CHAPTER 12

APPLYING A RESILIENCE FRAMEWORK IN THE PURSUIT OF SUSTAINABLE LAND-USE DEVELOPMENT IN THE LITTLE KAROO, SOUTH AFRICA

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ABSTRACT

Land-use management policies in rangelands have typically been top down, singularly focussed on achieving maximum sustainable yields from ecosystems, and have generally failed to halt land degradation. Natural resource management approaches which adopt a more holistic outlook, focusing on the integrated nature of social and ecological systems, appear to hold promise for sustainable land-use development, particularly when focussed on the resilience of these systems. The objectives of this chapter are: to demonstrate the potential of adopting a broader integrated research approach, using a resilience framework; to examine the interconnectivity of the social-ecological system of the Little Karoo, a rangeland area with additional focus on intensive ostrich production and lucerne cultivation along water courses, in southern South Africa; and, to describe some future land-use and development scenarios for this area. This approach highlighted eight external shocks that impact this system (floods, droughts, water supply, finances, product prices, input costs, connectivity losses and property prices). It also clarified stakeholders’ perceptions of declining agriculture and collapse of the commercial farming community, and identified plausible government policies that will influence this system’s trajectory - including promoting tourism, sustainable agriculture and land-reform that addresses land ownership equity. This study not only demonstrates how complex sustainable land-use issues become when focussing on a social-ecological system, but it also shows the value of a resilience framework in logically establishing knowledge of past trends and influences on social-ecological systems. We argue that future sustainable land-use management of rangelands within the Little Karoo will benefit from an integrated focus on socio-ecological system resilience.

KEYWORDS

Degradation, environmental history, resilience, land-use strategies, semi-arid rangelands, plausible futures, social narrative, Vanwyksdorp, sustainability science

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MANAGING SEMI-ARID RANGELANDS

The challenges

The semi-arid rangelands of South Africa comprise some of the most biodiversity rich landscapes in the country. Decisions regarding their management, therefore, have important implications for this global asset (Mittermeier *et al.,* 2005). These rangelands are also some of the most poorly conserved regions in the country, falling below the national average of 6% of their area under protection (Reyers *et al.,* 2007). Options for expanding the protected reserve network are limited by budgets and tenure arrangements. Furthermore, the ecological processes and functions associated with these rangelands can operate over large geographic scales and establishing and expanding reserves alone will not ensure their protection (Desmet, 1999).

Rangeland conservation ultimately lies in the hands of the communal and commercial livestock farmers operating in these regions, and depends on their judicious use and careful management of this biodiversity. Such management is not only essential for conserving the unique wealth of rangeland biodiversity, it is also important in ensuring the continued provision of ecosystem services associated with livestock production which, in turn, rely on the underlying biodiversity and ecological processes and functions. These ecosystem services include nutritious grazing, soil retention, shelter and vegetation regeneration, and rely on the retention of biodiversity and ecological integrity (Diaz *et al.,* 2006). Unsustainable land-use practices, such as overgrazing, degrade these ecosystems, in that they result in soil erosion and a loss of palatable plant species number and cover. This leads to the loss of biodiversity and ecosystem services, at both local and regional scales – which has further ecological, economic and social ramifications.

Unsustainable land-use practices and the associated degradation of our semi-arid environments has occurred over extensive areas and is an issue that South Africans have been grappling with for well over a century (Hoffman and

Ashwell, 2001; Beinart, 2003). Concerns about land degradation were first expressed in the late 1800s (Hoffman, 1997), and numerous committees were formed and policies formulated to address this issue, stretching as far back as 1914 (Hoffman and Ashwell, 2001). Whilst a number of interventions resulted in improved rangeland condition, with some ecosystem service and biodiversity spin-offs, they generally failed to halt unsustainable land-use practices (Hoffman and Ashwell, 2001). Policies and related management actions focussed on developing controls over ecosystems and the resource base, fine-tuning the exploitation of this resource base, establishing carrying capacities, maximum sustainable yields and stock reduction schemes. Rangeland management approaches, and condition assessments techniques have also been wholly focussed on plant and animal production and predicting ecological responses under varying management conditions (Tainton, 1999). Social, economic and political influences on these systems have largely been ignored with respect to their long-term sustainable management.

New directions

The issue of managing ecological systems such as semi-arid rangelands for long term sustainability remains a challenge. There is a growing realisation that the way we currently conduct research and develop management interventions will not provide sustainable solutions to a variety of problems (Clark and Dickson, 2003; Max-Neef, 2005; Reyers *et al*., Chapter 5, this volume). Sustainable development requires focusing on the dynamic interactions of nature and society and engaging with the broader community in addressing related challenges (Clark and Dickson, 2003). Within the natural resource management arena this requires scientists and practitioners to focus on examining both the social and ecological components of landscapes as part of a single integrated and interlinked social-ecological system, or SES. Social-ecological systems by their nature are complex, affected by non-linear processes and feedbacks, operating at multiple scales, with numerous cross-scale linkages between systems (Cilliers, 2000; Burns *et al.,* 2006). Recent research efforts have yielded useful developments in our understanding and management of these SESs (e.g. Abel *et al.,* 2006; Cumming *et al.,* 2006; Janssen *et al.,* 2006). Of particular interest to the challenge of managing semi-arid rangelands is the development of the notion of resilience in SESs. Determining how an SES responds to external factors that originate beyond the system boundaries; internal system variables that influence its stability and trajectory; and shocks or dramatic stochastic events, is seen as fundamental in understanding its resilience.

The concept of resilience emerged in the ecological literature in the early 1970s (Holling, 1973), and subsequently, this thinking has been applied in a number of settings. Le Maitre and O'Farrell, (Chapter 11, this volume) describe distinct differences between 'engineering resilience', or a measure of the rate at which a system returns to a single steady state (Peterson *et al.,* 1998) and 'ecological resilience', which describes the amount of change required to move an ecosystem from one state to another (Holling, 1973; Peterson *et al.,* 1998). Social-ecological system resilience emerged from the earlier thinking on ecological resilience, and has been defined by Walker *et al.* (2002) as a system's ability to absorb disturbances and recover from them whilst continuing to function in essentially the same way. Walker *et al.* (2004) identify components that define the resilience of an SES (**Figure 1**). These are:

- the state or the space a resilient system will remain in when influenced by a range of factors, conditions or variables – described as a 'basin of attraction';
- the latitude of the system, or the amount the system can change before losing its ability to recover;
- the resistance or the degree of ease with which a system can move between states or basins;
- the precariousness of a system, which describes the degree of imminence of shift in system state; and,
- cross-scale effects on a system.

Two additional variables must be considered in understanding resilience and the evolutionary trajectories of SESs, since they are central in explaining the development trajectories of many systems through various phases of what Holling (1986) describes as the adaptive renewal cycle. These variables are:

- the 'connectedness' of a system, which relates to the strength of the internal connections that regulate the effect of external controls of system functioning; and,
- the 'potential' of a system, or the future development possibilities of that system.

It is important to note that the state of an SES and the space or basin of attraction in which it occurs is not static; it can change under certain conditions, when influenced by changes in one or more of the variables listed above.

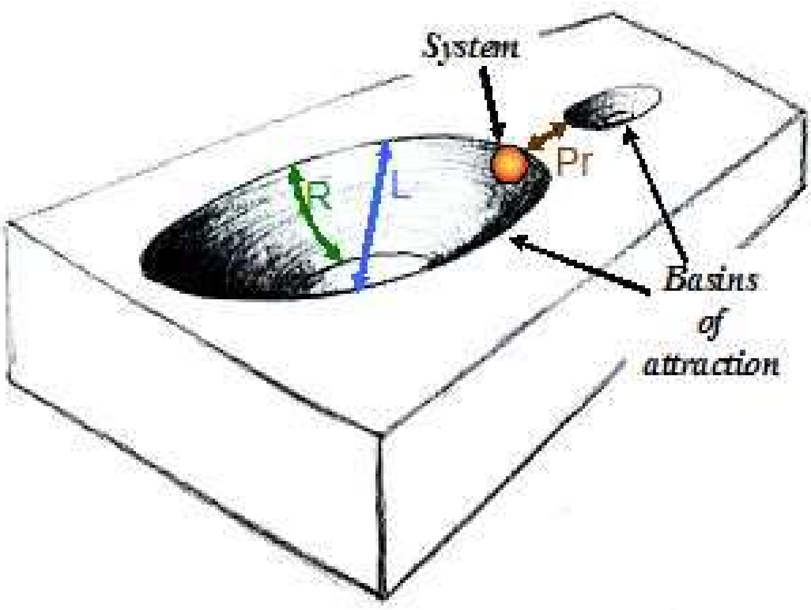

Figure 1. Components that define the resilience of a socio-ecological system: basins of attraction, the latitude of a system (L), the resistance (R), and precariousness (Pr), with the system being able to shift between basins or remain stationary. Taken from Burns (2007).

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No SES can be understood by examining it at a single spatial or temporal scale since systems assumes their definition in a context defined by other systems functioning at a range of scales (Walker *et al.,* 2004). This implies that SES latitude, resistance, precariousness, connectedness and potential are affected by what is happening at scales both 'above' and 'below' the one of interest, and by 'neighbouring' SESs. For a detailed description of resilience and its contributing variables see Walker *et al.* (2004), Burns (2007) and the Resilience Alliance (2007).

These ideas and frameworks for understanding the resilience of an SES are relatively new and are largely untested with real world examples; however, they appear to hold promise in the study and management of such systems (e.g. Cummings *et al.,* 2005). This chapter aims to demonstrate the contribution they could make to the management of South Africa's semi-arid rangelands. We hope that this will provide some new insights into the management of semi-arid systems and that these insights will assist in building understanding of the interactions and linkages within and between social and ecological components of a SES. Importantly we use a real world example of an SES to explore key factors that determine the resilience of these coupled systems.

EXPLORING RESILIENCE IN THE LITTLE KAROO

Context of the study

Commercial agriculture is practised on approximately 80% of the land surface of South Africa and, therefore, provides a useful context for the investigation of SES resilience. Our study focuses on the SES resilience of commercial agricultural landscapes in the Little Karoo, a semi-arid rangeland region in southern South Africa. Here, we analyse and describe the land-use strategies, sociological processes, ecosystem function and the resilience of the Little Karoo SES that we describe. We also undertake more detailed investigations of an SES nested within the Little Karoo, one that encompasses the farming area surrounding the town of Vanwyksdorp in the Ladismith municipal area (**Figure 2**). This approach provides us with farm-scale data on land-use, ecological and social system conditions with which to contrast regional scale data - giving us an understanding of cross-scale effects within and between SES's of different scales.

We treat ecosystems and social systems within our study area as comprising interacting SESs (at two scales). In order to do this we use the history of land use and its social and ecological consequences as a departure point. We propose that land use is the integrator of social and ecological systems, determining the structures, functions and, therefore, the resilience of both. We aim to: (a) describe the interconnectivity and resilience features of the SESs that we define; (b) detail how historical land use decisions and policies decreased system resilience; and, (c) use this knowledge to describe some scenarios for future commercial agriculture in the Little Karoo. This chapter is complemented by resilience analysis undertaken by Le Maitre and O'Farrell (Chapter 11, this volume), which examines historical developments and the current use of water resources in the Little Karoo and options for moving towards more sustainable use patterns.

Study area

The Little Karoo is a region located in central southern South Africa, between the coastal Langeberg and Outeniqua mountains and the inland Anysberg, Swartberg and Antoniesberg mountain ranges. It extends from the town of Montagu in the west to Uniondale in the east, and encompasses four local municipal areas or districts, Ladismith, Calitzdorp, Oudtshoorn and Uniondale (**Figure 2**).

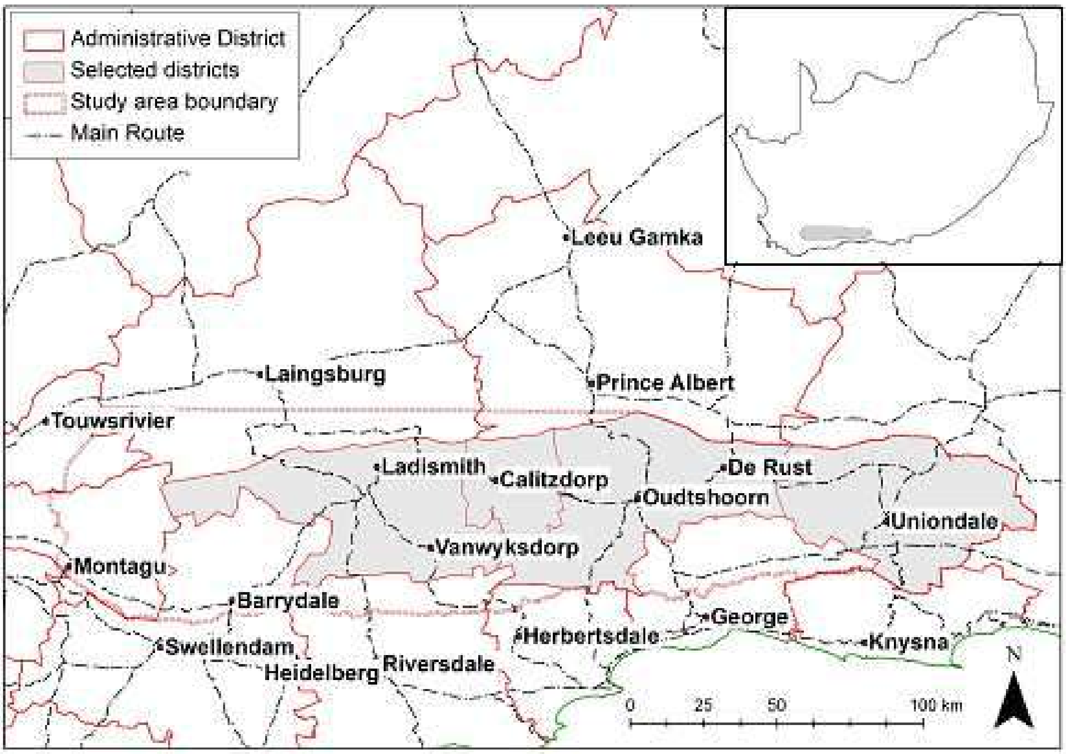


Figure 2. The Little Karoo study area, showing major towns

The Oudtshoorn district has the largest population, with approximately 87 000 inhabitants, and is the only district to show substantial population growth over the last 100 years. The other districts' populations range from 6 000 to 15 000. There has been no appreciable growth in the populations of Calitzdorp and Ladismith over the last 100 years, and in the case of Uniondale there has been a decline in population - as indicated by populations census data for these districts (Stats SA, 2007).

Climate

The Little Karoo lies in the transition zone between the summer and winter rainfall climatic systems (Tyson, 1986). The amount of winter rainfall is strongly influenced by the region's location in the rain shadow of the coastal mountains, with only intense cold fronts bringing rain to the mountains further inland and to the inter-montane lower-lying areas. The mountain crests receive more than 1000 mm of rainfall, with lower-lying areas receiving between 150 and 300 mm. Some areas in the western Little Karoo receive as little as 20 mm of rainfall annually. The eastern part of the Little Karoo generally receives more rainfall, with a considerable proportion occurring in summer (**Figure 3**). Extreme rainfall events are associated with cut-off low pressure systems and ridging anticyclones occurring during spring and autumn (Desmet and Cowling, 1999). In the Oudtshoorn area, the rainfall in about 65-70% of the years is less than 85% of the mean annual rainfall (Venter *et al.,* 1986). Areas receiving winter rainfall generally have more reliable rainfall than those receiving summer rainfall, and the difference increases as the mean annual rainfall increases (Milton *et al.,* 1997; Desmet and Cowling, 1999). The Little Karoo has a quasi 10-12 year climate cycle: roughly 5 years with more, and 5 years with less rainfall than the mean – with a range of 10-30% either side of the long-term mean (Tyson *et al.,* 1975; Palmer *et al.,* 1990).

The mean daily temperature in February exceeds 30℃ in the low-lying areas and exceeds 25℃ in the mountainous areas (**Figure 3**). In July the corresponding temperatures are 20-22℃ and 12-14℃ respectively. The daily temperature range is greater in the east (14-17℃ in the summer months and 11-14℃ in the winter months) than in the west (12-14 and 11-13℃ respectively). The number of frost days per year ranges from less than 30 in the central region to greater than 90 in the high-lying montane areas, especially in the Groot Swartberg (Schulze *et al.,* 1997). Frost generally occurs between June and August in the low-lying areas, and over a longer period in the montane areas (Venter *et al.,* 1996; Schulze, 1997).

The annual potential evaporation, A-pan equivalents (Schulze *et al.,* 1997), exceeds 2000 mm/yr over most of the region, and in the drier western part exceeds 2250 mm per year, which is more than 10 times the annual rainfall.

For a more detailed overview of the physical and climatic environment of the Little Karoo, with an emphasis on water resources, see Le Maitre and O'Farrell (Chapter 11, this volume).

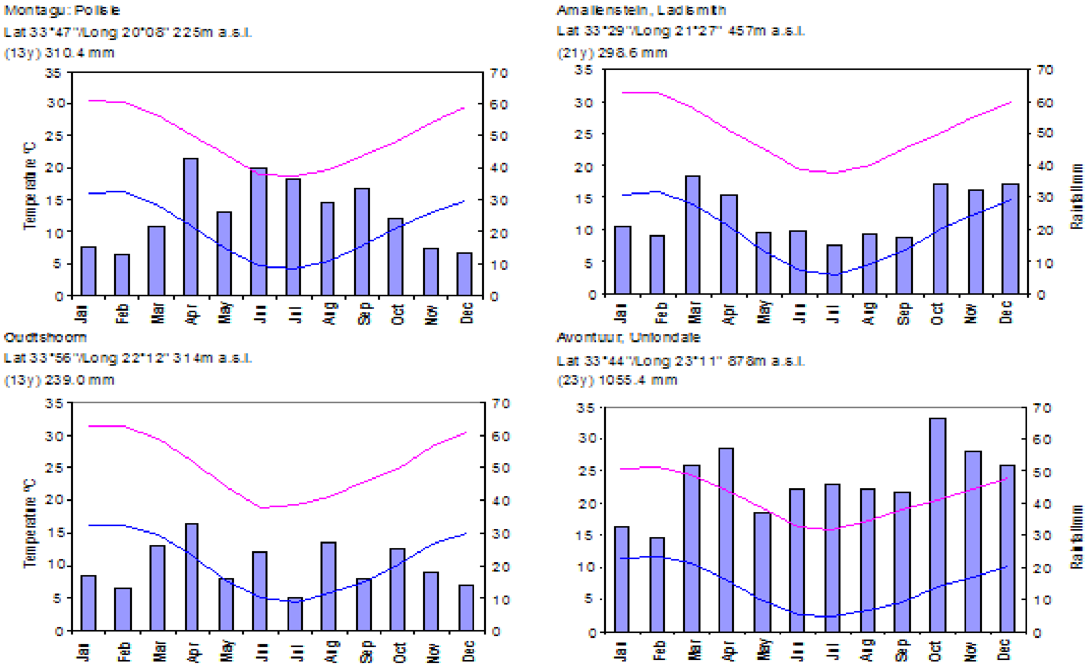


Figure 3. Climate diagrams for selected stations ranging from the western (Montagu) to the eastern (Avontuur, Uniondale) part of the study area. Data obtained from the Weather Bureau and from the Department of Agriculture.

Vegetation

The Little Karoo falls within an area where four broad vegetation types meet in a complex mosaic (**Figure 4**), each having a distinct structure and complement of species. The Succulent Karoo vegetation is found in the low-lying areas, where soils are nutrient rich and mean annual rainfall is less than 350 mm per year (Vlok *et al.,* 2005). This vegetation type is part of the broader Succulent Karoo Biome (Milton *et al.,* 1997), which is internationally recognised as being one of only two biodiversity hotspots found in arid regions (Mittermeier *et al.,* 2005). Subtropical Thicket occurs in discrete bush clumps and is found in areas receiving a minimum of 100 mm of rainfall in the summer months and protected from both frost and fire. Fynbos occurs on sandstones where the soils are nutrient poor, and Renosterveld is found on the more nutrient-rich, shale-derived soils. Riverine Vegetation is found along the water courses of the region, comprising two sub-types: the lowlands form, which is closely related to the Thicket Biome; and, the montane form, which is allied to the Fynbos Biome.

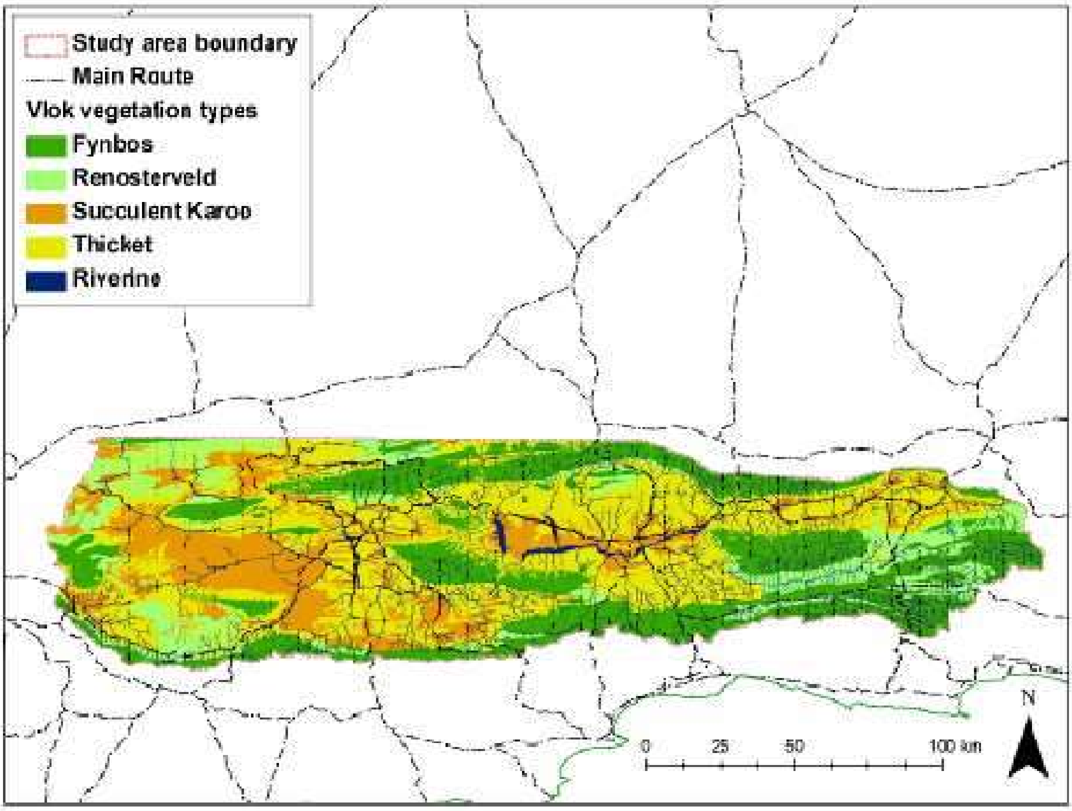


Figure 4. Vegetation map of the Little Karoo. Adapted from Vlok *et al*. (2005).

Land-use patterns

The Little Karoo is primarily an agricultural region, where the economy is strongly dependent on the very limited surface and ground water supplies for irrigated agriculture and range-fed livestock. Lucerne is the dominant cultivated crop; however, a variety of vegetables (produced both for seed and food) as well as fruit trees, and the cereal crops, wheat, oats, barley and rye, are also grown. The Little Karoo is especially recognized for its ostrich production, although a number of different livestock are ranched in the region, including dorper sheep, merino sheep, angora goats, boer goats and a variety of cattle breeds. It has been suggested that landscape heterogeneity accounts for the variety of livestock managed by local farmers (Cupido, 2005).

A detailed vegetation degradation assessment of the Little Karoon (**Figure 5**), based on phytomass cover and productivity, indicates that 10% of the region is cultivated, 15% severely degraded due to poor grazing practices, 53% moderately degraded (i.e. restorable), and 22% pristine (Thompson *et al.,* 2005). The most severely affected biome is the Succulent Karoo where 35% is severely, and 65% moderately, degraded. The riverine vegetation has also been severely affected, with 58% being severely degraded and only 27% pristine. The lowland river systems are almost completely degraded. The consequences of degradation attributable to overgrazing include high rates of soil erosion and resultant sedimentation of rivers (Le Maitre *et al.,* 2007). Excessive extraction of water from rivers for irrigation has degraded the riverine ecosystems - a situation which is aggravated by the high salinity of the surplus water that is returned to the river systems. The montane and lowland river systems have been heavily invaded by a range of alien plants including *Acacia mearnsii*, *Populus canescens*, *Hakea species* and *Arundo donax* (Versfeld *et al.,* 1998), which have reduced river flows and replaced much of the natural riverine vegetation.

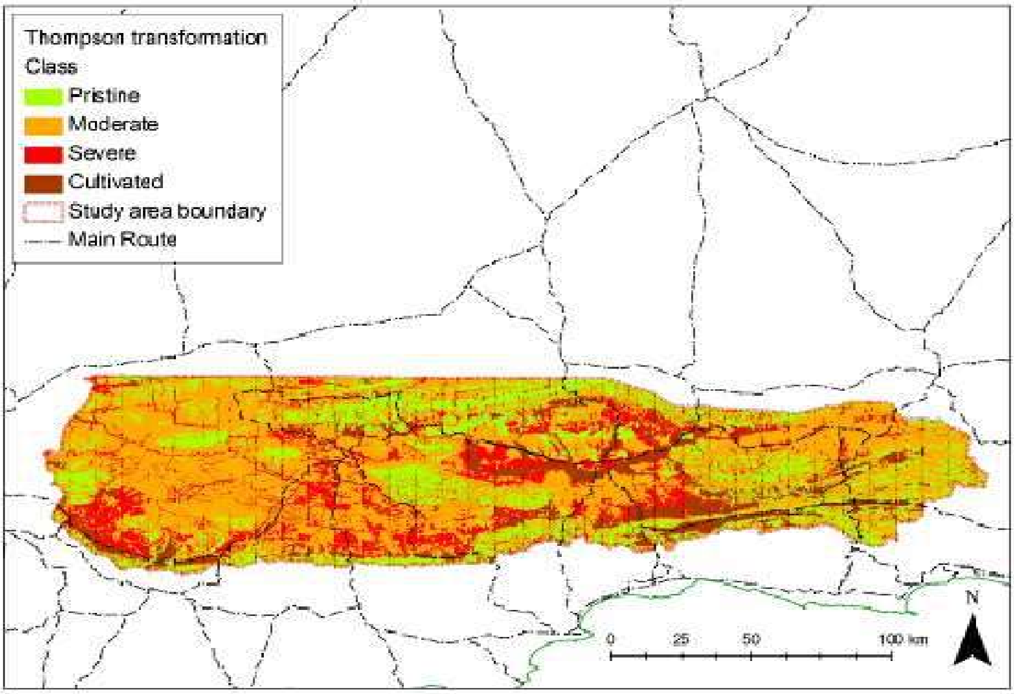


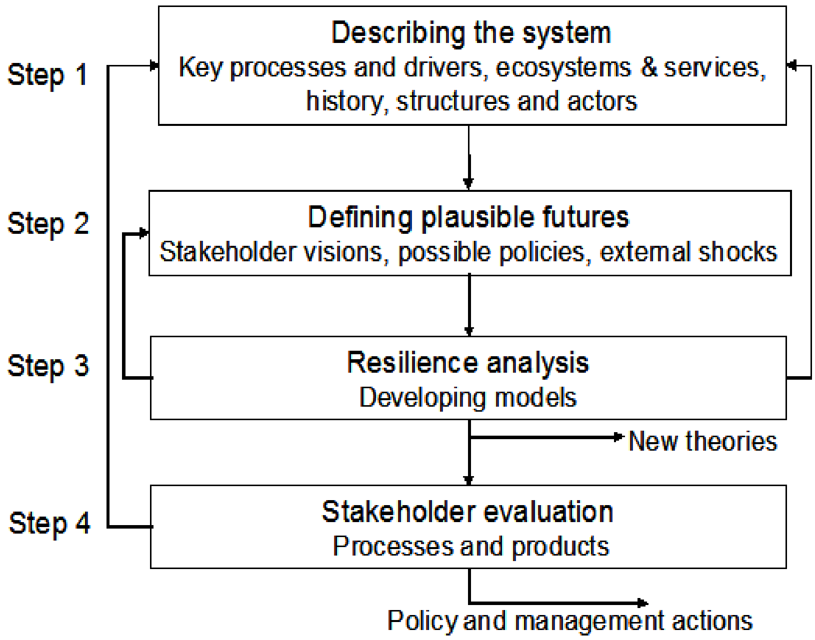
Figure 5. Vegetation degradation map of the Little Karoo (Thompson *et al*. 2005) showing the areas that are classified as pristine (still structurally and functionally intact), moderately degraded (potentially restorable) and severely degraded. Most of the pristine areas are located in the mountain areas where the soils are non-arable. Cultivated lands are located mainly on the alluvial deposits along river valleys and in the foothills of the mountain ranges that form the southern boundary of the Little Karoo.

RESEARCH APPROACH ADOPTED

A resilience framework

Despite the emergence of the concept of ecological resilience in the 1970s (Holling, 1974), and its extension to social-ecological resilience in the mid 1990s, only a few frameworks have been developed for the specific purpose of investigating and analysing the resilience of social-ecological systems. Walker *et al.* (2002) present a coherent framework for such a study (**Figure 6**) and our analysis is based largely on this framework, with particular emphasis on its steps 1-3. The guidelines given in the book *Assessing resilience in* *social-ecological systems* (Resilience Alliance, 2007) were also used in guiding this study.

The first step of SES resilience analysis, indicated in **Figure 6**, requires a detailed understanding to be developed of the SES - its historical background and development, the key processes that drive and impact on the system, the ecosystem services that sustain human needs, and an understanding of its social structure and who the stakeholders are. This understanding should be developed in tandem with stakeholders who are involved from the inception of the analysis. The second step requires the drivers and pressures, and their impacts on the system, to be established as well as the perceptions of stakeholders regarding the dynamics of change within the SES – i.e. the state into which it appears to be advancing. Drivers could include external physical shocks, such as drought or flood, or anthropogenic influences, such as policy decisions. The third step entails an analysis of SES resilience, which firstly, requires the knowledge of the SES to be organised into a model that describes the system’s composition and the relationships/processes that link the system components. The model should also reflect the relative strength of the systems’ components and drivers, their contribution to the state of the system, and their ability to influence its trajectory. Models will be context-specific, ranging from simple conceptual models to detailed mathematical models. The final step of the analytical process requires stakeholders to assess the usefulness of the process and its information outputs in developing the policy and management actions that can direct the SES along a preferred trajectory. Although this last step is an important component, it was not feasible to include this step in our short-term non-reflexive analysis; however, we regard the publication of this chapter as partially fulfilling this communication requirement.



Data collection and sampling procedure

Figure 6. A framework for the analysis of social-ecological resilience. Adapted from Walker *et al*. (2002).

Adopting Walker *et al.*'s (2002) framework required developing a detailed understanding of the SES of the Little Karoo over a range of geographic and temporal scales (Step 1). The multifaceted nature of an SES requires access to a diversity of data sources and collection methods. These included: reviewing literature on the Little Karoo area; homing in on literature and studies related to land-use and its social and economic consequences; interviewing stakeholders; and, analysing both climatic and agricultural databases. These databases included rainfall records for the large towns for the last 100 years, district level livestock census data for the period 1886-2003, and district level crop data (wheat, oats, barley, rye and lucerne). For three of the districts (Oudtshoorn, Ladismith, and Uniondale), the crop data covered the period 1911-1998, and for one district (Calitzdorp), 1948-1988.

Using this data we constructed a general social-ecological history of the Little Karoo. In our detailed analysis of the Vanwyksdorp SES, a smaller system nested within the Little Karoo SES, we interviewed residents to capture social and ecological data from the last 100 years as seen through their eyes. We interviewed 16 residents using a semi-structured interview technique (Patton, 1990; Pretty, 1995), which uses open-ended questions and a loose framework to simultaneously allow the interview to be directed whilst providing opportunities to explore issues that emerge during each interview. The interviews solicited information on land-use trends for specific time periods in the past, and captured local perceptions of the current and possible future state of the SES – i.e. meeting the requirements of step 2 of the resilience analysis framework (**Figure 6**). The interviews provided an understanding of the ecosystem services used by farmers, as well as perceptions surrounding the use and supply of these services, and disturbances to the SES - also a requirement of step 2 of the analytical framework. In addition to these interviews we contrasted historic photographs of the Vanwyksdorp area with current landscape conditions to obtain visual evidence of changes over the last 70 years. We compared sets of images taken at eight fixed points between 1917 and 1959, with a series of repeat photographs taken at the same sites in 1993 and 2006.

For step 3 of the resilience analysis, we developed a conceptual cause-and-effect model, which defines and highlights the key components and interrelationships between the identified drivers and their controlling variables, and current and future basins of attraction for the system. In analysing system resilience we focus specifically on the variables we have described earlier: latitude, precariousness, resistance, connectedness and potential.

RESEARCH FINDINGS

<u>Resilience analysis - Step 1: Describing the system</u>

The Little Karoo social-ecological system

Pre-colonial period

Our knowledge of the Little Karoo SES dates back 10 000 years before present. Klein (1984) describes a relatively rapid decline in large mammal diversity over the last 10 000 years, attributing this to both ecological change and human impact by the Khoi San hunter-gatherers and Khoikhoi pastoralists who were the earliest human inhabitants of the Little Karoo. The Khoikhoi were known to use this region on a transhumance basis, moving with their livestock both annually and seasonally as pasturage was available. Archaeological excavations have encountered calcined sheep dung dating back to 1700 BP, and large numbers of sheep bones in the Boomplaas cave, just north of Oudtshoorn, indicating that the area was intensively grazed (Deacon *et al.,* 1978).

Colonial period: 1652-1910

The first European colonists entered the Little Karoo in 1689 when an expedition passed through to trade goods for livestock with the Khoikhoi (Burman, 1981). They were followed by European hunters and migratory livestock farmers. The first farms were permanently settled in the Montagu area in 1725 and by 1767 permanent farms had been established throughout the Little Karoo. The farmers kept sheep and cattle and grew a range of subsistence crops (Shearing and Van Heerden, 1994; Beinart, 2003). The key ecosystem services they relied on included forage production by the drought-adapted rangelands, protein from nomadic fauna that moved with the unpredictable rains, and perennial water supply (Dean and Roche, 2007). Many of the early farmers adopted, or attempted to mimic, the transhumance grazing strategies of the Khoikhoi. They also engaged in hunting and traded with the Khoikhoi before these communities were displaced to the north as a result of the farm settlement (see Funke *et al*., Chapter 10, this volume, who describe the demise of the Khoisan under similar forcing conditions). The main focus of these colonial nomads was on increasing their livestock numbers. These included the original domesticated sheep of the Khoikhoi, the Cape fat-tailed sheep, which were estimated to have increased by 1806 to around 1.5 million in the broader Cape colony. These sheep were later replaced with wool bearing merinos, of which numbers had risen to more than 5 million by 1855 (Beinart, 2003). By the late 1700s the Khoikhoi remaining in the Little Karoo had been largely assimilated as farm workers (Penn, 1986 cited by Smith, 1999), the exceptions being the communities at Zoar and

Dysselsdorp, where mission stations, established respectively in 1817 and 1838, provided sanctuary for these people (Burman, 1981).

Until the takeover of South Africa by the British government, the Dutch East India Company attempted to control all trade to ensure that it had first right to farmers’ produce at favourable prices. The company gradually provided farmers with greater security of tenure over their land by changing the rental system in an attempt to limit their movement and keep them within the official frontiers of the colony (Whiting Spilhaus, 1966). When the British took control of the Cape in 1806 free trade in agricultural produce was permitted in order to stimulate the economy, marking an economic shift from direct company purchase of farmers’ products to government taxation on trade in goods.

The construction of the first road passes into the region, between 1740 and1810, facilitated trade in goods to other parts of South Africa. The completion of several more passes between 1847 and 1888 (Ross, 2002) opened-up markets for non-perishable goods such as wool, tobacco and dried fruit both within South Africa and internationally (Burman, 1981). The tobacco growing industry developed rapidly after 1845, especially in the Grobbelaars River valley near Oudtshoorn, as did the wool industry (Beinart, 2003). The towns of Oudtshoorn, Montagu, Ladismith, Uniondale and Calitzdorp were established between 1845 and 1859, introducing a second tier economy with merchants, transport companies and shop owners. This increased the local markets for goods as well and also improved access to external markets.

The discovery of the Kimberly diamond fields in 1870 drew many immigrants to the interior, driving up mutton prices over the next few years (Archer, 2000) and encouraging farmers to increase their flocks as well as crop production. Further economic stimulation was provided by the discovery of the Witwatersrand gold reefs in 1886, starting a phase of national economic growth that continued until the late 1890s (Beinart, 2003).

Union and apartheid era: 1910 to 1994

After the formation of the Union, and in the aftermath of the hardships of the First World War, the Union government was particularly keen to establish South Africa as an independent and self-sufficient country. The expansion and diversification of the agricultural industry was seen as critical to this end. The formation of the Land and Agricultural Bank of South Africa in 1910 provided for low interest loans and, together with the Agricultural Credit Board, provided loan finance to farmers who did not have access to the commercial banking sector. The Land Acts (1913, 1936) heralded an era during which the interests of white farmers were promoted and access to land was racially segregated. This did not have a major impact on the Little Karoo; however, these and other measures such as the Marketing Act (1937) forced many subsistence farmers off their land (Kassier Report, 1992; Vink and Kirsten, 2000). These people were forced into becoming migrant labourers, settling wherever jobs could be found and expanding the populations of the towns in the Little Karoo.

By the 1920s the growing market for cereals (especially wheat) and dried fruit had encouraged farmers to build dams and develop irrigation schemes near Calitzdorp, Barrydale, Ladismith and Oudtshoorn. The construction of railway links, beginning in 1904 when Oudtshoorn was first linked to Port Elizabeth and the interior, and then to George and Mossel Bay harbour in 1913 (Ross, 2002), opened up markets for fresh goods. Similar developments benefited the western region of the Little Karoo when the railway linking Ladismith and Touws River was commissioned in 1931.

Following the collapse of the ostrich industry in 1914, the Little Karoo farmers saw the value in farming as an organised and unified body. The Kango Tobacco co-operative was, therefore, formed in 1926 (the first in South Africa) to promote the interests of wine and fruit farmers. In 1945 the mandate of this body was extended to include control over the ostrich industry, eventually converting it into a monopoly in 1960 that tightly controlled the volume of ostrich products sold both locally and internationally. The Ladismith co-operative was formed 1939 to market fruit, wine, dairy products and wheat, leading to the development of the Towerkop dairy processing factory, which now forms part of the Italian/multi-national, Parmalat. In 1940 the Langeberg co-operative was formed which, in addition to dealing with table grapes and wine, established a canned fruit and vegetables factory in Ashton (near Montagu), which marketed its products locally and internationally under the Koo label. In the late 1950s some farmers began producing vegetable seed, notably onions, for export to the USA and Europe. This market has grown steadily, with farmers being able attain high yields from small areas under irrigation, whilst keeping fields isolated to prevent diseases. This development helped to compensate for the steady decline in the demand for tobacco, notable especially in the 1990s (Elsenburg, 1999). Lucerne production increased in all the districts except Calitzdorp over the period 1910 to 1994 (**Figure 7**). Oudtshoorn is the district showing the highest production of lucerne, which peaked in 1981 with 14 793 ha under cultivation. The 1973 global oil price shocks, and knock-on inflationary effects, had a marked impact on agricultural production in the Little Karoo due to high fuel-related and fertilizer input costs.

The 1980s and 1990s introduced a new era in agriculture in South Africa with a shift in government policies away from protective import tariffs, subsidised finance for agriculture and government controlled markets and prices (Vink and Kirsten, 2000; Kirsten and Vink, 2003). These developments affected the entire country and resulted in a reduction in the area under dryland grain crops. In the Little Karoo, there was a significant decrease in wheat production, and to a lesser extent other cereals (**Figure 7**). The area was particularly badly affected by high transport costs, marginal rainfall, and high inter-annual variation in rainfall, which created conditions of high risk of uneconomically low yields or crop failure. In the livestock ranching industry many farmers reintroduced game animals, particularly springbok, in response to good venison prices. Although the venison prices have subsequently declined, many farmers have maintained stocks of game species because they browse and utilise the vegetation differently to domestic livestock and are also hardier.

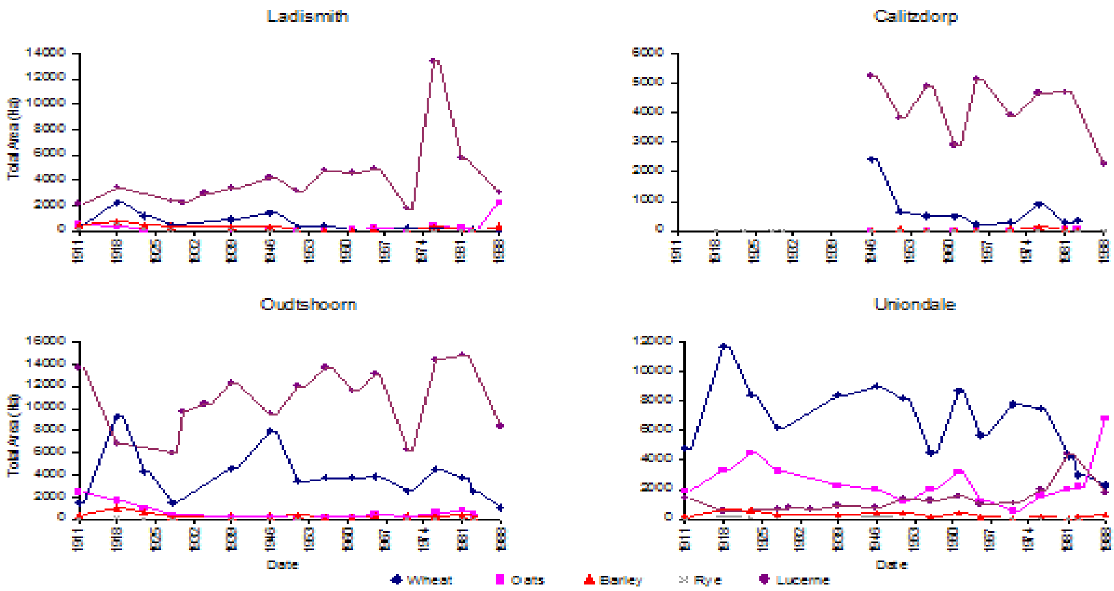


Figure 7. Total area (ha) of land used for the production of wheat, oats, barley, rye and lucerne in the magisterial districts of Ladismith, Calitzdorp, Oudtshoorn, and Uniondale, for the period 1911-1988.

Democracy: 1994 to date

The election of a new government in 1994 resulted in a major shift in agriculture in South Africa. A high priority was given to redressing the inequalities of the past and launching programmes of policy reform, land redistribution and support for previously disadvantaged non-white groups. The political parties previously in power, supported by the large scale commercial farmers, have become minority parties, and their ability to influence political developments has been substantially reduced. This reduced influence on policy, combined with the land reform process, has had a major impact on agriculture at the national scale, but less of an impact on the Little Karoo - partly because there are few land claims in the area. Substantial investments have been made in the communities at Zoar and Dysselsdorp and the latter, for example, has succeeded in developing a small company that produces liquorice extracts and other products. The biggest impact on the Little Karoo has been the free-market approach to agriculture, which was introduced by the 1996 Marketing of Agricultural Products Act (Vink and Kirsten, 2000). Despite the disappearance of sectoral policy protection, the vegetable seed, fruit and wine industries were able to remain stable or grow over the last 15 years. A regional shift away from cereal crops towards these products is evident (Vink and Tregurtha, 2005). This period has also been marked by an increase in house prices in select country towns as wealthy city dwellers buy country homes for weekend and holiday use. A number of new residents have settled in the Little Karoo, purchasing farms and redeveloping these as game reserves either for their own use or as luxury attractions for tourists. In many cases, they have introduced animal species that either did not occur in the area or were only present seasonally.

There are no studies of the historical development of tourism in the Little Karoo; however, the hot springs at Montagu, Warmwaterberg and Calitzdorp have attracted travellers and visitors since the early 1700s (Burman, 1981). By the late 1800s there were many visitors to the Montagu springs, and the Cango caves also began to gain visitor popularity. In 1921 the Oudtshoorn municipality took over the management of visitor access to the Cango caves and has since maintained control over this major tourism attraction. Highgate was the first ostrich farm to open its gates to tourists in 1930 and has remained a major attraction for visitors. Several other ostrich farms have followed suit.

A new tourism market has been developing since the 1990s. This is of self-guided visitors who have their own transport and stay in guest facilities on farms and in the smaller towns. The primary attractions for this group are the relatively untransformed landscapes, the very low density of people, and the resultant tranquillity of the area. The annual Klein Karoo Nasionale Kunstefees (locally known as the KKNK and translated as the Little Karoo National Arts Festival), which was launched in 1995, has been growing rapidly. In 2004 an estimated 120 000 tourists attended this event over about a week and their total expenditure in Oudtshoorn was estimated to be R89 million (Oudtshoorn, 2005). The expansion of “do it yourself” tourism is an excellent example of the way in which the internet opens up new marketing channels, removing some of the barriers of distance and remoteness. Visitors from Europe can now browse the internet and set up their own tours based on easily accessible information and their personal choices. This type of tourism is expected to expand rapidly in future, provided visitors are confident that risks to personal safety are acceptable and tourist densities are low enough to meet their preference for undeveloped and sparsely inhabited environments. These visitors’ inclination for farm accommodation provides farmers with a way of diversifying their income base and also increases employment opportunities on farms.

Ostrich industry

In many ways the history of the ostrich industry reflects that of the whole of the Little Karoo. The potential of the Little Karoo for ostrich farming for feathers was realised in the early 1800s when international demand for this product manifested (**Table 1**). By 1850 the system of maintaining breeding birds at low densities in large paddocks, and rearing feather and slaughter birds at high densities in small paddocks, had been developed. The key innovations that allowed the industry to grow rapidly were the development of an egg incubator in 1869 and the introduction of irrigated lucerne for fodder in the early 1870s (**Table 1**). The industry expanded rapidly, becoming the dominant farming activity throughout the Little Karoo. Many farmers switched from other crops, such as tobacco, to lucerne and from other livestock to ostrich during this time – although high wool prices in the late 1800s encouraged farmers to stock merino sheep as well. The narrow focus on ostriches increased the vulnerability of farmers to fluctuations in the prices for ostrich products. Importantly, the emphasis on ostrich feather production intensified the degradation effects on rangelands as stocking rates increased, and grew in tandem with lucerne production.

The ostrich industry flourished in the late 1800s, with total feather exports growing from about 915 kg in 1852 to 120 500 kg in 1882 (**Table 1**) (Burman, 1981). During much of this period the Cape Colony experienced a severe economic depression (Beinart, 2003) and the Little Karoo was, therefore, seen as a good place to establish farms and businesses. The feathers were very valuable exports, reaching their first production peak in about 1882 before experiencing a decline as the prices declined. During the early 1900s the ostrich feather industry boomed once more until 1913, only to collapse again when women's fashions began changing and when anti-plume campaigns were mounted during the period immediately before the start of the First World War. The revival of the industry did not occur for several decades, probably because the farmers themselves, or their parents, remembered the hardships caused by the 1913-14 crash and were wary of the risks involved.

The industry has slowly redeveloped itself since the formation of a co-operative in 1945. The focus of production is now on ostrich leather and meat, rather than on feathers, although small quantities of top quality feathers are still in demand (Burman, 1981). The monopoly over local production and markets was phased out in 1993 as the government shifted towards market-orientated agricultural policies (**Table 1**). There is also growing competition from ostrich producers in a number of other countries (van Zyl, 1996). There have been a number of setbacks to production, with Newcastle disease becoming a problem in the 1990s (**Table 1**) and drastic stock losses following an outbreak of bird flu in 2004/5. The number of birds peaked at about 300 000 in 1996, before declining in response to an over supply linked to the deregulation of the industry. Despite its decline since 1996, the ostrich industry in the Little Karoo remains economically important and accounted for approximately R157.5 million in 2001. Secondary industries associated with ostrich products are expected to generate about the same value again. The growth of the industry has resulted in a general shift in the agricultural profile of the region, with traditional crop and livestock production giving way to the production of ostriches and their main feed, lucerne (**Figures 7** and **9**). The Oudtshoorn district illustrates this trend most strongly.

Table 1. Key events and phases in the ostrich industry. Information taken from Burman (1981) and Klein Karoo (2006) unless otherwise indicated.

Date	**Event**
1821	The 1st record of ostrich feather exports, about 1230 kg
1850	An ostrich breeding system is developed with large paddocks and very low densities of breeding birds; slow growth of the industry during the following two decades
1869	An ostrich egg incubator is developed allowing the farmers to remove eggs from laying females nests, inducing them to lay more eggs
1870	Start of the first boom with ostrich feather exports of 14 250 kg
1882	Ostrich feather exports 120 500 kg, the peak before a decline due to the average price collapsing: from R18/kg[#] in 1882 to R10/kg in 1885
1885	A low point in the industry, exacerbated by flood damage in Oudtshoorn
1903	Post Boer War Ostrich boom starts and continues though to WW1 (1914); some date the start of the 2nd boom as 1905
1913	Ostrich numbers reach 776 313; £3 million is earned with 464 000 kg of feathers
1914	Ostrich industry crashes after peaking in 1913. All the areas of the Little Karoo are drastically affected and many farmers and townspeople lose fortunes overnight
1926	Kango Agricultural co-operative launched, mainly for cultivated crops
1945	Klein Karoo Agricultural co-operative is registered to negotiate, procure and sell on behalf of ostrich producers, a position which was strengthened in 1960 (Beinart 2003)
1993	Newcastle disease outbreak, continues sporadically through the 1990s (Alexander 2000). Industry deregulated to open markets.
2004-2005	16 month European Union ban on imports and restricted sales elsewhere because of the H5N2 bird flu virus; massive losses to the 1200 members, job losses ± 20%; local sales about R20 million 2004/5.
2006	The KLEIN KAROO Group made a profit of R15 million, gross income from the local market R100 million in 2005/6

#: These values are as given in Burman (1981) and probably a direct conversion from the £ value at R2 per £.

Land degradation and interventions

During the gradual build-up of livestock numbers in the 19th century, the authorities began to realise the degrading effects that increased stocking rates were having on rangelands. By the late 1870s there was serious concern in this regard. The authorities attributed much of the degradation to the practice of nomadic transhumance and encouraged more intensive sedentary farming. However, as the population of settlers grew, so did the number of herded livestock, increasing the extent and rate of degradation and intensifying the pressure for land. The authorities responded in 1878 by changing the land rights system to private ownership, with full title to the land and agricultural rights (Talbot, 1961). Thus, a form of social engineering was achieved through the privatisation of the rangelands. This reduced transhumance, with indigenous communities forced to become farm workers; also, many settlers were forced to choose non-farming occupations (Beinart, 2003).

Throughout this period, the economic development of the livestock industry was largely *ad-hoc*, driven by demand and supply. Growing markets for meat and wool significantly increased livestock numbers. Carrying capacities tended to be based on periods of high rainfall (Beinart, 2003). The farmers perceived drought as unusual and did not stockpile fodder to sustain production during periods of drought. The inclination was thus to maintain high populations of livestock on the land in the hope of rain – this, in spite of an emerging view, particularly held by farmers, that droughts were increasing in frequency and that the timing of rainfall was changing, causing rangeland degradation (Brown, 1875 cited in Beinart, 2003). Persistent overstocking resulted in impoverished plant cover, reducing both primary and secondary production. Ostriches have a significant impact on rangeland vegetation because they pull out plants rather than bite off foliage. In addition, trampling and territorial displays lead to soil compaction, the removal of the biological soil crust and the formation of pathways which channel surface water causing erosion (Cupido, 2005). The widespread introduction of wind pumps in the late 1800s (Alexander, 2000; Vegter, 2000) meant that farmers could expand the number of stock watering points, thereby increasing stocking rates. This simultaneously increased their vulnerability to droughts because groundwater abstraction exceeded recharge, with the result that the water table dropped below viable pumping depths – with little opportunity for intervention.

The proclamation of the Fencing Act in 1912, which required farmers to fence their land, brought about a shift towards a more technologically dependant production system. An amendment to this act in 1922 required farmers to make their fences vermin-proof (Dean *et al.,* 1995). The introduction of fencing created more intensive, localised degraded patches of rangeland, typically around watering points for stock (Dean *et al.,* 1995). Natural systems were, therefore, severely affected by formalised ownership, fencing and boreholes - all of which were intended to maximise yields and productivity. These efforts at maximising yields confounded farmers' ability either to respond quickly to sporadic periods of abundance or to adapt to droughts. Droughts in the past typically displaced native herbivores thereby buffering the effects of the droughts on rangelands. A consequence of this was the reduction in rangeland resilience.

A select committee on droughts, rainfall and soil erosion was formed in 1914 to draw together information on these issues (Senate S.C.2, 1914). However, it was not until the 1920s, following eight years of drought and economic decline, that formal action was taken with the establishment of the Drought Investigation Commission to report on rangeland degradation issues (UG 49-23, 1923). The commission widely reported the need for a change in livestock management practices and the appropriate use of natural resources in order to guarantee agricultural production. It also commented on the lack of evidence with regards to claims of decreases in rainfall – closely connected to carrying capacity. Actions that decrease the long-term carrying capacity, such as short-term overstocking, had been overlooked, and the resultant decreased yields were incorrectly perceived as being related to change in rainfall patterns, specifically a decrease in rainfall (**Figure 8**). Rainfall records for the study districts, although incomplete, do give some indication of variation in rainfall, and low and high rainfall years for each of the districts. Currently, the data do not show a clear downward trend in annual rainfall for the study area.

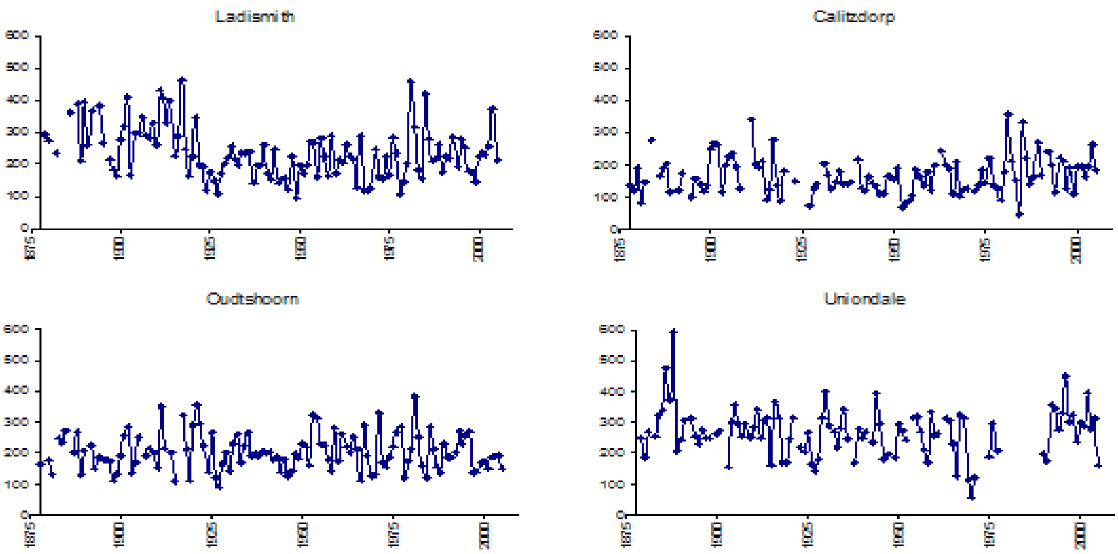


Figure 8. Mean annual rainfall (mm) plotted for all districts for the period 1878-2005.

By the 1930s the government was determined to act against rangeland degradation, attempting to guarantee agricultural production by protecting and enhancing natural resources, in particular, rangeland. However, policies that emerged at the time were often in conflict, illustrated by the fact that although a dominant view was one aimed at decreasing stocking rates, there were a number of veterinarian measures aimed at increasing livestock numbers. The growing agricultural debt and the economic depression in the late 1920s and 1930s drove livestock numbers up to levels that were twice as high as those during the period 1900-1910 (**Figure 9**). The increase was partially because animals were often left untended on the land as farming communities moved to towns and cities - as there was no market for livestock and, therefore, no economic incentive for selling off stock. Following the severe drought of 1933 and evidence of soil loss associated with extensive gulley erosion, an advisory council was established to provide subsidies to farmers to build dams and implement anti-erosion projects, such as fencing off degraded areas and soil stabilization, and improve plant growth (Beinart, 2003).

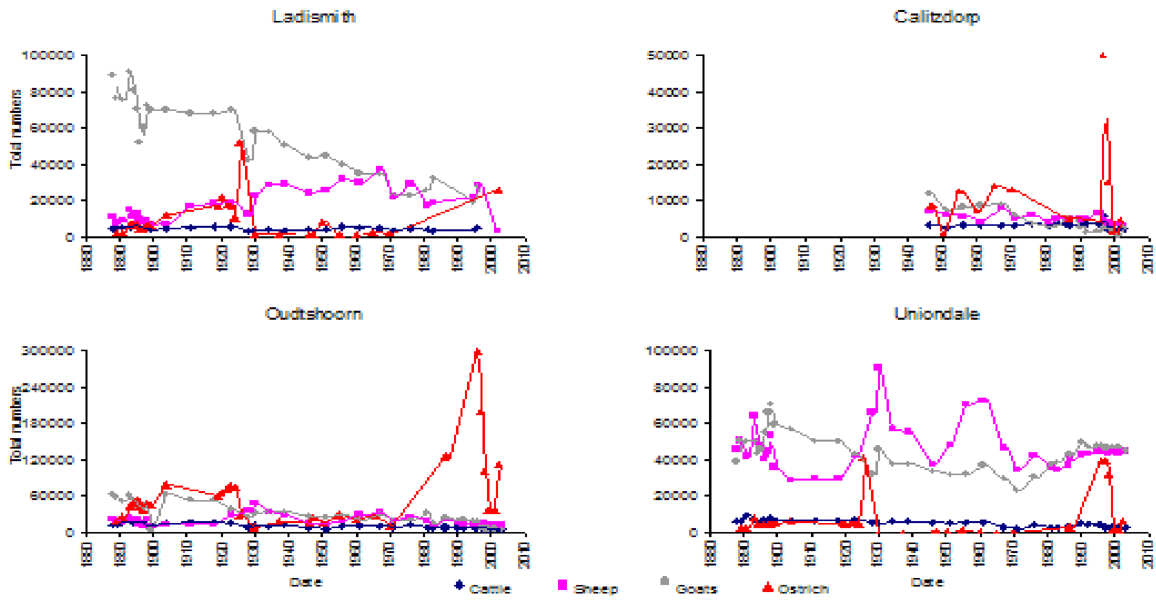


Figure 9. Total numbers of cattle, sheep, goats and ostriches in the magisterial districts of Ladismith, Calitzdorp, Oudtshoorn, and Uniondale, for the period 1888-2003.

The 1946 Soil Conservation Act (act. No. 45 of 1946) established a division of the Department of Agriculture that focussed on soil conservation and the provision of extension services to farmers (Donaldson, 2002; Beinart, 2003). Extension officers were tasked with promoting behavioural change amongst farmers by establishing soil conservation committees that regulated community behaviour and increased community ownership and responsibility for this issue. By the 1970s, 819 soil conservation districts had been proclaimed in South Africa, and by 1980, 262 conservation committees, with more than 1000 trained members, had been established (Beinart, 2003). Soil conservation committees were found to work most effectively where there was an enthusiastic uptake by local farmers (Beinart, 2003). The Soil Conservation Act was revised in 1969 and led to the establishment of the voluntary Stock Reduction Scheme, which remained in effect from 1969-1978. Farmers in targeted areas were paid to reduce their stocking levels by one third of the Department of Agriculture’s recommended carrying capacity, thereby resting a third of their land. Over 7000 farmers across the country participated in this scheme, and 15 million animals were effectively removed from 20.3 million ha of privately owned farmland. Stocking rates declined, on average across all districts in the Cape, from approximately 7.5 LSU/km^2 in the late 1800s to about 4.5 LSU/km^2 in the late 1900s (Dean and Macdonald, 1994). Similar trends can be seen in the four districts of the Little Karoo, particularly for goats (**Figure 9**). Ostriches were the exception, with all districts showing an increase in total numbers over the period, particularly Oudtshoorn.

It is believed that the Department of Agriculture’s approach in developing wide-ranging legislation, monitoring its effectiveness, and revision based on monitoring results - in conjunction with extension, outreach and financial support - successfully contributed to improved rangeland condition and ecological resilience since the 1960s (Beinart, 2003). This partly counteracted the effects on arid rangelands of heavy stocking rates applied by the early settlers, which are still evident in the state of the present vegetation of the region (Dean and Roche, 2007). Recent studies indicate localised recovery of the rangelands, with no further degradation (Dean and Roche, 2007), although the magisterial districts of Oudtshoorn and Calitzdorp are identified by Hoffman and Ashwell (1996) as the most degraded areas in the Western Cape. Recovery is a slow process requiring prolonged resting from grazing, and often active intervention. This incurs short-term opportunity costs for farmers and is economically unattractive when there are pressures for short-term profit. This is compounded by the fact that interventions such as the deliberate reseeding of vegetation to facilitate restoration have a high likelihood of failure because of unpredictable droughts (Wiegand *et al.,* 1995).

The Vanwyksdorp social-ecological system

Pre-1900s settlement

Settlers moved into the area south-west of Ladismith in the early 1800s. Most of the remaining old farming families in Vanwyksdorp can trace their family's links to this area to the mid 1800s when individual farms' quit-rent agreements and later title deeds were granted by the government. There were few social services before the turn of the 20th century and markets were remote. People had a very simple subsistence lifestyle, producing very little additional goods for external markets (**Figure 10**). There was a strong dependence on game animals such as kudu as a source of protein and farmed livestock included predominantly boer goats, which were hardy and able to utilise the entire landscape. Vegetables and tobacco were grown in the valley bottoms and along river courses where water was easily accessible, although small dams were constructed on farms to provide water for stock and vegetable irrigation. Farmers often lived near the rivers during the dry summer months, moving to more temporary housing away from the river in the wet winter months in an attempt to spread the impact of grazing more evenly across their farms. Farmhouses were very basic only with one or two small rooms and dry stone walls. Labour was predominantly found within large families.

The establishment of the ostrich industry in the late 1800s resulted in the creation of the first commercial local market for feathers produced at Vanwyksdorp (**Figure 10**). Ostriches did not require a large area, which was important because farms had been subdivided within families - in effect, shrinking the size of individual farming areas. Lucerne was grown at Vanwyksdorp predominantly for ostrich feed, following the trend elsewhere in the Little Karoo (**Figure 7**).

Establishment of a farming village: 1900-1920

By the turn of the century, the population of the Vanwyksdorp area had grown substantially, as evidenced by the construction of a large church and the establishment of a school and boarding house on the farm Buffelsdrift in 1904 (**Figure 10**). A large population also lived in the countryside surrounding the village, with schooling demand met by at least seven farm schools. This created and formalised the settler community in the area. During this period goats were still the dominant livestock species, but cattle and sheep were also introduced for local consumption. Cream was sent away to the Cape to be processed into first butter and later milk and cream for cheese production. There were also a large number of draught animals, mostly donkeys and oxen, many of which grazed on communally owned lands. Extensive areas were ploughed for dryland farming of grains, especially wheat and barley. Farmers near the village also produced a variety of fruits including peaches, figs and walnuts, which could all be processed locally and transported in dried form. Pears and grapes were important crops, with a portion of the grape harvest used for wine production and alcohol distillation.

Irrigation furrows were established in the early 1900s, with flood irrigation developed for lucerne, fruit trees and vines. The system was fed from two permanent springs originating on the south-facing slopes of the Rooiberg mountain. These springs were fed by groundwater recharge into the sandstone that forms the bulk of this mountain range and were very reliable, providing assured irrigation in an area with unreliable rainfall. An extensive network of irrigation canals was also built along the Groot and Buffels rivers.

People living in the Vanwyksdorp area around the turn of the century had a variety of sources of income in addition to farming, for example, associated with teaching, milling and butcheries. Family labour was supplemented by the employment of workers who were either descended from the original indigenous people, the Khoikhoi, or settlers who did not have title to their own farms. The Boer War, which extended in a number of stages from 1897 to 1902, did not have a major impact on this area.

The First World War and Great Depression: 1920-1940

With the collapse of the ostrich feather industry, just before the start of the First World War (**Figure 10**), the Vanwyksdorp farmers lost a major component of their disposable income. Ostrich feather prices crashed and many birds were simply released into the wild to avoid maintenance costs. However, the war created a demand for the dried fruit and nuts produced in the area, which helped offset this loss of income. Commercial tapping of aloes also began during this period, whilst cream continued to be sent to the Cape for butter production.

The global economic depression of 1930-1933 had a major impact on the area – an effect that was intensified by a general drought throughout South Africa at this time, and exacerbated by the impacts of a severe local drought in the mid-1920s. There was no market for livestock and numbers, therefore, increased at a time when carrying capacity was decreasing. Today, many farmers identify this period as the time when the greatest degradation of rangeland occurred. At the time, men left their farms to find alternative income, often leaving women to manage the farms. Many people worked on government public works programmes linked to infrastructure development. Dams, irrigation canals and railway cuttings were built in the area as part of this programme. Following the depression, the area experienced its first episode of depopulation with many people who had found work in towns and cities selling their farms and moving away permanently.

Establishment of commercial agriculture: 1940 – 1960

From the 1940s rural depopulation became widespread. One consequence of this was the consolidation of many farms. Subsidies were provided in the 1950s for erecting internal fences, eliminating the need for corralling (kraaling) animals and thereby reducing the effects of trampling as animals were moved backwards and forwards from corrals. This also decreased labour requirements as shepherds were no longer necessary. Livestock production was mainly focused on small stock, with equal numbers of dorper sheep and boer goats, both of which were raised for meat production.

Motor vehicle transport replaced draught animals, and public transport in the form of railway buses, which transported people and goods, was established. Farm produce, including apricots, figs, potatoes, wool and mohair, were collected from central depots, enabling small-scale farmers to get their produce to distant markets. The widespread formalization and control of agriculture, with the establishment of co-operatives to which all produce had to be delivered materialised in this period. Minimum production volumes and quotas were set for certain crops, particularly dryland cereals. Fruit production was encouraged at this time, both as dried fruit and fresh fruit for canning (**Figure 10**). Several canning factories were established in nearby towns. Fruit production also provided a diversity of job opportunities as it required picking, pruning, sorting, grading and packing.

As was the case elsewhere in the Little Karoo, large areas of land were ploughed to produce commercial dry land wheat at this time because the subsidies, protective import tariffs, and fixed market prices made this highly profitable. The establishment of the Towerkop dairy in Ladismith (**Figure 10**) provided farmers with an important regular income **-** in contrast to the income from fruit crops, which were generated once a year. Many farmers kept dairy cattle, and a dairy tanker was sent out to these farms allowing small scale farmers to be involved in this agricultural sector. Dairy farming was labour intensive and provided employment in the area.

Widespread state controlled commercial agriculture: 1960-1980

The construction of large-scale, government-funded irrigation schemes, which took place between 1960 and 1980, also affected Vanwyksdorp. The Floriskraal dam was completed in 1967 and provided a relatively reliable source of water for some of the Vanwyksdorp farmers who fell within the boundaries of the scheme. Farmers within the scheme focussed on large scale lucerne production, both for seed and fodder. The farmers who were outside the scheme had a less reliable source of water after the development of the irrigation infrastructure because of decreased downstream river flow (see Le Maitre and O'Farrell, Chapter 11, this volume). Many farmers bought their own tractors during this period, facilitating lucerne production and to a lesser degree fruit production. Many boreholes were established for farmhouses, general use and for watering of livestock. There was also widespread dryland wheat production at this time.

A number of boom periods for wool and mohair production occurred during this period, with mohair being a very important product during the early 1970s in the Vanwyksdorp area (**Figure 10**). This was a boom period for the town, assisted by high prices for apricots, and even small land holders were able to take advantage of these high prices. There were also a large number of local fruit buyers, with about five fruit depots established in Vanwyksdorp.

In response to rangeland degradation, primarily in the form of reduced vegetation cover and soil erosion, the government implemented widespread agricultural extension in the Vanwyksdorp area to assist with erosion control. This included subsidies for fencing and establishment of watering points for stock. There were also subsidies for feed during droughts and this was later followed by subsidies for stock reduction. Some people used these subsidies to relocate to towns, resulting in large areas of the region remaining ungrazed. Both the rural and urban population continued to slowly decline, leading to the closure of the high school in Vanwyksdorp in this period.

Free market commercial agriculture: 1980-2000

Further depopulation of this area occurred in the 1980s and 1990s due to pre-democracy political instability, safety concerns, economic fragility and the decrease in government support for agriculture. During a large scale flood event in this region in 1981, the Laingsburg flood (**Figure 10**), farmers lost large amounts of infrastructure and stock as well as sections of productive alluvial cropland (Kovacs, 1982). Government grants helped to clear and re-establish orchards and lucerne lands, but equipment was not replaced. As a result, many farmers used these grants to change direction away from production that had become less profitable, for example, replacing vineyards and orchards with lucerne. Other farmers sold off land and moved away, allowing neighbours to consolidate their land holdings.

The railway link between Ladismith and Touws River was also destroyed by the 1981 flood and was not re-established. This had a significant impact on the Vanwyksdorp local economy – a situation that was aggravated when the railway bus service was terminated in 1993. Those without private transport were isolated from markets and services, although this is assumed to only have had a limited impact on the commercial farming community of the area.

Electricity was provided in 1989 and generally improved quality of life in Vanwyksdorp. It was used, for example, to power water pumps leading to improvements in irrigation techniques, which increased lucerne production. As a result, many fruit tree orchards were converted to lucerne fields – a change that was spurred on by declining tinned fruit prices because of international boycotts of South African products. Dryland wheat production continued to decline and areas previously used for this purpose were utilised for livestock grazing. Angora goats remained an important component of livestock production systems until 1986 when the mohair market crashed in response to shifting fashions.

The monopoly held by the ostrich co-operative had kept the prices of ostrich products stable at the time of deregulation of the industry in 1993. Many large scale farmers in the Vanwyksdorp area shifted out of dairy production, a relatively stable industry, to take advantage of high profits in ostrich production. This affected small scale dairy producers as it became less profitable for the dairy industry to send out tankers to the area to collect milk, forcing these farmers to shift strategies as well. As might be anticipated, the influx of new ostrich producers resulted in overproduction, speculation and a severe and rapid market decline in the ostrich industry in 1997 (**Figure 10**). European Union import controls and concerns over Newcastle disease further reduced demands for ostrich products (**Table 1**).

Increased recreational land use and continuing decline in farming population: post-2000

With the transition to democracy in 1994 there was an increase in alternative sources of income for local farm labourers, such as government welfare grants; farm labour therefore became scarce. Farmers in the Vanwyksdorp area attempted to simplify their operations to reduce dependence on labour by moving away from the production of vegetable seeds, dairy and fruit, towards the production of meat. This shift was also driven by an increase in the price of meat and a decline in the price of fruit, particularly apricots. However, farming profitability generally declined because increases in product prices failed to match the inflation in input costs, particularly transport. The farmers' general strategy became one of downscaling their operations and focussing their activities on lucerne, cattle, and ostriches. Many farmers have now diversified their income streams to include tourism and off-farm activities, for example, transportation and construction activities.

The drought period of 1997-2000 created widespread difficulty for farmers in the Vanwyksdorp area, forcing many to sell their properties (**Figure 10**). A flood in 2003, which destroyed irrigation infrastructure, had the same effect with a number of farmers selling their land because they could not afford to repair or replace the damaged infrastructure. In 1996 there were 42 farmers belonging to the local Vanwyksdorp Farmers Association – a number that was reduced to six by 2007. With the decline in the active number of farmers, the virtual collapse of the farmers' association and more land either unmanaged or used for conservation, the perceived threat of stock predators has increased. Vermin control, previously regarded as a community activity with everyone patrolling fences and hunting jackal on each others' farms, is now up to the individual. The remaining farmers have had to change their farming practices, for example, using Anatolian sheep dogs to protect small stock, or shifting into cattle production. Most recently, land purchases have been for recreational purposes and game farms – a significant departure from traditional agricultural. This has had the effect of driving up land prices to three times their agricultural value, making land purchases for farming unviable.

The major events identified above are summarised and plotted as a timeline against the available rainfall records for the town of Ladismith 60 km northwest of Vanwyksdorp. Rainfall is variable, and there are no clear discernable trends linking good or bad rainfall years with positive or negative events (**Figure 10**) – largely dispelling a popular local view that the decline in agriculture is linked to a long-term trend of diminishing rainfall.

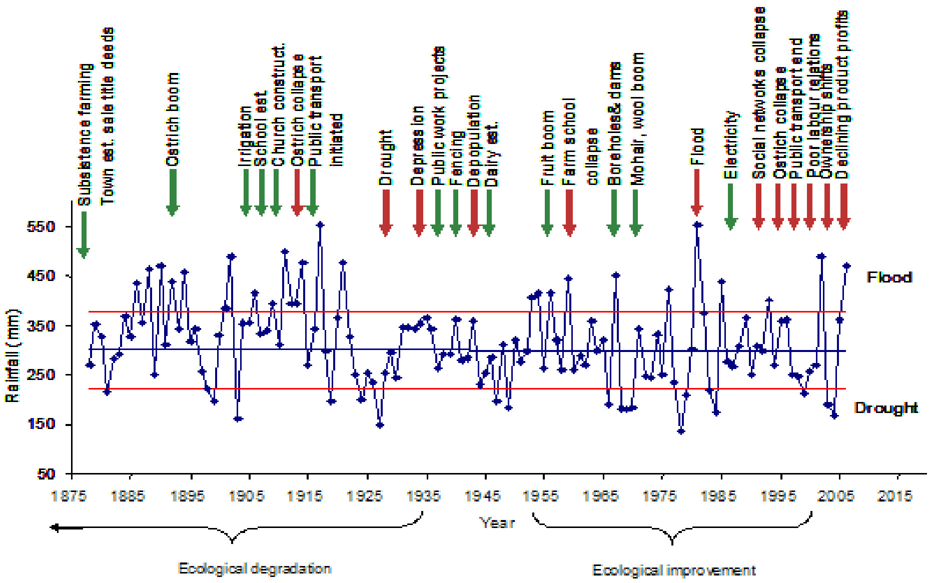


Figure 10. Major socio-economic and ecological events (green for positive, and red for negative events) for the town of Vanwyksdorp plotted against rainfall for Ladismith.

NOTE TO PUBLISHER: THIS FIGURE IS IN COLOUR. IT MAY NEED TO BE ENLARGED

Past and present status of the systems across scales

Our understanding of the SESs of the Little Karoo and Vanwyksdorp is summarised in **Figure 12**. This shows the change in system resilience over a 400 year interval as represented by commercial farming viability and the state of the Little Karoo's most expansive ecosystem service, which is the rangeland used for dryland grazing. Clearly, the Little Karoo is in a vulnerable position. Agricultural options have narrowed, to the extent that this economic sector relies heavily on ostrich farming and irrigated lucerne, which is essentially a component of the ostrich industry. The region’s water use is above the sustainable yield, and this is having a significant impact on the ecological components of the SES and, therefore, long-term agricultural potential (Le Maitre and O’Farrell*,* Chapter 11, this volume).

The repeat photography that we examined for the Vanwyksdorp area shows an increase in plant cover over the last 50 years (**Figure 11**, sequence on the left). Although it is difficult to detect a change in species composition, there are indications that ecological succession towards an historical former condition may be occurring. The sequence on the right in **Figure 11** shows that although there have been changes in the degree of erosion of this site since the first picture in 1927, the subsequent changes have been relatively limited and the state, while undesirable, may now be fairly stable.

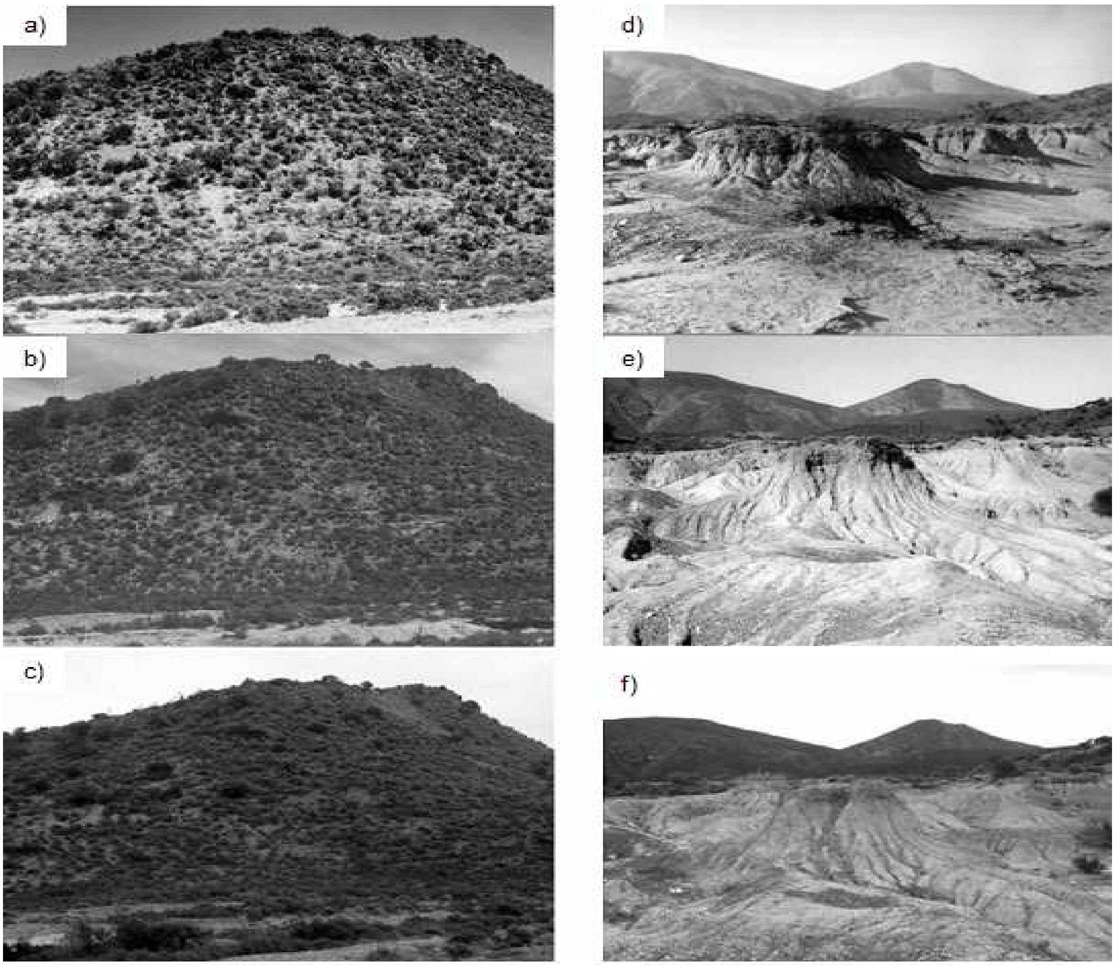


Figure 11. Two series of matched photographs for two sites just west of Vanwyksdorp taken in: a) 1959 (Acocks); b) 1993 (M.T. Hoffman); c) 2006 (P.J. O’Farrell); d) 1929 (M. Levyns); e) 1993 (M.T. Hoffman); and, f) 2006 (P.J. O’Farrell).

Whilst the ecological condition of some areas appears to have shown some signs of recovery, current potential carrying capacity is not likely to have reached pre-colonial levels. Ostrich farming continues to degrade the landscape, particularly the Succulent Karoo vegetation, although current ostrich stocking levels are lower than in previous years following industry shocks. The other mainstays of the Little Karoo agricultural economy - fruit, vegetable seed, meat, dairy products, and lucerne production - are all vulnerable to droughts, a phenomenon that is likely to manifest more strongly in the future given the climate change predictions of reduced winter rainfall for the region (Midgley *et al.,* 2005). Tourism is a rapidly developing sector in the Little Karoo, especially for "do it yourself" tourists. Accommodation and recreational opportunities on farms provide an alternative and potentially substantial income.

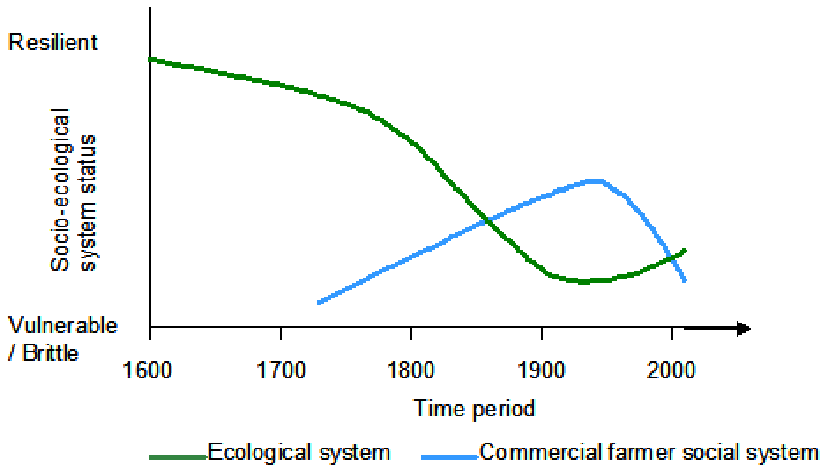


Figure 12. Past and present SES resilience as determined by commercial farming (proxy for social system elements) and rangeland state (proxy for ecological system elements) at both the regional and local scale, showing generalised trends over the period indicated.

<u>Resilience analysis - Step 2: Defining plausible futures</u>

Defining the plausible futures for the Little Karoo can be best summarised by the following four questions:

1. What are the external shocks or perturbations that the system is exposed to?
2. What are the residents' and stakeholders' perceptions and vision for the future?
3. What are plausible government policies going to be for the future?
4. What is the trajectory of the SES?

External shocks

Our investigations of the Little Karoo, and the Vanwyksdorp SESs, show that there are a at least seven major external shocks and drivers that affect them. These include: floods, periods of drought, financial shocks, product price shocks, agricultural input cost increases, social policy shifts and property price shifts.

Floods and periods of drought have been seen to impact the system, reducing production and damaging infrastructure (e.g. dams, pumps, pipelines). Flooding has a near instantaneous effect on the SESs, destroying infrastructure over a very short time, whereas drought has a slower, more prolonged effect, causing ecological degradation that affects rangeland and soil production for decades.

Water supply is a crucial issue in the future development of the Little Karoo. Rainfall variability and current demand, which exceeds the sustainable yield of the water supply schemes, will have major impacts on high water demand activities and, therefore, of the future development trajectory of the system. This issue is reviewed by Le Maitre and O’Farrell (Chapter 11, this volume).

Financial shocks have typically taken the form of interest rate increases, changing subsidies and inflationary increases in input costs. Related financial impacts manifest, for example, as property sales and property consolidation within an area and as rangeland degradation resulting from overstocking aimed at meeting increased debt obligations.

When these external shocks occur simultaneously the result has been a pattern of change in land ownership, usually under conditions where there are few alternatives for the seller. A farmer may be forced to incur debt through increased interest rates and when affected, for example, by large-scale loss of infrastructure associated with a flood, he may be unable to raise the necessary capital to restore production - and is, therefore, forced to sell his property. This marginal farming area, which regularly experiences both drought and flooding events, coupled with South Africa’s weak economic position in the international market (particularly its exposure to currency fluctuations) renders the farmers of both Vanwyksdorp and the Little Karoo, in which it is located, vulnerable to the devastating effects of a coupled external shocks.

Agricultural product price shocks affect farmers regularly. Product prices shift in response to market demand, competition and foreign exchange rates. Input cost increases affect the viability of a farming enterprise as it is often not possible to shift the total cost increase on to the consumer, with the result that profit margins shrink. The outbreak of bird flu has demonstrated the vulnerability of the area to sudden changes in demand and has exposed the narrow dependency of the region on ostrich meat and leather exports for its economic survival. Increases in global oil prices, over which farmers in the Little Karoo have no control, have had a serious impact on the economy of the region.

Social policy shifts relate to changes in both social connectivity and physical connectivity. In the Vanwyksdorp SES, social connectivity was highest when there were a large number of people living in the area and institutions such as schools and churches were established. However, as depopulation occurred, critical thresholds were exceeded, such as unaffordable teacher-to-pupil ratios, and social institutions (e.g. the Farmers Association) collapsed. This, in turn, had economic impacts and caused further cycles of depopulation. Physical connectivity represents the transport systems required to move products and people and, for example, to facilities for receiving/processing products. In the Little Karoo the establishment of transport routes and mountain passes into areas was vital for economic development. Bus services and the railway provided necessary transport to larger towns enabling the movement of products to markets. The collapse of these services particularly affected small scale producers and the poorest people who had no other access to transport. Vanwyksdorp interviewees, indicated that this resulted in a loss of social connectivity and the collapse of inter-community social bonds. Un-tarred roads were also an issue raised by farmers, preventing them from responding to market shifts from canned fruit to fresh fruit varieties because fruit would be damaged en route to depots.

Property price increases have effectively established a barrier to new farmers entering the area because profit margins are too low to make it financially viable to purchase land for traditional agricultural practices. Whilst the Little Karoo region has always had a small steady stream of tourists, this has increased over the last 10 years with the establishment and marketing of tourism routes. Many of the land purchases in the region over the last ten years have been for the purpose of creating tourist features such as private luxury game parks. This is true for the Vanwyksdorp area as well, where the bulk of recent property transfers has been for the establishment of large nature-based tourism developments. Property price increases have also been fuelled by the desire of wealthy urban residents to own country retreats, resulting in the subdivision of land and the creation of housing shortages for permanent residents in many Little Karoo towns. As a result, there are many absentee landlords linked to properties that do not bring in much revenue for local businesses as they are uninhabited for most of the year.

Exploring stakeholder perceptions

Our interviews with the Vanwyksdorp stakeholders uncovered the perception that agriculture in the area is in a state of decline. The general farming population has shrunk, and it is difficult for farmers to maintain their desired lifestyle by engaging in farming. Currently active farmers may practice this as a retirement pastime; others farm as a secondary activity having other primary business interests. The loss of a critical mass of farmers has had an adverse impact on the economic viability of the farmers who remain in the area, due to reduced access to markets (an economy of scale issue), their ability to control small stock predators, their small political voice and their low resistance to pressure from external developers. The remaining farmers have consolidated their activities, either focusing on cattle or ostriches, and lucerne. Perceived difficulties of finding the labourers needed for hard physical work for low wages, have also contributed to the consolidation process and downscaling.

A dominant stakeholder perception is that a general diversification of economic activities away from farming has taken place, with more people engaging, for example, in tourism activities. A complete shift away from current farming practices towards some other form of economic activity appears to be quite possible in the future. The same trends are evident across the Little Karoo with the agricultural sector coming under increasing pressure. How the economics and social dynamics of agriculture-sustained towns such as Oudtshoorn will respond to this pressure is uncertain. It is clear though that the one will affect the other and it may be time to revisit the urban-rural compact, re-examining the equity of flows between rural and urban areas, as defined by Gutman (2007).

Plausible policies

There are combinations of plausible future government policies that will impact on this region – in particular, those that might promote ecotourism, land-reform and, possibly, attempted agricultural revival.

The promotion of ecotourism and land reform are already actively being pursued. The national and provincial governments have been trying to promote ecotourism to South Africa, with the tourism sector of the economy experiencing more growth than any other sector. Tourism is seen as very important in promoting economic growth in the future (ASGISA, 2006). However, interactions with local government suggest that the broader benefits of tourism are not well recognised or accounted for at this administrative level. This is illustrated by the current staffing and budget available for tourist information centres, which is minimal and often relies on volunteers. Land-reform policies, which seek to address both dispossession and the racial imbalances in land-ownership due to apartheid, have been pursued since democracy in 1994 – although the challenge is to speed up implementation. Government policies on agriculture have, until recently, been characterized by an open market approach with the withdrawal of subsidies, preferential loans, and tariff protection. The Accelerated Growth Initiative of South Africa (ASGISA) notes the importance of boosting the agricultural sector, with particular emphasis on irrigated agriculture (ASGISA, 2006). Coupled with land reform, protective measures that will enhance the economic contribution of agriculture to development within the Little Karoo appear likely.

Plausible future trajectories for the Little Karoo social-ecological system

Considering the evidence from the socio-ecological narrative presented above, we speculate on three possible futures of the Little Karoo SES:

- 'Business as usual' – Resilience within the Little Karoo SES, is promoted by a range of economic activities, with small scale agricultural production pursued as a secondary activity.
- 'Ecotourism boom' – SES resilience is promoted through the dominance of ecotourism, which takes the form of private nature reserves, coupled with residential development consisting of second homes for city residents. The future of agriculture is uncertain, but it is likely to continue to decline, becoming narrowly focused on only a few products.
- 'Agricultural revival' – SES resilience is promoted through support to farmers and land policies promote productive utilisation of the Little Karoo agricultural landscapes. This is seen to apply to current commercial farms and, in particular, to recently redistributed farms. The healthy agricultural sector is able to support the "do it yourself" tourism sector and to diversify its income base.

Resilience analysis - Step 3: Social ecological resilience analysis

Through both regional and local perspectives, this study has sought to understand and determine the socio-ecological resilience of the Little Karoo SES (including an example of a smaller, nested SES) to external shocks. Determining the resilience of a social-ecological system requires an understanding, firstly, of where and how the system is placed within its basin of attraction, secondly, what the alternate basins are into which the system might be attracted, and thirdly, developing an understanding of the potential of the system to anticipate possible shifts.

Thus far, our description of the Little Karoo SES has highlighted what we perceive its main components to be, some important linking relationships, and what the characteristics are of the basin of attraction in which it is currently located. We regard this basin as typical of what we have defined in the previous section as the “business as usual” scenario. However, whilst there is evidence that the Little Karoo has existed in this general basin of attraction for the last 100 years, we argue that there have been developments over the past few decades that have created new potential basins of attraction into which the SES could shift - and that such a shift is imminent. In this regard, we speculate that plausible alternative basins of attraction for the SES include ones that align with the “ecotourism boom” and “agricultural revival” scenarios that we have just described. In the resilience analysis that follows we examine the identified variables or parameters of resilience that might determine the degree of attraction that these alternative basins might exert on the SES.

Conceptual model linking perturbations and basins of attraction

Cause-effect analysis, using Ishikawa, or Fishbone, diagrams – developed to facilitate understanding of organisational efficiencies in relation to developing products and the marketing of these products under different scenarios (Tague, 2004) - provides a useful graphical model for considering SES resilience. In **Figure 13**, the central arrow, or the backbone, can orient towards a number of basins of attraction that the system could occupy. The side arrows coming off the central arrow or spine, depict the range of primary external perturbations to the SES that we have previously described. The strength of these perturbations, and therefore the net orientation of the central arrow, is controlled by the factors attached to each. In our analysis, component strengths, adaptability (or the ability of the those people who are part of the SES, to influence each of these), and scale effects are considered as ultimately determining as to whether the system will shift from the "business as usual" state (the orientation indicated in **Figure 13**) into other possible states.

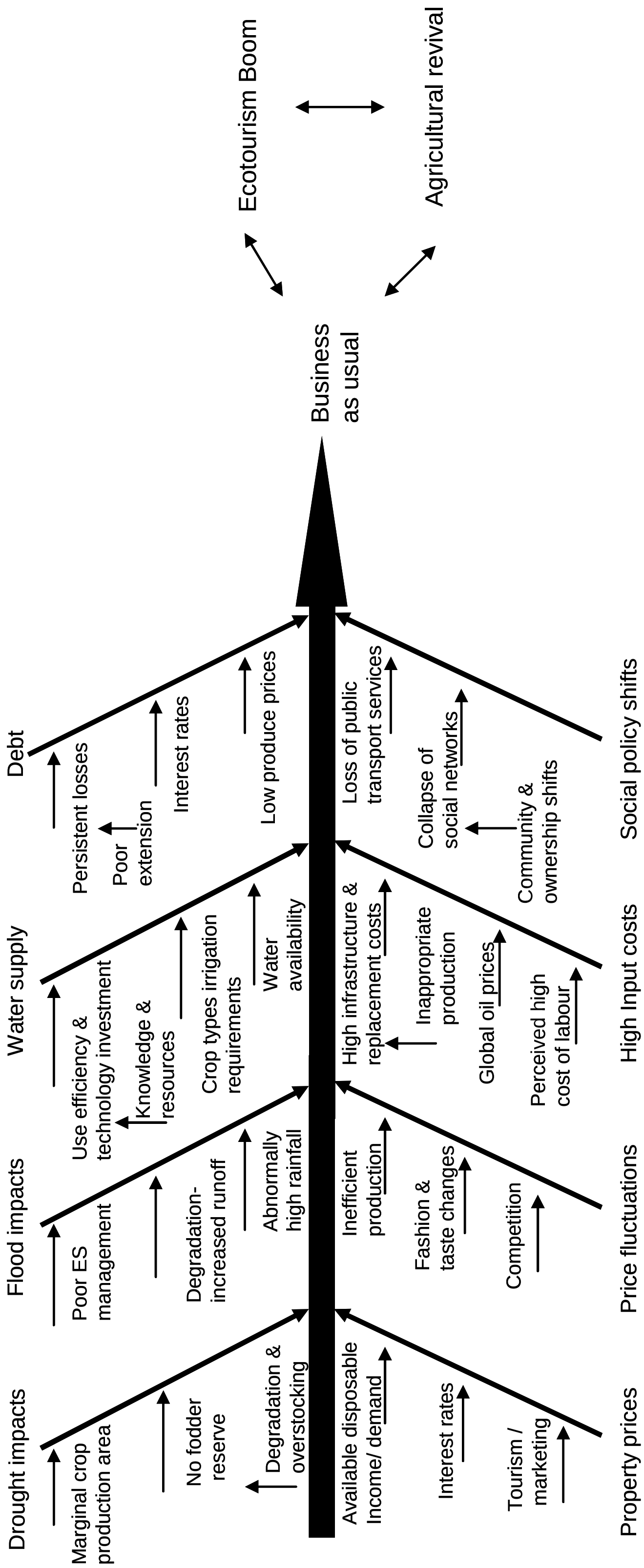


Figure 13. Ishikawa diagram showing external perturbations (causes), their drivers, and possible future states or basins of attraction for the Little Karoo SES.

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The external shocks that we have identified, which could force this SES to shift from its current basin of attraction, include: floods, droughts, water supply, finances, product prices, input costs, social policy shifts and property prices. Policies that may be formulated for the region, which we believe could strongly influence such a shift, include those that promote ecotourism, land-reform and agriculture. Depending on how stringently these are applied, they could facilitate the system shift to either of the alternate basins of attraction indicated in **Figure 13**. This would require making a combination of adjustments to the factors that influence, control, and exacerbate the identified perturbations. Whether these pressures will cause a shift into one of the alternative states depends on the current resilience of the system as defined by: the latitude, the precariousness, and the resistance characteristics of the current basin of attraction; cross-scale effects that influence this basin; and, on the levels of connectedness and potential within the system.

Latitude, precariousness, resistance, connectedness and potential

The latitude of a basin of attraction is an indication of how much the system can change, before losing its ability to recover (Walker *et al.,* 2004). In the study area, the latitude, or the flexibility of the entire Little Karoo SES and the nested Vanwyksdorp SES, appears to have generally decreased in recent decades. This is illustrated by the fact that in the 1950s farmers had multiple production opportunities open to them: fruit, meat (cattle, goats and sheep), wool and mohair, ostrich products and dairy products – i.e. opportunities that provided latitude. Over the last 50 years the external shocks we have described have decreased this latitude - illustrated by the few viable agricultural production options that are now open to remaining farmers. As a consequence, SES resilience and the force of attraction holding the system within the basin it currently occupies has diminished.

The narrowing of agricultural options and down-scaling of production activities, as well as clear evidence of farmers engaging in alternative income-generating activities, implies increasing precariousness of the system, as we have defined it. There is, therefore, increasing likelihood of a shift into an alternative basin of attraction – possibly, one characterised by the "ecotourism boom" scenario that we have defined. This will not necessarily be an adverse development; however, it would involve major shifts in the socio-economic base within the Little Karoo, including places such as Vanwyksdorp.

Those factors that contribute to resistance, or the inertia that holds the SES in the basin of attraction that it currently occupies, are also on the decline. We see factors contributing to resistance as being closely coupled to determinants of system connectedness. These include social connectivity, captured in the sense of belonging to a community and having a shared history, and, especially, past protectionist agricultural policies. The collapse of connectedness particularly within the Vanwyksdorp SES explains much of the change and diminished resilience that has occurred here. Connectedness that once existed, for example, between the farmers and the old political-economic regime that supported them and maintained the SES resilience, has been broken by a series of shocks to the system, particularly the establishment of a new political order in 1994. Protectionist policies ended in the 1990s and social connectivity continues to be lost as properties are sold and depopulation of the area occurs. We see these developments as rendering the basin of attraction ever shallower and, thereby, reducing resistance to a shift in system state. We recognise that the basin depth will not diminish below a certain minimum level as there will always be a small pool of commercial farmers in the region. A complete transition of the Little Karoo into, for example the "ecotourism boom" basin, would be difficult to achieve and such transition is likely to happen only in localised areas, with many areas persisting under the "business as usual" scenario. The effects of the possible emergence of this type of SES mosaic on the larger towns, such as Oudtshoorn, Ladismith or Calitzdorp, are difficult to predict, but it is likely that some of the established secondary industries (especially agriculture-based) in these centres would be severely impacted.

This study has highlighted examples of cross-scale effects. Decisions taken by individual landowners can have a regional scale effect, when a sufficient number of landholders take the same decision - for example, shifting to game farming or ecotourism. This in turn will have consequences for the remainder of the farmers in the area. We agree with Kinzig *et al.* (2006) that the paddock to local farm scale is primarily controlled by ecological thresholds; in our case study: species composition, level of degradation and requirements for restoration, and ease of growing a particular crop. The farm to landscape scale effects are controlled by economic thresholds; in our case study: profitability of production and alternative land-use practices. Regional scale effects are affected by socio-cultural thresholds; in our case study: political decisions, for example, regarding land reform Crossing thresholds between any of these scales can lead to undesirable alternative states, which may be difficult to move out of (Kinzig *et al.,* 2006). Having said this, threshold identification and quantification is not easy. Ecological thresholds can be subtle, with natural systems changing very slowly over time. The anticipation of an alternative system state may also be a matter of subjective evaluation. Social and economic thresholds are described as being driven by distant economic change, advances in infrastructure and technology, widening access to markets and information, growth and movements of populations, variation in climate and other exogenous forces (Frost *et al.,* 2006) as well as endogenous interactions.

The potential of the SESs we have studied has also shifted over time and is closely linked to the state of its social and ecological components. Some of the SES potential has leaked out of the system, for example in the form of ecological loss (degradation) following the initial settlement and development of the area, and more recent depopulation and social changes. As a result, the once well-structured SES definition that was perceived has been either lost or severely blurred. However, some system potential remains and this is being re-organised, through, for example land sales, into a new embryonic SES. The emerging definition of this SES must still be established (e.g. through competition, trial and error combinations of system elements) in the exploitation phase of the adaptive cycle (Holling, 1986; Holling and Gunderson, 2002), before a relatively stable SES establishes, possibly within a new basin of attraction.

In summary, our trends in the five variables that have formed the basis of our SES resilience analysis reveal a situation of incremental loss of resilience, where all variables have been negatively affected (**Table 2**). As a result, it appears likely that the nested SESs will assume a definition quite different to that which has prevailed for the last century.

Table 2. Trends in the variables forming the basis of the Little Karoo SES resilience analysis.

System variables and their possible states	**SES current state**
Latitude – expanded / no change / contracted	Contracted
Precariousness - increased / no change / decreased	Increased
Resistance - increased / no change / decreased	Decreased
Connectedness - established / no change / broken	Broken
Potential – increased / no change / decreased	Decreased

CONCLUSIONS

We have found that using a resilience framework to study SESs adds value in four ways: it improves understanding of the components, linking relationships and drivers of change within these complex systems; it facilitates understanding of historic system shocks and responses to these shocks, thereby informing understanding of the current SES resilience and ability to deal with future shocks; it clarifies the role of human agents in SES and the limitations imposed on systems by natural resources; and, it thereby informs management interventions.

Our research has shown that resilience analysis can contribute to our understanding of the forces affecting semi-arid rangelands and their management – not only in terms of ecological resilience, but also SES resilience. SES resilience analysis forces one to: confront the complexity of these systems; identify important controlling variables, including shocks and key drivers of these systems; learn from past experiences; and, avoid becoming confounded by the details (Frost *et al.,* 2006). Our study has outlined the fortunes and failures of the Little Karoo and nested Vanwyksdorp SESs. The resilience of these SESs has been influenced by various shocks (many originating far beyond the boundaries of the systems), which have been mediated (more or less effectively) by internal system responses such as shifts in agricultural production choices, the establishment of irrigation schemes, and switches to alternative economic bases such as ecotourism. However, the picture that emerges is one of incremental loss of system resilience. The SESs are currently in a precarious position where significant change may occur, resulting in the systems assuming quite different future definitions and character to those that have prevailed for much of the last century. The nature of the basins of attraction into which the SESs may shift is not clear; however, there are two plausible scenarios that we envisage.

Our study demonstrates that the human element of the SESs has the capacity to take stock of the current situation and anticipate what might happen in the future with different interventions and the emergence of different development opportunities. However, the natural resource base of these SESs introduces some very definite limitations in this regard, with water scarcity and high variability in supply (Le Maitre and O’Farrell, Chapter 11, this volume) and rangeland productivity being key. Whichever development trajectory is selected as the most socially equitable and desirable, the sustainable use and conservation of the natural resource base will have a determining influence on the resilience of the SES along this trajectory. Interventions need to be focussed on building latitude into these SESs and reducing precariousness where this is known to exist, such as appropriately managing the limited water resources and rangeland environments. This requires a deviation from many past management practices and experimentation at points of leverage within the SESs in order to build resilience , probably within a new basin of attraction.

Managing SESs is complex. it is multifaceted, socially contentious and fraught with uncertainty (Chee, 2004). Different stakeholders desire different outcomes, and there is also no single measure that captures all the values of the different stakeholders within a system (Walker *et al.,* 2002). Policies typically need to stimulate self-organization and the development of social mechanisms that enable resource users to deal flexibly with change and uncertainty in developing equitable management strategies (Redman and Kinzig, 2003; Anderies *et al.,* 2004; Cummings *et al.,* 2006; Folke, 2006; Kareiva *et al.,* 2007; Olsson *et al.,* 2007). Evolving and emerging institutions and management actions must also be at scales that are responsive to key ecological processes (Redman and Kinzig, 2003; Anderies *et al.,* 2004; Cummings *et al.,* 2006; Folke, 2006; Kareiva *et al.,* 2007; Olsson *et al.,* 2007). Within the Little Karoo this requires certain fundamental conditions to be in place that would enable communities to self-organise, establish a common vision of what is important, and to focus their combined efforts on increasing system resilience through adaptive management strategies that can respond to both unexpected events and stochastic events that can be anticipated. This is an enormous and politically fraught task, but one that can be informed by the continuous improvement in SES understanding. Resilience analysis too needs to be seen as an iterative process of constant re-evaluation and concomitant adaptive management response.

We believe that the complexity of SESs does not permit narrow, deterministic management approaches to policy-making and management. Le Maitre and O'Farrell (Chapter 11, this volume) make the point that these approaches are based on engineering resilience-thinking, which incorrectly assumes that systems can be controlled, managed and maintained indefinitely within pre-determined states (Holling and Meffe, 1996; Anderies *et al.,* 2006). The use of a resilience analysis framework in our case study helped to systematically identify and probe the factors that drive change in SES resilience, which were not immediately obvious and which could have been overlooked in more traditional analytical approaches. It is only with an holistic understanding of the factors that determine SES resilience, in particular those that define essential human-environment relationships, that we will be able to manage such systems, in an adaptive way, along a sustainable trajectory.

REFERENCES

Able, N., Cumming, D. H. M., and Anderies, J. M. (2006). Collapse and reorganisation in social-ecological systems: Questions, some ideas, and policy implications. *Ecology and Society*, **11**(1): 17. Available [online] at: http://www.ecologyandsociety.org/vol11/iss1/art17/. (Last accessed on 15 November 2007).

Alexander, D. J. (2000). Newcastle disease in ostriches (*Struthio camelus*): A review. *Avian Pathology*, **29**: 95-100.

Anderies, J. M., Janssen, M. A. and Ostrom, E. (2004). A framework to analyze the robustness of social–ecological systems from an institutional perspective. *Ecology and Society*, **9**(1):18. Available [online] at: http://www.ecologyandsociety.org/vol9/iss1/art18. (Last accessed on 15 November 2007).

Anderies, J. M., Walker, B. H. and Kinzig, A. P. (2006). Fifteen weddings and a funeral: Case studies and resilience-based management. *Ecology and Society***, 11**(1): 21. Available [online] at: http://www.ecologyandsociety.org/vol11/iss1/art21/. (Last accessed on 15 November 2007).

Archer, S. (2000). Technology and ecology in the Karoo: A century of windmills, wire and changing farming practice. *Journal of Southern African Studies*, **26**: 675-696.

ASGISA (2006). Background document: A catalyst for Accelerated and Shared Growth-South Africa (ASGISA). Media briefing by Deputy President Phumzile Mlambo-Ngcuka. Available [online] at: http://www.info.gov.za/speeches/briefings/asgibackground.pdf. (Last accessed on 6 February 2006).

Beinart, W. (2003). *The rise of conservation in South Africa. Settlers, livestock and the environment 1770-1950*. (New York, Oxford University Press).

Boonzaier, E., Malherbe, C., Smith, A. and Berens, P. (2000). *The Cape herders. A history of the Khoikhoi of southern Africa*. (Cape Town, David Philip).

Boyd, J. W. and Banzhaf, H .S. (2005). Ecosystem services and government accountability: The need for a new way of judging nature's value. *Resources*, Summer 2005:16-19.

Burman, J. (1981). *The Little Karoo*. (Cape Town, Human and Rousseau).

Burns, M., Audouin, M. and Weaver, A. (2006). Advancing sustainability science in South Africa. *South African Journal of Science*, **102**(9/10): 379-384.

Burns, M. (2007). Resilience theory as an approach to sustainability analysis. *International Journal of Environmental, Cultural, Economic and Social Sustainability*, **3**. Available [online] at: http://www.Sustainability-Journal.com. (Last accessed on 15 November 2007).

Chee, Y. E. (2004). An ecological perspective on the valuation of ecosystem services. *Biological Conservation*, **120**: 549–565.

Cillers, P. (2000). What can we learn from a theory of complexity? *Emergence*, **2**(1): 23-33.

Clark, W. C. and Dickson, N. (2003). Sustainability science: The emerging research paradigm. *Proc. Natl Acad. Sci*. USA, **100**(14): 8059–8061.

Cousins, B., Hoffman, M. T., Allsopp, N. and Rohde, R. F. (2007). A synthesis of sociological and biological perspectives on sustainable land use in Namaqualand. *Journal of Arid Environments*, **70**(4): 834-846.

Cumming, G. S., Barnes, G., Prez, S., Schmink, M., Sieving, K. E., Southworth, J., Binford, M., Holt, R. D., Stickler, C., and Van Holt, T. (2005). An exploratory framework for the empirical measurement of resilience. *Ecosystems*, **8**: 975-987.

Cumming, G. S, Cumming, D. H., and Redman, C. L. (2006). Scale mismatch in social-ecological systems: Causes, consequences, and solutions. *Ecology and Society,* **11**(1):14. Available [online] at: http://www.ecologyandsociety.org/vol11/iss1/art14/. (Last accessed 15 November 2007).

Cupido, C. F. (2005). Assessment of veld utilisation practices and veld condition in the Little Karoo. Masters of Science thesis (Agriculture), Department of Conservation Ecology, University of Stellenbosch.

Deacon, H. J., Deacon, J., Brooker, M., and Wilson, M. (1978). The evidence for herding at Boomplaas Cave in the southern Cape, South Africa. *South African Archaeological Bulletin*, **33**: 39-65.

Dean, W. R.J . and Macdonald, I. A. W. (1994). Historical changes in stocking rates of domestic livestock as a measure of semi-arid and arid land degradation in the Cape Province, South Africa. *Journal of Arid Environments*, **26**: 282-298.

Dean, W. R. J., Hoffman, M. T., Meadows, M. E. and Milton, S. J. (1995). Desertification in the semi-arid Karoo, South Africa: Review and reassessment. *Journal of Arid Environments,* **30**: 247-264.

Dean, W. R. J. and Roche, C. J. (2007). Setting appropriate targets for changed ecosystems in the semiarid Karoo, South Africa, in: J. Aronson, S. J. Milton and J. N. Blignaut (Eds), *Restoring natural capital. Science, business and practice*. (Washington, Island Press).

Desmet, P. G. (1999). Conservation in the matrix: Are biodiversity conservation and grazing compatible in arid rangelands? Perspectives from the Succulent Karoo of South Africa, in: D. Eldridge, and D. Freudenberger (Eds), *People and rangelands: Building the future*. Proceedings of the 6th International Rangeland Congress, 19-23 July 1999, Townsville. (Aitkenvale, Australia, Australia. VI International Rangeland Congress, Inc.). Pages 654-656.

Desmet, P. G. and Cowling, R. M. (1999). The climate of the Karoo: A functional approach, in: W. R. J. Dean and S. J. Milton (Eds), *The Karoo: Ecological patterns and processes*. (Cambridge UK, Cambridge University Press). Pages 3-16.

Diaz, S., Fargione, J., Chapin, F. S., and Tilman, D. (2006). Biodiversity loss threatens human well-being. *PLoS*, **4**: 1300-1305.

Donaldson, J. S. (2002). Biodiversity and conservation farming in the agricultural sector, in: S. M. Pierce, R. M. Cowling, T. Sandwith and K. MacKinnon (Eds), *Mainstreaming biodiversity in development. Case studies from South Africa*. (Washington, World bank). Pages 43-55.

Ellis, F. and Lambrechts, J. N. (1986). Soils, in: R. M. Cowling, P. W. Roux and A. J. H. Pieterse (Eds), The Karoo biome: A preliminary synthesis. Part 1: Physical environment*. South African National Scientific Programmes Report* No 124. (Pretoria, Foundation for Research Development). Pages 18-37.

Elsenburg (1999). *Klein Karoo streekontwikkelingsprogram*. (Elsenburg, Landbou-ontwikkelingsinstituut).

Esler, K. J., Milton, S.J . and Dean, W. R. J. (2006). *Karoo veld: Ecology and management.* (Pretoria, Briza Publications).

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, **16**: 253–267.

Frost, P., Campbell, B., Medina, G. and Usongo, L. (2006). Landscape-scale approaches for integrated natural resource management in tropical forest landscapes. *Ecology and Society*, **11**(2): 30. Available [online] at: http://www.ecologyandsociety.org/vol11/iss2/art30/. (Last accessed on 15 November 2007).

Gutman, P. (2007). Ecosystem services: Foundations for a new rural-urban compact. *Ecological Economics*, **62**: 383-387.

Hoffman, M. T. (1997). Human impacts on vegetation, in: R. M. Cowling, D. M. Richardson and S. M. Pierce (Eds), *Vegetation of Southern Africa.* (Cambridge UK, Cambridge University Press). Pages 507-534.

Hoffman, M. T., Cousins, B., Meyer, T., Petersen, A. and Hendricks, H. (1999). Historical and contemporary land use and the desertification of the Karoo, in: W. R. J. Dean and S. J. Milton (Eds), *The Karoo: Ecological patterns and processes*. (Cambridge UK, Cambridge University Press). Pages 257-273.

Hoffman, T. and Ashwell, A. (2001). *Nature divided: Land degradation in South Africa*. (Cape Town, University of Cape Town Press).

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, **4**: 1-23.

Holling, C. S. (1986). The resilience of terrestrial ecosystems: Local surprise and global change, in: W. C. Clark and R. E. Munn (Eds), *Sustainable development of the biosphere*. (Cambridge UK, Cambridge University Press).

Holling, C. S. and Gunderson, L. H. (2002). Resilience and adaptive cycles, in: L. H. Gunderson and C. S. Holling (Eds). *Panarchy: Understanding the transformations in human and natural systems*. (Washington DC, Island Press). Pages 25-62.

Holling, C. S. and Meffe, G. K. (1996). Command and control and pathology of natural resource management. *Conservation Biology*, **10**(2): 328-337.

Janssen, M. A., Bodin, Ö., Anderies, J. M., Elmqvist. T., Ernstson, H. Mc Alister, R. R. J., Olsson, P. and Ryan, P. (2006). Towards a network perspective of the study of resilience in social-ecological systems. *Ecology and Society*, **11**(1): 15. Available [online] at: http://www.ecologyandsociety.org/vol11/iss1/art15/. (Last accessed on 15 November 2007).

Kareiva, P., Watts, S., McDonald, R. and Boucher, T. (2007). Domesticated nature: Shaping landscapes and ecosystems for human welfare. *Science*, **316**: 1866-1869.

Kassier, W.E. (1992). *Report of the committee of inquiry into the Marketing Act*. (Pretoria, Department of Agriculture).

Kirsten, J. and Vink, N. (2003). Agricultural policy changes in South Africa 1996-2002. Paper presented at the Roles of Agriculture International Conference, 20-22 October 2003, Rome, Italy. (Rome, Agricultural and Development Economics Division (ESA), Food and Agriculture Organization).

Kinzig, A. P., Ryan, P., Etienne, M., Allison, H., Elmqvist, T., Walker, B. H. (2006). Resilience and regime shifts: Assessing cascading effects. *Ecology and Society*, **11**(1): 20. Available [online] at: http://www.ecologyandsociety.org/vol11/iss1/art20/. (Last accessed on 15 November 2007).

Klein Karoo Group (2006). Annual Review Klein Karoo Group, 2006. Available [online] at: www.kleinKaroo.com. (Last accessed in July 2007).

Klein, R. G. (1984). Mammalian extinctions and Stone Age people in Africa, in: P. S. Martin and R. G. Klein (Eds), *Quaternary extinctions: A prehistoric revolution*. (Tuscon, Univ. Arizona Press).

Kovacs, Z. P. (1982). Documentation of the January 1981 floods in the south-western Cape. *Technical Report* No TR 116. (Pretoria, Division of Hydrology, Department of Environment Affairs).

Le Maitre, D. C., Milton, S. J., Jarmain, C., Colvin, C.A., Saayman, I. and Vlok J. H. J. (2007). Landscape-scale hydrology of the Little Karoo: Linking ecosystems, ecosystem services and water resources. *Frontiers in Ecology and the Environment*, **5**: 261-270.

Max-Neef, M. A. (2005). Foundations of transdisciplinarity. *Ecological Economics*, **53**(1): 5-16.

Midgley, D. C., Pitman, W. V., and Middleton, B. J. (1994). *The surface water resources of South Africa: 1990*. 1st Edition. Volumes 1-6. Report Numbers 298/1.1/94 to 298/6.1/94 (text) and 298/1.2/94 to 298/6.2/94 (maps) and CD-ROM with selected data sets. (Pretoria, Water Research Commission).

Midgley, G. F., Chapman, R. A., Hewitson, B., Johnston, P., De Wit, M., Ziervogel, G., Mukheibir, P., Van Niekerk,, L., Tadross, M., Van Wilgen, B. W., Kgope, B., Morant, P. D., Theron, A., Scholes, R. J. and Forsyth, G. G. (2005). A status quo, vulnerability and adaptation assessment of the physical and socio-economic effects of climate change in the Western Cape. (Stellenbosch, CSIR Division of Water, Environment and Forestry Technology).

Milton, S. J., Yeaton, R .I., Dean, W. R. J. and Vlok, J. H. J. (1997). Succulent Karoo, in: R. M. Cowling, D. M. Richardson and S. M. Pierce (Eds), *Vegetation of Southern Africa*. (Cambridge UK, Cambridge University Press). Pages 131-166.

Mittermeier, R. A., Gil, P. R., Hoffman, M., Pilgrim, J., Brooks, T., Mittermeier, C. G., Lamoreux, J., and da Fonseca, G. A. B. (2005). *Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions*. (Mexico City, Cemex Books).

Olsson, P., Folke, C., and Berkes, F. (2004). Adaptive comanagement for building resilience in social-ecological systems. *Environmental Management*, **34**: 75-90.

Oudtshoorn (2005). Oudtshoorn economic profile. (Oudtshoorn, Oudtshoorn Municipality). Available [online] at: www.oudtshoorninfo.com/files/oudtshoorn_economic_profile.pdf. (Last accessed in July 2007).

Palmer, A. R., Hobson, C. G. and Hoffmann, M. T. (1990). Vegetation change in a semi-arid succulent dwarf shrubland in the Eastern Cape, South Africa. *South African Journal of Science*, **86**: 392-395.

Palmer, M. A, Bernhardt, E. S, Chornesky, E. A., Collins S. L., Dobson, A. P., Duke, C. S., Gold, B. D., Jacobson, R. B., Kingsland, S. E., Kranz, R. H., Mappin, M. J., Martinez, M. L., Micheli, F., Morse, J. L., Pace, M. L., Pascual, M., Palumbi, S. S., Reichman, O., Townsend, A. R., and Turner, M. G. (2005). Ecological science and sustainability for the 21st century. *Frontiers in Ecology*, **3**(1): 4-11.

Patton, M. Q. (1990). Qualitative evaluation and research methods. (London, Sage Publications).

Peterson, G., Allen, C. R. and Holling, C. S. (1998). Ecological resilience, biodiversity and scale. *Ecosystems*, **1**:6-18.

Pretty, J. N. (1995). Participatory learning for sustainable agriculture. *World Development*, **23**: 1247-1263.

Redman, C. L. and Kinzig, A. P. (2003). Resilience of past landscapes: Resilience theory, society, and the longue durée. *Ecology and Society*, **7**(1): 14. Available [online] at: http://www.ecologyandsociety.org/vol7/iss1/art14/. (Last accessed 15 November 2007).

Resilience Alliance (2007). Assessing resilience in social-ecological systems. A workbook for Scientists. Version 1.1 Draft for Testing and Evaluation. Available [online] at: xxxxxxx. (Last accessed in July 2007).

Reyers, B., Rouget, M., Jonas, Z., Cowling, R. M., Driver, A., Maze, K. and Desmet, P. (2007). Developing products for conservation decision-making: lessons from a spatial biodiversity assessment for South Africa. *Diversity and Distributions*, **13**: 608-619.

Ross, G. (2002). *The romance of Cape mountain passes*. (Cape Town, David Philip).

Ross, R. J. (1977). Smallpox at the Cape of Good Hope in the Eighteenth Century. *Proceedings of a seminar on African historical demography*, 29-30 April, 1977, Edinburgh. (Edinburgh, Centre for African Studies). Pages 416-428.

Schulze, R. E., Maharaj, M., Lynch, S. D., Howe, B. J. and Melvil-Thompson, B. (1997). *South African atlas of agrohydrology and climatology*. Report TT82/96. (Pretoria, Water Research Commission).

Senate S.C.2 (1914). Report from the select committee on droughts, rainfall and soil erosion. (Cape Town, The Senate, Parliament of the Union of South Africa).

Shearing, D. and Van Heerden, K. (1994). *Karoo. South African wildflower guide 6*. (Cape Town, Botanical Society of South Africa).

Smith, A. B. (1999). Hunters and herders in the Karoo landscape, in: W. R. J. Dean and S. J. Milton (Eds), *The Karoo: Ecological patterns and processes*. (Cambridge UK, Cambridge University Press). Pages 243-256.

Stats SA (2007). Stats SA website available [online] at: http://www.statssa.gov.za/. (Last accessed 15 November 2007).

Tague, N. R. (2004). The quality toolbox, 2nd Edition. (Milwaukee, WI, ASQ Quality Press).

Tainton, N. (1999). *Veld management in South Africa*. (Pietermaritzburg, University of Natal Press).

Talbot, W. J. (1961). Land utilization in the arid regions of southern Africa, Part I: South Africa, in: L. D. Stamp (Ed.), *A history of land use in arid regions. arid zones research*. (Paris, UNESCO). Pages 299-338.

Thompson, M. W., Vlok, J., Cowling, R. M., Cundill, S. L. and Mudau, N. (2005). A land transformation map for the Little Karoo. Final Report, Version 2. (Cape Town, Critical Ecosystems Protection Fund).

Tyson, P. D. (1986). *Climatic change and variability in southern Africa*. (Cape Town, Oxford University Press).

Tyson, P. D., Dyer, T. G. J. and Mametse, M. N. (1975). Secular changes in South African rainfall: 1880-1972. *Quarterly Journal of the Royal Meteorological Society*, **101**: 817-833.

UG 49-23 (1923). Final report of the drought investigation committee, 1923. (Cape Town, Government printer).

Van Zyl, P. (1996). A global perspective on the ostrich industry. *American Ostrich*, **Feb**: 30-44.

Vegter, J. R. (2000). Groundwater development in South Africa and an introduction to the hydrogeology of groundwater regions. Report TT 134/00. (Pretoria, Water Research Commission).

Venter, J. M., Mocke, C. and De Jager, J. M. (1986). Climate, in: R. M. Cowling, P. W. Roux and Pieterse, A. J. H. (Eds) (1986). *The Karoo Biome: A preliminary synthesis. Part 1: Physical environment*, SANSP Report No 124. (Pretoria, Foundation for Research Development). Pages 39-52.

Versfeld, D. B., Le Maitre, D. C. and Chapman, R. A. (1998). Alien invading plants and water resources in South Africa: A preliminary assessment. Report No. TT99/98, (Pretoria, Water Research Commission).

Vink, N. and Kirsten, ??. (2000). Deregulation of agricultural marketing in South Africa: Lessons learned. FMF Monograph No. 25. (Johannesburg, The Free Market Foundation). Available [online] at: www.freemarketfoundation.com/htmupload/PUBDoc397.doc. (Last accessed in August 2007).

Vink, N. and Tregurtha, N. (2005). Agriculture and mariculture. First paper. Structure, performance and future prospects. An overview. Available [online] at: http://www.capegateway.gov.za/other/2005/10/overview_final_first_paper_agriculture.pdf. (Last accessed in August 2007).

Vlok, J. H. J., Cowling, R. M. and Wolf, T. (2005). A vegetation map for the Little Karoo. Unpublished maps and report for a SKEP project supported by CEPF grant no 1064410304, Cape Town, South Africa. Availoable [online]: http://bgis.sanbi.org/littlekaroo/index.asp. (Last accessed in January 2007).

Walker, B. H., Anderies, J. M., Kinzig, A. P. and Ryan, P. (2006). Exploring resilience in social-ecological systems through comparative studies and theory development: Introduction to the Special Issue. *Ecology and Society*, **11**(1): 12. Available [online] at: http://www.ecologyandsociety.org/vol11/iss1/art12/. (Last accessed on 15 November 2007).

Walker, B. H., Holling, C. S., Carpenter, S. R., and Kinzig, A. P. (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society*, **9**(2): 5. Available [online] at: http://www.ecologyandsociety.org/vol9/iss2/art5/. (Last accessed on 15 November 2007).

Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G. S., Janssen, M., Lebel, L., Norberg, J., Peterson, G. D., and Pritchard, R. (2002). Resilience management in social-ecological systems: A working hypothesis for a participatory approach. *Conservation Ecology*, **6**(1)14. Available [online] at: http://www.consecol.org/vol6/iss1/art14. (Last accessed on 15 November 2007).

Wiegand, T., Milton, S. J. and Wissel, C. (1995). A simulation model for a shrub ecosystem in the semi-arid Karoo, South Africa. *Ecology*, **76**: 2205-2211.

Whiting Spilhaus, M. (1966). *South Africa in the making 1652-1806*. (Cape Town, Juta and Company Ltd.).

Zucchini, W. and Adamson, P. T. (1984). The occurrence and severity of droughts in South Africa. Report No. 91/1/84. (Pretoria, Water Research Commission).