A systematic conservation assessment of habitat transformation and degradation in the Little Karoo, South Africa.

Thesis presented for the degree of Master of Philosophy in the Department of Botany at the University of Cape Town.

by

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Declaration

I, the undersigned, hereby declare that the work contained in the thesis is my own original and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature: ....Signed by candidate......**Date:** ...19 November 2008...

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To all those people who gave me words of encouragement to march forward I say: Umntu ngumntu ngabantu! (I am who I am because of you).

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Abstract

This study focuses on the state of the environment of the Little Karoo and is comprised of three main analyses. In the first analysis, a fine-scale vegetation map of the Little Karoo (Vlok *et al.*, 2005) comprised of 369 vegetation units and 56 habitats within 6 biomes (or sub-units of a biome) was linked to a degradation map (Thompson *et al.*, 2005) of the region. Using these data sets the extent of transformation and degradation with the major biomes, habitat units and vegetation units in the Little Karoo was quantified. The results were then compared with previous assessments of degradation in the area. In the second analysis, the output from the quantification of degradation was used to develop a map of the ecosystem status of the Little Karoo within four classes (Critically Endangered, Endangered, Vulnerable and Least Threatened). Conservation targets were modified according to the number of species and degree of endemism within each vegetation unit. Finally, using long-term climate and agricultural census records, the historic causes of degradation in the region were also investigated.

The results indicate that 53.4% of the habitat units are moderately degraded with 14.1 % considered severely degraded. The Succulent Karoo biome, Azonal habitats and Thicket biome are particularly affected by degradation. When comparing the results of this study to those of the South African National Land cover assessment, it appears that the extent of degradation in the Little Karoo has been substantially under-estimated in the past. In terms of ecosystem status it was found that of the 369 vegetation units mapped 26 (7.1%) were classified as Critically Endangered 58 (15.7 %) Endangered, 67 (18.2 %) Vulnerable and 218 (59.1 %) Least Threatened. The Succulent Karoo has the highest number (13) of Critically Endangered vegetation units in the study area.

An analysis of climate data of the study area did not show any statistically significant long-term changes in rainfall and temperature except for Ladismith which has experienced a decline in rainfall and increase in mean annual minimum temperature over the last fifty years. Lucerne is the dominant crop in the region and its production has increased. There has been a general decline in goat numbers but an increase in sheep and ostriches over the last 100 years. It is concluded that anthropogenic forces underline the changes that have taken place in the Little Karoo especially, grazing by domestic livestock, ostrich farming and lucerne cultivation.

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CHAPTER 1 GENERAL INTRODUCTION

1.1 The extent of the dryland degradation problem

Dryland ecosystems cover about one third of the Earth's land surface with more than 38% of the global population dependant on its services (Reynolds *et al.*, 2007). The United Nations Environmental Programme (UNEP) estimates that of the world's 5.2 billion hectares of agriculturally-used dry lands, 69% is degraded or subject to desertification (UNEP, 2004). As the majority of the population of arid and semi-arid regions depends largely on agriculture and livestock for subsistence, degradation can have significant and disastrous consequences for their livelihoods. Climate change and population growth pressures are likely to compound this problem. The general acceptance of the phenomenon of land degradation and desertification as a world-wide reality (Dean *et al.*,1995; Reynolds and Stafford-Smith, 2002), has lead to the mobilization of the international community in order to find appropriate responses to this problem.

The United Nation Conference on Desertification (UNCOD) held in Nairobi in 1977 originated as a result of several dryland concerns. These included the droughts in sub-Saharan Africa in the late 1960's and 1970's in which over 200 000 people and millions of animals died as well as the food crises of the early 1970's (UNCCD, 1994; Gibson, 2006). This gathering is regarded as the first attempt to address desertification as a worldwide problem (UNCCD, 2006). Recently, the General Assembly of the United Nations declared 2006 the International Year of Deserts and Desertification (IYDD), underlying its concerns for the exacerbation of desertification, particularly in Africa (UNCCD, 2006).

Severe periodic droughts often accompanied by famine and death and regarded as symptoms of desertification and degradation in Africa, have been subjected to world-wide publicity often making dramatic headlines in the print and electronic media. The widespread drought, famine and death of people and animals in the late 1960's and 1970's and, what Reynolds and Stafford-Smith (2002) regard as a combination of drought and a civil war in Ethiopia in the 1980's, are cases in point. As a result of these events, and despite the fact that desertification has been acknowledged by the former UN Secretary Kofi Annan as the 'world's most alarming process of environmental degradation', there is a common misperception that it is a "natural problem of advancing deserts in faraway developing countries" (IPCC, 1996). Yet, cases of land degradation from recent human settlements in the rangelands of the United States, Argentina and Australia have also been cited by Reynolds and Stafford-Smith (2002) which they argue, share many of the ecological consequences and social issues of dryland agriculture in Africa and China. Although these processes are now regarded as a global reality, the notion of a 'marching desert' as expounded by Acocks (1953) has not been substantiated (Dean *et al.*, 1995; Ellis *et al.*, 2002; Wessels *et al.*, 2007). Prince (2002) argues that much of the confusion surrounding the causes, the existence and extent of desertification could be resolved by setting clear space and time scale frameworks. He suggests that until spatial and temporal scales of different degradation processes are known, its causes and nature can never be properly understood. Similarly, Wessels *et al.* (2007) point to the inability of many studies to agree on or even locate areas where degradation has taken place, making it difficult thereafter to discuss the degree and extent or even the reality of degradation.

Nearly 91% of South Africa experiences arid, semi-arid or dry sub-humid conditions with only about 1% of the surface areas defined as humid (Hoffman and Ashwell 2001). Issues of drought, degradation and desertification have, therefore, attracted considerable attention as these processes have impacted historically on the socio-economic landscape of the country. For most of the last century, the Karoo region in particular, has served as a geographical focus for desertification (Hoffman 1995; Dean *et al.*, 1995).

Although South Africa was not officially represented in the Nairobi gathering in 1977, it ratified the United Nations Convention to Combat Desertification in 1997. However, for nearly a century, there have been a plethora of investigations and agricultural policy developments undertaken in order to understand and respond to observed environmental changes (Acocks 1953, Roux and Theron 1987; Dean *et al.*, 1995; Hoffman *et al.*, 1999a, Beinart, 2003). High level investigations and regulatory measures were introduced to mitigate the impact of non-sustainable agricultural practices. These included the Fencing Act of 1912, the Select Senate Committee on Droughts, Rainfall and Soil Erosion (1914), the Drought Investigation Commission (1923), the Desert Encroachment Committee (1951), the Commission of Investigation into Agriculture (1968) and the Departmental Committee for Veld Deterioration (Hoffman *et al.*, 1999b).

1.2 Causes of desertification and degradation

In many instances, the causes of desertification and degradation are typically classified as either bio-physical or socio-economic, exogenous or endogenous (Robbins *et al.*, 2002). As a result of this approach, attempts to understand the causes of desertification and land degradation have been underlined mostly by the desire to establish the extent to which degradation can be attributed either to 'naturally' driven (e.g. climate) or human-induced (e.g. grazing) factors. This compartmentalisation of causal factors tends to underestimate the interaction between bio-physical and socio-economic forces. The links between these dimensions are critical elements of the degradation process (DEAT, 2004). This concern has been raised by Hoffman and Todd (2000) who regard attempts to solve South Africa's land degradation problems as having been conducted in relative isolation in the past. They point to the lack of multidisciplinary approaches in understanding the causes and impacts of degradation. Xue and Fennesy (2002) outline a relationship between land cover and climate change in drylands in studies carried out in the Sahel and East Asia. In these regions it has been observed that re-occurring droughts have been associated with land-surface degradation as a result of population pressure in excess of the region's carrying capacity. It is for this reason that Stafford-Smith and Reynolds (2002) suggest a new integrated approach which links biophysical and socio-economic factors.

Desertification and degradation processes associated with human activities have been advanced as a major cause of global environmental change. In particular, the role and significance of over-grazing as a human-induced cause of land degradation, has occupied centre stage in the degradation debate for a long time and in many different regions of the world (Batterbury *et al.*, 2002; Meadows and Hoffman, 2002; Zhao *et al.*, 2005). However, even though desertification and degradation are often attributed to a number of human related activities, particularly grazing, these processes may be triggered or accelerated by climate (Nicholson, 2001). For example, Wessels *et al.* (2007) cite a number of studies that have shown that 'the perceived desertification in the Sahel can largely be attributed to variations in rainfall rather than human-induced land degradation'.

Elsewhere Cheng *et al.* (2007) report that the dry and warm climate in northern China over the last 50 years, has created conditions favourable for the desertification process. Hulme *et al.* (2001) have also identified the role and effects of El Nino in exacerbating regional climate changes in Africa. However, Wessels *et al.* (2007) suggest that changes in the land surface such as vegetation cover and soil moisture can also affect local climate. In the Sahel for an example, anthropogenic changes in the land surface, particularly land degradation and desertification, are considered to have contributed significantly to the decline in rainfall (Nicholson, 2001). Midgley *et al.* (2005) make the point that the impact of climate change manifested by a warmer and drier climate is likely to be a progressive impoverishment in species richness in recognized biodiversity hotspots such as the Succulent Karoo biomes. The United Nations Framework Convention on Climate Change signed by 154 governments in Rio de Janeiro during the United Nations Conference on Environment and Development (UNCED) in June 1992 was an attempt to address these challenges.

In the Karoo, the use of land by pre-colonial hunter-gatherers (Bushmen) and nomadic pastoralists (Khoi) groups had relatively minor impacts on the natural landscape although there is evidence of relatively localised changes in natural vegetation (Dean *et al.*, 1995). Although changing climatic patterns would have influenced the vegetation of the Karoo in the pre-colonial period, the region has undergone significant vegetation changes since its early colonial occupation 200 years ago. Soon after this occupation, the semi-arid and arid regions of South Africa began to show signs of progressive degradation (Dean and Macdonald, 1994). Already, by the 1770's writers and travellers noted widespread visible changes and expressed concerns about the future outlook of the semi-arid Karoo (Beinart, 2003).

It is believed that over the last century, it has been the mismatch of agricultural land use practices with the production potential of the land which has led to negative changes in the entire Karoo landscape. A decline in agricultural productivity has also been attributed directly to agricultural impacts and in particular, to overgrazing (Dean and Mcdonald, 1994). Because of noticeable physical changes of the natural land cover, climate changes have often been proposed as the main cause of changes on the ground. Although southern Africa has been subjected to shifts in climate in the last 2000 years (Dean *et al.*, 1995), there is no conclusive evidence that this is the case in the Little Karoo with respect to rainfall and temperature distribution patterns.

1.3 Defining desertification and degradation

Many different and sometimes confusing definitions have been used for the terms 'desertification' and 'degradation' (Prince, 2002). Several studies and reviews have been carried out to try to re-define desertification and degradation processes and explain the extent of the problem (Dean *et al.*, 1995, Hoffman, 1995; Milton and Dean, 1999; Hoffman and Ashwell, 2001; Reynolds and Stafford-Smith, 2002). The most widespread and commonly-accepted definition of desertification is that contained in the United Nations Convention to Combat Desertification (UNCCD).

The UNCCD defines desertification as: *'land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities'* Land degradation, in turn, is defined as the *'reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigation cropland, or range, pasture, forest and woodlands resulting from land uses or from a combination of processes, including processes arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical and biological or economic properties of soil; and (iii) long-term loss of natural vegetation'* (United Nations, 1994). This definition is considered adequate and has been adopted for the purpose of this study.

1.4 Assessment of desertification and degradation

Various attempts have been made to assess degradation and desertification at a wide range of spatial and temporal scales. However, there is still no accurate large-scale assessment of the extent, nature and degree of degradation and desertification (Nicholson, 2001). Assessing degradation and desertification has its challenges. Prince (2002) points to assessment problems related to amongst others, difficulties in mapping desertification and expensive ground-based assessments. He also refers to an initiative of the Global Assessment of Soil Degradation (GLASOD) undertaken by the International Soil Reference Centre (ISRIC), and the World Atlas of Desertification (UNEP, 1997) which relied on qualitative measurement and is considered by Gibson (2006) to have incorporated significant subjectivity in its analysis. On the other hand, where a quantitative approach has been adopted in assessment, there is a tendency to neglect the human dimensions of desertification and degradation and over-emphasise biophysical factors of land cover change (Leemans and Kleidon, 2002).

The conventional wisdom in many assessment studies is to associate severe degradation that causes species change in arid areas, with a reduction in vegetation cover which is detectable with remote sensing techniques. However, Talbot (1986) argues that an assessment of vegetation cover does not always provide a useful indication of species change in arid areas due to the coarse resolution of satellite data which is normally used. In South Africa there has not been any coordinated effort to quantitatively monitor vegetation composition and productivity at the national scale and thus the true extent of land degradation and changes in species composition over time, remains uncertain. National syntheses of veld degradation following the publication of John Acock's Veld Types of South Africa (Acocks, 1953), include a perception-based land degradation study covering 367 magisterial districts by Hoffman *et al.* (1999b), and two land-cover mapping exercises (Driver *et al.*, 2005) conducted in 1995 and 2001/2002.

For South Africa, land use mapping using remote sensing techniques was initiated in the 1960's with considerable advances made during the 1970's in which up-to-date maps of the Fynbos biome were produced (Jacobson, 1983). Despite these efforts, Makhanya (1983) has raised the issue of the lack of information in the form of accurate land use and land degradation maps that cover the entire country. However, remote sensing technology cannot replace expert mapping, visual observation and interpretation as demonstrated in assessment initiatives such as the Succulent Karoo Ecosystem Project. According to Wessels *et al.* (2007), there is also a need for spatial monitoring systems that are able to distinguish human impacts on vegetation production from the effects of rainfall variability.

1.5 Motivation and objectives of the study

Although there is a considerable body of literature (Acocks, 1953; Dean *et al.*, 1995; Hoffman *et al.*, 1995) on the degradation of semi-arid areas in South Africa, the extent of the problem has not been quantified and mapped at a fine scale. Whilst these studies have shown that the semi-arid region of the Little Karoo region has been impacted upon by various forms of human activities over time, there remain significant gaps in our knowledge of the extent of these changes. Previous land cover assessment studies such as the National Spatial Biodiversity Assessment (NSBA) (Driver *et al.*, 2005), have acknowledged that there is a need for rigorous investigation of the true state of the environment in South Africa. Furthermore, the on-going monitoring of change in terrestrial ecosystems, and in particular the development of quantitative data on the extent of degradation and land transformation have been identified as national priorities for further research (DEAT, 2004; Driver *et al.*, 2005).

The aim of this study is to outline the extent of land degradation in the Little Karoo with specific focus on quantifying the spatial extent of degradation in this area. This thesis addresses four main objectives:

(i) To quantify the extent of land transformation and degradation in the major biomes, habitats and vegetation units of the Little Karoo;
(ii) To determine the ecosystem status of major habitat units in the Little Karoo in accordance with national research needs and priorities;
(iii) To compare the outputs of these approaches with other studies undertaken in the region;
(iv) To assess the historical causes of degradation in the region using long-term climate and agricultural census records.

1.6 General approach and thesis outline

Several detailed analyses in South Africa have also been carried out within the last decade as part of the following three major biome-level research programmes: the Succulent Karoo Ecosystem Plan (SKEP), the Cape Action for People and Environment (CAPE) and the Subtropical Ecosystem Plan (STEP). Two products, conducted within SKEP, are of particular interest to this thesis and contextualise the approach adopted.

The first is comprised of an expert-led collaborative study undertaken by Vlok *et al.* (2005) which resulted in a vegetation map of the Little Karoo. The second product, developed by Thompson *et al.* (2005), is a map derived from satellite imagery, of the extent of transformation and degradation in the Little Karoo. In this thesis, I link outputs from the Vlok *et al.* (2005) and Thompson *et al.* (2005) studies together and derive a table of the extent and severity of degradation in different vegetation types of the Little Karoo. I then use this product to map the conservation status of different habitats within the Little Karoo and compare this result with previous analyses carried out in the region.

In a separate analysis I investigate the causes of degradation in the Little Karoo through an independent analysis of the historical climate and land use changes in the region. A more detailed outline of this general approach is provided below for each chapter. In Chapter 1, I review historical events on land degradation and desertification at global, regional and national level. A discussion of government records on desertification and land degradation in South

Africa at the turn of the 20th century and insightful writings on farming, conservation and related policy developments (for an example Beinart, 2003), provide substance for this chapter which concludes with a statement of the key objectives and outline of the thesis. A comprehensive description of the Little Karoo as a study area is presented in Chapter 2. This description starts with an outline of the key biophysical variables which define the region and details the location, topography, climate and vegetation of the Little Karoo. The formal conservation status of the region's natural areas is also presented. This chapter ends with a brief outline of the key socio-economic drivers affecting the landscapes of the region.

The first data analysis chapter is presented in Chapter 3. The detailed vegetation map developed by Vlok *et al.* (2005) was processed so as to make it compatible with the land transformation map derived from satellite imagery by Thompson *et al.* (2005). Using ArcView GIS (Version 3.2) I then calculated the extent of land transformation in the Little Karoo within the major biomes, habitats and vegetation units in the region. The output of this analysis was compared with previous estimates of land degradation in the Little Karoo developed within the National Spatial Biodiversity Assessment (NSBA) (Driver *et al.*, 2005).

In Chapter 4, I used data on species richness and endemism for each vegetation unit (Vlok unpublished data) to derive conservation targets for each habitat in the Little Karoo. I used the results of this analysis, together with the outputs from Chapter 3, to assess the conservation status of each biome and habitat in the Little Karoo according to the NSBA (Driver *et al.*, 2005) classification framework. I compared the results from this detailed analysis with those of previous studies carried out within the CAPE, SKEP and NSBA research programmes.

In order to understand the causal factors for the current environmental status of the area, long-term climate and agricultural census data of the region were synthesized in Chapter 5. Changes in rainfall and temperature were analysed and trends in different agricultural practices (primarily cultivation and livestock production) were assessed. Since ostriches have a significant impact on natural ecosystems in the Little Karoo a relatively detailed account of the stocking rates of ostriches in the region has also been presented.

The final chapter (Chapter 6) summarises the key points developed in the main data chapters and discusses the results and implications of the thesis outcomes.

CHAPTER 2 THE STUDY AREA

2.1 Location and topography

The Little Karoo lies roughly between 33° 28′ S and 33° 97′ S, 20° 03′ and 23° 67′ E. It is separated from the Coastal Belt by the Langeberg and Outeniqua mountains, which forms its southern boundary (Nell, 2003). Its northern boundary is formed by the Swartberg mountain range which separates the Little Karoo from the Great Karoo. The area is fairly hilly, at elevations between 300 m to 600 m with soils that are generally deep and fertile, derived mainly from shales of the Bokkeveld Group and Karoo Sequence, and conglomerates of the Enon Formation in the Uitenhage Group (Low and Rebelo, 1996).

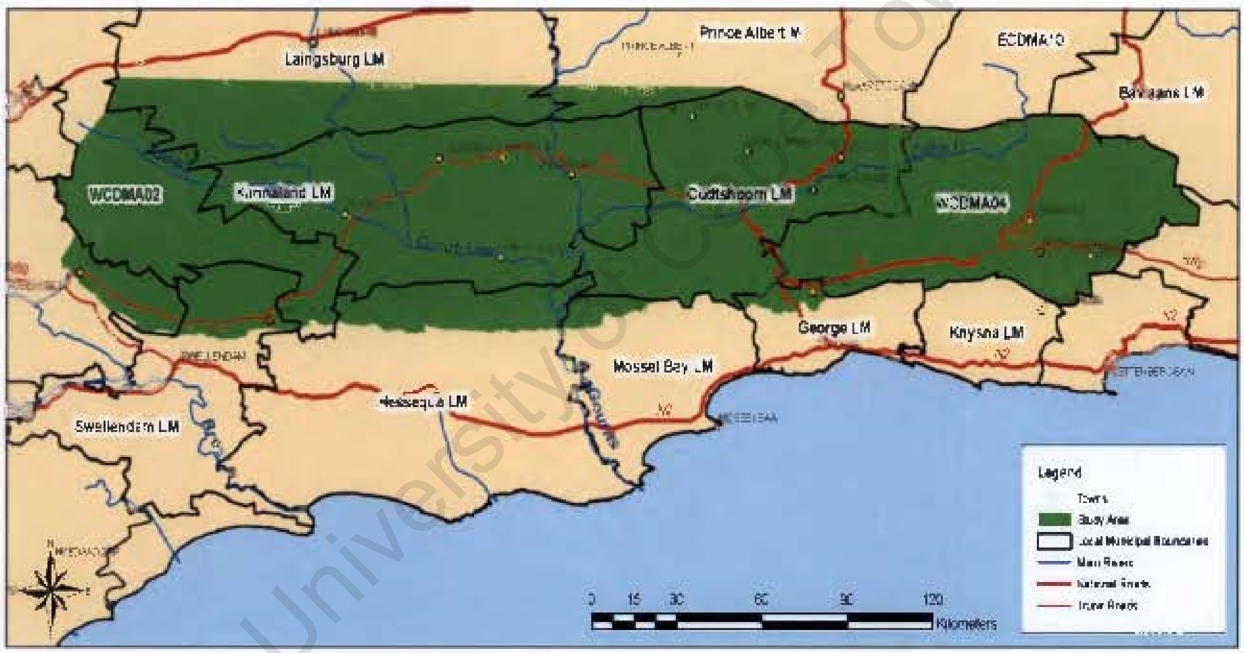


Figure 2.1 Location of the study area within the municipal boundaries with main towns, rivers and routes indicated.

The five magisterial districts covered by the study namely Montagu, Ladismith, Calitzdorp, Oudtshoorn and Uniondale (Figure 2.1), form part of the district municipality of Kannaland in the South Cape region of the Western Cape Province. The district has seven local municipalities. The southern part of the district is bordered by the scenic Garden Route, whilst the region's interior has the Cango Caves as one of the premier tourist destinations in the country.

2.2 Rainfall and temperature

The climate of the Little Karoo is affected by a variety of weather systems. Desmet and Cowling (1999), suggest that subtropical anticyclones, coastal lows, easterly and westerly waves, cut-off lows, southerly meriodional flows, cold fronts and thunderstorms are all key determinants of regional climates in the Little Karoo. These systems or circulation patterns produce a variety of weather conditions ranging from fine weather conditions to unpredictable cut-off lows which can cause flooding in the region.

In the Little Karoo, rainfall is generally low and ranges between 150 to 300 mm per year. The region falls within a transitional area between the winter and summer rainfall regimes of the west and east respectively (Low and Rebelo, 1996). The largest rainfall events in the Little Karoo are invariably associated with the less predictable cut-off lows. Cold fronts which bring considerable rain to the region, occasionally penetrate beyond the coastal mountain belt of the Langeberg and Outeniqua mountain ranges in the south. Rainfall reliability is greater in the west although the eastern part of the Little Karoo generally receives more rainfall and a greater proportion of summer rainfall (O'Farrell *et al*., 2008). Average monthly rainfall values for the five districts are presented in Figure 2.2.

High temperatures, low relative humidity and little and no cloud cover are also characteristic of the Little Karoo resulting in large daily fluctuations in temperature (Desmet and Cowling, 1999). Long-term temperature records for the study area were only available for Oudtshoorn and Ladismith (Figure 2.3). The average maximum and minimum monthly temperature values are similar for the two climate stations. The hottest months are from December to February while the coolest conditions prevail between June and August.

Figure 2.2 Average monthly rainfall records for the Little Karoo districts of Montagu, Ladismith, Calitzdorp, Oudtshoorn and Uniondale. Data are from the South African Weather Service (SAWS), Pretoria, South Africa.

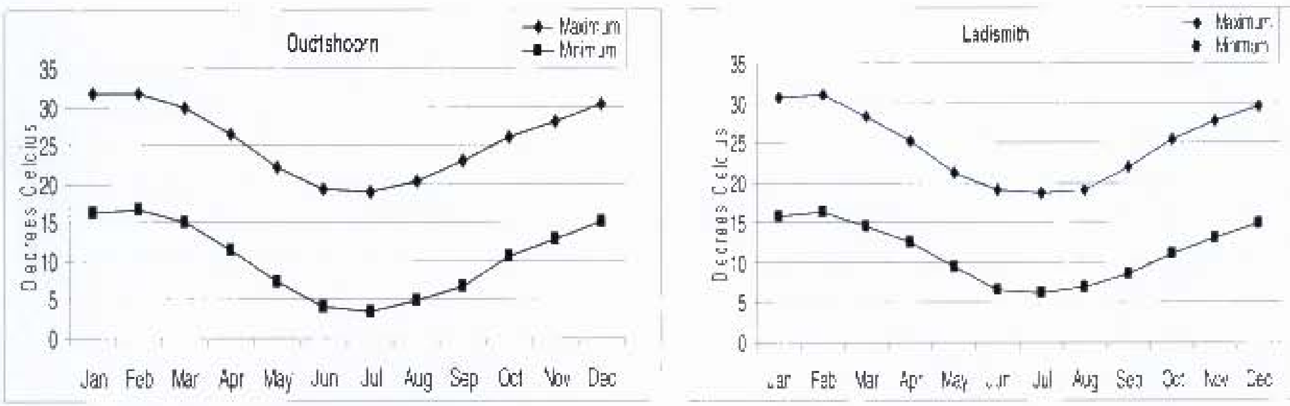


Figure 2.3. Average monthly maximum and minimum temperature for Oudtshoorn (left) and Ladismith (right). Data are from the South African Weather Service (SAWS), Pretoria, South Africa.

2.3 The vegetation of the Little Karoo

The level of plant diversity and endemism in the Little Karoo is extraordinary relative to the generally low diversity and endemism typical of most arid areas. The Little Karoo vegetation has been described by Mucina *et al.* (2006) and especially by Vlok *et al.* (2005) who map 369 vegetation units in the region. The vegetation of the Little Karoo is an assemblage of low non-succulent and succulent karoo bushes with taller shrubs and trees common on rocky outcrops and in river beds (Coetzee, 1981). Of the seven biomes described by Rutherford *et al.* (2006) in southern Africa, three occur frequently within the boundaries of the Little Karoo. These are the Succulent Karoo biome, the Fynbos biome (including Renosterveld) and the Albany Thicket biome (Figure 2.4). In addition to these biomes, a boundary interface between the Nama-Karoo and Succulent Karoo biome is present (Mucina *et al.*, 2006). Azonal habitats, comprised mostly of riparian vegetation also occur in the Little Karoo, particularly along major river courses in the region (e.g. the Gouritz River) (Plate 2.1). A detailed map of the major biomes as well as Renosterveld (considered a sub-unit within the fynbos biome) and Azonal habitats, which are mapped separately, has been carried out by Vlok *et al.* (2005) and is shown in Figure 2.5.

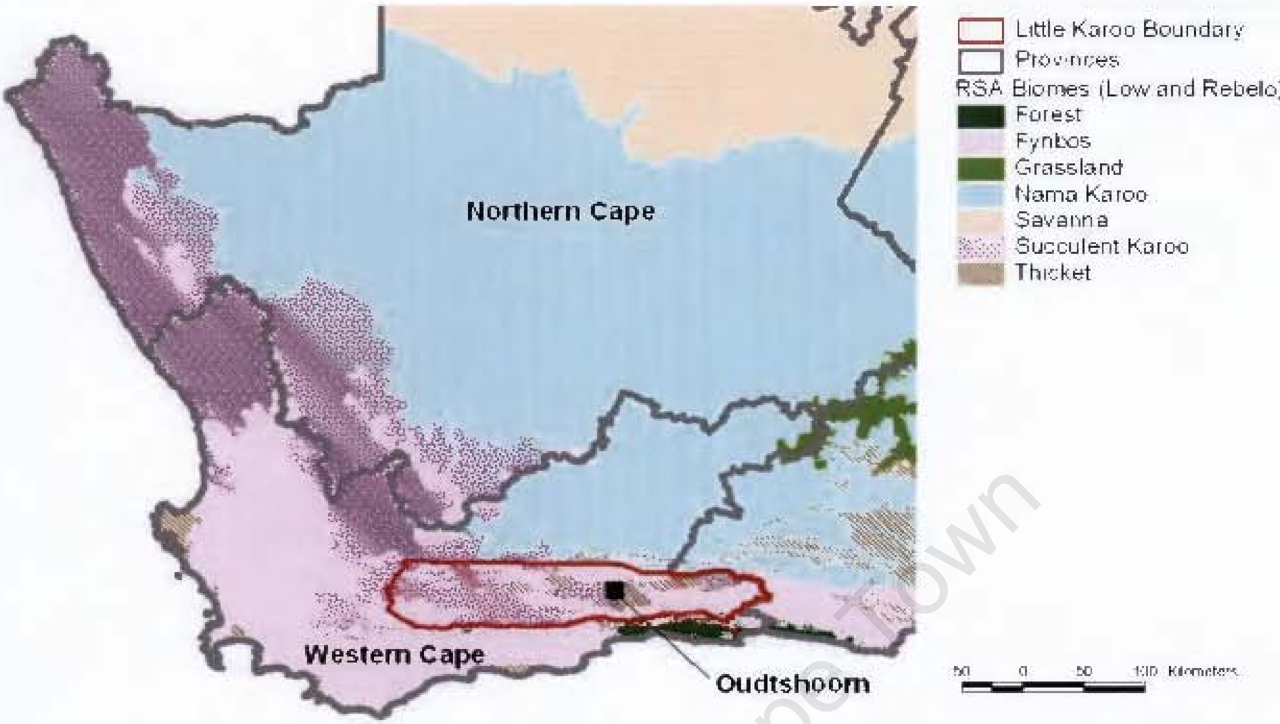


Figure 2.4. The major biomes within the Little Karoo region (after Low and Rebelo, 1996).

Plate 2.1 Wide, flat azonal habitats are frequently exploited for cultivation purposes in the Little Karoo.

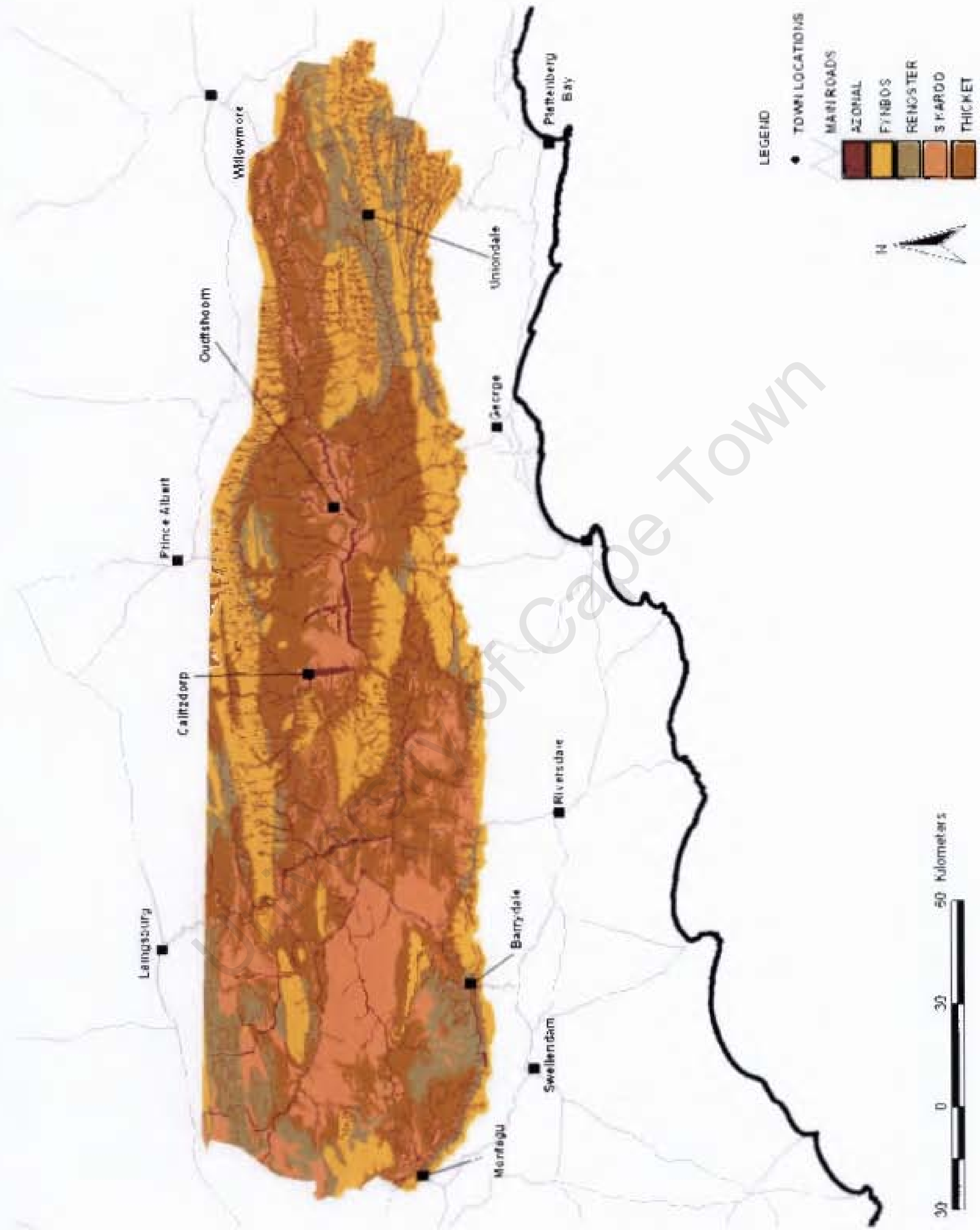


Figure 2.5 Fynbos, Succulent Karoo and Thicket are the predominant biomes in the Little Karoo. Renosterveld (grey areas) is a sub-unit within the Fynbos biome. Azonal (maroon linear areas) depict catchment areas, streams and rivers in the study area (Vlok *et al.*, 2005).

The Succulent Karoo biome is recognized as one of 25 bio-diversity hotspots, and is regarded as the world's only arid hotspot (Cowling *et al.*, 1989; Anonymous, 2003). It extends from the south-west through the north-western areas of South Africa into southern Namibia (Figure 2.4). Milton *et al.* (1997) characterise it by the predominance of low, succulent-leaved shrubs, few grasses, and a scarcity of tall shrubs and trees (Plate 2.2). Desmet and Cowling (1999) ascribe the rich biodiversity of the Succulent Karoo biome to an extensive and complex array of habitat types which themselves arise from the topographical and climatic diversity in the region's rugged mountains, semi-arid shrublands, and coastal dunes.

Plate 2.2 Isolated quartz fields dominated by *Gibbaeum* spp. are typical in some localities within the Little Karoo and form part of the Succulent Karoo biome in the region.

Plate 2.3 Ericaceous Fynbos on the slopes of the Kanetberg mountains forms part of the Fynbos biome in the Little Karoo region. (Photo by Jan Vlok).

The Fynbos biome borders the Succulent Karoo and the Albany Thicket in places and occupies most of the Cape Fold Belt (Rebelo *et al.*, 2006). The extent of the area is described by Rebelo *et al.* (2006) as including both north-south and east-west mountain chains and the low-lying areas between the mountains (Plate 2.3). Together with the Succulent Karoo, the Fynbos biome is recognised as one of the most important biodiversity hotspots in the world (Myers *et al.*, 2000). Endemism is high in this biome where 80 % of the plant species are known to be confined to the Cape Floral Kingdom (Low and Rebelo, 1996). The four vegetation types of the Fynbos biome namely; Mountain Fynbos, Grassy Fynbos, Central Mountain Renosterveld and South and South-west Coast Renosterveld occur in the Little Karoo (Low and Rebelo, 1996). Mountain Fynbos occurs in high altitudes in the Swartberg and Outeniqua mountain ranges and in Rooiberg, Gamkaberg and Anysberg. Grassy Fynbos, is found east of Uniondale on sandy soils derived from Cape Supergroup sandstones, the Witterberg and Enon conglomerates. Central Mountain Renosterveld is found on the fringes of the Little Karoo basin. The South and South- west Coast Renosterveld is found on clay soils derived from Bokkeveld and Kango shale (Low and Rebelo, 1996) (Plate 2.4).

Plate 2.4 Due to its rich soils, fairly flat slopes and high winter rainfalls, Renosterveld habitat in the Little Karoo has been impacted heavily by cultivation.

The Albany Thicket encompasses a variety of vegetation types and is described as dense, woody, semi-succulent and thorny vegetation, relatively impenetrable in unaltered condition (Hoare *et al.*, 2006). In the Little Karoo, Vlok *et al.* (2005) note that this density is uncommon as in most of the Little Karoo Albany Thicket vegetation occurs as discrete bush-clumps. In very arid areas these thicket bush-clumps are often reduced to only a single tree usually with a few succulents under or around it (Plate 2.5).

Plate 2.5 Isolated thicket bush clumps are typical of the Arid Thicket Mosaic vegetation units within the Little Karoo.

2.4 Land use and protection levels of the Little Karoo vegetation

The National Spatial Biodiversity Assessment of 2004 assessed the protection levels of terrestrial ecosystems to determine how well the protected area network is performing in terms of representing terrestrial biodiversity. Data on protected areas from different sources in South Africa was gathered and classified based on ownership and legal status into Type 1 (statutory reserves: e.g. National Parks, Provincial Nature Reserves and Dwaf Forest Reserves), Type 2 (non-statutory reserves: e.g. Private Nature Reserves and Botanical Gardens) and Type 3 (e.g. Game Farms, Game Reserves and Other Conservation Areas). From this classification it was determined that only 6.25 % of South Africa, Lesotho and Swaziland is under protection (Rouget *et al.*, 2006a, also see Figure 2.5).

Despite the uniqueness of the Little Karoo's biodiversity, the conservation status of its vegetation is regarded as poor (Low and Rebelo, 1996, also see Figure 2.5). As in the rest of the Western Cape, most of the protected areas in the region are located within mountainous landscapes associated with Fynbos and in some instances with Renosterveld vegetation types. Farming on natural rangeland still remains the major agricultural practice in the Little Karoo. Most of the land is used for livestock production. Ostrich farming is dominant but small stock (sheep and goats) and cattle are also kept. Cupido (2005) has noticed that in recent years there has been a significant increase in the number of farms which have been sold and converted to wildlife enterprises, including game farms. Because the soils of the Little Karoo are generally deep and fertile, cultivation has impacted heavily on the vegetation of the region. This is particularly true for the vegetation of the lowlands (e.g. Renosterveld shrublands) which has been cleared extensively for cropping. Grapes and grains (wheat, lucerne and oats) are the main agricultural crops in the area. The impact of ostriches on lowland vegetation over years has been severe and the expansion of the ostrich farming industry in the Little Karoo is likely to pose a greater threat in the future if no mitigation measures are taken (Low and Rebelo, 1996; Cupido, 2005). A further discussion on specific threats facing the Little Karoo biomes and habitats is presented in chapter 4 of this thesis.

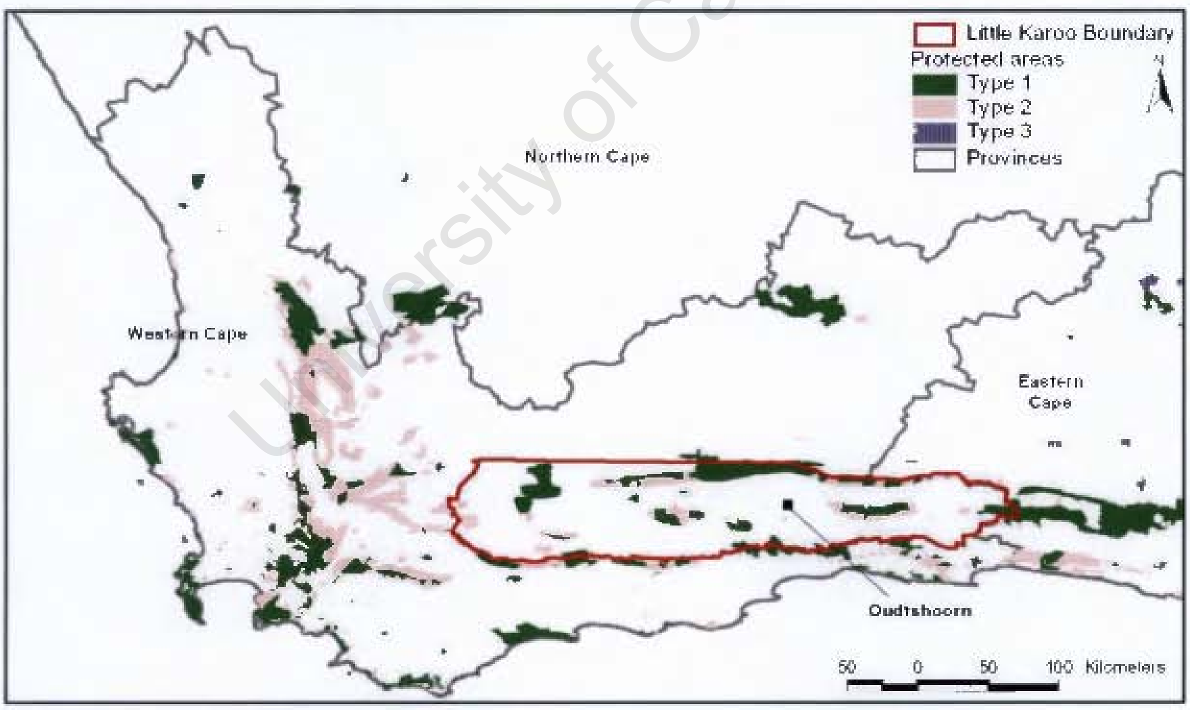


Figure 2.6 Protected areas in the Little Karoo according to the NSBA (Driver *et al.*, 2005) assessment. Protected areas were classified according to Type 1, Type 2 and Type 3 areas although no Type 3 areas are evident in the study area.

2.5 Socio-economic development and the environment of the Little Karoo

Environmental changes are often a product of complex and dynamic interactions between biophysical and socio-economic factors. This thesis attempts to understand the combined role played by these forces. The discourse of the science of desertification and degradation has evolved over time. The coming together of poverty and environmental research under the overarching theme of sustainable development with more attention given to the greater role of natural resources in sustaining livelihoods and vice-versa is a case in point (Campbell *et al.*, 2002, Shackleton *et al.*, 1999). One output from the 88th Dahlem Desertification Conference held in 2001 was the development of a framework for a more synthesized understanding of the various causes and consequences of environmental degradation and desertification (Stafford-Smith and Reynolds, 2002). There is now a shift towards the understanding of the possibilities and adaptive nature of people who inhabit drylands in what is referred to by Reynolds *et al.* (2007) as the Dryland Development Paradigm.

Biodiversity contributes to local and regional societies and economies through agriculture, tourism and a range of basic goods and services (e.g. water provision). In many instances this role is often not explicitly stated by biodiversity specialists (Pearce and Moran, 1994, Driver *et al.*, 2003). In the Little Karoo the economy of the region is perceived to have deteriorated over the last ten years. Cupido (2005) cites high levels of unemployment and low earnings of less than R1 500 per month for more than 75 % of the people living or working on farms in the region. He further predicts economic deterioration with the increasing mechanization of agriculture and conversion of commercial farms into game farms. There has also been a corresponding decline of small town economies of the Karoo region, which have been reduced to what Atkinson (2007) now regards as 'welfare' centres.

For the poorest population of this region, Cupido (2005) believes that the Land Redistribution for Agricultural Development (LRAD) programme, which aims to provide black farmers access to land for subsistence or commercial purposes, is one way to alleviate poverty. However, for this programme to succeed in the region it requires healthy landscapes and functioning ecosystems. The volume and quality of water, the stability and salinity of soils and the quality of the vegetation for its fodder value and productivity form the basis for sustainable livestock and arable land production. The growth in tourism-related activities could be regarded as beacon of hope but the scenery, unusual biota, and un-spoilt habitats are critical natural capital assets which underpin the tourism industry in the region. It is therefore, important to take into account both socio-economic and bio-physical forces when investigating possibilities of adaptation, restoration and future scenarios in the Little Karoo.

CHAPTER 3 HABITAT TRANSFORMATION AND DEGRADATION OF LITTLE KAROO HABITATS

3.1 Introduction

The loss of habitat through land use impacts has been recognized as the major threat to biodiversity (Driver *et al.*, 2003, Rouget *et al.*, 2006b). The industrialisation of economies, the intensification of agricultural activities, and expansion of urban development are but some of the major agents of habitat transformation. Although causes of habitat degradation are diverse and often complex, there is mounting evidence that there has been and continues to be, extinctions of flora and fauna at a disturbing rate (Barrow, 1991). Habitat degradation has often led to disastrous consequences both in terms of the natural environment and the well-being of people affected. Food insecurity, poverty and disease out-break-outs, are but some examples that occur too frequently with significant costs to nation states and humanity as a whole (Hoffman and Ashwell, 2001). The loss of biodiversity and its consequences has therefore been a matter of considerable policy concern (Scholes and Biggs, 2005). In fact, it is believed that historical agricultural policy development in the Karoo arose out of the concern over the degradation of the region in the first part of the 20th century (Hoffman *et al.*, 1999b).

The most extensive pressures on the biodiversity of the Little Karoo are cultivation and livestock grazing. Goat, sheep, ostrich and small game farming are common land use types and signs of overgrazing are evident over much of the landscape. Ostrich farming in particular, (due to the species' ability to survive in dry areas), poses the greatest threat to biodiversity in this region not only through direct impacts but also through the impacts created by the cultivation of lucerne for ostrich feed. A spatially explicit mapping exercise to describe degradation status within the vegetation units, habitats and biomes of the Little Karoo is therefore important. For, apart from being critical for the location of priority areas for the conservation and restoration of biodiversity, such an analysis is also considered to be vital for informed grazing management, policy making and land-use planning for the region (Thompson *et al.*, 2005). On the basis of the data sets available for this project, this chapter determines the spatial patterns and extent of habitat transformation and degradation as a result of land use impacts on the biomes, habitats and vegetation units in the Little Karoo. It also compares the extent of habitat transformation and degradation in the study area with other studies carried out in the past (e.g., the National Land cover map of 1996, 2000).

3.2 Methods

3.2.1 Defining transformation and degradation

While activities such as mining and urbanisation result in the complete transformation of natural vegetation, well managed grazing areas on the other hand can be compatible with conservation in certain biomes. For the purpose of this chapter, a distinction has been made between transformation and degradation. Transformation is defined as the outright loss of vegetation as a direct result of urbanisation or cultivation. The impacts of grazing on the other hand are defined as degradation and range from a significant loss of vegetation to relatively minor changes in vegetation cover or structure (Cowling and Pressey, 2003). The mapping undertaken in the region described three levels of degradation namely pristine, moderate and severe degradation which are described further in Table 3.1.

Table 3.1 Degradation class boundaries for each of the major biomes (after Scholes and Biggs, 2005; Thompson *et al.*, 2005).

Degradation class	**Description**	**Examples**
Pristine	Sites where the natural vegetation has been least impacted by domestic stock. Although vital ecological processes may have been altered to some degree, they are still operative.	Mountainous or steep areas (e.g. Swartberg).
Moderate	Sites where natural vegetation has been impacted by domestic stock resulting in changes to their present communities, but has not been altered to such a degree that removal of grazing pressure would not reverse these vegetation communities to their original condition. Vital ecological processes may have been altered to some degree and may require minor restoration actions to ensure long-time survival of the species present in the affected area.	Grazed areas are within sustainable carrying capacity.
Severe	Sites where the natural vegetation has been impacted by domestic stock to such a degree that species richness and ecological functioning of the original plant community has been altered. At this level of impact, the removal of grazing pressure alone would not result in natural restoration of affected areas to their original condition.	Areas subject to intense overgrazing (e.g. ostrich camps, feedlots)

3.2.2 Data sets used to quantify transformation and degradation within Little Karoo biomes, habitats and vegetation units

Two data sets were acquired and processed for use in this chapter. The first was a recently derived vegetation map for the Little Karoo covering an area of 2 343 900 hectares in which 369 vegetation types and 56 habitats within five biomes (or sub-units within biomes) were mapped at a scale of 1:50 000 in the field (Vlok *et al.*, 2005, also see Figure 3.1). The second data set assessed the extent of degradation in the Little Karoo region (Thompson *et al.*, 2005). Degradation was mapped using remote sensing data. A combination of dual-date medium resolution Landsat and multi-date low resolution MODIS time-series satellite image data was used to map and demarcate different transformation and degradation classes caused by land use practices such as cultivation or grazing (Thompson *et al.*, 2005, also see Figure 3.2). Using a combined analysis of the vegetation map (Vlok *et al.* 2005) and the remote-sensed degradation map of the Little Karoo (Thompson *et al.* 2005), I quantified the extent of degradation and transformation in the biomes, habitats and vegetation units of the region.

In a final comparative analysis, the National Land Cover (NLC) data of 1996 and 2000 (Driver *et al.* 2005), which consisted of 31 aggregated land cover classes and used by the National Spatial Biodiversity Assessment in 2004, was acquired from the South African National Biodiversity Institute. The data of the NLC studies was aggregated into the same transformation and degradation classes used in this study of the Little Karoo and the results compared with each other.

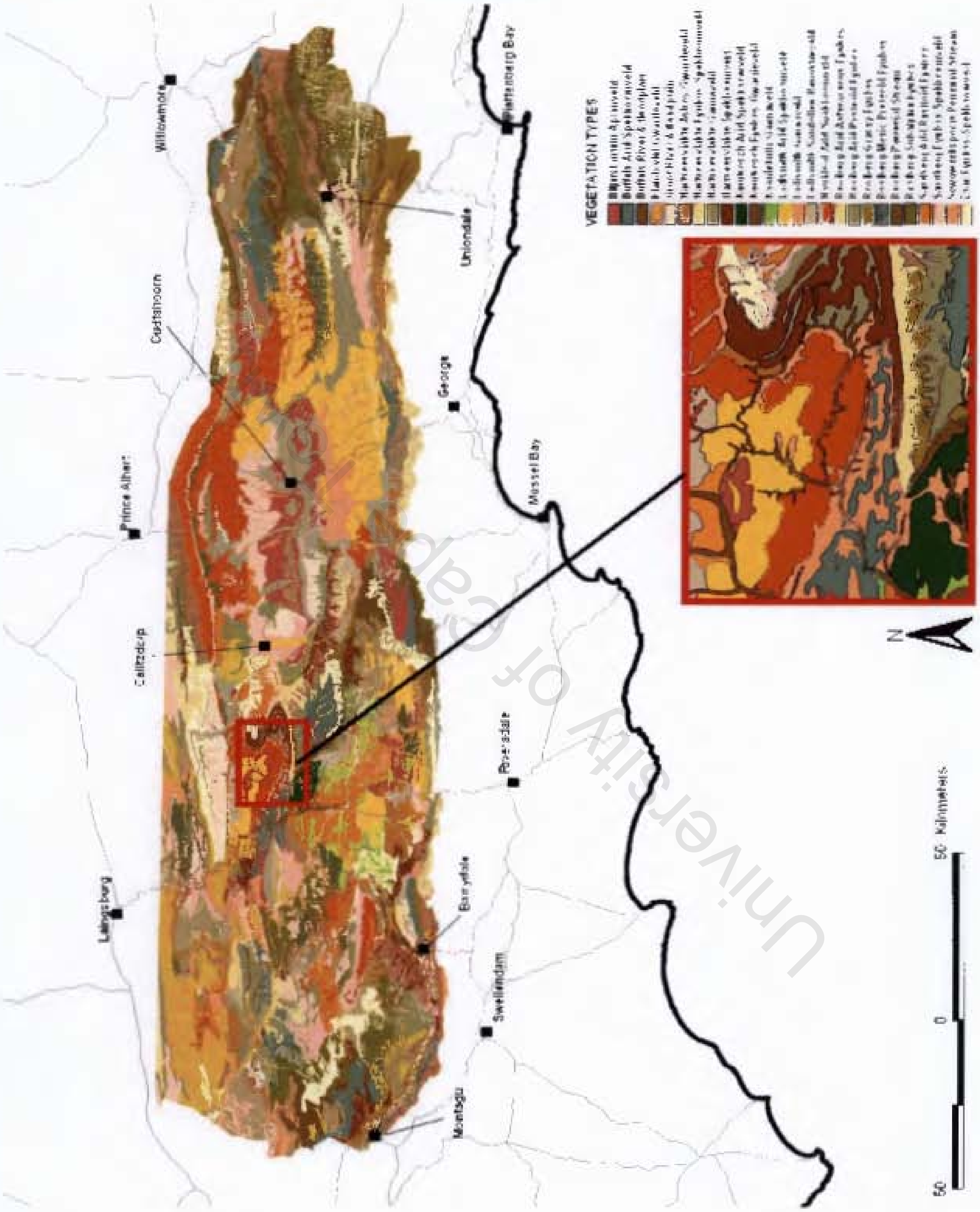


Figure 3.1 The general distribution of the 369 vegetation units mapped in the Little Karoo by Vlok *et al.* (2005) with a detailed sample map of a selection of vegetation units in the Ladismith magisterial district.

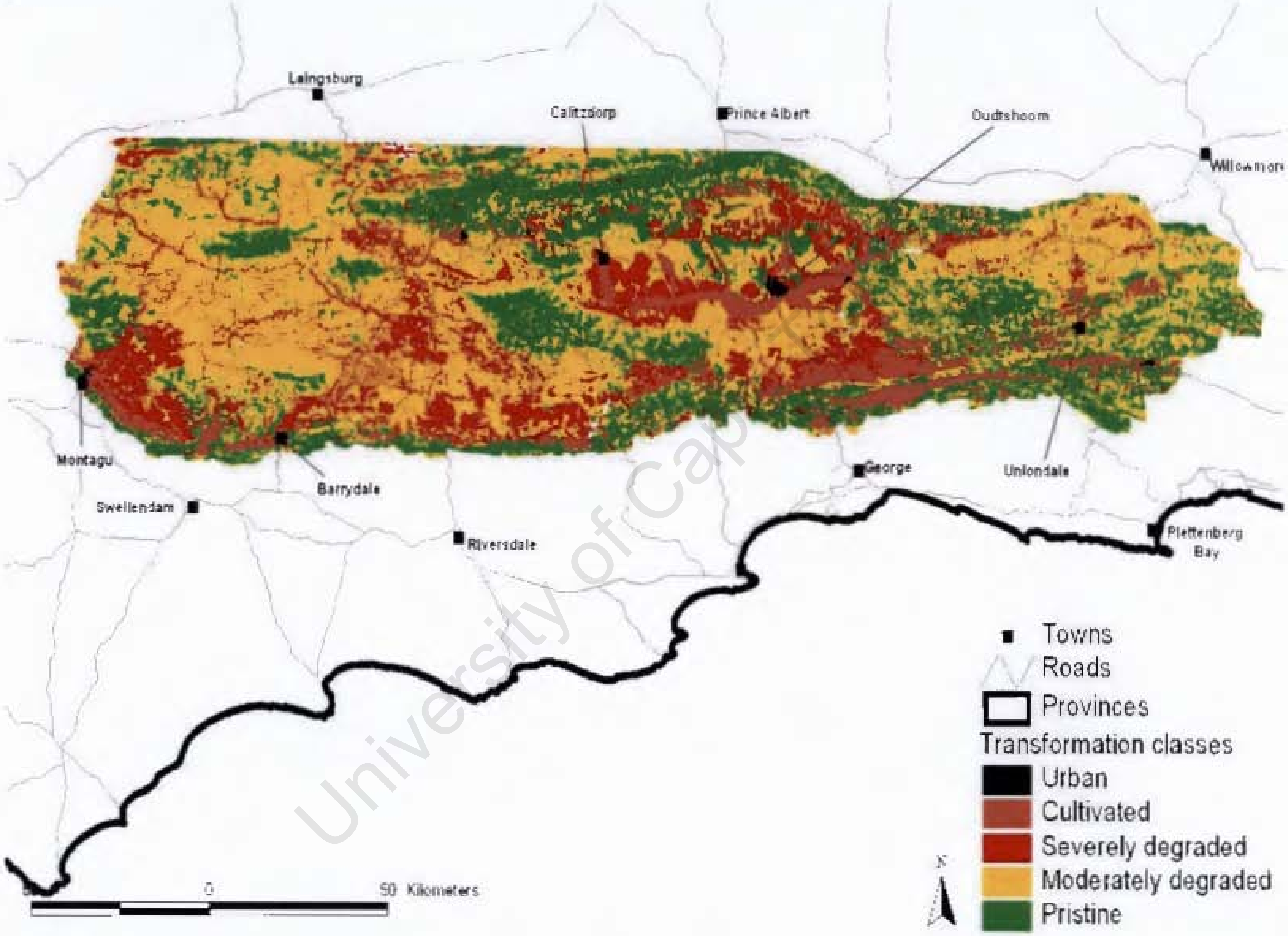


Figure 3.2 Transformation and degradation classes in the Little Karoo as defined and mapped by Thompson *et al.* (2005).

3.2.3 Data analysis

Three main GIS operations were undertaken in this chapter namely, data manipulation or editing, data querying (e.g. querying attributes such as selecting certain vegetation units), and using tables for attribute manipulation and the calculation of areas. The vegetation map of Vlok *et al.* (2005) was originally generated in a grid file format while the degradation map of Thompson *et al.* (2005) data was generated in raster format. The vegetation and degradation maps received were projected to the designated UTM (zone 34S), WGS84 map projection format using meters as units in order to calculate area, prior to manipulation and querying. Grids of transformation and degradation classes were re-classified and in-depth queries and calculations were made by selecting certain vegetation units in the Little Karoo. The data computed in GIS was imported into an Excel spreadsheet and used to calculate the number of vegetation units under each transformation and degradation class. The statistics of vegetation transformation and degradation was derived by summarizing each vegetation unit according to the extent of transformation and degradation using frequency tables. Once the region was classified according to biome, habitats and vegetation units, the statistics for each transformation and degradation class was derived and summarized using pivot tables.

3.3 Results

3.3.1 Transformation and degradation of Biomes of the Little Karoo

The spatial pattern and extent of transformation and degradation in the Little Karoo is not homogenous (Table 3.2). Clearly, some biomes, habitats and vegetation units are more severely transformed than others. Urbanisation and cultivation are the main drivers of transformation in the Little Karoo. However, only 0.2% of the study area has been transformed by urban settlements whilst cultivation accounts for 10%. Cultivation occurs mostly in low lying areas near streams or catchment areas. Whilst transformation is localised around urban points and low lying areas or rivers, degradation on the other hand is widespread. The western and central areas (incorporating the districts of Montagu, Ladismith, Calitzdorp and Oudtshoorn) have mostly been affected by degradation (Figure 3.3). Transformation is shown to be more severe around major towns and in close proximity to areas where cultivation has occurred.

The extent of degradation in the study area is wide spread with 53.4% of the vegetation moderately degraded and 14.1% severely degraded (Table 3.2). Only 21.9% of the region, according to the degradation criteria used in this analysis is considered to be pristine. Although the Succulent Karoo vegetation covers only 17.4% of the Little Karoo area, it is the most affected by severe degradation in the region (27.6%). Whilst degradation seems to affect mostly the Succulent Karoo and Thicket biomes, Azonal areas have also been heavily impacted by grazing. In contrast, more than half of the fynbos biome (excluding Renosterveld) is considered pristine.

Table 3.2 The percentage of each biome transformed by urban and cultivation and the percentage of each biome subjected to different degradation levels. The total area covered by each biome in the Little Karoo is also presented.

	Transformation		**Degradation**			
Biome	**Urban** %	**Cultivated** %	**Severe** %	**Moderate** %	**Pristine** %	**Total area** ha
Azonal	0.4	53.9	20.8	20.1	4.8	172,893
Fynbos	0.0	4.2	5.6	37.7	52.6	501,328
Renosterveld	0.3	20.6	3.3	50.3	25.5	243,473
Succulent Karoo	0.8	9.0	27.6	61.2	1.4	336,017
Thicket	0.1	6.2	19.2	65.3	9.2	680,492
Total Area (%)	**0.2**	**10.0**	**14.1**	**53.4**	**21.9**	**1 934,103**

3.3.2 Transformation and degradation of the Habitats of the Little Karoo

Approximately 193600 hectares of vegetation cover have been transformed whilst severe degradation covers an area of 279,431 hectares in the Little Karoo (Table 3.3). Renosterveld and low, lying thicket habitats are the habitats which have been most transformed by cultivation. Severe degradation is most evident in Thicket mosaic and Succulent Karoo habitats.

Table 3.3 The percentage area within each habitat (Vlok *et al.*, 2005) in the Little Karoo within two transformation classes (urban and cultivated) and three degradation classes (severe, moderate, pristine). The total area (ha) covered by each habitat is also presented.

Habitat	**Urban**	**Cultivated**	**Severely degraded**	**Moderately degraded**	**Pristine**	**Total hectares**
DRAIN River	0.9	34.7	15	43.2	6.9	106502
FYNBOS Arid Asteraceous	0.0	0.0	5.8	18.8	75.4	10493
FYNBOS Arid Proteoid	0.0	1.7	7.3	37.6	53.4	82976
FYNBOS Arid Restioid	0.0	1.9	24.4	73.4	0.3	18632
FYNBOS Ericaceous	0.0	0.0	5.0	16.4	78.7	2841
FYNBOS Grassy	0.6	1.2	22.4	3.3	17.6	68794
FYNBOS Grassy Mos Waboomveld	0.0	0.3	41.5	56.5	1.7	6798
FYNBOS Mesic Asteraceous	0.0	0.0	7.3	27.5	65.3	101
FYNBOS Mesic Proteoid	0.0	1.7	18.6	58.8	20.9	150923
FYNBOS Mesic Proteoid Mos Waboomveld	0.0	0.0	1.7	2.6	95.7	1145
FYNBOS Restioid	0.0	1.7	7.3	37.6	53.4	1855
FYNBOS Sandolien	0.0	1.9	17.6	46.1	34.4	18636
FYNBOS Sandolien Mos Renosterveld	0.4	27.4	24.1	40.4	26.4	26479
FYNBOS Subalpine	0.0	0.0	15.2	84.8	0.0	8394
FYNBOS Waboomveld	0.6	6.6	3	11.1	79.3	102401
FYNBOS Waboomveld Mos Forest	0.0	0.8	20.4	76.0	2.7	862
RENOSTER Arid Renosterveld	0.2	17.0	12.5	24	9.3	5708
RENOSTER Mesic Renosterveld	0.0	52.0	4.4	24.2	18.4	30188
RENOSTER Mos Arid Fynbos	0.0	2.4	37.5	60	0.0	50156
RENOSTER Mos Asbosveld	3.9	26.1	4.0	47.4	22.1	42844
RENOSTER Mos Grassy Fynbos	0.0	0.6	0.9	82.7	15.8	18888
RENOSTER Mos Proteoid Fynbos	2.0	31.5	27.6	27.4	33.3	9204
RENOSTER Mos Sandolienveld	0.0	22.1	2.5	48.5	26.9	52265
RENOSTER Mos Succulent Karoo	0.0	15.3	4.6	56.8	23.3	11304
RENOSTER Mos Waboomveld	0.0	21.4	3.1	47.7	27.2	22916

Habitat	Urban	Cultivated	Severely degraded	Moderately degraded	Pristine	Total hectares
Succulent KAROO Apronveld	0.0	26.4	51.8	16.5	1.3	77690
Succulent KAROO Asbosveld	0.0	10.4	60.8	27	1.8	5392
Succulent KAROO Gannaveld	0.1	13.3	58.8	13.2	14.6	97318
Succulent KAROO Gravel Apronveld	0.0	0.1	60.0	38.2	1.7	30940
Succulent KAROO Kalkveld	0.0	0.1	3.3	45.7	50.9	901
Succulent KAROO Quartz Apronveld	0.1	2.1	5.2	92.1	0.6	8655
Succulent KAROO Quartz Asbosveld	0.6	21.2	43.4	35.2	0.2	4454
Succulent KAROO Quartz Gannaveld	0.0	6.4	5.7	44.8	43.0	10338
Succulent KAROO Randteveld	0.0	0.8	69.6	59.7	36.0	87113
Succulent KAROO Scholtzbosveld	0.0	0.4	5.5	71.3	22.7	13216
SOURCE Stream	0.0	19.2	5.8	39.7	35.2	66291
THICKET Arid + Spekboom	0.0	1.8	4.3	29.5	64.4	27207
THICKET Arid + Spekboom + Fynbos	0.0	0.7	2.6	47.6	10.0	23875
THICKET Arid + Spekboom + S Karoo	0.0	2.4	11.0	66.4	70.5	171328
THICKET Arid + Spekboom + S Karoo + Sandolien	0.0	13..3	11..3	43.7	94.8	24573
THICKET Arid + Spekboom + Sandolien	0.0	11.6	2.5	70.2	15.0	6034
THICKET Arid Mos Asbosveld	0.4	24.8	30.6	40.4	2.1	70855
THICKET Arid Mos Fynbos	0.0	0.4	4.8	62.8	32.0	21890
THICKET Arid Mos Renosterveld	0.0	5.3	19.8	74.9	0.0	49471
THICKET Arid Mos Succulent Karoo	0.0	4.7	38.3	49.6	7.4	152493
THICKET Mos Sandolienveld	0.1	24.7	37.0	23.9	14.5	10311
THICKET Mos Waboomveld	0.0	15.8	46.4	21.6	16.1	10477
THICKET Thicket Mos Asbosveld	0.0	2.8	45.9	45.5	5.8	370
THICKET Thicket Mos Renosterveld	0.0	20.4	40.6	28.0	11	18572
THICKET Thicket Mos Waboomveld	0.1	2.9	5.3	86.6	5.2	9522
THICKET Valley + Spekboom	0.0	1.4	14.3	78.1	5.7	14304
THICKET Valley + Spekboom + Fynbos	0.0	1.4	4.4	14.0	80.1	10342
THICKET Valley + Spekboom + Renoster	0.0	2.3	11.9	79.1	6.6	5718
THICKET Valley + Spekboom + S Karoo	0.2	4.5	0.7	83.2	11.7	35269
THICKET Valley + Spekboom + Sandolien	0.0	4.5	21.6	68.6	5.1	3246
THICKET Valley Mos Succulent Karoo	0.0	3.4	6.2	67.6	22.7	14636
Total hectares	**4325**	**193600**	**279231**	**1033419**	**423351**	**1934103**

3.3.3 Transformation and degradation of Little Karoo vegetation units

In the majority of vegetation units, less than 10% of the area has been transformed by cultivation and urbanization (Figure 3.4). Moderate and severe forms of degradation, however, covering more than 80% of the area of a vegetation unit, occur in nearly half of the vegetation units of the Little Karoo. The area of pristine vegetation in each vegetation unit is relatively small and in nearly half of the vegetation units 10% or less of their area is still considered intact.

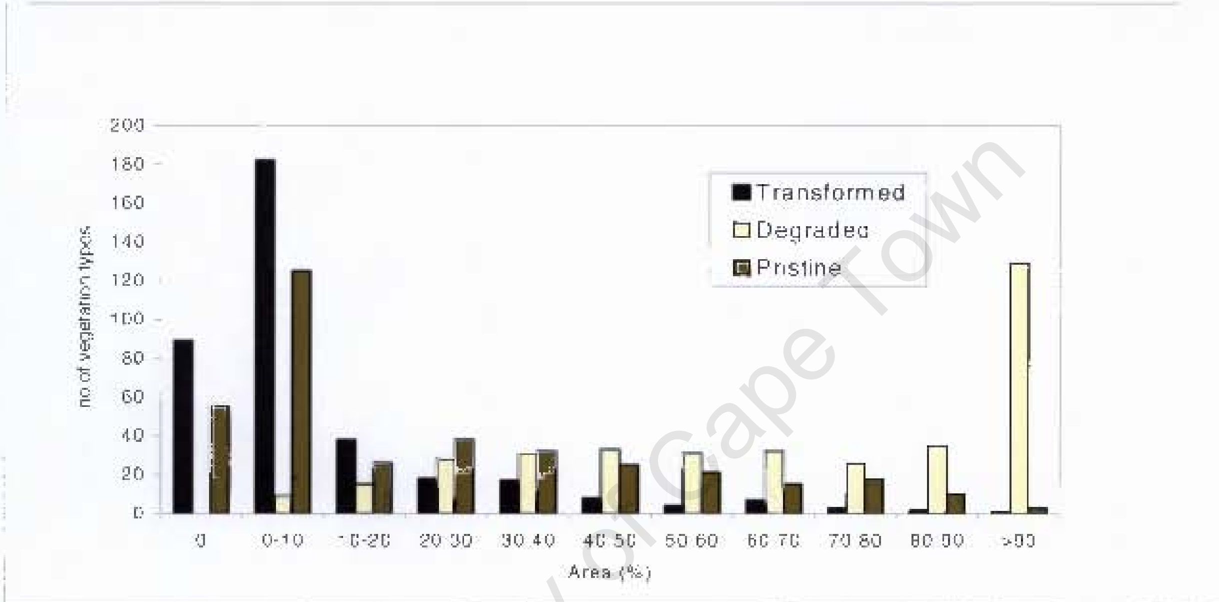


Figure 3.3 Extent of habitat transformation (urban and cultivated land), degradation (sum of moderate and severe degradation classes) and pristine vegetation in the 369 vegetation units mapped by Vlok *et.al.* (2005) in the Little Karoo.

3.3.4 Comparisons with previous degradation studies in the Little Karoo

The outputs of this transformation and degradation analysis for the Little Karoo are clearly different from those of previous comparable studies carried out in the region. The South African National Land Cover (NLC) assessment (Driver *et al.*, 2005) significantly underestimated the extent of degradation in the region (Figure 3.5). Many vegetation units in the study area currently classified by the National Land Cover data as least threatened, are degraded to a large extent. Similarly, the results of the Biodiversity Intactness Index (BII) as calculated by Scholes and Biggs (2005) are also significantly different from the results of this study. Although Scholes and Biggs (2005) acknowledges that the main cause of biodiversity loss in arid shrublands is land degradation, their analysis suggests that the Little Karoo is 86.9% pristine and 2.7% degraded as compared with the results presented here which suggest that 32.6% of shrublands are in a pristine condition while 59.9% are degraded. Most of the areas classified as least threatened by both the NLC (Driver *et al.*, 2005) and Scholes and Biggs's (2005) estimates appear degraded when inspected closely (Compare figure 3.2 and 3.4 for example).

Figure 3.4 The spatial extent of transformation and degradation in the Little Karoo in 1996 (left) and 2000 (right) according to the National Land Cover database (Driver *et al.*, 2005).

3.4 Discussion

Losses in biodiversity have been widely reported, but it is the advances in remote sensing which have provided techniques to show the scale of landscape transformation and, by inference, of biodiversity loss (Spellenberg, 1992). Although biodiversity cannot be observed directly using remote sensing, patterns of cover and cover change can be used to identify desertification and land degradation (Prince, 2002). Whilst the visual evidence from these techniques is striking, quantifying these losses has become more important. Detailed land-use surveys are useful for degradation analysis but quantifying land degradation using remote sensing in dry areas is difficult (Pickup and Chewings, 1994).

Loss of natural habitats due to urban and cultivated areas can be identified easily using remote sensing techniques, and has been reflected in the National Land Cover data (Driver *et al.*, 2005). However, in arid ecosystems remote-sensing techniques often fail to identify land degradation (e.g. overgrazing, erosion) accurately. Yet, this is where habitat loss is more likely to take the form of degradation rather than outright conversion of vegetation cover. It is also difficult in these ecosystems to capture grazing impacts on the ground yet, accurate up-to-date information on land cover and land-use is essential for strategic planning, sustainable resource management and environmental research (Fairbanks *et al.*, 2000).

The fine scale (localized) mapping of the study area and the subsequent transformation map represents a first assessment of the current transformation and degradation status of vegetation types in the region. Such an assessment is suitable for medium-scale application and interpretation as it is based on a minimum unit of +_ 20-25 ha (Thompson *et al.*, 2005). This is an important milestone in terms of understanding the true extent of habitat loss due to grazing impacts taking into account the difficulty of mapping grazing as a land use.

Although transformation and degradation classes have been shown to be different in the Little Karoo depending on the habitat described, it is clear that cultivation and livestock grazing are the main land uses impacting on vegetation. Low-lying areas such as River and Floodplain habitats in the Little Karoo region have been particularly negatively affected by a number of agricultural activities. According to Vlok *et al.*, (2005), most of the fresh water that used to run from the upper catchment areas into the river systems has been cut off and is now used primarily for agricultural purposes. This has resulted in changes in the composition of the natural vegetation in riverine areas. Various forms of Renosterveld habitat units and Fynbos found in low lying areas at the foot of mountains have also been severely impacted by cultivation. Soils found in these areas have been described as deep and relatively fertile and are therefore mostly targeted for cultivation purposes. The Subtropical Thicket habitat types appear to be very vulnerable to impacts relating to overgrazing by domestic stock and most of the vegetation in these habitats cannot recover naturally when seriously overgrazed. Vegetation removal by ostrich grazing and trampling has been observed widely in the study area (Cupido, 2005; Lambrechts, 2004). Lambrecht's study (2004) in the Ladismith area describes the farming systems used in the ostrich industry where young and breeding birds are maintained on natural veld. Because of this practice almost 75% of the natural ostrich population are maintained in flocks in the natural veld.

Vegetation transformation is often accompanied by a reduction in the production potential of soils, changes in water quality due to processes of soil pollution, plant invasion, etc. Bestelmeyer *et al.* (2006) therefore, stress that it is important for assessment and monitoring technologies to be relevant to the processes and patterns driving change in particular settings. South Africa has a comprehensive legislation encompassing monitoring and auditing systems. The National Environmental Management Act (1998) is an overarching framework for environmental legislation in South Africa and has been established in an attempt to overcome these challenges. Although this study did not investigate other elements contributing to vegetation change, it is clear that there are a multitude of factors driving it and according to Bestelmeyer *et al.* (2006), these can be detected only by measuring particular variables at specified scales.

CHAPTER 4 LAND DEGRADATION, ECOSYSTEM STATUS AND THE SETTING OF BIODIVERSITY CONSERVATION TARGETS IN THE LITTLE KAROO

4.1 Introduction

The Millennium Ecosystem Assessment initiative, undertaken in 2001 under the auspices of the United Nations aims, to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems. In realizing the rate and extent of biodiversity loss, and the fragmentation of ecosystems, the Parties to the Convention on Biological Diversity, committed themselves to achieve by 2010, a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation (UNEP, 2004). The desertification synthesis report of the Millenium Ecosystem Assessment (Adeel *et al.*, 2005) cautions on '*the growing demand for ecosystem services such as food and clean water, whilst human actions are diminishing the capability of many ecosystems to meet these demands...*'

In an attempt to focus conservation efforts and monitor progress in this regard, the biodiversity assessment also aims to improve the IUCN Red Data List as it will play a vital role in tracking progress towards the 2010 target and beyond. Fortunately, in South Africa threatened species and ecosystems are protected by Chapter 4 of the Biodiversity Act (10 of 2004) which established the South African National Biodiversity Institute (SANBI), a national public sector entity dedicated to biodiversity conservation. This policy framework and legislation allows for the listing of threatened and protected ecosystems (Driver *et al.*, 2005).

Ecosystem status is determined from the setting of biodiversity targets. For each vegetation type, there is a need to specify through quantitative targets, how much of the area is required to conserve a representative bio-diversity landscape. A target is expressed as a percentage of the total area and targets may differ according to the vegetation type, number of species occurrences or species response to anthropogenic threats (Rouget *et al.*, 2006b). The IUCN (2001) recommended a 10% target to represent each vegetation type (or other land class) in the reserve system. However, there are a wide range of other approaches and methods for setting targets. Targets can also be set at different scales using different surrogates i.e., by countries or regions, vegetation types, ecosystems, species, etc (Margules and Pressey, 2000). There is a body of literature on the inherent strengths and shortcomings of each methodology of setting targets (Margules and Pressey, 2000; Cowling and Heijnis, 2001; Pressey, *et al.*, 2003; Driver, *et al.*, 2003; Desmet and Cowling, 2004). Because of the rapid fragmentation of ecosystems, there has been a shift from an emphasis on species only in environmental assessments (Margules and Pressely, 2000). Other studies have even concluded that a strong relationship between species richness and endemism does not always exist (Orme *et al.*, 2005). In recent years, policy driven targets have been used but these have also been heavily criticized for their lack of biological foundation and possible negative consequences (Svancara *et al.*, 2005).

This chapter aims to fulfil the following objectives:

(i) To determine the status of ecosystems in the study area taking into consideration both the extent of habitat transformation and degradation;

(ii) Using species-area relationships, to set conservation targets taking into consideration species-richness and endemism;

(iii) Compare the ecosystem status of the Little Karoo with earlier assessments undertaken in the region.

4.2 Methods

The National Spatial Biodiversity Assessment's (Driver *et al.*, 2005) framework for categorising the status of ecosystem was adopted in the Little Karoo (Figure 4.1).

Figure 4.1 Classification of vegetation conservation status based on the percentage of remaining untransformed area and the biodiversity target (Driver *et al.*, 2005)

Least Threatened (LT): Least Threatened ecosystems are of high conservation value or of high national or provincial importance. They contain widespread and abundant taxa and still posses more than 80 % of their natural habitat.

Vulnerable (VU): These are ecosystems with 60-80% of natural habitat remaining which have a high risk of undergoing significant degradation of ecological structure, function or composition as a result of human impacts. In these ecosystems, habitats have lost up to 20 % of their original extent, which could result in some ecosystem functions being altered.

Endangered (EN): These are ecosystem with less than 60% natural habitat remaining and which are exposed to partial loss of ecosystem function.

Critically Endangered (CE): These are ecosystems where the percentage of natural habitat remaining is less than the target (i.e., not enough natural area to achieve the target). In this category, ecosystems have been transformed or degraded to such an extent that the remaining habitat is less than what is required to represent 75% of species diversity (i.e., the biodiversity target).

All vegetation units in the Little Karoo were classified into Critically Endangered, Endangered, Vulnerable and Least Threatened based on the target percentage (adjusted for species richness and endemism) and the degree of transformation and degradation of the vegetation unit (Chapter 3). There were three target levels set: 15%, 25% and 35%. These coincide with the percentage target range set by the NSBA (Driver *et al.*, 2005) which falls between 16-36% (Figure 4.1). The IUCN's standard 10% target for conservation was not adopted in this analysis. In previous studies undertaken in South Africa such as the CAPE (Pressey *et al.*, 2003) and SKEP (Driver *et al.*, 2003) projects, it was learnt that this target is not appropriate for ecosystems within the winter rainfall region because it is not based on their biological characteristics, and leads to under-representation of biodiversity pattern, especially for land classes that support many rare species (Driver *et al.*, 2003).

Some vegetation units have higher species richness than expected based on species-area relationships while some have lower species richness. An unpublished data set (Jan Vlok, unpublished data) of the number of species in each vegetation unit was used to determine their species area relationship (Figure 4.2). The conservation target was increased for vegetation units where species richness was higher than expected. The rationale was to place greater emphasis on species-rich vegetation units. Conversely, targets for vegetation units with lower species richness than expected were lowered.

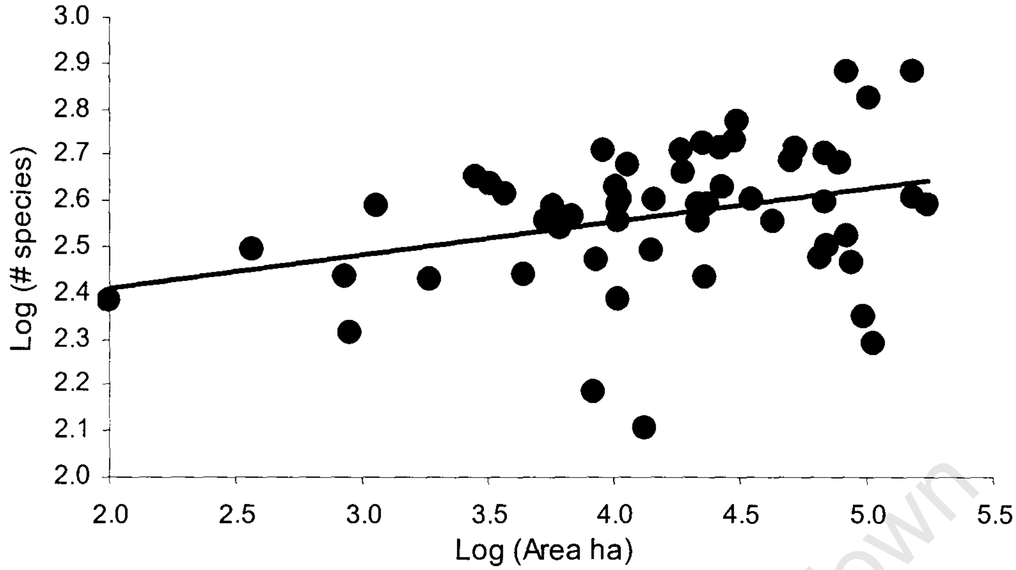


Figure 4.2 Species richness plotted as a function of the area of each of the 56 habitat units in the Little Karoo. (n = 56; y=0.0744x + 2.2602; R^2 = 0.1104; $p<0.05$).

Conservation targets based on endemism were adjusted using Vlok's unpublished ancillary data for the number of endemic species in each of the vegetation units in the Little Karoo. For vegetation units with five or more endemic species, the conservation target was increased to 35%. However, if a vegetation unit was less than 1,000 ha in extent and had 4 endemic species the target was also increased to this level. This affected 46 vegetation units. Using standard GIS techniques in ArcView 3.2, the Little Karoo ecosystem status maps were calculated to derive a percentage of total area per status category (LT, VU, EN and EN). These results were compared to previous assessments undertaken by SKEP, CAPE, NSBA in the study area.

4.3 Results and Discussion

4.3.1 Conservation targets for the Little Karoo

The percentage of each habitat unit needed conserve the plant diversity of the Little Karoo is shown in Table 4.1 and the areas that need to be set aside in order to conserve the plant diversity of the Little Karoo are shown in Figure 4.3.

Table 4.1 Percentage of the habitat unit needed to conserve a representative sample of biodiversity. The targets are derived from an analysis of the number of species and degree of endemism in each of the 369 vegetation units (amalgamated into the 56 habitat units) and are arranged according to mean target values.

HABITAT UNITS	No. of vegetation units	Mean Target	Minimum Target	Maximum Target
SUCCULENT KAROO Asbosveld	2	15.0	15	15
THICKET Thicket Mosaic Asbosveld	1	15.0	15	15
THICKET Valley + Spekboom + Fynbos	1	15.0	15	15
THICKET Valley Mosaic Succulent Karoo	3	18.3	15	25
RENOSTERVELD Mosaic Succulent Karoo	4	20.0	15	25
THICKET Arid + Spekboom	2	20.0	15	25
THICKET Thicket Mosaic Waboomveld	2	20.0	15	25
THICKET Arid + Spekboom + Fynbos	5	21.0	15	35
THICKET Arid Mosaic Fynbos	11	22.3	15	35
RENOSTERVELD Mosaic Sandolienveld	8	22.5	15	35
FYNBOS Grassy	9	23.9	15	25
FYNBOS Mesic Proteoid Mosaic Waboomveld	1	25.0	25	25
FYNBOS Sandolien	8	25.0	15	35
RENOSTERVELD Arid Renosterveld	1	25.0	25	25
RENOSTERVELD Mosaic Proteoid Fynbos	1	25.0	25	25
SUCCULENT KAROO Randteveld	20	25.0	15	35
THICKET Arid + Spekboom + S Karoo	18	25.0	15	35
THICKET Arid + Spekboom + Sandolien	1	25.0	25	25
THICKET Mosaic Sandolienveld	2	25.0	25	25
THICKET Valley + Spekboom + Renoster	1	25.0	25	25
THICKET Valley + Spekboom + Sandolien	1	25.0	25	25

THICKET Arid Mosaic Succulent Karoo	37	25.5	15	35
DRAINAGE Stream	17	25.6	15	35
SUCCULENT KAROO Quartz Gannaveld	9	26.1	15	35
DRAINAGE River	7	26.4	15	35
SUCCULENT KAROO Gannaveld	26	26.5	15	35
SUCCULENT KAROO Apronveld	19	26.6	15	35
FYNBOS Sandolien Mosaic Renosterveld	5	27.0	15	35
SUCCULENT KAROO Quartz Apronveld	8	27.5	15	35
RENOSTERVELD Mosaic Waboomveld	7	27.9	15	35
FYNBOS Arid Asteraceous	3	28.3	15	35
FYNBOS Arid Restioid	6	28.3	15	35
THICKET Valley + Spekboom + S Karoo	3	28.3	25	35
RENOSTERVELD Mosaic Asbosveld	8	28.8	15	35
SUCCULENT KAROO Gravel Apronveld	8	28.8	25	35
THICKET Arid Mosaic Renosterveld	9	29.4	15	35
FYNBOS Restioid	2	30.0	25	35
RENOSTERVELD Mosaic Grassy Fynbos	2	30.0	25	35
THICKET Arid + Spekboom + S Karoo + Sandolien	2	30.0	25	35
THICKET Valley + Spekboom	2	30.0	25	35
THICKET Arid Mosaic Asbosveld	5	31.0	25	35
RENOSTER Mesic Renosterveld	8	31.3	25	35
SUCCULENT KAROO Scholtzbosveld	3	31.7	25	35
FYNBOS Waboomveld	15	32.3	15	35
FYNBOS Arid Proteoid	16	33.1	25	35
FYNBOS Mesic Proteoid	18	33.3	25	35
RENOSTERVELD Mosaic Arid Fynbos	6	33.3	25	35
FYNBOS Ericaceous	3	35.0	35	35
FYNBOS Grassy Mosaic Waboomveld	1	35.0	35	35
FYNBOS Mesic Asteraceous	1	35.0	35	35
FYNBOS Subalpine	5	35.0	35	35
FYNBOS Waboomveld Mosaic Forest	1	35.0	35	35
SUCCULENT KAROO Kalkveld	1	35.0	35	35
SUCCULENT KAROO Quartz Asbosveld	3	35.0	35	35
THICKET Mosaic Waboomveld	1	35.0	35	35
GRAND TOTAL	**369**			

Figure 4.3 The range of biodiversity targets (within the classes 15%, 25% and 35%) for vegetation units of the Little Karoo adjusted for species richness and endemism.

4.3.2 Ecosystem status of the Little Karoo

The ecosystem status map (Figure 4.4) provides a spatially-explicit analysis of the Critically Endangered, Endangered, Vulnerable and Least Threatened areas of the Little Karoo. It shows several Critically Endangered areas which were not mapped before. An analysis by vegetation unit grouped into biomes (Table 4.2) showed that of the 369 vegetation units classified, 26 (7.1%) were classified as Critically Endangered, 58 (15.7 %) Endangered, 67 (18.2 %) Vulnerable and 218 (59.1 %) Least Threatened. The Succulent Karoo biome has the highest number (13) of Critically Endangered vegetation units in the study area.

Table 4.2 The number of vegetation units in each of the major biomes within each ecosystem status class in the Little Karoo.

Ecosystem status	**Biome**					
	Azonal	**Fynbos**	**Renosterveld**	**Succulent Karoo**	**Thicket**	**Total**
Least Threatened	11	75	22	42	68	218
Vulnerable	6	16	8	22	15	67
Endangered	7	2	10	22	17	58
Critically Endangered	-	1	5	13	7	26
Total	**24**	**94**	**45**	**99**	**107**	**369**

The percentage area of each of the 56 habitat units within each of the four ecosystem status classes is shown in Table 4.3. This analysis highlights the impact of the transformation and degradation trends that are specific to the Little Karoo region. Most of the Critically Endangered areas are within the Succulent Karoo, Renosterveld and Thicket areas while a significant proportion of the riparian areas are considered Endangered or Vulnerable. Fynbos habitat units are generally considered to be in the Least Threatened ecosystem status class. This could be attributed to the fact that most of the Fynbos vegetation in the Little Karoo occurs in protected mountainous areas.

Table 4.3 The percentage area of each of the 56 habitat units in the Little Karoo within the four ecosystem status classes as defined by the NSBA classification system.

Habitat	Critically Endangered	Endangered	Vulnerable	Least Threatened
DRAINAGE River	0.0	19.8	8.9	0.0
DRAINAGE Stream	0.0	3.0	6.9	2.8
FYNBOS Mosaic Arid Fynbos	1.2	0.0	0.0	4.3
FYNBOS Sandolien Mosaic Renosterveld	0.0	1.2	4.7	0.5
FYNBOS Sandolien	0.0	0.3	2.3	0.9
FYNBOS Arid Restioid	0.0	0.2	0.0	1.6
FYNBOS Restioid	0.0	0.0	0.0	0.2
FYNBOS Mesic Asteraceous	0.0	0.0	0.0	0.0
FYNBOS Mesic Proteoid	0.0	0.0	5.8	11.5
FYNBOS Waboomveld	0.0	0.0	4.1	7.8
FYNBOS Arid Proteoid	0.0	0.0	1.7	6.7
FYNBOS Grassy	0.0	0.0	0.0	6.0
FYNBOS Arid Asteraceous	0.0	0.0	0.0	0.9
FYNBOS Subalpine	0.0	0.0	0.0	0.7
FYNBOS Grassy Mosaic Waboomveld	0.0	0.0	0.0	0.6
FYNBOS Ericaceous	0.0	0.0	0.0	0.2
FYNBOS Mesic Proteoid Mosaic Waboomveld	0.0	0.0	0.0	0.1
FYNBOS Waboomveld Mosaic Forest	0.0	0.0	0.0	0.1
RENOSTERVELD Mesic Renosterveld	11.6	3.0	2.2	0.3
RENOSTERVELD Mosaic Sandolienveld	0.0	9.1	1.3	2.0
RENOSTERVELD Mosaic Asbosveld	0.0	5.9	0.0	1.7
RENOSTERVELD Mosaic Waboomveld	0.0	4.0	3.6	0.5
RENOSTERVELD Mosaic Proteoid Fynbos	0.0	0.0	2.8	0.0
RENOSTERVELD Arid Renosterveld	0.0	0.0	1.7	0.0
RENOSTERVELD Mosaic Succulent Karoo	0.0	0.0	1.2	0.7
RENOSTERVELD Mosaic Grassy Fynbos	0.0	0.0	0.0	1.6
SUCCULENT KAROO Gravel Apronveld	38.4	0.6	0.8	0.0
SUCCULENT KAROO Gannaveld	35.9	7.9	9.8	0.9
SUCCULENT KAROO Quartz Asbosveld	1.2	0.9	0.0	0.0
SUCCULENT KAROO Randteveld	0.0	2.5	3.8	5.6
SUCCULENT KAROO Apronveld	0.0	1.8	6.1	4.4
SUCCULENT KAROO Scholtzbosveld	0.0	1.7	0.0	0.6
SUCCULENT KAROO Asbosveld	0.0	1.2	0.0	0.1
SUCCULENT KAROO Quartz Gannaveld	0.0	0.5	0.8	0.5
SUCCULENT KAROO Quartz Apronveld	0.0	0.4	0.7	0.4
SUCCULENT KAROO Kalkveld	0.0	0.0	0.0	0.1
THICKET Arid Mosaic Succulent Karoo	8.4	8.6	9.0	7.3
THICKET Arid + Spekboom + S Karoo	3.3	0.0	10.4	11.8
THICKET Arid Mosaic Asbosveld	0.0	13.7	0.0	1.5
THICKET Arid Mosaic Renosterveld	0.0	6.7	0.4	1.9
THICKET Thicket Mosaic Renosterveld	0.0	4.8	0.0	0.0
THICKET Thicket Mosaic Waboomveld	0.0	2.4	0.0	0.0
THICKET Arid + Spekboom	0.0	0.0	5.2	0.9
THICKET Valley + Spekboom	0.0	0.0	4.3	0.0
THICKET Valley + Spekboom + S Karoo	0.0	0.0	1.0	2.8
THICKET Arid Mosaic Fynbos	0.0	0.0	0.4	1.8
THICKET Thicket Mosaic Asbosveld	0.0	0.0	0.1	0.0

THICKET Arid + Spekboom + Fynbos	0.0	0.0	0.0	2.1
THICKET Arid + Spekboom + S Karoo + Sandolien	0.0	0.0	0.0	2.1
THICKET Valley Mosaic Succulent Karoo	0.0	0.0	0.0	1.3
THICKET Valley + Spekboom + Fynbos	0.0	0.0	0.0	0.9
THICKET Arid + Spekboom + Sandolien	0.0	0.0	0.0	0.5
THICKET Valley + Spekboom + Renoster	0.0	0.0	0.0	0.5
THICKET Valley + Spekboom + Sandolien	0.0	0.0	0.0	0.3
Total	**100 %**	**100 %**	**100 %**	**100 %**

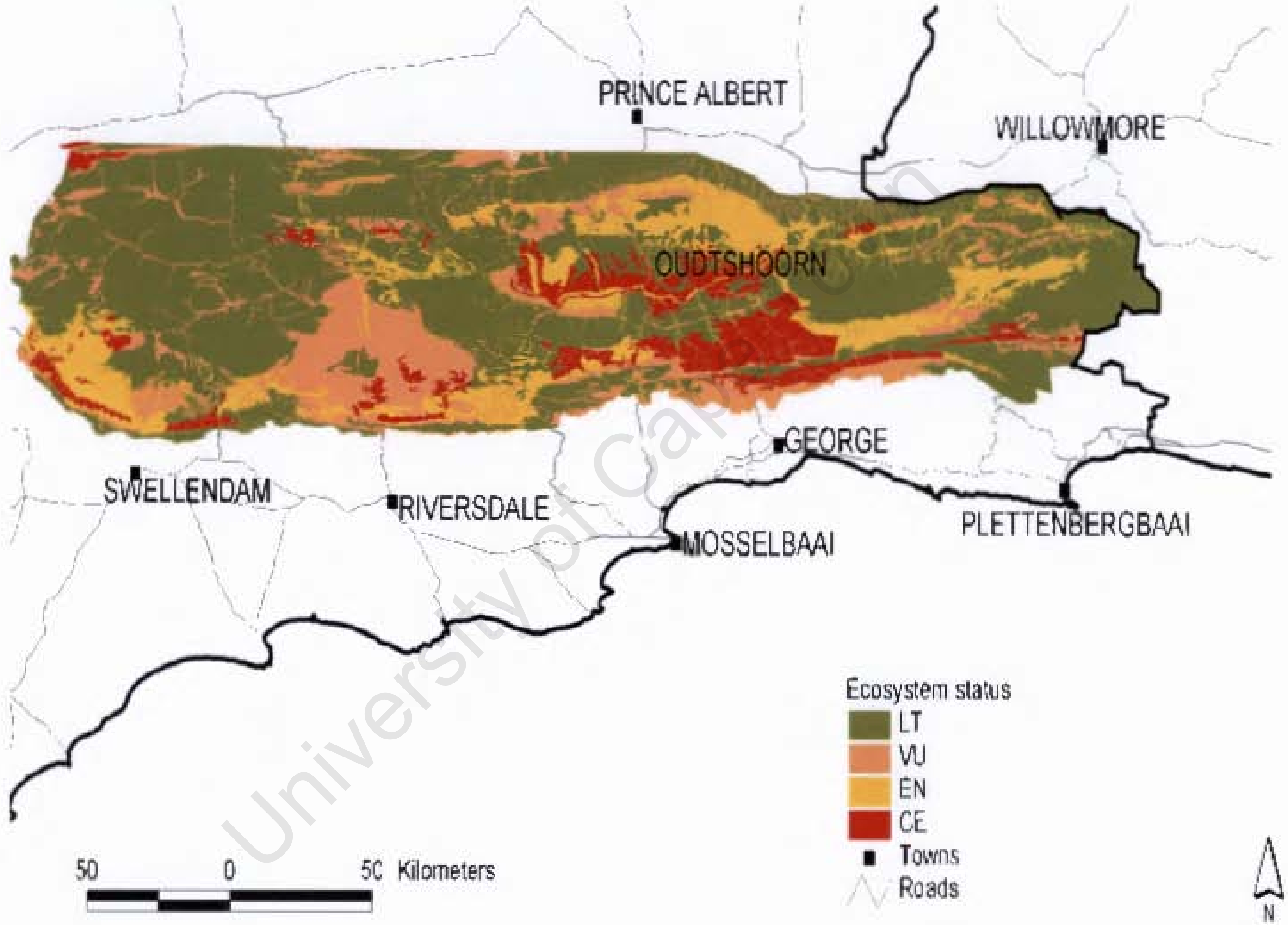


Figure 4.4 Ecosystem status of the Little Karoo within four classes.

4.3.3 Comparing the Little Karoo ecosystem status with previous assessments

In making comparisons between the Little Karoo and previous assessment studies, it is acknowledged that these studies were undertaken at different scales and the boundaries of different vegetation types do not always overlap. When the results of the assessments of these studies are compared to the results of this study, a change in status is clearly evident. The statistics for ecosystem status in CAPE, SKEP and NSBA studies, indicate that over 90 % of the vegetation types falling within the Little Karoo study are Least Threatened compared to 59% in the present study (Table 4.4). This study also shows a higher percentage of Vulnerable, Endangered and Critically Endangered classes.

Table 4.4 Statistics of ecosystem status for the Little Karoo as derived from the studies of CAPE (Cowling and Pressey, 2003), SKEP (Driver *et al.*, 2003) and NSBA (Driver *et al.*, 2005).

STATUS	CAPE	SKEP	NSBA	This study
Least Threatened	92.4	93.8	94.4	59.3
Vulnerable	7.6	3.8	2.9	17.0
Endangered	<0.01	0.2	2.7	16.2
Critically Endangered	-	2.2	-	7.5

The influence of land degradation in the Little Karoo on conservation target-setting is underlined in Figure 4.5. The degradation factor was underestimated in the other studies hence the contrast observed by Rouget (*et al.*, 2006b) between remotely-derived estimates of degradation by Scholes and Biggs (2005) and those derived from field assessments by Vlok *et al.* (2005).

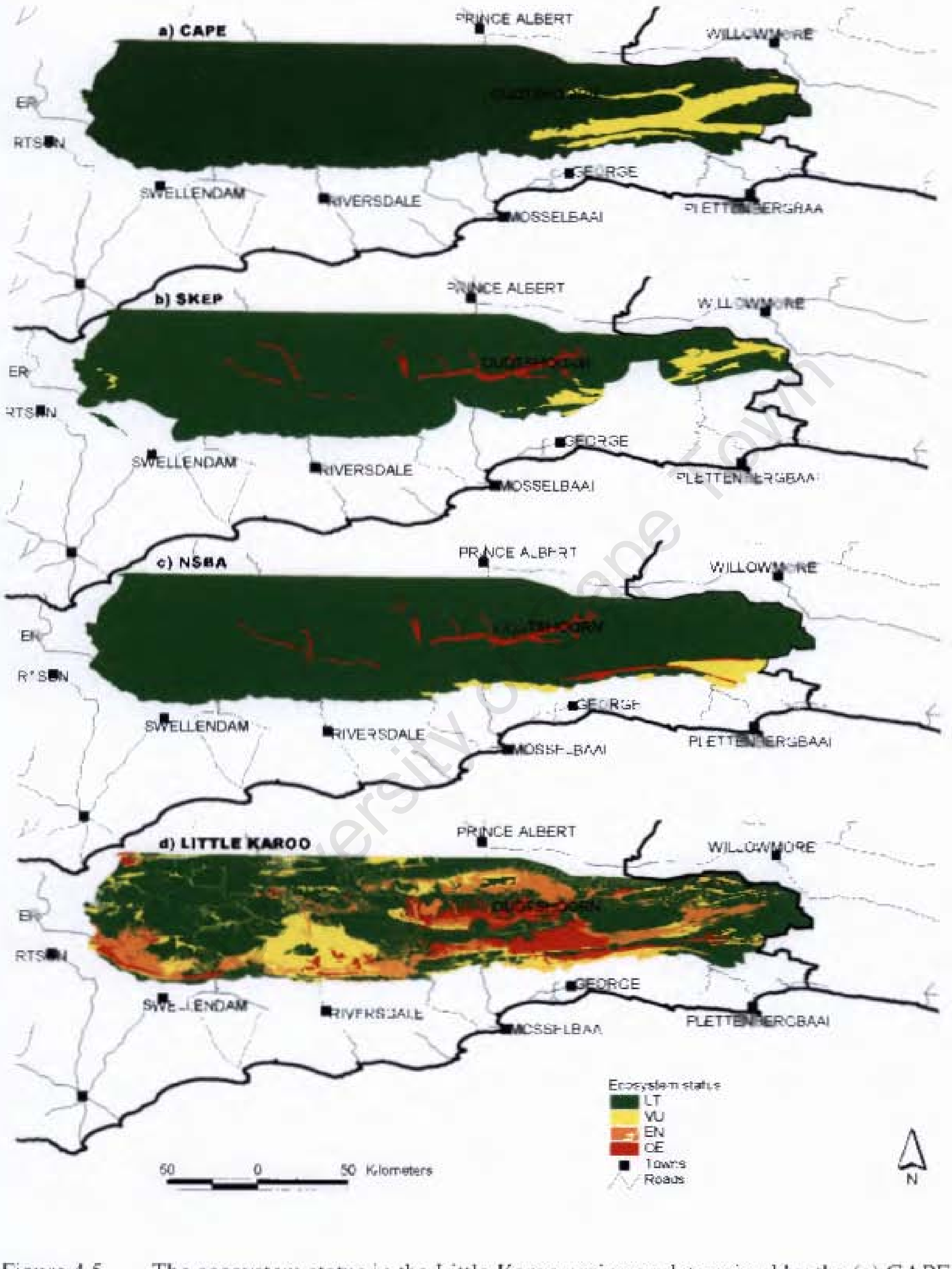


Figure 4.5 The ecosystem status in the Little Karoo region as determined by the (a) CAPE, (b) SKEP (c) NSBA and (d) this study

4.3.4 Threats facing Little Karoo Biomes and Habitats

The ecosystems of the central and eastern Little Karoo habitats have been impacted significantly by cultivation and grazing activities. Several habitats such as Gravel Apronveld, Gannaveld, Mesic Renosterveld and Arid mosaic Succulent Karoo are Critically Endangered. Ostrich ranching on natural rangelands is widely regarded as the main threat to the ecosystem status of these habitats. Many localized vegetation units are known to occur in these habitats.

In the western part of the region, Renosterveld is dominant and occurs mostly in areas rich with nutrients and high winter rainfall (Low and Rebelo, 1996, Vlok *et al.*, 2005). Due to these characteristics, vegetation units of the Renosterveld habitats have been cleared for cultivation. Related to cultivation in the west and south of the region, is the disturbance of river ecosystems where streams are used for irrigation purposes, thus rendering many of the Renosterveld vegetation units Endangered. Interestingly, although the Little Karoo is a semi-arid region, Vlok *et al.* (2005) noted in their vegetation map that 10 % of its landscapes consists of riparian vegetation units. Although these vegetation units play a critical role especially in arid regions, they have generally not been adequately mapped in many vegetation studies (Mucina *et al.*, 2006).

Together with a number of Thicket habitats, those in the Succulent Karoo are considered Vulnerable in areas where degradation is prevalent. Surprisingly, few fynbos habitats emerged as Critically Endangered, Threatened or Vulnerable perhaps because many of the vegetation units are to be found in high lying areas such as the Swartberg and Outeniqua mountains. Cultivation and afforestation activities at the foot of the mountains however, are a threat to some vegetation units within the fynbos biome (Rouget *et al.*, 2003; Rebelo *et al.*, 2006).

CHAPTER 5 ENVIRONMENTAL CHANGES AND LAND USE IN THE LITTLE KAROO

5.1 Introduction

Land degradation and desertification is driven by various environmental changes over time and cannot be considered as a simple and static event (Vogel and Smith, 2002). Although there is no consensus as to whether or not the degradation of the Karoo landscape is irreversible (see chapter 1), the extent of land degradation has clearly increased over time (Hoffman and Ashwell, 2001). There is an ongoing debate, as to the relative contribution that climate change and land use impacts make towards land degradation. In the case of the Sahel, the significant decline in annual rainfall in the 1970's and 1980's led to wide-spread loss of animals and regional famine (Nicholson, 2001). Given the fact that there is no conclusive evidence that rainfall has decreased in the 20th century in southern Africa and in the study area in particular (Hoffman, 1995; Wartburn and Schulze, 2005), inappropriate land management practices have usually been cited as the major cause of this change (Palmer *et al.*, 1990; Dean and Macdonald, 1994; Hoffman, 1995 and Cupido, 2005). While Hoffman and Todd (2000) support this view, they further argue that it is the combination of socio-economic and biophysical factors that give rise to the greatest extent of land degradation in South Africa. Unsuitable land use practices which are carried out on steep, easily-eroded slopes lead to high degradation levels.

In the Little Karoo, Dean and Macdonald (1994) suggest that grazing by domestic livestock can be considered as the major anthropogenic force leading to degradation. In their study of the changes in stocking rates of domestic livestock in semi-arid and arid regions of the Cape Province, they concluded that the overall reduction in the 20th century of domestic livestock in the arid and semi-arid regions of the Succulent Karoo has occurred primarily as a result of the decrease in the production potential of rangelands. In the same study it was noted that reductions in stocking rates were generally not significantly correlated with an index of rainfall variability nor an index of drought. This, according to these authors, suggests that stock reduction is unlikely to be a function of only climate or economic considerations. Although changes in the short-term patterns of local rainfall have been observed in semi-arid and arid areas of South Africa there is no evidence that the amount of rainfall over the century and a half is decreasing. Thus, Dean and Macdonald (1994) reason, that it may actually be a change in the effectiveness of rainfall on the surface cover caused by vegetation removal which is induced by heavy grazing activities that pastoralists have observed over the years as a reduction in rainfall amounts. Cupido (2005) confirms the conclusion drawn by Dean and Macdonald (1994) in his study of the impact of livestock on the natural veld in the Little Karoo. Cupido's study describes a series of disturbances caused by grazing which leads to transformed and degraded habitats. When grazing is intense flowering and seed set is reduced, thus affecting vegetation cover as the rate of removal exceeds that of recovery. Severe degradation has particularly been ascribed to ostrich farming in the Karoo region. Plant destruction by these animals is not solely by eating and the trampling of plants but also because of the disturbance of root systems by scuffling and compaction of the surface which reduces rainfall infiltration in the ground (Beinart, 2003, O'Farrell *et al.*, 2008). Under these conditions topsoil becomes vulnerable to wind erosion under dry conditions. Cupido (2005) has even suggested that grazing in the past by large mammals such as cattle had less of an impact than ostriches.

Finally, Mucina and Rutherford (2006) argue that grazing pressure on the vegetation of the Karoo poses a challenge but that climate change is perhaps a greater threat to these environments. The Intergovernmental Panel on Climate Change (IPCC, 1996) have reported that global temperatures may have increased over the last century and predict a further increase of about 1.3 ºC over the next 50 years in sub-Saharan Africa. It is predicted that shifting climate patterns for the succulent Karoo would be devastating if the region becomes drier or if there are significant changes in rainfall seasonality from winter to summer rainfall patterns.

Midgley *et al.* (2005) in fact, argue that populations for some succulents are on the decline at the extremes of their distribution suggesting that change may already be having a negative impact on these habitats. The aim of this chapter is to assess the historic causes of degradation in the Little Karoo using long-term climate and agricultural census records on land use to establish their relationship in triggering or exacerbating the environmental problem of land degradation in the region.

5.2 Methods

Analyses carried in this chapter on climate, livestock and crop production were based on raw historical data sets from various sources (primarily government publications), although secondary sources have also been consulted for the discussion provided in the chapter. Rainfall and temperature data was sourced from the South African Weather Services (SAWS). Annual rainfall values were taken from Lynch (2003) with additional data for the period after 2000 from the South African Weather Service. Rainfall data was obtained for all five districts in the study area from 1880 to 2005. The annual summer and winter rainfall figures were plotted for each district. Mean annual maximum and minimum temperature data were derived from Schulze and Maharaj (2003) for the period 1950-2000 for Oudtshoorn and for the period 1963-2000 for Ladismith. These data were augmented by SAWS data for both climate stations for the period 2001-2005. A Mann-Kendall test for trend in the rainfall and temperature data was carried out according to the procedures outlined in Modarres *et al.* (2007).

Historical livestock data were compiled from the Department of Agriculture's census statistics which were published for most years from the mid-19th to the 20th century and are available in both Stellenbosch and the University of Cape Town's Government Publications collections. Part of the ostrich data in the Little Karoo was kindly provided by Dr Helet Lambrechts of the Department of Animal Sciences at Stellenbosch University. These were obtained from various secondary sources (for an example, Smit and van Zyl, 1963, Osterhoff, 1979 and Statistics SA, 2006). In Calitzdorp, livestock records were only available from 1945 to 1999. In Montagu records were available from 1910 to 1995 whilst other district's records began from 1865 to 1995. The livestock data was plotted as total numbers per km^2 of cattle, sheep and goats for each district over the years in which the data was available. A separate chart of the average Large Stock Units (LSU) produced per hectare in each district between 1865 and 1995 was carried out. The conversion factors used to compute LSU from cattle, sheep and goats were as follows: cattle=1.10, sheep=0.15, and goats=0.15 (Anonymous, 1984).

The analysis of ostrich data was done separately from other kinds of livestock because of the prevalence of this land use activity in the Little Karoo. The data records were from 1865 to 2004. Historical cropping data were also taken from the Department of Agriculture's census statistics. The crop data covered five types of crops historically produced in each of the five districts namely; maize, wheat, oats, barley and rye from 1911 to 1988 although only wheat, oats and barley are of any significance in terms of area cultivated and are the only crops shown in the primary analysis. A separate analysis was carried out on lucerne production in each district from 1910 to 1988 since lucerne is the crop which covers the greatest area in the Little Karoo. A summary of the total area (ha) of all crops (including lucerne) from 1910 to 1988 was plotted.

5.3 Results

5.3.1 Average annual rainfall

Average annual rainfall trends in all districts of the Little Karoo are presented in (Figure 5.1). The distribution of rainfall in the five districts shows variability from year to year. The average annual rainfall total for all five climate stations for the 125-year rainfall record is 279 mm. All districts recorded high rainfall figures in 1981. Severe floods took place in 1981 in the region resulting in considerable destruction in the town of Laingsburg.

Only Ladismith showed a significant downward trend (by 15%) in its long-term rainfall record ($n = 122$, $z = -2.47$, $p<0.05$). For Montagu ($n = 122$, $z = -0.81$, $p>0.05$), Calitzdorp ($n = 122$, $z = 0.18$, $p>0.05$), Oudtshoorn ($n = 122$, $z = -0.29$, $p>0.05$) and Uniondale ($n = 122$, $z = -1.34$, $p>0.05$), there was no significant upward or downward trend in annual rainfall.

5.3.2 Mean annual maximum and minimum temperatures

Changes in maximum and minimum temperatures for the districts of Oudtshoorn and Ladismith are shown in Figure 5.2. There was no significant trend in annual maximum temperature over the observation period for either Ladismith ($n = 43$, $z = 0.33$, $p>0.05$) or Oudtshoorn ($n = 53$, $z = 0.94$, $p>0.05$). Although the trend in Oudtshoorn's minimum temperature values was not significant ($n = 53$, $z = -0.51$, $p>0.05$), there was a significant increase in the mean annual minimum temperature at Ladismith ($n = 43$, $z = 4.08$, $p<0.001$).

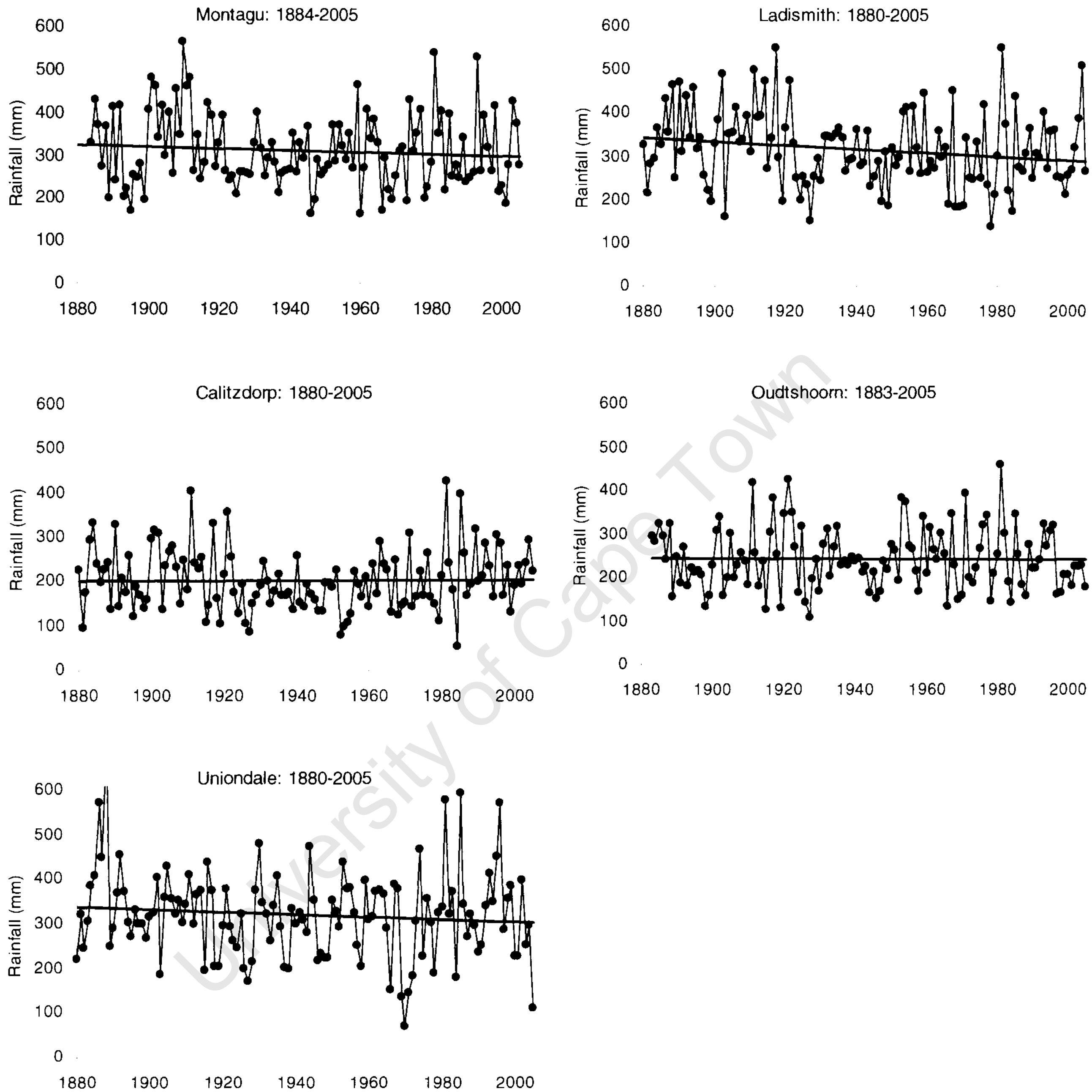
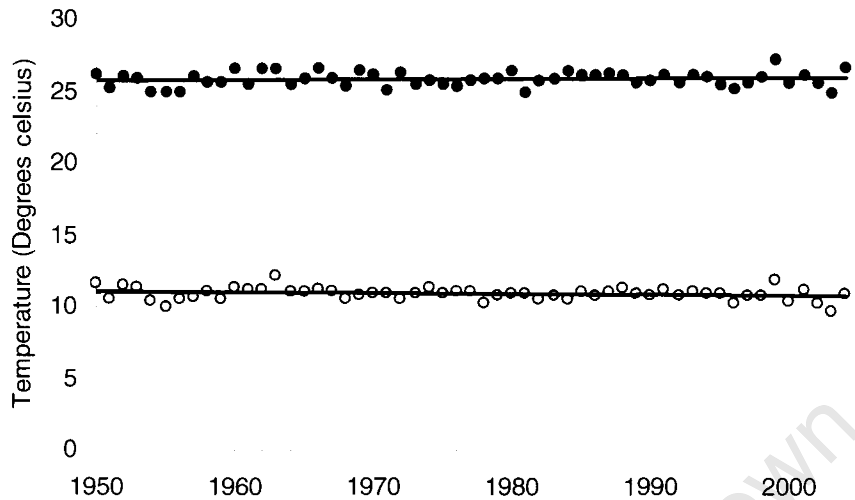


Figure 5.1 Annual average rainfall for the five districts in the Little Karoo for the period (1880-2005).



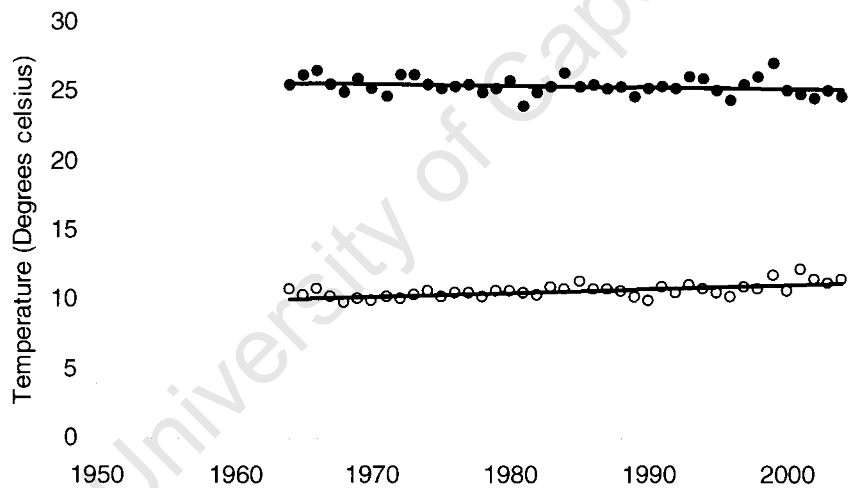


Figure 5.2 Mean annual maximum (upper line) and minimum (lower line) temperature for the districts of Oudtshoorn (1950-2004) (top graph) and Ladismith (1964-2004) (lower graph).

5.4 Land use

5.4.1 Livestock production

The total number of cattle, sheep, and goats kept in the five districts of the Little Karoo is shown in Figure 5.3. In all districts it is clear that goats constituted a higher proportion of animals kept in the region but that their numbers have decreased significantly over the 20th century. Sheep numbers, on the other hand have generally increased over this same period with a peak in the 1930's until the late 1960's when numbers dropped. Cattle numbers shown by the data from the 1860's have remained low in the Little Karoo. The interest in keeping cattle was most probably overtaken by the fact that ostrich farming was fast becoming a profitable business in the early 1870's.

There has been a dramatic rise and fall in ostrich numbers over years (Figure 5.4). For nearly 50 years from 1865 to 1914 there was an increase in bird numbers. Historical records show a total of only 80 birds in the study area in 1865. By 1914 this number had risen to approximately 770 000. The effect of the two world wars (1914 and 1948) saw a drop in numbers as the export market collapsed. Ostrich numbers have stabilized again after the health scare events of the late 1990's in the ostrich industry (see Table 5.1 below). Overall stocking rates were high in the study area in the mid 1880's with averages of up to 8 ha per LSU (Figure 5.5). Ladismith, Calitzdorp and Oudtshoorn have shown a decline in overall stocking rates, while Montagu and Uniondale have maintained fairly consistent overall stocking rates over the period on record.

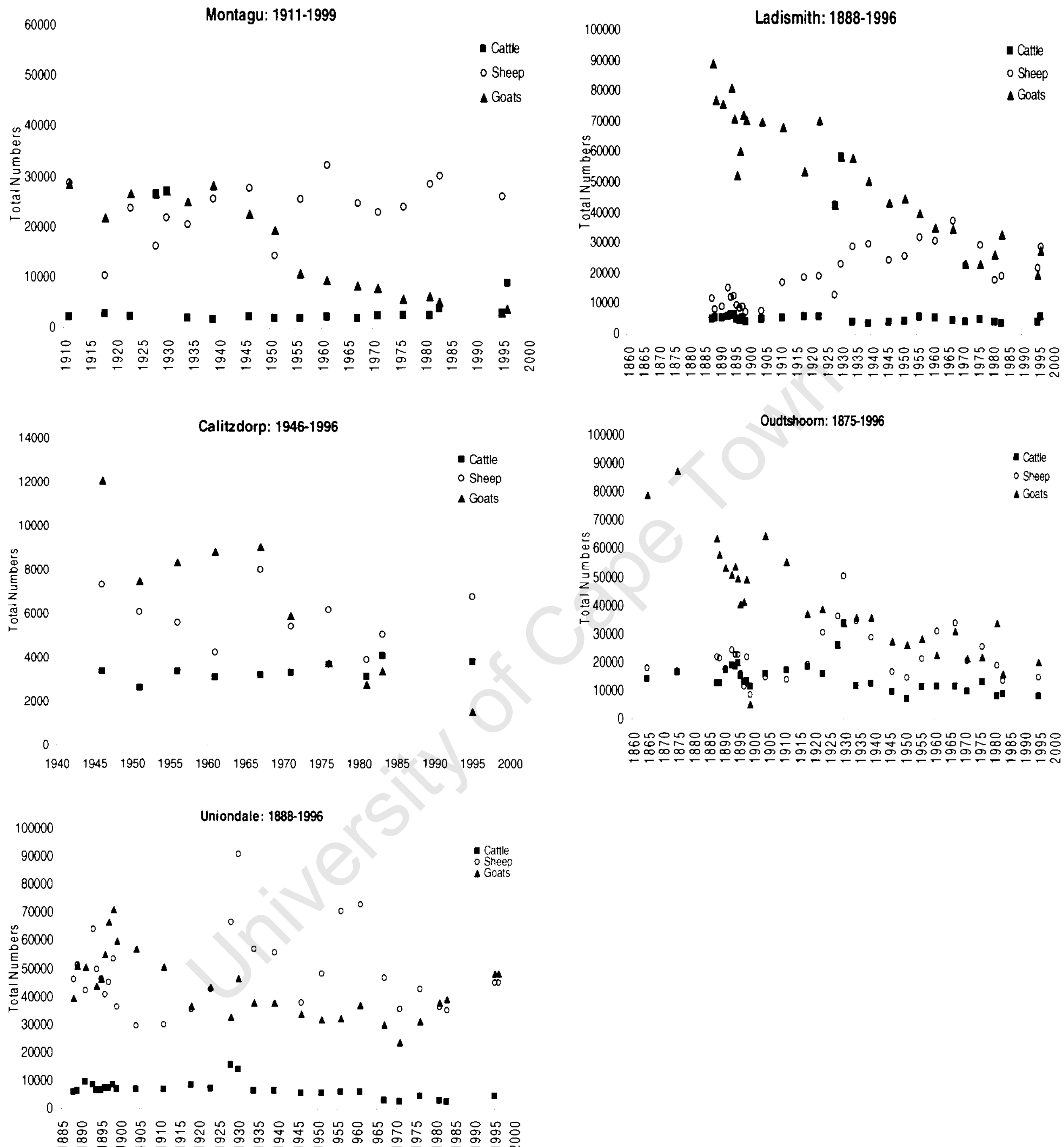


Figure 5.3 Total number of cattle, sheep and goats in the districts of Montagu, Ladismith, Calitzdorp, Oudtshoorn and Uniondale

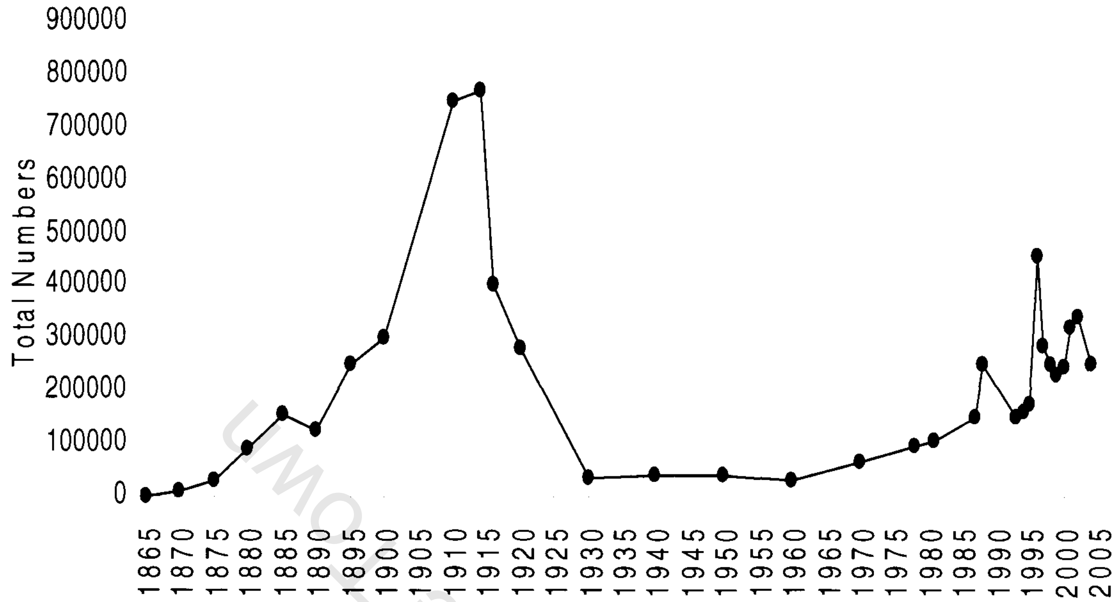


Figure 5.4 Total number of ostriches in the Little Karoo from 1865-2004.

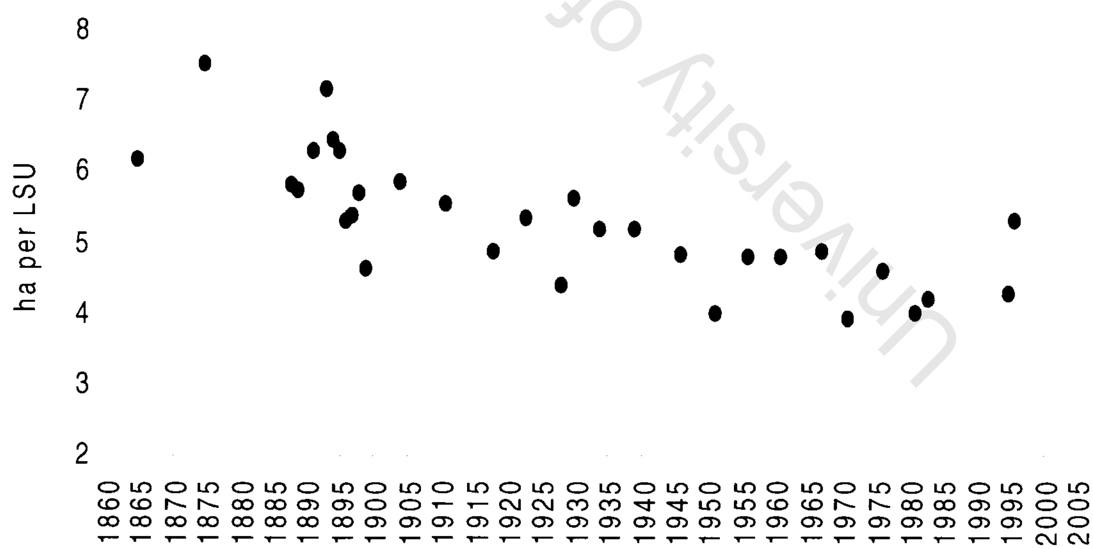


Figure 5.5 Average stocking rate of all stock (ha per LSU) in all magisterial districts of the Little Karoo from 1860-2005.

Table 5.1 Historical events in ostrich farming and industry in South Africa (after Lambrechts, 2004)

Year	Event
1838	Beginning of exporting of feathers to Europe
1850	Efforts to increase the number of ostriches and tame wild ostriches
1863-1869	Invention of an artificial incubator
1870	Ostrich farming becomes a profitable enterprise (together with introduction of wire fences and lucerne)
1900-1914	First feather boom era
1910	Increased competition from American ostrich breeders in terms of feather production
1913	Feathers listed fourth on SA list of exports in terms of earnings
1914	Industry collapsed due to worldwide socio-economic effect of World War One. Reasons include: (i) the overproduction of feathers and disorganised marketing (ii) feathers could no longer be exported by ship; (iii) the development of the automobile meant that women couldn't wear hats with feathers anymore.
1914-1948	Slump continued
1959	Establishment of one-channel co-operative marketing system
1964	The first abattoir was built
1970	Tannery was built and became operational
1993	Deregulation of industry, ostrich farming activities commenced throughout SA.
1993-1996	Increase in bird numbers due to the 'uncontrolled' initiation of ostrich farming throughout SA
1997	Overproduction of skins caused prices to fall. Since then the improved control of the production of slaughter birds has effected the number of birds that are produced and the products thus 'released' into the respective markets. Together with improved marketing strategies the aim is to try and prevent future collapses in the industry.
2001	BSE (mad cow disease) crisis in Europe, which caused an increase in the demand for ostrich meat.
2005-2007	Fears of outbreaks of bird flu

5.4.2 Crop Production

Figures (5.6, 5.7 and 5.8) show the total area of land used for the production of crops in the five magisterial districts of the Little Karoo. Specific crops have tended to dominant in certain parts of the study region. Considering the fact that the region falls within a transitional rainfall zone, this would be expected. Wheat has, however, been cultivated in all the districts of the region. The data show a general declining trend in crop production (excluding lucerne) in the districts with the exception of wheat and oats in Montagu. The total area used to produce lucerne has been on the increase for most of the districts especially in the district of Oudtshoorn. In 1981, over 14 000 hectares were planted with lucerne in this district.

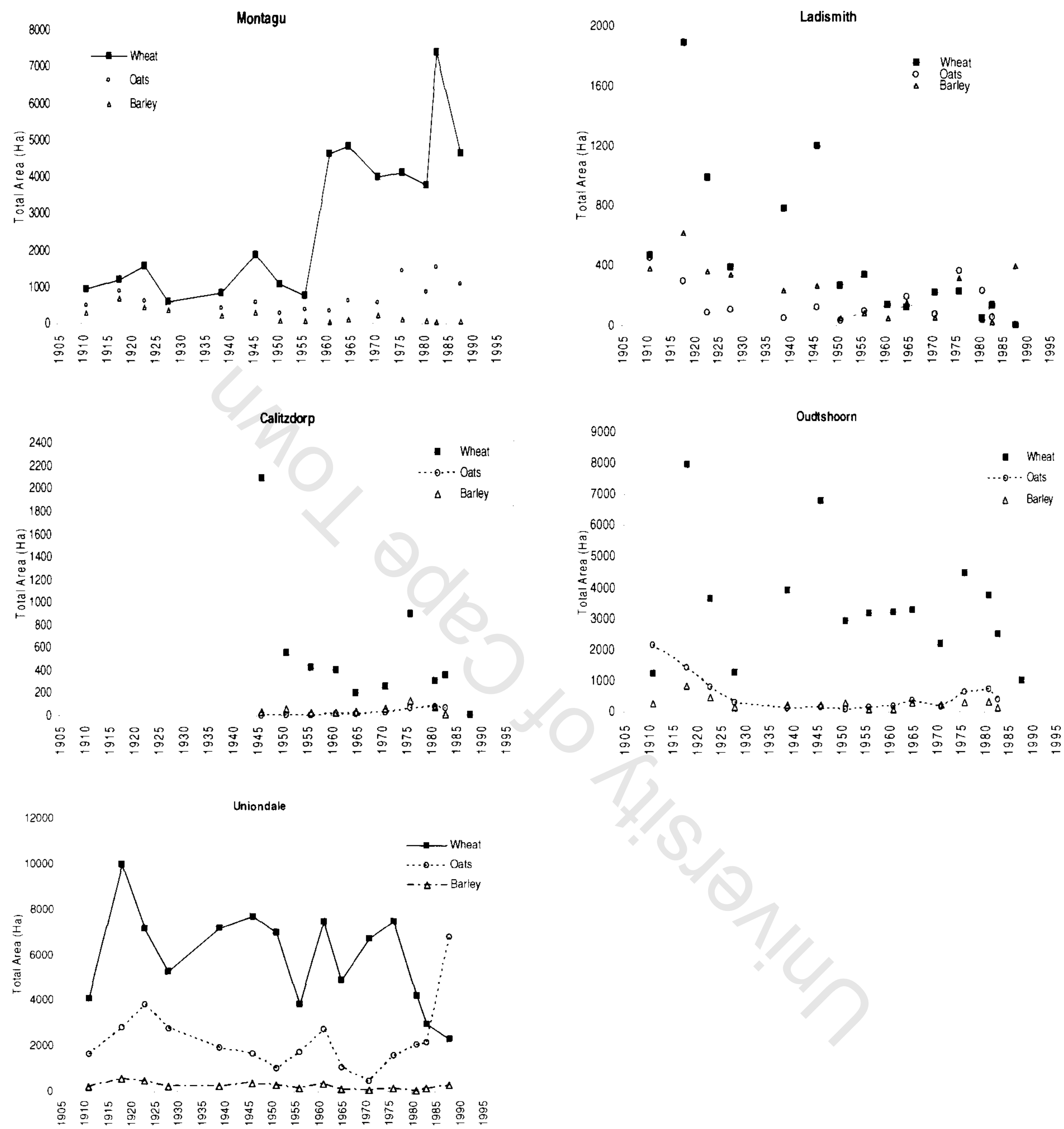


Figure 5.6 Total area (ha) of land used for the production of wheat, oats and barley in the districts of the Little Karoo.

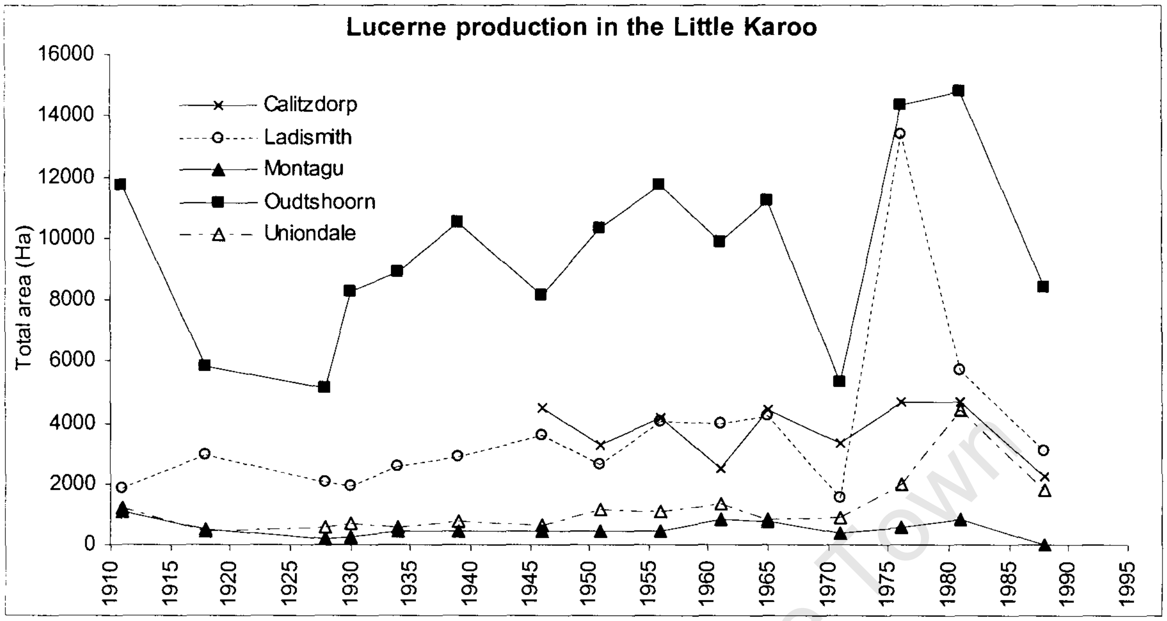


Figure 5.7 Total area (ha) of land used for the production of lucerne in all Little Karoo districts (1910-1990).

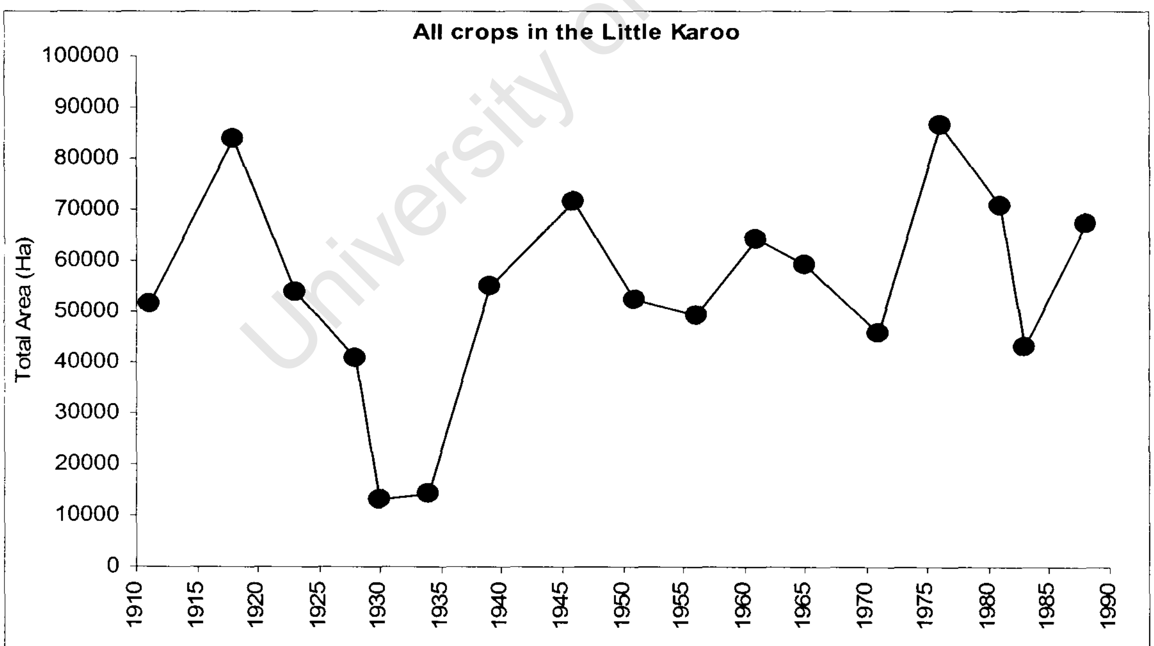


Figure 5.8 Total area (ha) of land used for the production of all crops including lucerne in the Little Karoo (1910-1995).

5.5 Discussion

5.5.1 Climate trends

The results of this chapter show variations in rainfall and temperature over the years in the Little Karoo. These results follow a similar pattern to that described by Nicholson (2001) for drylands. Rainfall and temperature are described as key features of dryland climates. Such regions are characterised by low rainfall that is highly variable in time and space with localized rainfall events of short duration but usually high intensity, and generally temperature extremes with high daily and annual temperature ranges (Nicholson, 2001). Although Ladismith has experienced a significant decrease in annual rainfall and a significant increase in minimum temperature values this pattern is not widespread in the region. There appears not to be a general trend of climate deterioration in the Little Karoo. These results confirm a widely held view that environmental changes in the region are a result of the cumulative impact of land use over many years (Dean and Macdonlad, 1994).

5.5.2 Land use in the Little Karoo

There is little evidence to suggest that pre-colonial pastoralists communities who occupied the Karoo degraded their environment in any significant way (Hoffman, 1995). Downing (1978) suggests that the land use practices (e.g. fire and grazing) of these inhabitants were unlikely to have irreversible environmental impacts. However, the livestock production systems of the pastoralists communities and those of Trekboers and later commercial farmers differed widely. While early pastoralists engaged in transhumance movement in order to exploit seasonal differences in the availability of grazing and water resources (Hoffman and Cowling 1990) this was not the case with the more sedentary lifestyles of 19th and 20th century agriculturalist. Concern over the extent of environmental change in the Karoo was reported as earlier as 1775 (Downing, 1978). However, it is the period between 1850 and 1950 where deterioration has been reported to have been greatest (Downing, 1978; Hoffman *et al.,* 1999a; Beinart, 2003). This has been attributed to an expansion of agricultural activity which occurred during this period. Hoffman and Cowling (1990) also highlight the role of specific farming systems such as the 'kraaling system' which was blamed in 1877 for the degradation of the Karoo rangelands. Technological advancements in farming practices such as windmills, artificial water sources and wire fencing are also thought to have brought about environmental changes in the Little Karoo (Archer, 2002). The trend has been to commercialise the livestock industry and this has resulted in a decline in goats (for which there is not a ready commercial market) and a modest increase in the number of mutton sheep, particularly Dorpers. Beinart (2003) also ascribes this rise in sheep numbers to the wool demand which became the major focus of production from the 1830's to the 1930's. These breeds are less able to utilise the high-lying rocky areas and prefer to feed on the vegetation of the succulent karoo. Their concentration around low-lying habitats with palatable shrub cover has partly been responsible for the high levels of degradation evident in these habitats. Cupido's (2005) assessment of veld utilisation practices and veld condition in the Little Karoo concluded that grazing by domestic livestock is a major anthropogenic force that has changed the landscape of the region.

The ostrich industry has also had a large impact on the vegetation of the succulent karoo biome in the Little Karoo. The South African ostrich industry was established in 1838 with the export of feathers to Europe to supply the fashion industry (Palmer *et al.*, 2006). In the Little Karoo, ostrich farming as a new agricultural practice started between the years 1857 and 1864 (Cupido, 2005). For over a century, the industry has been through boom and bust periods as a result of a combination of several factors (see Table 5.1). This economic activity still occupies the greater part of the Little Karoo because besides meat and leather, there are secondary products such as feathers, eggs and ecotourism which add value to the industry.

The extent and intensity in crop production has shifted over years in the area under study. After 1920, there was a general decline of crop production in all districts and a rise in production levels from the 1930's especially in wheat production. These trends could be linked to a number of factors such as the reliance during the earlier years on rainfall and rivers that do not run during the dry season. With improved irrigation systems, these natural challenges could be overcome. Lucerne on the other hand, has been on the rise in the Little Karoo throughout the 20th century. Ostrich farming has encouraged the expansion of crop types such as lucerne since it is used extensively by farmers for feeding birds.

CHAPTER 6 SUMMARY AND CONCLUSION

6.1 Introduction

The objective of this chapter is to highlight salient issues raised during the course of discussion in the main body of this thesis. The aim of this study was to outline the extent and causes of degradation in the Little Karoo. In order to achieve this, it sets out to realise the following objectives:

(i) To quantify the extent of land transformation and degradation in the major biomes, habitats and vegetation units of the Little Karoo;

(ii) To determine the status of major ecosystems in the Little Karoo

(iii) To compare the outputs of these approaches with other studies undertaken in the region and;

(iv) To assess the historical causes of degradation in the region using long-term climate and agricultural census records.

These objectives were achieved by this thesis. Issues raised in the course of this study are synthesised and presented below.

Evidence gathered for this study showed that the Little Karoo region is extensively degraded. Whilst studies done in the past have acknowledged visible vegetation changes, the extent of environmental degradation seems to have been underestimated. An analysis of historical rainfall data covering a period of over 100 years does not provide conclusive evidence that there has been major climatic change over the last century. Environmental changes observed, and documented over time are therefore mainly attributed to the mismatch of agricultural land use practices, especially grazing.

With its long agricultural history spanning more than two centuries, the Little Karoo has contributed to farming innovations and the economy of South Africa as a whole. On the other hand, its biodiversity as part of the world's only arid hotspots faces a real threat from consistent land use mismanagement practices. In order to assist decision-makers at a local level, it has now become more important to show as well as to quantify the scale of biodiversity loss over time in the region. The advances in remote sensing techniques in recent years together with local knowledge have added value in understanding the true extent of biodiversity loss especially in semi-arid and arid Little Karoo region.

Issues raised in the introductory literature section in this thesis above are not new within the context of the desertification and degradation debate but, new approaches reviewed in understanding the complexity of the problem are refreshing. Drawing from these new approaches and as suggested by Prince (2002), this study places the Little Karoo degradation debate in an appropriate spatial and temporal context.

6.2 Quantifying degradation at a fine scale

The quantification of transformation and degradation of the Little Karoo habitats was an important milestone for the region. It has been widely acknowledged that assessing degradation is a difficult exercise especially in dry areas. Often degradation assessments studies tend to describe its existence without specifying the what, how much and where questions of degradation. As degradation processes are most often triggered by localised actions at a household, or village level, an appropriate scale is critical if suitable responses are to be made. The fine scale (1:50,000) at which the vegetation map was compiled adds value to assessment attempts if conservation efforts at the local land user scale are to be made part of the restoration and mitigation policies.

The use of vegetation cover as the only proxy in assessing land degradation has been cited as a weakness in many assessment studies and can be misleading as it does not necessarily measure the biodiversity of an area. For an example, Cupido's study (2005) found that farmer's assessment of the veld condition in the Little Karoo was mostly based on the condition of the vegetation cover without considering other factors such as soil condition, alien invaders, and palatable plant species composition. As a result of this approach Wessels *et al.* (2007) argue that many studies tend to show results that depict drastic land cover or land use changes and mask any land degradation that is generally more subtle and gradual. Although species composition matters, the emphasis of contemporary assessment studies including the Millennium Ecosystem Assessment is on healthy functioning ecosystems. However, the hierarchical classification system of functional vegetation units used in mapping the study area, and a linked degradation data set discussed in chapter three of this thesis, is a relatively novel approach in this field. Even though there is no comprehensive account of pre-historic vegetation composition in the Little Karoo region, it is fair to reason that after over two centuries of constant land use in an ecosystem such as that of the Succulent Karoo, the ability of some species to persist would have been compromised.

The results of this study suggest that degradation in the Little Karoo is far more extensive than previously indicated. Although more than half of the region has a moderate level of degradation, restoration is possible if land management practices are aligned more closely with conservation objectives. Not withstanding their limitations, recent studies have indicated localised recovery of the rangelands following several years of rest from grazing in the Succulent Karoo (Rahlao *et al*,. 2008). More concerning is the finding that 28% of the Succulent Karoo biome, 21% of Azonal habitats and 19% of Thicket biome vegetation are considered severely degraded in the region. The long-term impact of livestock production is primarily responsible for the relatively high degree of degradation in the region.

6.3 An assessment of ecosystem status in the Little Karoo

The status of Little Karoo ecosystems using conservation targets was determined for the first time in an analysis based on transformation and degradation data of the region. Taking into account global efforts to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation (UNEP, 2004), this study represents an important contributions towards these efforts. Previous ecosystem assessments studies have consistently raised the need to consider degradation as a factor in future assessment. The results of the ecosystem status analysis used in this study have indicated that the Little Karoo is widely degraded compared to other regions within the National Spatial Biodiversity Assessment (Driver *et al.*, 2005). Although 59% of the 369 vegetation types can be considered Least Threatened, 7% are Critically Endangered, 16% Endangered and 18% Vulnerable. The Succulent Karoo has the highest number (13) of Critically Endangered vegetation units in the study area. Unlike the NSBA which was a general national spatial assessment, the result of the ecosystem status determination in this study is a resource that can be utilised at the lower level of end-users.

6.4 A holistic approach in understanding complexities of the Little Karoo landscape

Any attempt to understand the current trends of land degradation and prediction of the future state or land use options in the Little Karoo cannot be undertaken in a historical vacuum. Environmental problems are often not only underlined by isolated scientific-technical and static events, but by an array of complex biophysical human interactions which re-enforce each other over time. Past attempts at assessing and describing degradation have often been dominated by the visual impacts on the ground shown by satellite images and other technological devices. The analysis and presentation of these images have therefore been done by experts in these fields. The growing interest by multi-disciplinary teams of botanists, geo-hydrologists, anthropologists and socio-economists in coming together to map the Little Karoo environment benefited this study greatly. The Dahlem Desertification Paradigm (Reynolds and Stafford-Smith, 2002) recognised the need for better multidisciplinary teams in order to formulate research frameworks that respond to the needs on the ground. A holistic approach in addressing degradation is necessary for the implementation of adaptive management policies especially for the natural ecosystems of the Little Karoo.

6.5 What are the main drivers of habitat degradation in the Little Karoo?

Because biophysical factors such as plant cover and rainfall variability tends to dominate physical characteristics of dry areas, degradation and desertification are often regarded as naturally-induced phenomena. While the rainfall records for the five main districts in the study area suggest a high degree of inter-annual variation in rainfall, there is no evidence (except for Ladismith) that rainfall has decreased over the last 100 years. Even though Meadows and Hoffman (2002) have observed that there has been a reduction in rainfall over some parts of southern Africa over the last two centuries, albeit over short periods, land degradation in the Little Karoo can largely be regarded the result of mismanagement of land over time rather than a reduction in rainfall. An analysis of changes in temperature was hampered by the lack of a suitable network of climate stations for the area. However, data for Oudtshoon and Ladismith suggest that there has not been a significant increase in mean annual maximum temperature since 1950. There has, however, been a significant increase in mean annual minimum temperature at Ladismith. This increase is most noticeable in the last five years and it is unlikely that changes in the minimum temperature at Ladismith are responsible for the high degree of degradation recorded in this district.

6.6 Towards planning and implementation

Over the last two centuries a number of institutional arrangements and policy directives have been undertaken in the study area to address the problem of land degradation. These were made necessary by changes taking place on the ground and which were noted as early as the 1770's. The Fencing Act of 1912, the 1946 Soil Conservation Act (Act No. 45 of 1946) and other statutory measures are but some examples. However some of these policies have not always been effective at addressing the root cause of the problem. In many instances land-use management policies have typically been top down with little or no stakeholder consultation. The Herschel district in the north Eastern Cape is a case in point, where a popular resistance by the rural masses in the 1930's was an attempt to block a variety of unwanted government interventions (Beinart, 1989). Land tenure re-arrangements in this region led to serious environmental consequences which rendered it a wasteland with dongas (large erosion gullies) and ruins of homesteads serving as monuments to this history.

Fortunately, in South Africa there is now a suite of national, provincial and local government policies and regulations which govern the management of the environment. These policies subject some land uses to a thorough legal process. Currently at the implementation level, (i.e. at Local Municipality and District Council level) there are biodiversity laws governing planning and implementation programmes such as the District State of Environment Reports (SoER) Spatial Development Frameworks (SDF) and Spatial Development Plans (SDP). These policy frameworks flow from the National Biodiversity Act which was passed in South Africa in 2004.

The new laws governing the use of natural environments require landowners, land managers, environmental conservation agencies and regional planners to take informed decisions on sustainable land-use practices. As was the case with the detailed map of the vegetation of the Little Karoo region, there is need for appropriate baseline biodiversity information available for the easy use of the end-user in order to make informed decisions on conservation, sustainable commercial farming and land-use planning. A rapidly-constructed map at a fine scale (for an example farm boundary or municipality) showing key biodiversity features could be produced using products of this research. Such map products are of value to both planners and land users.

6.7 Future research opportunities

There is a need to constantly monitor environmental changes as conditions change. This will also necessitate a new set of tools and expertise. In the Little Karoo, a holistic approach presents opportunities for collaborative research. Policies often drive behaviour and actions on the ground. An opportunity exists to assess historical policy directives and relate these to environmental changes in the region over time. The objective would be to assess and see if relevant policies have any impact on changes on the ground. Furthermore, this study has suggested that a high proportion of the Little Karoo is moderately degraded but will recover if managed appropriately. There is a need to develop such approaches and to record the rate and extent of recovery on different vegetation types in the region. It is also important for land use planners to know the cost-effectiveness of different restoration interventions.

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