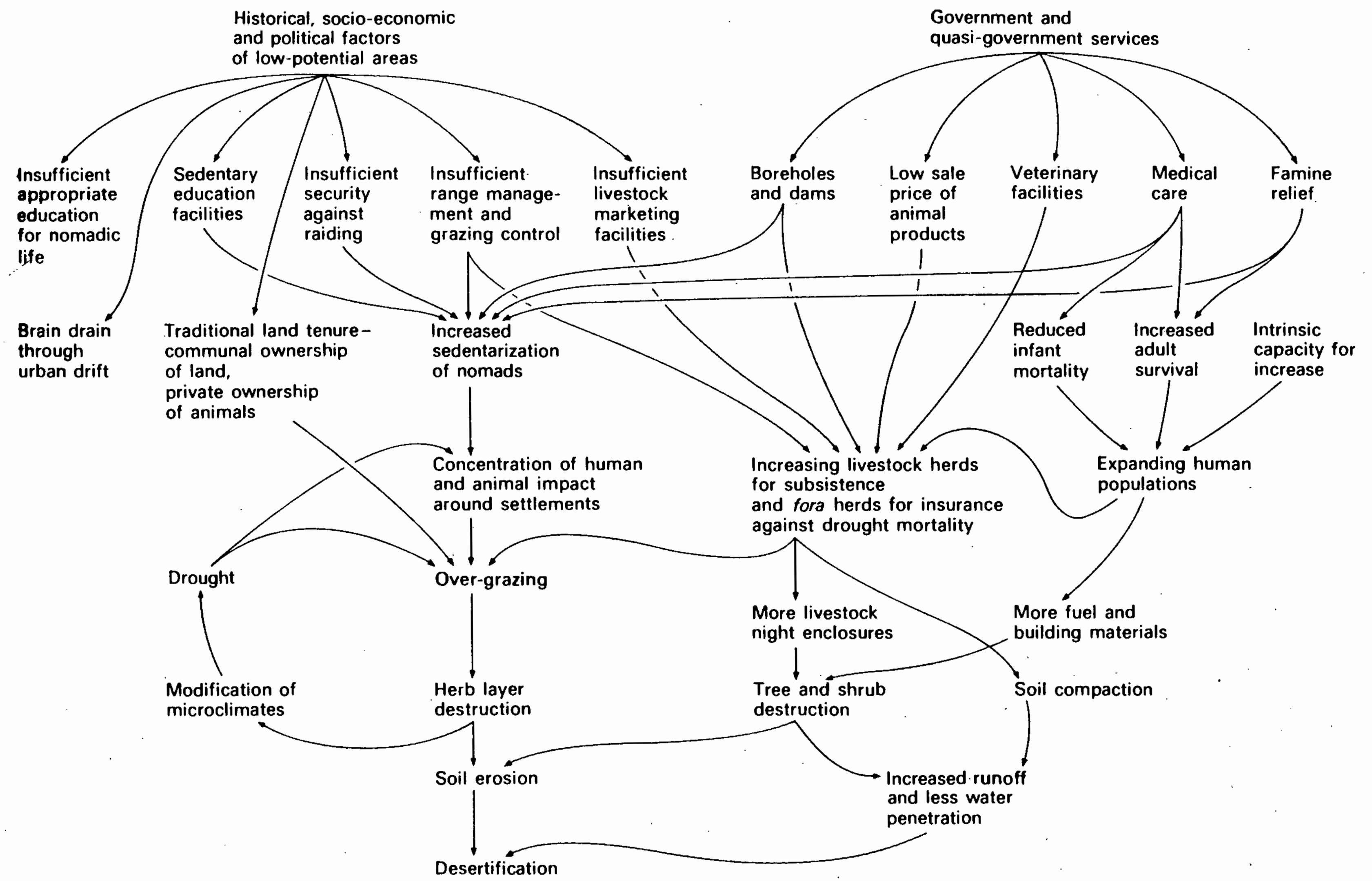



**Figure 2.1.** Some causal factors in dryland degradation (Adapted from Goudie, 1986: 48).

Many of the traditional views of the direct causes of degradation are being challenged. Subsistence pastoralists have, in particular, been blamed for degradation of rangelands. They have been viewed as irrational, holding excessively large herds and flocks which, because land is held in common, results in mismanagement and degradation (Livingstone, 1991; Scoones, 1996). However, considerable problems have been identified on commercial rangelands as well (Thomas and Middleton, 1994). Increasingly, the value and importance of local indigenous knowledge and management practices is being recognised and forces outside local control are now seen as crucial causative agents of degradation (Dahlberg, 1994).

## *2.3 Conclusion*

Degradation has been defined here as a human-induced irreversible reduction in productivity. This requires that, if it is to be identified, the origins or causes of a state of the environment have to be known. However, difficulties exist in separating human influences and from naturally induced environmental changes such those brought about by climatic variability (Johnson and Lewis, 1995). It is thus important that the indicators of environmental dynamics are viewed within an appropriate temporal context given the nature of drylands. The following chapter develops this idea and discusses the importance of a historical perspective in identifying degradation.

# Chapter 3

# 3. Environmental Dynamics, Degradation and Time

Degradation, defined as a human-induced irreversible decline in productivity, implies changes in the nature of the environment. Time is thus a crucial component of degradation implicit in the existence of a 'before' and an 'after'. Yet, in many areas supposedly subject to degradation, assessments are subjective as opposed to being based on long term environmental monitoring (Thomas and Middleton, 1994). Often recognition of degradation rests on the instantaneous interpretation of the indicators listed in Table 2.1 yet, due to the nature of drylands, without a temporal perspective many of these indicators may not be useful. Measurements of change should be based on an understanding of the structure and dynamics of the systems being measured (Haines-Young, 1994). In the highly complex and variable systems that prevail in arid and semi-arid regions, this is especially important.

## *3.1 Vegetation Dynamics in Drylands*

Conventional range management relies on vegetation as an indicator of changing productivity (Behnke and Scoones, 1993). New ideas have emerged, however, on the functioning of semi-arid and arid rangelands as resilient flexible systems (Mills, 1995) that bring into question the validity of these indicators, especially in short term monitoring. Traditional understanding of rangelands has been based on range succession-retrogression models prompted by Clementsian ecology where populations are regulated in density-dependent feedback relations (Westoby *et al.*, 1989; Friedel, 1991; Laycock, 1991; Dodd, 1994; Ellis, 1995). Accordingly, rangelands are, in essence, viewed as isolated and closed biotic systems, and species gradually equilibrate to 'stable' external conditions (Sullivan, 1996a). Under such systems external pressures such as grazing result in a shift in the successional state to a lower one (Westoby *et al.*, 1989). The state of vegetation is seen as being held in balance between the opposing forces of succession and competition by the effect of grazing and is amenable to control by adjustment of stocking rates (Illius *et al.*, 1996). Management thus aims to balance grazing pressure to maximise production (Scoones, 1995a).

Such models of vegetation change may fail, however, in many dryland systems (Westoby *et al.*, 1989; Friedel, 1991). Changes in vegetation can occur in response to particular sequences of events such as a very dry year followed by a very wet year, two successive years of drought, etc. (Walker, 1993). New views stress the random occurrence of such external events and the idiosyncratic and unpredictable effects of externalities on ecosystem dynamics, populations and species (Ellis *et al.*, 1993).

Drylands are characterised by the high variability of rainfall in both time and space and its unpredictability (Jacobson *et al.*, 1995). Rainfall, rather than biotic interactions or nutrients, limits production and aperiodic and idiosyncratic rainfall events in time and space drive the biotic system in an event dependent fashion (Sullivan, 1996a). Such event dependent systems are termed *non-equilibrial* systems (Ellis and Swift, 1988; Behnke and Scoones, 1993) and they differ fundamentally from equilibrium models where outside perturbations are treated as noise. In non-equilibrial systems, however, frequent random noise dominates, and it becomes more useful to think of this noise as the system itself (Behnke and Scoones, 1993).

Large fluctuations in species composition, plant biomass and cover are thus characteristic of drylands (Westoby *et al.*, 1989). As Skarpe (1991: 355) noted 'there is no such thing as a stable, typical savanna.' At the extreme form of non-equilibrium systems, no density dependent regulation of animal or vegetation processes occurs at all, because populations are small relative to those supportable during the growing season (Illius *et al.*, 1996). Environmentally disastrous stocking rates are not reached because environmental perturbations cause livestock numbers to crash before environmental degradation is established i.e. the animals are the first system component to fail (Mace, 1991; Perkins and Thomas, 1993; Warren and Khogali, 1992 cited in Thomas and Middleton, 1994). Wiens (1994 cited in Illius *et al.*, 1996) suggests that in fact most systems fall along a continuum from equilibrial to non-equilibrial. Ecosystem productivity may appear more sensitive to variability in rainfall than long term grazing intensity (Hanan *et al.*, 1991) yet short term fluctuations can still be overridden by grazing management (Mills, 1995; O'Connor and Roux, 1995).

Distinguishing between human-induced irreversible 'degradation' and productivity dynamics induced by climatic variation is thus problematic (Tucker *et al.*, 1991; Friedel, 1991; Johnson and Lewis, 1995). An example is provided in Figure 3.1. These pictures illustrate the dramatic variation in productivity that can occur in drylands. In Figure 3.1a, the lack of vegetation cover may lead to an assessment of degradation. As illustrated in Figure 3.1b, however, when rain occurs perennial grassland arises. Thus the situation observed in Figure 3.1a may be part of the natural dynamics of the system and not indicative of degradation. Similar problems apply to interpreting qualitative vegetation change in the form of shifts in species composition, where the dynamics could be due to climatic variation and not necessarily grazing induced changes (Behnke and Scoones, 1993).

**a.**

**Figure 3.1.** An area in the Kunene region before and after heavy rains began in February 1995. **a.** Barren ground before. **b.** Extensive perennial grass cover by mid-April. (Jacobson *et al.*, 1995: 120.)

**b.**

## *3.2 Time and Productivity Dynamics*

Given the above variability in productivity and the complexity of changes involving not just quantity but also quality of vegetation and interactions with grazing, how does one distinguish climatically induced vegetation dynamics from long term irreversible human-induced declines in productivity? Stafford Smith and Pickup (1993) have characterised changes in vegetation in terms of their mean, variance and autocorrelation structure or 'memory'. 'Memory' results from long term impacts. This characterisation can be extended to a simple hypothetical model of productivity changes in non-equilibrium or partly equilibrial environments. Several different types of changes in productivity with time can then be represented as they are in Figure 3.2.

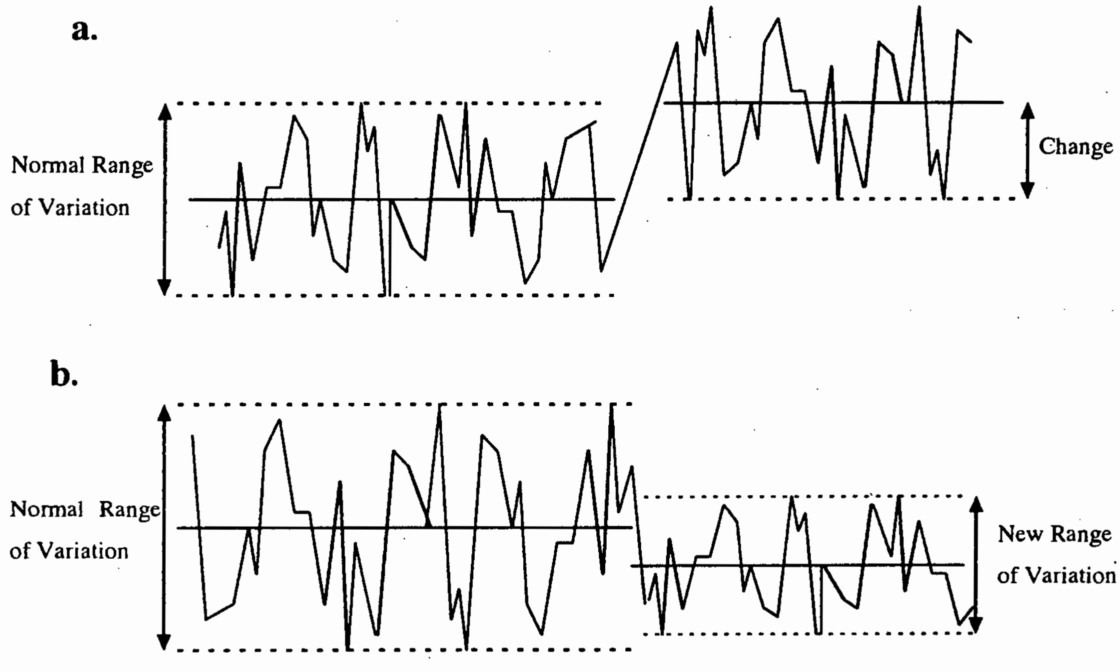



**Figure 3.2.** The x-axis represents time and the y-axis represents some simplified measure of productivity.
**a.** This represents a shift in productivity from one range of variation to another, a so called change in state. This can occur abruptly as represented here or gradually, and can occur positively or negatively.
**b.** This represents a shift in productivity within the range of variation, which could also occur abruptly or more gradually. The systems ability to respond to events is either decreased in response to positive events (a decrease in productivity) or its resistance in the face of negative events is increased (an increase in productivity).

Although productivity in dryland systems is inherently variable so that defining a 'normal' state is problematic (Sullivan, 1996a), a system will probably show variation within certain limits under certain conditions, the 'low' point of which might be represented by Figure 3.1a. The community might thus be said to be in a certain 'state' as defined by Westoby *et al.* (1989). Such states are in reality abstractions encompassing a certain amount of variation in space and time (Westoby *et al.*, 1989). The state in the above model is more simplistic than a specific vegetation state, representing a state of productivity defined according to a specific management goal, which can include productivity indicators such as stocking rates. Changes in state as shown in Figure 3.2a are not always reversible (Westoby *et al.*, 1989, Friedel, 1991; Laycock, 1991).

Shifts in productivity can thus be represented as shifts in the range of variation or in changes in the mean. However changes in system productivity might be more subtle than this. Changes could occur in what Stafford Smith and Pickup (1993) define as memory or the response time of a system to events. Detrimental productivity changes would be represented by increasing response time to positive events and decreasing response times to negative events (Figure 3.3).

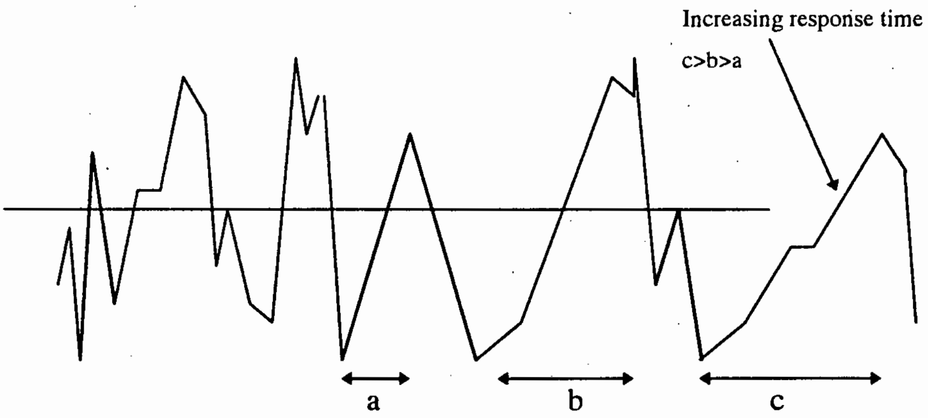



**Figure 3.3.** Increasing response time to positive events and decreasing response time to negative events. This may potentially lead to the situation in Figure 3.1b, as productivity does not have enough time to reach former high levels before it declines again.

As can be seen, depending on an observer's point in time, very different impressions of the productivity of a rangeland will be gained. One way to elucidate whether any long term change has occurred is to utilise a historical perspective.

An example illustrating the complexity of systems and the value of historical perspective is vegetation change in the Karoo. Shifts in vegetation composition from perennial grass dominated range to dwarf shrubland resulting in declines in productivity have been blamed on the expansion of European agriculture (Dean *et al.*, 1995a). Apportioning 'blame' is however not as simple as this. Historical evidence such as fixed point photography and archival accounts suggest a role for climatic variability as opposed to human-induced degradation in vegetation shifts (Hoffman and Cowling, 1990; O'Connor and Roux, 1995). Other long term studies of carbon isotopes indicate that land use is the driving force in vegetation change (Bond *et al.*, 1994).

Studies by O'Connor and Roux (1995) suggest more complicated interactions exist and that, although short term community change is mostly driven by rainfall variation, over the longer term grazing does influence longer lived perennial species. They conclude by stating that a complete understanding of the influence of rainfall and grazing on vegetation change in a temporally varying environment will only be revealed by data sets longer than patterns of variation (O'Connor and Roux, 1995). These vegetation changes can be represented in the simple model of productivity by Figure 3.2b, if the amount of perennial grass is taken as a measure of productivity. Changes in grass to shrub ratio would be variable and dependent on climate. Grazing induced changes would be represented by a decline within the range of variation, to a lower quantity of perennial grass. At an extreme, the point of irreversible degradation, one would get a shift to a lower state where perennial grass is excluded completely due to irreversible loss of soil seed banks (O'Connor, 1991; Seely *et al.*, 1995). This situation represents more complex variation on the basic models of productivity change presented.

The value of a historical perspective in identifying degradation in such situations is clear. The dynamics of variable systems can be followed and naturally induced changes to be differentiated from human-induced changes or degradation. In such situations historical perspectives can be valuable as opposed to short term 'snapshot in time' assessments.

An important point to note is that changes in productivity such as those modelled above can occur in response to unusual natural events. For example, changes in species composition are commonly episodic as both establishment and mortality in plants depend on particular conditions (Walker, 1993). Thus in analysing productivity changes over time as modelled, it is important that such changes are analysed in conjunction with climatic and other records of natural events in the time period of interest. What is important to note is that the effects expected from a rainfall sequence may be attenuated, enhanced or even reversed when the impact of grazing and other processes are added (Stafford Smith and Pickup, 1993).

## *3.3 Dynamics in Space*

Landscapes are not uniform, an aspect which has not been taken into account by the above model, which assumes uniform productivity across a landscape. Vegetation responses to external events may differ because of the spatial variability of factors such as variations in the soil environment and the redistribution of water, seeds, soil and nutrients (Stafford Smith and Pickup, 1993). In addition, landscapes are not utilised uniformly due to both heterogeneity in the landscape such as 'key resource' areas of greater richness (Mills, 1995; Scoones, 1995b) and the existence of areas of intense impact such as water points (Andrew, 1986). Environmental dynamics in arid and semi-arid areas are, not just temporally highly variable, but spatially as well. Interpretation of the production models over time outlined in the above section should take into account this spatial heterogeneity.

Assessments made of single small points or single landscape units, even if done from a historic perspective will not take into account the importance of a spatially heterogeneous landscape. Changes in resources are not just single point processes, increases in one part of a landscape can reflect decreases in another (Stafford Smith and

Pickup, 1993). Cattle in Zimbabwe have been shown to make extensive use of landscape heterogeneity (Scoones, 1995b). They show preference on a seasonal basis for particular parts of the landscape, notable 'key resource' habitat types with high levels of available herbaceous biomass. 'Key resources' can be created by patterns of erosion and deposition that exist within rangelands resulting in a mosaic of higher productivity patches in a background of low production (Walker, 1993). Stafford Smith and Pickup (1993) characterise these as erosion cells that consist of an eroding zone, a transfer zone and a zone of deposition. These zones shift with time and are impacted upon by grazing. Assessments of environmental dynamics to identify degradation can therefore, give misleading ideas as to the overall changes in productivity of a rangeland if spatial heterogeneity and patterns of use are not taken into account. Identification of degradation does not just require an analysis of productivity over time but also consideration of spatial shifts in productivity.

Another example of the interlink between spatial impacts and time are 'piospheres'. These are zones of attenuating impact that exist round water points (Andrew, 1986). A widely recognised component of ecosystem destruction around permanent water points is bare ground or a 'sacrifice' zone that is a consequence of heavy trampling and grazing (Thomas and Middleton, 1994) (Figure 3.4). A well established premise of these piospheres is that over time degradation spreads outwards from boreholes and wells under continued pressure exerted by livestock (Rapp, 1974 cited in Perkins and Thomas, 1993; Goudie, 1986). Several studies have challenged this established view, however. Remote sensing studies by Hellden (1984, cited in Thomas and Middleton, 1994) and Hanan *et al.* (1991) have shown that these 'sacrifice zones' do not expand significantly over time. In addition, Perkins and Thomas (1993) showed that impacts on the grazing resource were far from exclusively negative. Enhanced levels of nutrients accumulate in soils in sacrifice zones because of the concentration of dung and urine inputs (Perkins and Thomas, 1993; Reid and Ellis, 1995). Over the long term, these nutrient rich patches can become important key resources as enhanced vegetation recruitment can occur in the absence of disturbance (Mills, 1995; Reid and Ellis, 1995).

**Figure 3.4.** Heavily grazed and trampled zone around a permanent borehole in northern Damaraland.

Interpretation of degradation from a temporal perspective should not therefore, just rest on following changes in productivity. Time and spatial components are intricately linked in landscapes, and degradation is a process that can start locally and expand (Illius *et al.*, 1996).

## *3.4 Time Scale*

As environmental dynamics operate at varying time scales it becomes important, in determining whether land degradation has occurred, to consider the time period over which changes should be looked at. One aspect of this consideration relates to the 'irreversibility' of changes as discussed in Chapter 2. In defining degradation, a temporal scale relevant to people was suggested, a generational time scale the basic unit of which is approximately 20 or 30 years. However, in identifying degradation 20 or 30 years may be too short a time to understand and cover the full range of dynamics that a variable system can exhibit.

An example occurs in Borana in southern Ethiopia. Rainfall is fairly high and stable and the environment is a more equilibrial one, therefore livestock can have significant impacts on vegetation due to density dependent dynamics (Behnke and Scoones, 1993). Coppock (1993) has shown that bush encroachment occurs under heavy grazing when shrubs gain a competitive advantage over perennial grasses. As encroachment continues, the area is abandoned by pastoralists. Shorter term analysis of environmental dynamics may, at this point indicate that the area has undergone severe reductions in productivity and is degraded. As time continues, however, shrub recruitment is slowed, soil nutrients are replaced by leaf litter and grasses gradually re-establish as fire and senescence thin out trees. In a cycle that takes 60 to a 100 years to complete the area becomes productive once again (Coppock, 1993). Long term environmental monitoring in this case indicates that what might be perceived as degradation, is part of a longer term cycle. Consideration of an appropriate time scale for analysis of environmental dynamics can, therefore, be problematic. Longer temporal scales do, however, enable the structure and dynamics of systems to be understood more fully.

Consideration of longer time scales may be important if landscapes are out of equilibrium with current conditions due to long term climatic change (Roberts, 1996). Landscapes may be undergoing readjustment in the form of accelerated erosion or deposition, for example, that is unrelated to human influence (Dahlberg, 1994). Long term consideration may, therefore, establish how typical present rates of environmental dynamics are, compared to the past and may indicate if human disturbance i.e. degradation is the cause of reductions in productivity.

It is not useful, however, to analyse reductions in productivity from 'pristine' landscapes caused by human utilisation and call the results land degradation, as human survival requires environmental disturbance (Beinart, 1996). What should be analysed is whether environmental dynamics in these 'human created' landscapes are showing signs of reductions in productivity (Behnke and Scoones, 1993) such as those discussed earlier. Agriculture is based on the modification of environments (Beinart, 1996) and temporal considerations of dynamics, encompassing 'pristine' landscapes, to ascertain whether degradation has occurred should recognise that there will inevitably be changes in primary productivity. Such changes could be termed what Johnson and Lewis (1995) have described as 'creative destruction'. The objectives of changing land users, therefore also have to be taken into account (Dalhberg, 1994). Changes from lower intensity use such as hunting and gathering to higher intensity use such as pastoralism, could account for reductions in productivity. As stated in Chapter 2, land degradation has to be viewed in the context of the present land user, and such initial productivity reductions may be regarded as acceptable. Such environmental change can then be regarded as transformation rather than degradation (Beinart, 1996). If analysis reveals that productivity has not 'stabilised' within a certain range (see Figure 3.2), however, such changes may be regarded as land degradation.

## *3.5 Conclusions*

Recognition of land degradation requires the use of a temporal perspective in drylands. Productivity in the event driven systems that characterise these areas is highly variable and often may be largely dependant on rainfall. Distinguishing human-induced degradation from climatically induced productivity changes is problematic. Recognition of long term reductions is facilitated by the use of a historical perspective. Analysis of environmental dynamics and reductions in productivity should take into account spatial heterogeneity, the time scale of analysis and should be done within the context of the land use history of the area. The following chapter presents an overview of the environment and land use in the study area as a background within which an analysis of environmental dynamics over time can be done and an understanding of the system gained.

# Chapter 4

# 4. Overview of Northern Damaraland

The study area falls within the former ethnic 'homeland' of Damaraland. Following Namibia's independence, new administrative regional boundaries were proposed and the former Damaraland now encompasses the southern part of the Kunene region and the northern part of the Erongo region (Mhone, 1994). The case study area falls within the Khorixas regional constituency and covers over 15 000 $km^2$ as indicated in Chapter 1 (Figure 1.2). The population of former Damaraland has increased dramatically in the last 20 years. Between 1971 and 1981 it doubled due to resettlement and in 1991, there was a 40% increase over the 1981 census figure (Rohde, 1994). In 1991 the population of former northern Damaraland including the Sesfontein regional constituency, which is not part of the study area, was 17 628 (Mhone, 1994). Population figures specifically for the study area were not available.

In terms of physical environmental conditions, the study area is highly heterogenous, with a very variable climate. Land tenure in the area is communal and livestock, typically small stock, farming predominates. Much of the information presented in this chapter may also be found within the MPhil Baseline Report (1997) which was a precursor to this report.

## *4.1 Biophysical Profile*

### 4.1.1 Climate

The study area can be classed as semi-arid to arid. A very steep rainfall gradient exists from east to west over the study area, and mean annual rainfall varies from less than 100mm in the west to over 300mm in the east (Jacobson *et al.*, 1995) (Figure 4.2). The effect of such a low annual rainfall is increased by its marked seasonal variation. Most rain falls from October through to May, with the main rainy period in February and March (Jones, 1993). Rainfall occurs in the form of strong convective thunder storms which causes flooding of ephemeral river channels (Jacobson *et al.*, 1995). These storms mean, however, that a high proportion of the annual average may fall within a very short period of time, and it may be weeks before substantial precipitation occurs again in the same area (Jones, 1993). The strong seasonality of rainfall is an important driving force of biological and social processes (Jacobson *et al.*, 1995). Periods of high productivity are limited to the wetter season, and movements of animals and people may often become necessary during the dry season.

As mean annual rainfall declines, its variability increases, both temporally and spatially and most of the area falls within the 50-70% variable isohyet for rainfall (Jacobson *et al.*, 1995). This means that an area receiving a long term mean of 240mm has a 95% probability of getting between 80mm and 400mm per season (Jones, 1993). The marked variation in rainfall can be seen in the records for Khorixas in Figure 4.1. Rainfall in the study area is thus highly variable; accordingly the area is characterised by both droughts and floods. The high variability in both time and space presents a constraint to productivity and the biotic system in the area may be described as an event driven system, as discussed in Chapter 3.

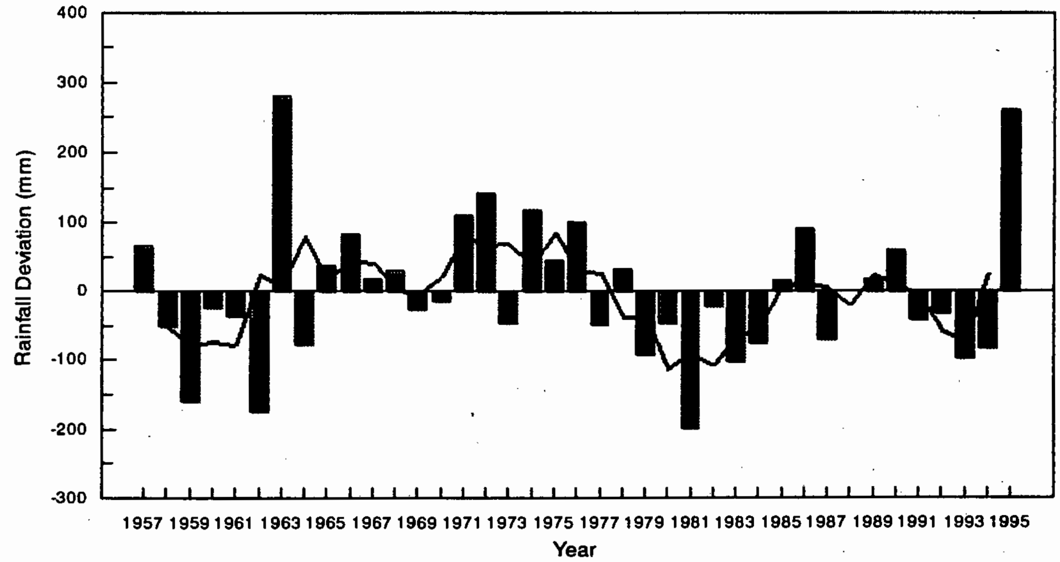
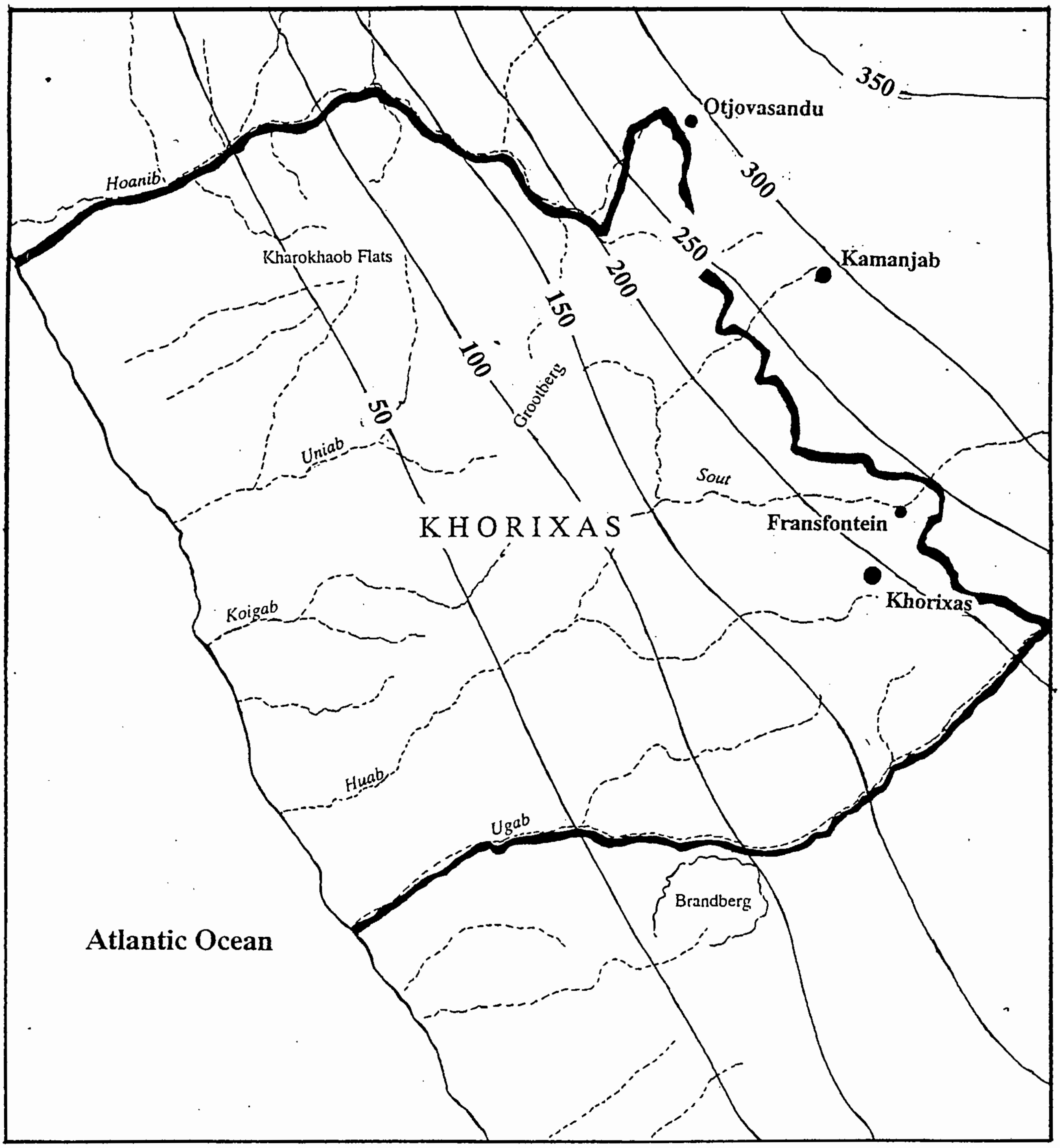



**Figure 4.1.** Deviation from mean annual rainfall at Khorixas. The line represents the 3 year running average.




**KEY**

Isohyet (mm of rainfall)

River

Rainfall station

km

0 20 40

NORTH

**Figure 4.2.** Mean annual rainfall gradient in the study area

The extremely low and variable rainfall is exacerbated by an annual evaporation rate of about 3000mm a year, more than 10 times the mean annual precipitation (Jacobson *et al.*, 1995). Temperatures in the study area vary from less than 0° to over 40° through the year (Simmonds and Forbes Irving, 1994). The very high daytime summer temperatures contribute to evaporation and exacerbate moisture deficits in the area. Rainwater is lost rapidly from the system and is generally not available on the surface for much of the year (Jacobson *et al.*, 1995). Permanent settlement is therefore limited to springs, wetlands or boreholes.

The unpredictable nature of the climate and high moisture deficits in the study area therefore present serious constraints for agriculture and the potential for crop farming is limited. Irrigation is needed but high evaporation rates present salinisation problems (Jacobson *et al.*, 1995). Livestock farming is also constrained and much of the study area is marginal for cattle farming, especially the drier western areas (Simmonds and Forbes Irving, 1994). Farming practices are required that place emphasis on flexible responses to uncertain events, and on mobility to allow the optimal use of a heterogeneous environment (Scoones, 1995a). The rain gauge network in the study area is poor and reliable long term records are generally not available for the whole area (Jacobson *et al.*, 1995). The most reliable data comes from the more eastern side of the constituency.

### 4.1.2 Topography, Geology and Soils

Topographically and geologically, the area is highly heterogenous (Jacobson *et al.*, 1995). It is characterised by elevated mountainous areas in the centre and east in which occur the deeply incised drainage course and flood plains of the main, westward draining ephemeral rivers (Simmonds and Forbes Irving, 1994). The ephemeral rivers are dependent on rain for their flow and usually only flow on the surface during the wet season (Jacobson *et al.*, 1995). Floods in these rivers, resulting from rain in the eastern part of their catchment areas, re-charge aquifers and maintain riparian vegetation in the drier western regions (*ibid.*).

The study area is underlain by Pre-Damara Basement, Damara Sequence, Karoo sediments and volcanic and recent surficial deposits. In the south-east region granites of Damaran age give rise to very characteristic undulating topography, with dome shaped hills and large boulders (Simmonds and Forbes Irving, 1994). Surficial sediments of Quaternary to recent age occur along the valleys of certain ephemeral rivers, and include alluvial deposits, calcrete and tufa (*ibid.*). Soils vary in association with the diverse geology of the area (Jacobson *et al.*, 1995) and the aridic moisture regime is the overriding factor determining the pace of soil development and governing present soil status (Simmonds and Forbes Irving, 1994). Soils are generally thin and poorly developed and may be described as coarse textured alkaline sands to sandy loams (*ibid.*). Much of the area is covered by sand derived from decomposed granite and soils are shallow to moderately deep, calcareous, non saline and weakly structured (Jones, 1993; Simmonds and Forbes Irving, 1994). These soils often overlie hard rock surfaces, are very stony and give way to the underlying rock frequently (Figure 4.3) (Jacobson *et al.*, 1995). Deep alluvial and colluvial deposits are more common in the major river valleys.

**Figure 4.3.** Soils in the study area are very stony.

Few in depth studies have been done on soils study area, however, the poorly developed nature of the soils limits the potential for irrigated agriculture (Jacobson *et al.*, 1995). The topography and geology with stony soils, granite outcrops and frequent steep slopes limits the available area of rangeland.

### 4.1.3 Vegetation

Rainfall is the overall determinant of vegetation in the study area (Jacobson *et al.*, 1995) and as rainfall declines to the west (Figure 4.2), vegetation becomes more xeric and cover thins. According to the classification of Geiss (1971), most of the study area falls within the *mopane savanna* vegetation type. The more western regions fall within Karoo-Namib scrubland (Jones, 1993). The highlands support different vegetation from the flood plains and drainage courses. Variations in the topography and geology, result in sites of increased conditions of suitability for plant growth which are characterised by dramatic increases in plant productivity (Jacobson *et al.*, 1995).

The riparian forests or 'linear oases' supported in the larger ephemeral river courses are an important source of food and water forage for livestock in the arid landscape and especially during the dry season (Jacobson *et al.*, 1995; Sullivan, 1996b). *Colophospermum mopane* and the ana tree *Faidherbia albida* along with the camelthorn *Acacia erioloba* and *Acacia nebrownii* are found in these water courses (Jones, 1993). Spreading thickets of *Salvidora persica* and *Tamarix usneoides* occur (Figure 4.4). These riparian forests are largely dependent on river floods for water and nutrients (Jacobson *et al.*, 1995).

Most of the highlands are covered by open xeric savanna, often dominated by *C. mopane* and a dense grass understorey springs up following good rain (Jacobson *et al.*, 1995). *Acacia mellifera* is common on clayey-calcrete soils and the red sandy plans are dominated by two species of grass, *Stipogrostis uniplumis* and *Stipogrostis hirtigluma*. *Cenchrus ciliaris* occurs in the river beds and *Antephora ramosa* on granite outcrops (*ibid.*).

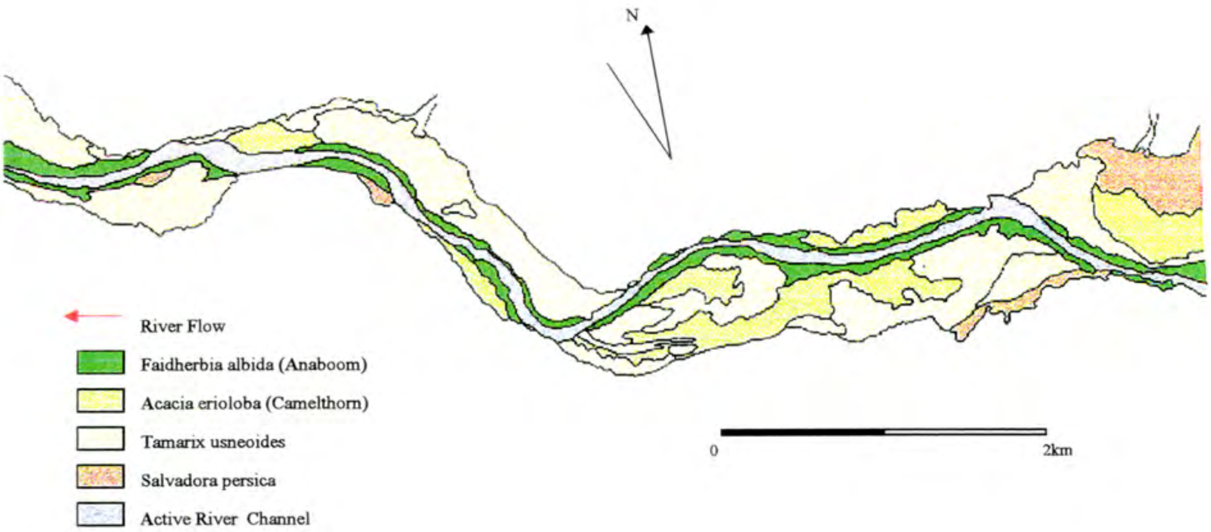



**Figure 4.4.** Vegetation map of the Kuiseb upstream of Gobabeb, an ephemeral river similar to those found within the study area, showing patterns of vegetation growth , common to all riparian forests within larger ephemeral rivers (Jacobson *et al.*, 1995: 41).

The suitability of vegetation for livestock farming in the study area is unclear. Although large numbers of stock are supported by the area (approximately 144 000 in 1996), whether the such use is sustainable in the long term is unknown (Jacobson *et al.*, 1995). A recent study indicated that much of the southern part of the study area was unsuitable for livestock farming without the implementation of strict conservation measures (Simmonds and Forbes Irving, 1994). Data was unavailable on the nutrient status of vegetation and its overall suitability for livestock farming.

In conclusion, the study area is a highly heterogenous environment with a variable climate, that has numerous constraints for agriculture. Rainfall is unreliable, droughts are frequent, and much of the area consists of poor soils and terrain inappropriate for use as rangeland.

## *4.2 Land Use History*

### 4.2.1 Pre-Colonial Land Use

Prehistoric inhabitants of the arid and semi-arid area lived a nomadic existence as hunter-gatherers or pastoralists. Early hunter-gatherer cultures were transformed within the last four thousand years into pastoral ones through the introduction of livestock from further north in Africa (Jacobson *et al.*, 1995). Before the colonial area, early pastoral land use was based on nomadism, with people moving and settling in response to changes in the availability of water, food and grazing (Kinahan, 1989). This included extensive movements between pastures. In essence, movement of people was controlled by water availability (Jacobson *et al.*, 1995). Archaeological sites are mainly found in close vicinity to springs and river courses, where water was available year round (Kinahan, 1989). Movements of people appeared to occur seasonally, with retreat to permanent water sources during the dry seasons and utilisation of wet season pastures (Jacobson *et al.*, 1995). Although European influence in the area occurred from the 15th century onwards, major changes in land use were initiated towards the end of the 19th century after the declaration of Namibia as a German protectorate (Kinahan, 1989; Jacobson *et al.*, 1995).

### 4.2.2 'Colonial Era' and Commercial Farming

The arrival of German colonialists followed by the South African administration resulted in the alienation of land from the original inhabitants and its enclosure for use as livestock ranches (Sullivan, 1996b). In 1884 Germany declared Namibia a protectorate. Before the turn of the twentieth century, a series of 'native labour reserves' were established such as Sesfontein, Fransfontein, Otjohorongo and Okombahe (Lau and Reiner, 1993), of which the Fransfontein falls within the study area (Figure 1.2). These reserves served nearby settler farming communities. Agriculture in these reserves remained essentially based on a communal system, though much reduced and restricted, with access to previous seasonal pastures denied (Moorsom, 1982). Expansion of settler agriculture occurred and the region which later became Damaraland was among the last to be settled due to its aridity and peripheral location to more established agricultural areas (Rohde, 1993). According to information from Department of Lands records studied by Kambaktuku (1996) the farms were first advertised under a state settlement plan in 1954 for landless white farmers to apply for grazing licences.

Farming was highly subsidised and loans were granted for activities such as fencing and animal fodder for drought relief (Kambaktuku, 1996). Karakul sheep and goats were principally farmed, with minimal large stock numbers (Jacobson *et al.*, 1995) and the arid environment and sparse grazing meant that stock were continually moved considerable distances between camps, water points and enclosures (Rohde, 1993). Livestock movements in the area were frequent and farmers often applied to Land Board to assist others with grazing and water on their farms (Kambaktuku, 1996). As long as stock numbers on farms did not exceed the official carrying capacity such movements were permitted (*ibid.*). Kambaktuku (1996) points out however, that it was unclear how these capacities were determined and they were often estimated. In any event, concepts of static carrying capacity in such variable environments are of debatable use (Behnke and Scoones, 1993; Scoones, 1993).

Many farms in the area were being utilised as grazing reserves by farmers in other areas or, more commonly, were abandoned by the time the Odendaal Commission's[1] recommendations were implemented due to the unreliable production associated with the areas climate (Jacobson *et al.*, 1995; Kambaktuku, 1996). The Administration then bought these farms up and many were leased out as emergency grazing between 1964 and 1969/70 to drought stricken white farmers from the rest of the country (Kambaktuku, 1996).

[1] The Odendaal Commission in 1964 resulted in the creation of homelands. The recommendations involved the creation of 11 black authorities responsible for the administration of ethnically defined Bantustans in line with South Africa's policy of separate development (Sullivan, 1996a).

### 4.2.3 Communal Land Use

Damaraland was created by the Odendaal commission around the Fransfontein, Okombahe and Ojtohorongo Reserves and included Sesfontein to the north and over four million hectares of surveyed and fenced commercial farms, unsurveyed State land and game reserves (Sullivan, 1996b). Although the commission stated that the new reserve offered 108 hectares of land per individual, this does not reflect the fact that well over half of the region is unsuitable for farming as it is too arid (Rohde, 1993). The former commercial farms that the Administration had bought were eventually made available for communal use by the Bantu Commission in the early seventies (Kambaktuku, 1996), although some may have been settled earlier (MPhil Baseline Report, 1997). On the former commercial farms, boreholes were located at what became the site of primary habitation, and at the farm posts established for providing water to livestock being herded in remote areas of the farm (Jacobson *et al.*, 1995). Thus human settlement and the 'kraaling' of livestock is determined largely by the location of functioning boreholes (Sullivan, 1996a). Normally on an 'Odendaal farm', as the former commercial farms are known, there is a main settlement at the old homestead, with a number of settlements at the posts (MPhil Baseline Report, 1997). This is not always the case as, at times, the borehole at the original homestead may yield insufficient water (Sullivan, 1996b). Settlements vary in size from two to three people to over twenty people (MPhil Baseline Report, 1997).

Small livestock farming with goats, is the economic mainstay of the area (Rohde, 1994) due to the xeric, highly variable climate and harsh landscape. Some cattle are kept in the study area, but numbers are much lower than the hardier small stock such as sheep and goats. Utilisation of grazing is totally dependent on water, and most farmers rely on boreholes, although in some areas springs exist (MPhil Baseline Report, 1997). Farming practices tend to vary, from farmers who rotate their stock through camps to those who graze stock in an open extensive system (*ibid.*). Although the old boundaries of the 'Odendaal farms', still exist to some extent, these mask complex movements of people and livestock (Sullivan, 1996b). Large scale stock movements took place in 1990-1992, for example from the south to the north and east toward better grazing (Jacobson *et al.*, 1995). Although communal resources are theoretically open and accessible to all communal residents (Rohde, 1994), control over access to these resources is unclear. The absence of any form of secure land tenure has resulted in conflict and disincentives to manage resources effectively (MPhil Baseline Report, 1997). In addition, as stated, the population of the area in increasing rapidly, leading to further scarcities in resources and conflicts.

A flexible system of reciprocal exchange and risk spreading operates in Damara culture, particularly amongst kin, and herd building is based on the multiple ownership of herds within the family (Rohde, 1993). Although livestock farming is important, it is not productive enough to meet subsistence or cash livelihoods and these are supplemented from sources such as pensions and cash from salaries of family members living in towns.

Both the former commercial farming in the study area and present communal farming share some similarities despite differing aims in production, the former commercial farms being more money oriented, where as stock in the communal system have other value such as for their milk (Jacobson *et al.*, 1995). The constraints inherent in the environment, with its aridity and variability, have resulted in rangeland management practices in both former commercial farming and present communal farming (Sullivan, 1996b) that accommodate and adapt to these constraints to some extent. Both land use systems are characterised by movement, especially during droughts, and neither system is capable of completely supporting the farmers (*ibid.*). Drought relief and other income sources such as subsidies for commercial farmers and pensions in communal farming play an important role in supporting livelihoods (MPhil Baseline Report, 1997).

## *4.3 Contemporary Environmental Dynamics in the Study Area*

Claims that widespread land degradation is taking place in the more arid areas of Namibia are not easy to verify (Rohde, 1994; Jacobson *et al.*, 1995). Concerns exist that the provision of permanent water points has encouraged sedentarisation and promoted degradation, especially in the study area (Jacobson *et al.*, 1995; MPhil Baseline Report, 1997). In addition there are concerns that the growing population in the study area is outstripping the ability of the natural resources of the area to sustain it. As stated, at present, livestock farming is not sufficient to sustain livelihoods in the study area (MPhil Baseline Report, 1997). The existence of irreversible productivity reductions in the area, however, are difficult to verify.

During the initial project that preceded this report, problems were encountered in identifying environmental impacts and whether such impacts could be classed as degradation or not. The extremely short time period of the observations meant that human-induced degradation could not be differentiated from climatically induced variability. For example, soils around boreholes and homesteads were heavily trampled due to animal traffic (MPhil Baseline Report, 1997). How far this extends from water points, however, or whether such soil disturbance remains spatially confined could not be ascertained. Due to the nature of the climate of the study area, it was also not possible to determine whether vegetation productivity had irreversibly declined. Although signs of heavy grazing and browsing were observed, this on its own in not necessarily indicative of land degradation (MPhil Baseline Report, 1997). Farmers in the area indicated that grass recovery was good following rainfall., suggesting productivity was still acceptable. The time frame within which observations were undertaken was inadequate to determine whether any human-induced vegetation deterioration apart from that observed around water points had occurred, never mind whether actual land degradation was occurring. The following chapter attempts to utilise certain available historical evidence to identify whether land degradation is in fact occurring in the study area. Hopefully a longer term perspective will enable environmental dynamics to be analysed more fully.

# Chapter 5

# 5. Analysis and Evaluation of Historical Evidence of Environmental Dynamics

Identification and analysis of environmental dynamics from a temporal perspective can be done using a variety of data sources and techniques. Depending on the time scale of interest and the availability of data, what is ultimately utilised will vary (Roberts, 1994). Aerial photography (Knapp *et al.*, 1990; Watson, 1990; Soboil, 1996) and satellite data (Hanan *et al.*, 1991; Hellden, 1991; Tucker *et al.*, 1991; Ringrose *et al.*, 1996) have been applied in the monitoring of environmental dynamics and assessment of the extent and occurrence of degradation. These methods look at productivity changes in relation to factors such as soil erosion and changes in primary productivity i.e. shifts in vegetation composition or cover. Historical analysis of archival information in the form of stock numbers (stocking rate analysis) has been useful in identifying changes in productivity (Tapson, 1993; Abel, 1993; Dean and MacDonald, 1994).

A more qualitative method of historical analysis is the use of documentary evidence in the form of travellers reports and fixed point photographs. For example, in the Karoo it has been used to test hypotheses of vegetation change (Hoffman and Cowling, 1990). Dynamics over longer time periods or places where historical records are scanty or non-existent can be investigated using archaeological and palynological studies (Bousman and Scott, 1994) and biogeochemical evidence such as carbon isotope analysis (Bond *et al.*, 1994; Roberts, 1994).

## *5.1 Methodology*

Aerial photography and data on stock numbers were utilised to identify and interpret environmental dynamics in the study area to discern whether land degradation has occurred. The choice of data was based on the accessible nature of these data, the relatively low costs involved and the limited duration of the study.

Potential indicators of degradation such as changes in vegetation cover, species composition or vegetation state can be monitored over time using aerial photography. Trends independent of normal rainfall related vegetation dynamics, such as those discussed in Chapter 3, leading to reductions in productivity could be indicative of land degradation. Aerial photography can also be used to monitor soil changes leading to reduced productivity such as increases in eroded areas and the extent of erosion gullies. Analysis of stock numbers or stocking rates could indicate reductions in productivity that are independent of rainfall induced productivity changes. Livestock are dependant on rangeland for survival and any productivity changes resulting from degradation in a rangeland will be reflected in reduced livestock productivity. Due to the nature of drylands, any temporal analysis should be done with reference to rainfall, a main determinant of productivity.

### 5.1.1 Rainfall records

Both aerial photographs and stock numbers were analysed in relation to rainfall. Available rainfall records were obtained from the Weather Bureau in Windhoek, for four stations that were within of close to the study area, Fransfontein, Khorixas, Otjovasandu and Kamanjab (Figure 4.2). Data were summed for the stations for each year and averaged to give a rough approximation of the average rainfall in the study area in any one year.

Unfortunately, as can be seen in Figure 4.2, these stations are in the relatively wetter eastern part of the study area. Due to the steep rainfall gradient that exists, they can therefore not be regarded as representative of an average of rainfall over the area. The rain gauge network in western Namibia is poor (Jacobson *et al.*, 1995) and this includes the present study area for which other data were not readily available. Data for Fransfontein cease after 1980, further reducing the sample size.

### 5.1.2 Aerial Photography

Panchromatic aerial photographs were obtained from the Directorate of Mapping in Cape Town. In order to facilitate interpretation of changes observed in aerial photographs, the original intention was to compare biophysically similar areas subject to different land uses, over time. Three different types of areas were identified based on the land uses described in Chapter 4 for the study area:

- communal use only - the Fransfontein Reserve
- commercial to communal use - the 'Odendaal farms'
- commercial use only - farms outside the communal area.

Based on the available photographs, two areas were then selected, one in the northern part of the study area and one further south (Figure 5.1). The northern area was selected because photographs were available from 1943. Not all three different land use types could be compared in the north, as no communal use only area was present, therefore, an area in the south was selected. In the north two farms were chosen, Bruno (No. 614) and Emmanuel (No. 613). In the south photographs of the farm Horison (No. 489) and part of the former Fransfontein Reserve were obtained. Details of the photographs are presented in Table 5.1 along with the land uses the farms have experienced.

**Table 5.1** Details of aerial photographs and generalised land use for farms.

| Year | Job | Scale | Month | Strip | Farm | Land Use |
|---|---|---|---|---|---|---|
| **Northern Area** | | | | | | |
| 1943 | 46 | 1:25 000 | Unknown | 31/32/33 | Bruno | Commercial |
| | | | | 33/34/37 | Emmanuel | Commercial |
| 1961 | 501 | 1:36 000 | August | 12 | Bruno | Commercial |
| | | | | 13 | Emmanuel | Commercial |
| 1974 | 725 | 1:50 000 | August | 16 | Bruno | Commercial |
| | | | | 17 | Emmanuel | Communal |
| **Southern Area** | | | | | | |
| 1961 | 501 | 1:36 000 | August | 23/24 | Fransfontein Reserve | Communal |
| | | | | 24 | Horison | Commercial |
| 1975 | 746 | 1:50 000 | June | 3/4 | Fransfontein Reserve | Communal |
| | | | | 4 | Horison | Communal |

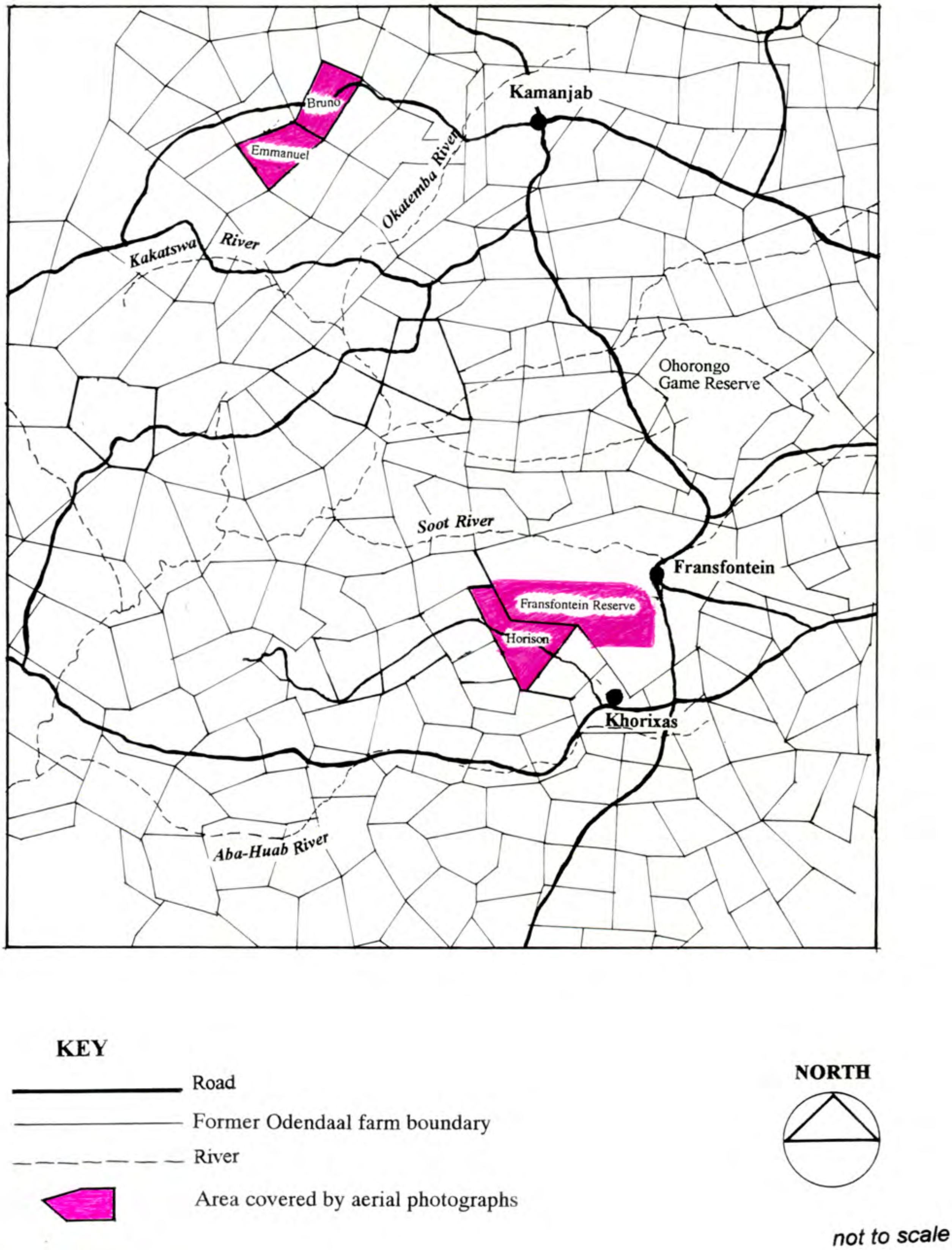



**Figure 5.1.** Location of chosen areas for aerial photography

Unfortunately, photographs later than 1975 were not available and no photographs earlier than 1961 could be obtained for the southern area. A field visit was undertaken during the precursor to this report but biophysical data was only obtained for the southern area and this data was gained prior to the decision to use aerial photography in this report. Ground based observations could, therefore, not be used in the verification or analysis of the data obtained from the aerial photographs. Photographs were viewed stereoscopically utilising a Sekkosha stereoscope. Analysis was concentrated on settlements and water points identified from 1:50 000 topographical maps. In addition, analysis focused on ephemeral river courses, which provide important key resources in the area (Jacobson et al, 1995).

### 5.1.3 Stock Numbers

Livestock numbers were obtained from the Directorate of Veterinary Services in Windhoek. Numbers were only available from 1969 for the whole of Namibia and for the study area from 1978. The enumeration districts of the Directorate do not correspond with the present regional boundaries in Namibia and the figures obtained are for Damaraland North. This is an area comprising all of former Damaraland north of the Ugab River and does not correspond exactly with the study area. The Directorate could not supply the size of the enumeration district but it was worked out at approximately 15 200km$^2$ utilising a square grid method.

Stock numbers were divided into goats, sheep, cattle, horses and donkeys. It was decided to only evaluate goat and cattle numbers due to time constraints. Stock numbers could not be converted to large livestock units (LU) due to the unavailability of livestock weights in the area. Furthermore, the nature of the terrain in the study area means that the available, productive rangeland is far less than the total area of the enumeration district. Stocking rates (LU per hectare) could therefore not be analysed and whole stock numbers were utilised in analysis. Correlation was computed between stock numbers and rainfall to determine if any relationship existed.

## *5.2 Analysis and Evaluation of Environmental Dynamics*

### 5.2.1 Aerial Photography

Remote sensing, which includes aerial photography and satellite imagery, offers the possibility of gaining environmental data over large areas and relatively long time periods (Thomas and Middleton, 1994). Multi-temporal aerial photography provides information on the environment at different points in time (Baines, 1994) and comparative interpretation of the photographs allows changes to be followed and information on the nature of environmental dynamics to be gained. Processes and rates of change can be analysed and cause and effect relations can be traced when coupled with other historical and ground data.

Having compared photographs, it was not possible to discern any differences in vegetation cover or the extent of soil erosion between years in any land area other than minor changes. The landscape is very arid, and human impacts are hard to differentiate from overriding climatic ones. No erosion gullies were noted at all in the study area, both on the aerial photographs and during the initial field trip. Boreholes with their associated settlements were first identified on 1:50 000 maps, but no 'piosphere' effects were noted, apart from around one settlement on the farm Emmanuel in 1974 (Figure 5.2). This settlement is on the extreme north-western edge of the farm and was unfortunately not covered by photographs from earlier years, and therefore, comparative temporal analysis of this area could not be done. The absence of visible higher impact areas in the photographs is in contrast to the precursor to this report which identified higher impact areas around boreholes in the study area with heavily trampled soil and an absence of vegetation (MPhil Baseline Report, 1997). No significant vegetation changes were noted along the ephemeral water courses (see Figure 5.2 for an example of a small ephemeral river course). A distinct difference in contrast was noted on photographs from 1974 of the farm Bruno, which corresponded to the boundary between the farm and its neighbour, Ombande, and could be due to higher intensity grazing on one side of a fenceline (Figure 5.2). This contrast was not visible on earlier photographs of the area.

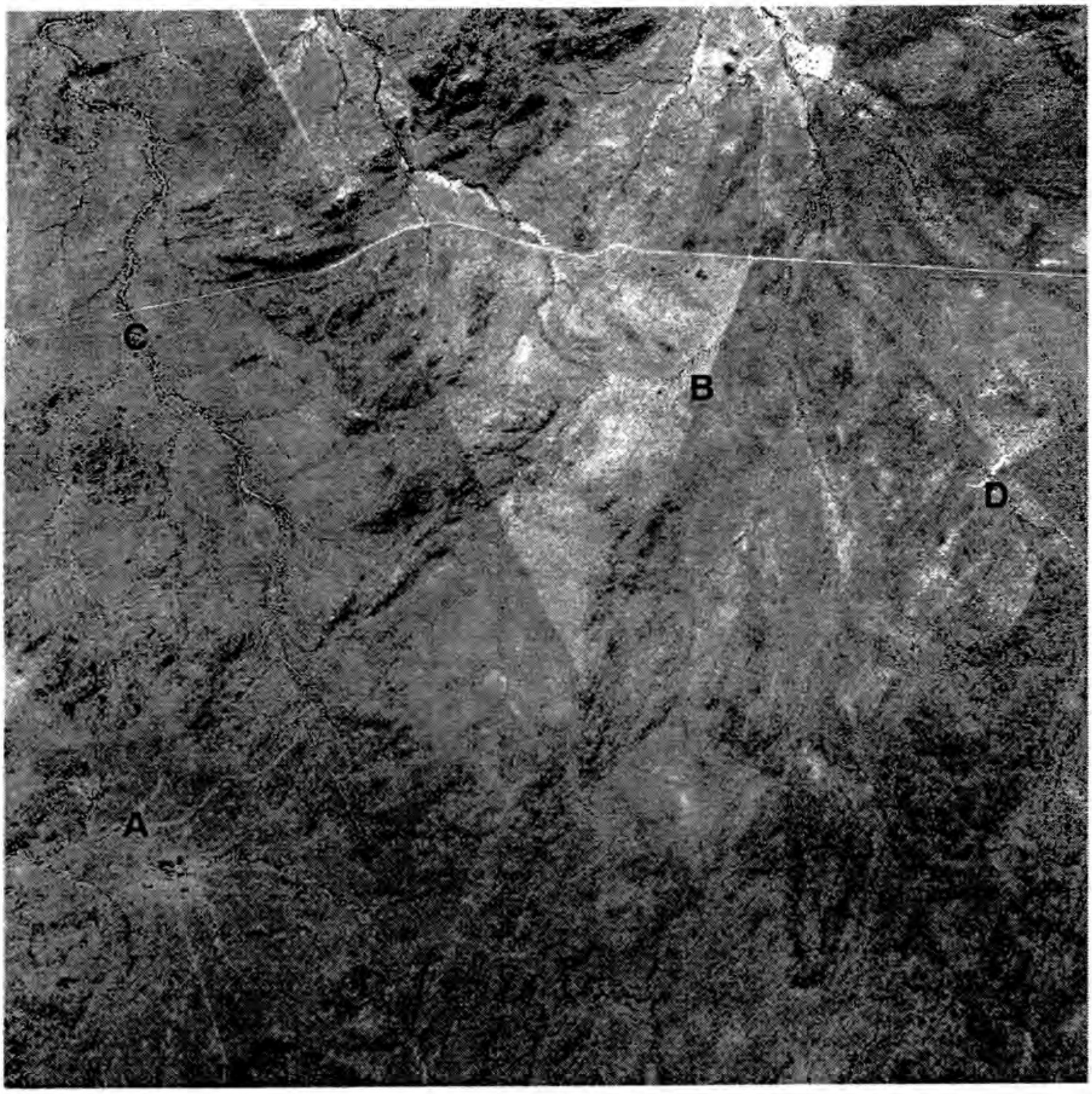



**Figure 5.2.** Aerial photograph from 1974 (Job 725, Table 5.1) **A.** A settlement at Emmanuel showing a higher impact zone or piosphere. **B.** A fenceline contrast between Bruno and Ombande (the lighter triangular area). **C.** One of the numerous smaller ephemeral water courses found in the study area. Such a small water course is a tributary to one of the main westward flowing ephemeral rivers found within the study region. **D.** A lighter toned area corresponding to an erosion feature.

There did not appear to be any appreciable differences between the different land areas that were identified, in terms of soil erosion and vegetation. Infrastructure around the homestead on the commercial farm Bruno was more developed than on other land units (Figure 5.3).

**Figure 5.3.** Aerial photographs of the farm Bruno (1974, Job 725). Note the well developed infrastructure at the homestead with fields at **A**.

The absence of any major discernible differences between the photographs could be due to an absence of significant environmental dynamics or degradation or a number of other factors. A number of problems and limitations were encountered in the use of the aerial photographs and methodology, that hindered the identification and analysis of significant environmental dynamics. The limitations of the photographs included the fact that they:

- were of too large a scale
- contrast between the photographs varied and ground based interpretative data were not available
- were taken at different times of the year
- only represented a single point in time, and short term changes might have been missed
- did not cover a long enough temporal period and none later than 1975 were available

These problems and limitations may explain to some extent why environmental dynamics could not be clearly identified in the study area and are discussed further below.

- **Scale Problems**

  Most of the photographs were of too large a scale (Table 5.1) and features could not readily be identified. The exceptionally arid nature of the study area means that vegetation is sparse and hard to identify. Environmental dynamics or indicators of rangeland degradation may not be observable at the scale of the photographs. Smaller scale features such as boreholes could not easily be identified on the photographs. The fact that zones of higher impact around borehole could not be seen except in the one case of Emmanuel, may be due to the large scale nature of the photographs. The photographs from 1943, although of a larger 1:20 000 scale, were very poor in contrast which hampered identification of features. Enlargement of the photographs may facilitate the identification of features and assist in analysis. This could not be done within the time frame of the report, however.

- **Interpretative Problems**

  Variations in tone have been used to differentiate different states of rangeland. In Kwa-Zulu Natal, virtually white toned surfaces were indicative of actively eroding surfaces (Watson, 1996) whilst gradations in tone from dark to light were indicative of lightly to heavily grazed rangeland in Botswana (Ringrose, 1987). The fenceline contrast observed in the photographs from Bruno (Figure 5.2) could be due to heavier grazing in the lighter toned area of Ombande. Ground surveys are needed, however, in order to correlate tonal variations in photographs with various environmental states (Watson, 1996). In this present study, location specific ground surveys were not possible, as the decision to use aerial photographs was taken after the initial field trip to the study area. The fenceline contrast is therefore only assumed to be due to differential grazing. Erosion features were also assumed to be lighter to white toned areas, such as point D in Figure 5.2. The size of observed erosion features did not appear to change much between photographs from the different years. Analysis of these features was hampered however, by contrast and tonal variations between sets of photographs. In addition, how severe erosion is within such features, or even whether such features represent actual eroded areas or only bare uneroded ground could not be ascertained without ground based surveys. A particular problem was encountered with the photographs from 1943 where contrast was exceptionally poor, making identification of features very difficult. The variation in contrast between photographs from different years hampered analysis of erosion features.

- **Temporal Problems**

  Most of the photographs were taken at the same time of the year (Table 5.1). One set was taken in June, however, and the month was not available for the 1943 photographs. The study area has strongly seasonal rainfall as discussed in Chapter 4 and therefore cumulative inputs of rainfall and moisture availability to the system over a season will differ depending on the time of year. Vegetation productivity and therefore the amount of vegetation present at a particular time, may be more highly dependent on rainfall in arid and semi-arid areas, such as the study area, than dependent on utilisation by livestock (Ellis, 1995; Sullivan, 1996a). Photographs taken in August of a year, may look 'worse' or have less visible vegetation than photographs taken earlier in the year when moisture inputs may have been more recent during the rainy season of February and March in the area. In addition, the high climatic variability in the area could lead to problems distinguishing human from climatic impacts, which may be unresolved by photographs that represent single points in time. Only two sets of photographs from 1961 and 1974/75 could effectively be analysed and these were thirteen years apart. This set is not comprehensive enough to observe the full range of dynamics in the study area. The fence line effect observed in Figure 5.2., for example, could be due to a short term grazing impact and not represent irreversibly degraded pasture. Without further photographs, this cannot be established. More comprehensive analysis covering a longer time period and shorter intervals may more fully reveal environmental dynamics in the study area.

The absence of discernible differences in the photographs may be due to the problems described above and not the absence of significant environmental dynamics or degradation. Other factors may also be relevant. For example, the lack of difference between the commercial farming area and the former 'Odendaal farms' or commercial to communal areas, could be due to the fact that people had not been settled for very long on these farms by the time the photographs were taken. The former commercial farms were only made available for resettlement in the early 1970's, not long before the photographs were taken and significant impacts may, therefore not have occurred by this time. Major differences were not noted between the communal only farming area and the other areas either. This would tend to suggest that at this time, the impacts of commercial and communal farming were not too different. No photographs later than 1975 were available and thus a period of rapid population growth and increasing impact in the study area was not covered. The population has more than doubled in the last twenty five years (Rohde, 1994) as discussed in Chapter 4, which has placed more stress on a marginal environment. Thus, although no significant differences were noted in the photographs over the time period, analysis of more contemporary photographs may reveal significant differences.

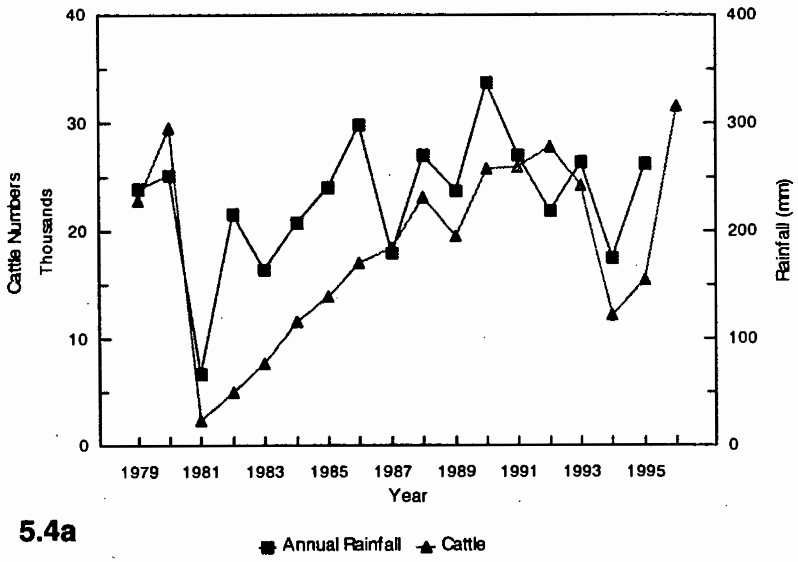
Many of the issues encountered in the analysis of the aerial photographs are to do with resolution and frequency, problems that are common to other remote sensing data sets such as satellite imagery (Thomas and Middleton, 1994). The resolution of aerial photographs is high (Baines, 1984), and photographs can be enlarged to a desired size. Frequency is a problem, however, as discussed. Multi-temporal or near continuous monitoring is not possible with conventional aerial photography, only single point in time assessments (Thomas and Middleton, 1994). This may be problematic in the highly heterogenous environment that characterises arid and semi-arid areas. Changes and trends in productivity dynamics discussed in Chapter 3, may not be discernible if the frequency of aerial photography becomes too low.

Use of satellite remote sensing may resolve this problem as data are often of a much higher frequency. The use of other lower frequency but higher resolution satellite data, such as Landsat multispectral scanner (MSS) and thematic mapper (TM) data, for example, has shown that complete vegetation recovery is not taking place in north-central Botswana (Ringrose *et al.*, 1996). This study only covers a short time period, however, and may not encompass the full range of variation of environmental dynamics in the area, or cover a long enough time period to show distinct trends towards reductions in productivity. Low resolution, high frequency data from NOAA satellites, using normalised difference vegetation indexes (NDVI), is also a valuable tool in assessing the spatial distribution and changing dynamics of green biomass (Hellden, 1991). The use of remote sensing data such as aerial photography and satellite data should preferably, cover as long a time period as possible.

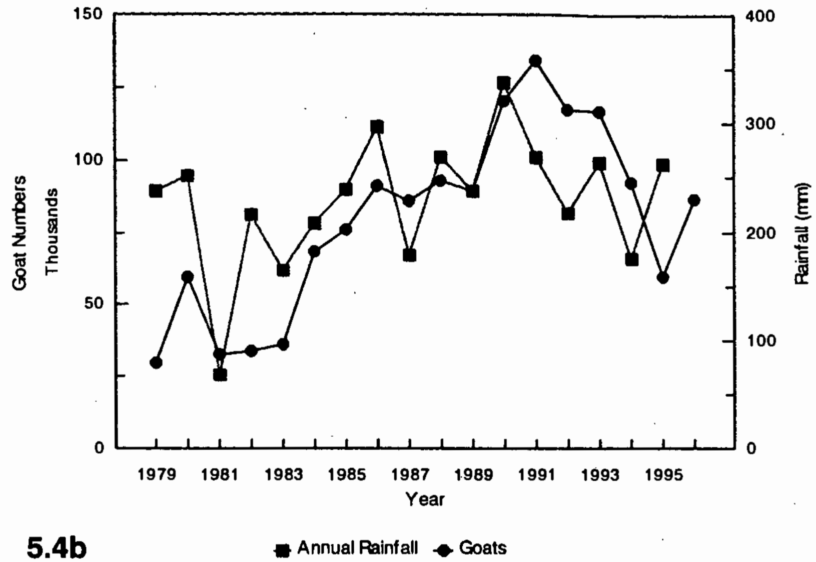
Many of the problems and limitations encountered in the case study could be overcome by a change in the methodology. This study attempted to cover a large, extensive area. Analysis would be aided if smaller key areas were analysed at a larger resolution, through the enlargement of photographs. In addition, surveys to 'ground truth' observations from the photographs would be invaluable in the interpretation of environmental dynamics. Analysis of more recent satellite data of the area in conjunction with aerial photography may also aid analysis.

### 5.2.2 Stock Numbers

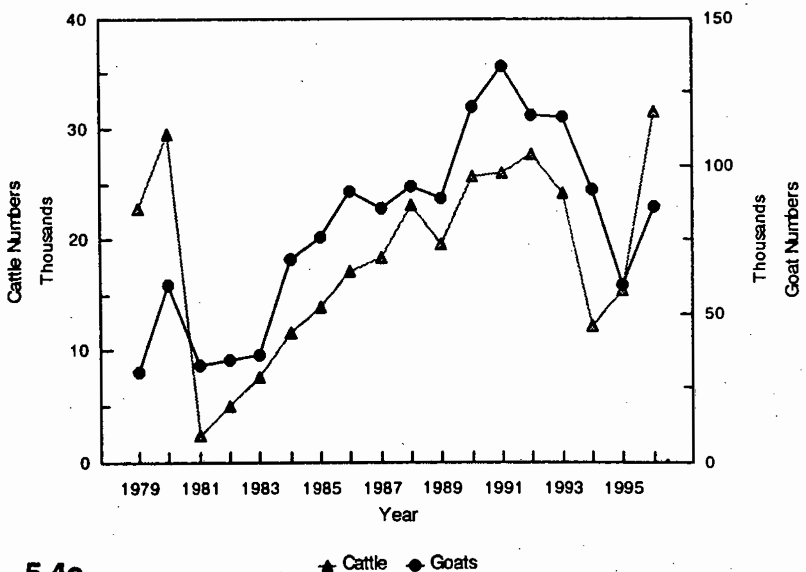
It has been shown that decreases in stocking rates can reflect decreases in the secondary productivity of rangelands (Dean and MacDonald, 1994). Dean and MacDonald (1994), using historical data, found a decline in the stocking rate in the Karoo since the early twentieth century which they suggest is unrelated to factors such as market forces or government policy but reflects a reduction in the production potential of the Karoo rangelands. In other areas, use of such historical data has shown no overall declines in productivity but rather increases or wide fluctuations in productivity. Tapson (1993) found no evidence of a decline in livestock productivity in Kwa-Zulu Natal over 15 years, despite 50 years of prior warnings that its rangelands were facing ecological collapse. Studies of livestock numbers in the Sahel and Kenya, have shown a strong correlation of livestock numbers with rainfall and the occurrence of 'boom and bust' cycles in response to droughts and wetter periods is clearly visible (Livingstone, 1991; Agnew, 1995 cited in Mills, 1995).




**5.4a**




**5.4b**




**5.4c**

**Figure 5.4. a.** Cattle numbers plotted with rainfall. **b.** Goat numbers plotted with rainfall. **c.** Cattle and goat numbers together.

As can be seen in Figures 5.4, livestock numbers are definitely not in equilibrium over time in northern Damaraland and appear to vary in response to rainfall. Both cattle and goat numbers show similar patterns of variation (Figure 5.4c). Cattle numbers dropped from a high of over 29 000 in 1980 to just over 2318 in 1981 during a drought and goat numbers dropped from over 59 000 to over 32 000 in the same time period. Both cattle and goat numbers recovered consistently, with cattle number reaching a maximum of 27 780 in 1992 and goat numbers peaking at 117 013 in 1991. Both cattle and goat numbers decreased slightly till 1994 and then started recovering again. A correlation statistic was calculated to determine if there was any relationship between rainfall and livestock numbers. Both cattle numbers and goat numbers are significantly positively correlated with rainfall (Table 5.2).

**Table 5.2.** Spearman rank correlation coefficients for cattle numbers vs annual rainfall, and goat numbers vs annual rainfall. Significant correlations are indicated with *.

| Variable | Correlation coefficient with rainfall | p-level |
|---|---|---|
| Cattle Numbers | 0.6373 | 0.006* |
| Goat Numbers | 0.5417 | 0.025* |

Rainfall limits vegetation productivity in arid environments (Sullivan, 1996a), which in turn will influence livestock survival. Often animal numbers will lag in response to rainfall (Walker, 1993) as can be seen in data from the Sahel (Figure 5.5) (Agnew, 1995 cited in Mills, 1995). A lagged correlation analysis was thus done to determine if livestock numbers correlated 'out of phase' with rainfall. No significant lag effects were found.

As discussed in Chapter 3, differentiating human-induced changes from climatic fluctuations is problematic in an arid climate such as that in the study area (Johnson and Lewis, 1995). The use of historical data in this study clearly shows the influence of rainfall on stock numbers. In order to determine if degradation is taking place, one would have to determine whether there are any trends in stock numbers apart from that induced by rainfall. Discerning whether any trends in stock numbers underlie this variation is difficult, however. Scatter plots of cattle and goat numbers show an overall increase in numbers with time (Figure 5.6). Numbers are correlated with rainfall and a scatter plot of rainfall (Figure 5.6c) also shows an increasing trend. However, stock numbers appear to have increased over and above the influence of rainfall. If in Figure 5.6a, the points from 1979, 1980, 1994 and 1995 may be regarded as outliers, a clear, increasing trend in cattle numbers exists.

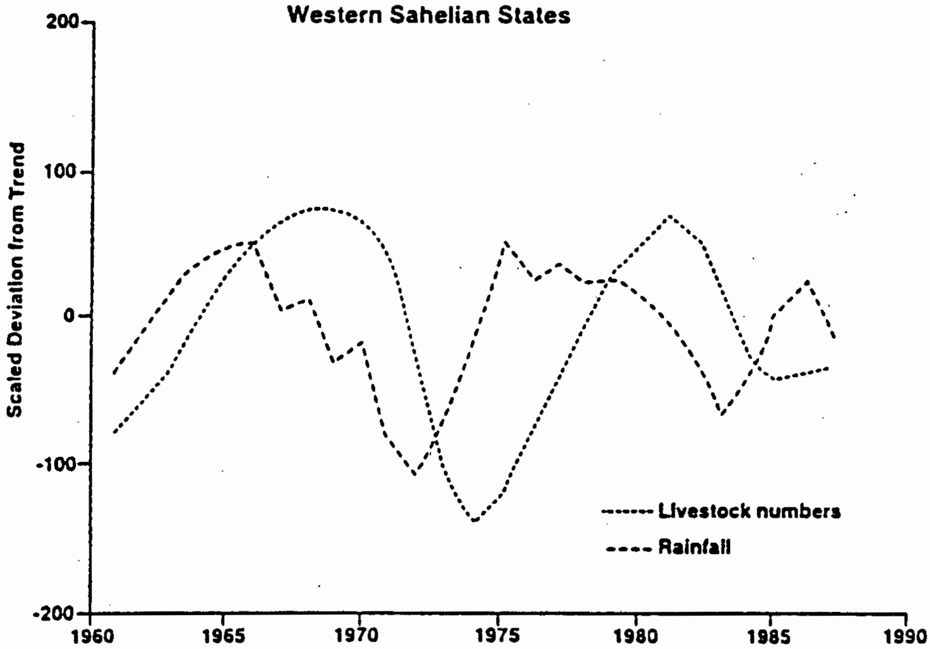
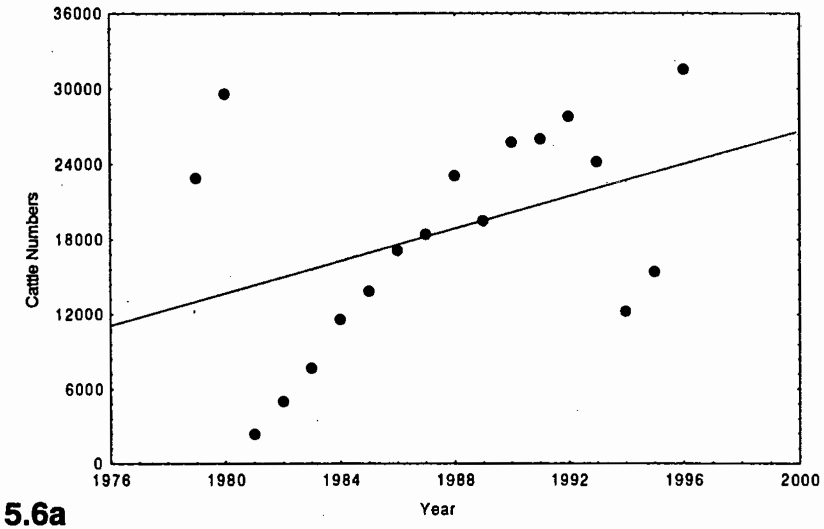
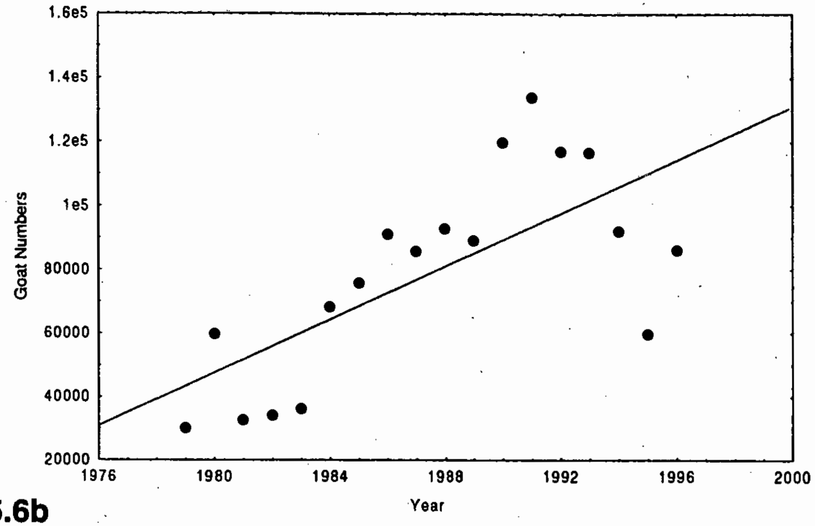



**Figure 5.5.** Changes in livestock numbers and rainfall in the Sahel (Mills, 1995: 17).

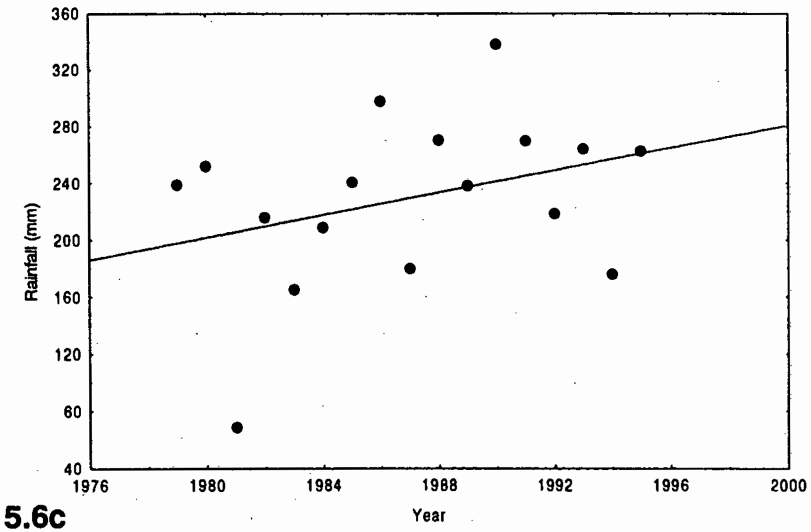
Recovery in the stock numbers for Damaraland North after the low in 1981 could be indicative of the absence of irreversible degradation and the resilience (ability to recover) of the area (Abel and Blaikie, 1989; Jacobson *et al.*, 1995). When interpreting trends in stock numbers, however, a number of other factors should be taken into account. For example, stock numbers could be influenced by the presence of disease or improvements in veterinary services (Scoones, 1993), or rise in response to increased migration into an area (Jacobson *et al.*, 1995). A number of hypotheses are suggested to explain variability in livestock numbers apart from that induced by rainfall in Damaraland North.




**5.6a**




**5.6b**




**5.6c**

**Figure 5.6.** Scatter plots of livestock numbers and rainfall with linear trend lines

- **Increasing Population and Development of New Areas**

  The population in Damaraland has increased dramatically in the last twenty years as stated in Chapter 4 (Rohde, 1994). More people in the area bring with them more stock thus contributing to the increasing trend in stock numbers observed in Figure 5.6. This inflates 'recovery' from drought as recovery (Jacobson *et al.*, 1995). Additional population pressure has probably resulted in the development of rangelands that were previously inaccessible due to a lack of perennial surface water, through the installation of boreholes (Dean and MacDonald, 1994; Jacobson *et al.*, 1995). Creation of new cattle posts through increased drilling of boreholes has occurred in the study area (MPhil Baseline Report, 1997). The development of these new areas may not mean real increases in the productivity of a rangeland as measured by livestock units per hectare of utilised rangeland and could mask declines in production potential. The use of data accessible in the form of a stocking rate (Livestock Units (LU) per hectare) would indicate whether this was occurring. An increase the density of functional livestock watering points would indicate if expansion into new rangelands is occurring (Dean and MacDonald, 1994). Any changes could then be correlated with stocking rates corrected for the influence of rainfall. A negative correlation would indicate a decline in production potential. Unfortunately, data on water points, although available, were not in a readily (within the limited available time) utilisable form.

- **Temporary Migratory Movements**

  Temporary migrations of people with their animals may introduce substantial variability in stock numbers. Extensive movements of people and livestock occurred in 1990-92 northward and eastward in former Damaraland (Rohde, 1993). If movements occurred between enumeration districts, they would be reflected in decreased livestock numbers in one area and an increase in another. It was not possible to discern to whether or to what extent this has occurred in the study area. As far as identifying reductions in productivity are concerned, such movements may not have to be corrected for. If livestock are moved with increasing frequency from one specific area to another, this could reflect a decline in the production potential of the initial area. Identifying such movements as the cause of variation in stock numbers can aid policy and planning and should not be disregarded.

- **Drought Relief**

Drought relief programmes often provide fodder (Jacobson *et al.*, 1995; MPhil Baseline Report, 1997). Provision of fodder may mask declines in the production potential of rangelands, enabling more rapid recovery of livestock numbers than would otherwise occur. Trends in productivity dynamics discussed in Chapter 3 (Figures 3.2 and 3.3), could be attenuated or masked by fodder provision. Real declines in the ability of rangelands to support stock would therefore not be detectable. The rapid rise in livestock numbers in Damaraland North could be due to provision of drought fodder and not reflect the overall capacity of the environment for recovery. Readily accessible data was not available on to what extent provision of drought fodder has occurred in the study area.

- **Disease**

Dynamics in the incidence of fatal disease will introduce variations in stock numbers. In Zimbabwe, livestock populations dropped from 1976 to 1979 due the abandonment of dipping services during the liberation war, which resulted in an increase in tick borne diseases (Scoones, 1993). Numbers rose from 1980 to 1982 as these services were restored. Disease-induced dynamics may lead to incorrect interpretations of productivity dynamics if not taken into account. In Namibia, since independence in 1990, government policy has been aimed at boosting agriculture in communal areas (National Planning Commission, 1996). This policy may have resulted in an improvement in veterinary services in Damaraland North, which would result in decreased mortality and an increase in stock numbers. Records of livestock mortality from disease could be used to test this hypothesis and indicate what degree of influence disease has had on stock numbers. These data were not accessible within the time frame of this report.

- **Inaccuracies in the Data**

  The data obtained from the Directorate of Veterinary Services are thought to be highly inaccurate before 1988 (Dunkleu, Directorate of Veterinary Services, pers. comm.). Inaccuracies in data collection will be reflected in variations in livestock numbers. For example, the increasing trend in stock numbers observed after 1980 could reflect increasing accuracy in enumeration methods.

The above hypotheses represent a range of possible explanations for dynamics in stock numbers. Actual variation is probably due to a combination of these. Most of the trend of increasing livestock numbers can probably be explained by the increasing population in the area, which doubled between 1970 and 1981 and increased by 40% from 1981 to 1991. No data, however, is readily available to test this hypothesis.

A significant problem with the available data is that it only covers a very short time period. To be fully effective, historical analysis should cover a longer period that more fully encompasses the range of climatic variation in the area (O'Connor and Roux, 1995). Although data were not available from Directorate of Veterinary Services for the period prior to 1979 in the study area, records of stock numbers are found within the Department of Lands Archival files (Kambaktuku, 1996). These numbers are for individual farm records and are not complete. They do however represent an additional source of information on productivity dynamics in the study area over time. Accessing these records for analysis is a very time consuming process, and could not be done within the time frame of this report. Care would have to be taken in explaining underlying trends in stocking rates as evidence for or against degradation in the area, if these records are used. As discussed in Chapter 2, communal farmers may have different objectives to commercial farmers. Stocking rates under commercial farmers may be lower than under communal farmers (Behnke and Scoones, 1993). Commercial farmers may wish to maximise productivity per animal which will require a lower stocking rate than when productivity is maximised in terms of animal numbers (Abel, 1993). This can be explained with reference to a simple diagram (Figure 5.7). The 'ecological carrying capacity' is a stocking rate determined by the limitations of available forage whilst the 'economic carrying capacity' is the point at which animal production per unit is maximised (Bartels *et al.*, 1993). Optimum stocking rates or 'carrying capacities' will vary with the natural temporal variability in arid and semi-arid areas. with space and also depend on the objectives of farmers (Bartels *et al.*, 1993; Mills, 1995). It is therefore important that in the analysis of productivity dynamics of rangelands through proxy measures of stock numbers, the objectives of the farmers should be accounted for over time. Changes in productivity as represented by changes in stock numbers or stocking rates could reflect changes in the objectives of farmers.

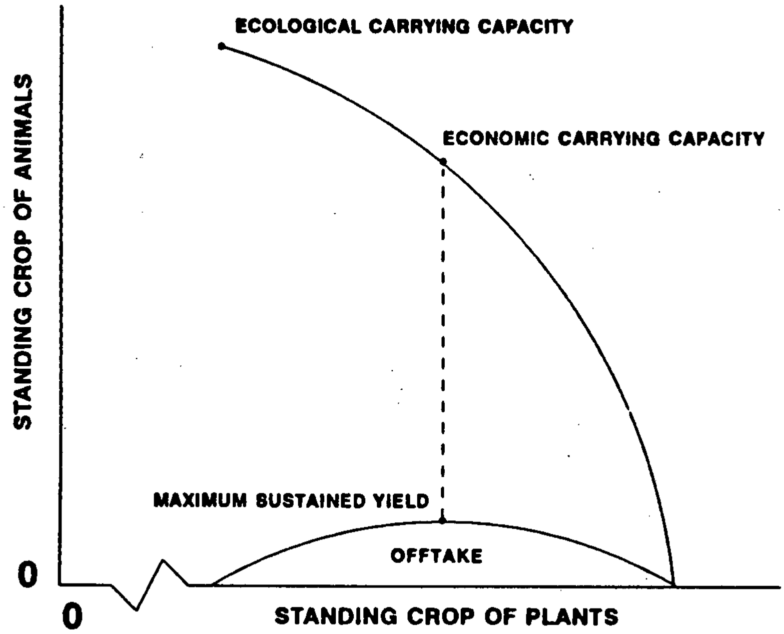



**Figure 5.7.** The relationship between plant and animal populations in a hypothetical grazing system (Behnke and Scoones, 1993: 5)

## 5.3 Conclusions

It could not be ascertained from a temporal analysis of environmental dynamics in Damaraland whether degradation has occurred. This does not exclude the possibility that localised degradation problems do exist. Problems exist with the resolution of the data used and the unavailability of longer time series data. The absence of significant differences in the comparison of the photographs may be due to various other factors and not due to an absence of environmental dynamics or more specifically, land degradation. The use of larger scale photographs, ground surveys and the addition of more recent photographs, may reveal significant changes that could be due to land degradation from an increasing population. Although analysis of the dynamics of available data of stock numbers in northern Damaraland did not reveal whether degradation has occurred, the important influence of rainfall on stock numbers was. Stock numbers are significantly correlated with rainfall. Rainfall data are not spatially comprehensive, however, as discussed, and there is a need for greater spatial resolution. Data for smaller spatial areas would also be valuable as the area is highly spatially heterogenous. In combination with greater spatial resolution of rainfall data, analysis of stock numbers for smaller areas may reveal more localised reductions in productivity. In addition, the need for longer time series data is clear. The present data do not fully cover the range of climatic variation in the area.

More comprehensive analysis of aerial photography, the use of longer time series data and data of a higher spatial resolution, and the analysis of stock numbers in terms of stocking rates may reveal the existence of localised degradation in the area. Future analysis of environmental dynamics in northern Damaraland should also utilise data that could not be accessed due to the time constraints of this report.

# Chapter 6

# 6. Discussion and Conclusions

An evaluation of the use of a historical perspective and some pertinent issues relating to the identification of dryland degradation are discussed in this Chapter and it concludes by drawing together the information presented in this report.

## *6.1 Discussion*

### 6.1.1 Practical Considerations

Theoretically, a long term perspective in analysing environmental dynamics and identifying dryland degradation is clear. Drylands are characterised by event driven systems, where large fluctuations in productivity occur (Westoby *et al.*, 1989; Sullivan, 1996a) and distinguishing between human induced degradation and climatically induced changes may be problematic (Friedel, 1991; Johnson and Lewis, 1995). A historical perspective will to some extent enable this distinction to be made, as discussed in Chapter 3. However, the practical implementation and use of such a perspective may be fraught with problems as the case study amply illustrated. The paucity of reliable extensive data was a major limitation. This problem may very well extend to many other regions where such a perspective could add valuable insights to the understanding of environmental dynamics. An important consideration is that available data may not cover a long enough time period, as happened in the case study. It is especially important in the highly heterogeneous environments that characterise drylands, that data for as long a time period as possible is analysed, as a complete understanding of environmental dynamics in such temporally variable environments may only be revealed by long term data sets (O'Connor and Roux, 1995).

The spatial resolution of data is also important. Drylands are spatially heterogeneous and large scale data may not reveal finer scale localised problems. Key resource areas which may be important during dry seasons and droughts are found in many dryland areas

(Scoones, 1995b; Jacobson *et al.*, 1995). Degradation of these areas is potentially more serious than if less intensively utilised resources are degraded. Low spatial resolution of data was encountered in the case study. For example, rainfall figures were of a low spatial resolution and biased towards the eastern, wetter margin of the study area. Stock numbers were also of a low spatial resolution as numbers could only be obtained for the whole of northern Damaraland and not smaller areas. Thus the analysis of the dynamics of stock numbers may not have been accurate. The importance of analysing environmental dynamics from a historical perspective within the context of land use history, is also clear. In the case study, for example, analysis found that stock numbers were correlated with rainfall with an underlying increasing trend. When these numbers were analysed in the context of the land use history of the area, a number of alternative explanations other than an increase in productivity could be postulated.

Although, in practice, the use of a historical or temporal perspective maybe difficult and the conclusion of the case study was that it was not possible to ascertain whether degradation had occurred in the study area, this does not diminish the value or importance of such a perspective. Much can be gained by some knowledge of past environments, climate and land use (Dahlberg, 1994). In the study area, the important influence of rainfall on livestock productivity was demonstrated, and environmental dynamics could be viewed in association with changing land uses over time. The paucity of data and difficulties encountered in the case study were exacerbated by time constraints. The methodology utilised in this report could be improved upon in the ways suggested in Chapter 5 and many of the problems encountered in the analysis could be resolved with time as more data could be gathered. In conclusion; although theoretically a temporal perspective is valuable, it may be practically difficult to implement and analysis will be restricted by available data.

### 6.1.2 Sustainability

Dryland degradation was defined in this report as an irreversible reduction in productivity on a scale of 20 to 30 years. Recognising irreversible changes from reversible ones, is difficult without a complete understanding of ecosystem dynamics.

Even a historical perspective may not fully resolve problems. In addition, as the processes leading to degradation proceed, restoration of rangelands may become more costly in terms of the loss of secondary productivity and the expenditure of energy (Milton *et al.*, 1995). It may be more useful, in utilising a historical perspective, to recognise not degradation *per se*, but overall declines in productivity that may not yet represent land degradation as they are reversible. Recognition of such reductions may allow corrective action to be taken before land degradation occurs. One problem that may be encountered with this is, is that vegetation communities in many arid rangelands may effectively change to a lower productivity 'state' abruptly, discontinuously and irreversibly (Westoby et al., 1989; Laycock, 1991) as was discussed in Chapter 3. A long term perspective will enable one to recognise if such changes have taken place, but it may not be able to predict if such changes are going to occur. If overall declines in productivity above those dynamics induced by climate are detected, however, policies could be implemented to halt such trends. The rate at which reductions in productivity are occurring should be considered and the benefits of introducing corrective policies assessed. Analysis by Biot (1993) and Abel (1993) suggests, that given the rate at which soil loss (and thus a reductions in productivity) is occurring in Northern Botswana, and the relative benefits to be gained from destocking, the implementation of policies to encourage destocking to reduce soil erosion are not worth it. Soil erosion is occurring at rates that suggest that significant declines will only be experience in 400 years time (Biot, 1993). A long term perspective may therefore aid in assessing the sustainability of land use in dryland areas. Care should be taken in extrapolating the results of analysis to other areas, however, as dryland are extremely diverse.

### 6.1.3 Perceptions of Environmental Dynamics

Although land degradation was defined as a human-induced reduction, reductions were viewed exclusively in the context of livestock farming. In other words, in the case study, identification of degradation meant that there had to be discernible negative affects that would affect livestock productivity. Perceptions of degradation will vary, however, depending on the objectives and point of view of the interested parties or observers. Different people, scientists and non-scientists alike, claim different truths about the environment (Blaikie, 1997). A conservationist may therefore have a different view and truth about the nature of observed environmental dynamics than a subsistence pastoralist, as discussed in Chapter 2. Biot *et al.* (1995) question whether degradation can in fact be defined and measured unequivocally.

Rangelands were only viewed in terms of their use value and ability to yield livestock products. Other resource values, including aspects such as suitability for tourism and ecosystem services such as ground water recharge and wildlife production have been ignored, but may be negatively affected (Jacobson *et al.*, 1995). Although, for example, changes leading to a reduction in a landscapes value for tourism may have occurred, this would not be regarded as land degradation in a paradigm where use value for livestock is more important. The value of a temporal perspective to identify environmental dynamics is not lessened by such considerations however. The interpretation and meaning that is attached dynamics identified by a long term perspective, has to be negotiated within society.

## *6.2 Conclusion*

The aim of this report was to demonstrate why an historical perspective of environmental dynamics is valuable in drylands for the identification of degradation and to evaluate the use of such a perspective using northern Damaraland as a case study. In order to achieve this aim, several objectives were addressed, these being:

- to provide a clear and unambiguous definition of the term 'dryland degradation' or 'land degradation'
- to review possible indicators and agents of environmental change and land degradation

- to provide a conceptual framework that emphasises the importance of a historical perspective, and the role of arid rangeland dynamics, in evaluating environmental change

- to analyse environmental dynamics in northern Damaraland from a historical perspective, utilising aerial photography and archival data in the form of stock numbers

- to highlight inherent problems and the utility of an historical perspective

Dryland degradation is widely viewed as a major environmental issue, however, too often pronouncements of degradation may be based on limited and a poor understanding of the context and functioning of arid systems. The usage of the term is often unclear and may mean different things to different people. The term dryland degradation or land degradation was thus clearly defined in this report as a human-induced irreversible decline in usable primary and secondary productivity. Perceptions of degradation will vary depending on the objectives and point of view of interested parties or observers. Its causes are complex and there exists a multitude of interacting physical processes along with human values and constraints. Degradation is not caused by drought and many of the traditional indicators used to identify it may be reinterpreted as natural reversible traits of a variable environment.

Differentiating human-induced degradation from natural climatically induced variation may be difficult in drylands as productivity is characteristically highly variable and rainfall dependent. A historical perspective may, therefore facilitate the recognition of long term reductions in productivity. The dynamics of these event driven systems can be followed utilising such a perspective, which will be more valuable than 'snapshot' assessments. The consideration of average values or single points in dryland landscapes may give a misleading idea as to the production potential of an area, however. Spatial heterogeneity is high in these areas and thus consideration of spatial dynamics is important. Analysis of environmental dynamics to identify degradation should also be done in the context of the land use history of the area.

The use of a historical perspective was evaluated with northern Damaraland as a case study. This is an arid region with a highly variable climate, both temporally and spatially. Consequently, a short time period is inadequate for the accurate identification of dryland degradation. The population is growing rapidly and concerns exist that widespread degradation may be occurring. Analysis of aerial photographs and stock numbers could not ascertain whether degradation has occurred however. A paucity of data limited the analysis as the data did not cover a long enough time period and were of a poor resolution. The analysis did not exclude the possibility that localised problems with land degradation exist. Although the results were largely inconclusive as far as identifying degradation is concerned, the analysis was still valuable. The important influence of rainfall on stock numbers was illustrated, for example. The methodology that was used, could be improved. Aerial photography analysis should concentrate on larger scale photographs of smaller spatial areas and ground based surveys should be done. Analysis of stock numbers should concentrate on smaller areas, and use should be made of stocking rates as opposed to whole stock numbers. Further investigations in northern Damaraland may be able to utilise other potential data that could not accessed due to the time constraints of this report.

The case study showed that though theoretically a historical perspective on environmental dynamics may be valuable, practically, utilisation of such a consideration is problematic. Dryland degradation is a contentious issue and this report has demonstrated the importance of historical considerations of environmental dynamics in its identification. The importance of analysis within a context that encompasses the objectives of land users and the changing land use history of an area is also clear.

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