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Faculty of Science

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A socio-ecological analysis of environmental change in the Kannaland Municipality of the Klein Karoo, South Africa, over the last 100 years

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DECLARATION

I declare that “Understanding the relationship between the environment, land use change and natural vegetation, over the past 100 years, in the Klein Karoo, South Africa” is my own work; that it has not been submitted for any degree or examination in any other university; and that all sources I have used or quoted have been indicated and acknowledged by complete references.

Amy Louise Murray

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ABSTRACT

This study utilizes a cyclical socio-ecological systems approach to explore change in natural vegetation and land use within the Kannaland Municipality of the Klein Karoo. Repeat ground photography, historical climate and agricultural data, and in-depth, semi-structured interviews were used to assess environmental, political and socio-economic change in the study area since the early 1900s. Few studies have had the opportunity to augment the analysis of repeat ground photography with contextual information from in-depth interviews making this study unique in its approach.

For most of the 20th century agricultural land use within the Klein Karoo has undergone fluctuations of increased and decreased productivity. However, during the later decades a noticeable decline in agricultural land use, especially sheep and goat production, has been recorded. Largely due to this, and contrary to degradation projections for this area, evidence of growth in cover of natural vegetation, especially over the last 20 years, was found. From the mid 1990s change from largely agricultural to recreational game and weekend farming as well as tourism-related land use has increased. Implications of recent land use change are perceived as both positive and negative. Increases in natural vegetation cover and potential associated biodiversity improvements are considered positive implications associated with the demise in extensive agricultural land use for the area. A decline in farm-based employment and agricultural productivity are considered negative implications of this land use change. Substantial increase in game farming within the study area is perceived to require stringent monitoring and research into the long term implications of this land use on natural vegetation.

For optimal land use management and conservation of natural vegetation this study recommends building the capacity of the agricultural and conservation extension services within the Klein Karoo. The study further promotes the diversification of land use inclusive of agricultural production, conservation of biodiversity and development, particularly within the tourism sector, as optimal for the sustainability of land use in the Klein Karoo.

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CHAPTER 1: Introduction

1.1. Background and motivation for research

The Klein Karoo is currently perceived to be one of the most degraded areas of South Africa (Hoffman et al, 1999; O'Farrell et al, 2008; Thompson et al, 2009). In the 1950s Acocks (1953) strongly promoted this opinion for the entire Karoo, attributing the degredation of this semi-arid region to over grazing (Boardman, 2001). While Acocks' view is still advocated (Boardman, 2001; Reyers et al, 2009) others (Davis & Shaw, 2001; Hannah et al, 2002; Hannah, Midgley & Millar, 2002; Root et al, 2003) place greater emphasis on climate change as the main driver behind future projections of Karoo aridification. Furthermore, the Klein Karoo falls within the winter rainfall region of South Africa, which is predicted to be the worst affected by climate change and future incidents of drought (Hoffman et al, 2009).

The Klein Karoo is internationally recognised as a biodiversity hotspot, with the meeting of three biomes namely the Succulent Karoo, the Albany Thicket and the Fynbos biome (Mucina & Rutherford, 2006). The Succulent Karoo biome is the dominant vegetation for the study area in this dissertation. It consists of over 5,000 species of which more than half are endemic to the biome. The vegetation of this biodiversity hotspot is also unique for a semi-arid landscape, adding to the strong motivation for its conservation (Hoffman & Rohde, 2011; Milton et al, 1997; O'Farrell et al, 2008; Reyers, 2009).

To determine the need for conservation intervention in the Klein Karoo it is first necessary to assess the current extent of degradation and the trajectory of environmental change. It is also important to place this change in its proper historical context (Hoffman & Rohde, 2011). There have been few long term studies in the Klein Karoo that explore change in vegetation over a set period of time, although some authors have emphasised the importance of this (Kraaij & Milton, 2006; Rahlao et al, 2008). Many studies aimed at determining the degradation in the Klein Karoo also do not take the socio-economic and political context of the area into account (Swetnam, Allen & Betancourt, 1999). In their exploration of resilience in the Klein Karoo O'Farrell et al (2008) emphasise the importance of the contextual history of the area when it is viewed as a socio-ecological system (SES). Feedbacks from internal and external factors such as social, economic and political influences have shaped the region's land use history and current status. It is crucial that such internal and external factors are considered in the debate between climate and land use as they are the main drivers for predicting land degradation in the Klein Karoo.

This study had the unique opportunity to make use of repeat ground photography dating back to the early 1900s in order to attain a historical perspective of vegetation change. The study explores the current state and long term pattern of vegetation and land use change in the Klein Karoo through reviewing these changes at a local scale in the Kannaland

Municipality. To acknowledge the complexity of exploring change, the study adopted a holistic SES approach. In doing so it considered the socio-economic and political context of the area. The study also investigated the relationship between environmental, social, economic and political drivers and their influence on the environmental change in the Klein Karoo.

1.2. Aim and objectives

This study documents change in natural vegetation and land use in the Kannaland Municipality of the Klein Karoo over the last 100 years and explores the main environmental and anthropogenic drivers of this change. Through a holistic SES approach the study helps in determining future land use management options and conservation strategies.

In order to meet this aim the study has the following objectives:

- To assess, using a series of historical photographs for the region, the long term changes in vegetation cover and composition within different land form units (e.g. slopes, plains, riverine areas) in the study area.

- To analyse, using the historical meteorological record, the extent of change in climate over the past 100 years within the study area with a specific focus on trends in rainfall and temperature.

- To document, using available agricultural census data, the major change in livestock and crop production that has occurred over the last 100 years in the study area.

- Using semi-structured interviews to understand the perceptions that people have about long term land use and land cover change within the study area and the role that environmental, political and socio-economic influences have had on these changes.

- Using a SES framework, to determine what best explains the observed changes in land use and to develop a narrative account of these changes.

- To use this information to inform land use, development and conservation options, with reference to local development plans, in order to contribute to the sustainability of natural vegetation and land use in the area.

1.3. Methodological approach

Young et al (2006) emphasise the difficulty in finding appropriate methodologies to analyze complex SES and recommend the utilization of various analytical techniques in order to substantiate and affirm findings. The objectives of this study were thus addressed through a combination of methodologies, both quantitative and qualitative, including repeat ground photography, historical climate and agricultural data, and in-depth semi-structured interviews.

The repeat photographs consisted of landscape views from 20 locations each one of which was repeated three times. Original images were from three different photographers and covered the period 1919 to 1959. These photographs were repeated in 1993 and again in 2014. The repeat ground photography allowed for an analysis of natural vegetation cover and composition change contributing largely to the first objective. Climate data from three weather stations within the study area was analysed to address the second objective of documenting the extent of climate change within the study area. Agricultural archival data obtained from the Plant Conservation Unit of the University of Cape Town (UCT) contain historical information on cropping and livestock production for the period from 1911 to 1993. These data were augmented with recent data obtained through the Department of Agriculture. The combined agricultural data set was analysed to meet part of the third objective to document long term change in land use in the study area. Finally, 31 in-depth semi-structured interviews with farmers, farm workers, non-farming land owners, knowledgeable people and relevant government officials were undertaken and contributed qualitatively to the remaining objectives in this study.

1.4. Thesis structure

Chapter 2 explores the literature on degradation and desertification; the historical context of the Klein Karoo; the Klein Karoo as a biodiversity hotspot; climate as a driver of natural vegetation change; land use as a driver of natural vegetation change; the SES approach and current development strategies of the Kannaland Municipality.

Chapter 3 introduces the study area and discusses the methodologies used in the study. The motivations behind the chosen methodologies are provided along with the ethical considerations and possible limitations to the study.

Chapter 4 explores the environmental drivers of land degradation and land use change in the study area. The change in natural vegetation cover, perceptions of degradation, climate change, and the influence of predators on livestock production are all explored within this chapter.

Chapter 5 explores the political, economic and social drivers of land degradation and land use change in the study area. Change in land use using the agricultural census data is firstly documented. Next, results from the semi-structured interviews are used to explore the political influence of relevant legislation, subsidies and support for the study area. Under economic drivers, the role of inflation, globalization, input costs versus income in agricultural production, market fluctuations and the introduction of new competing industries in the study area are discussed. Changing behaviours in farmers and farm labourers are also explored. Finally, the rise of outside interest in the region (e.g. the increase in lifestyle farmers and land owners who neither come from nor live in the area) is also assessed.

Chapter 6 integrates the environmental, political, economic and social drivers of land degradation and land use change through a SES framework. Future predictions for the area are explored based on data captured and the induction of the current trajectory of change. Interpretation of the SES trajectory of change is discussed.

Chapter 7 concludes with recommendations for land use, development and conservation strategies to contribute to the sustainability of natural vegetation and land use in the broader Klein Karoo region.

CHAPTER 2: Contextual background

2.1. Defining degradation and desertification

The term 'degradation' is used extensively in this study. It is defined in the United Nations Convention to Combat Desertification (UNCCD) as: *"reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns such as: (i) Soil erosion caused by wind and/or water; (ii) Deterioration of the physical, chemical and biological or economic properties of soil; and (iii) Long-term loss of natural vegetation."* (United Nations, 1994)

Although this definition encompasses a broad range of factors and fails to note the reversibility of degradation in its definition (Hoffman et al, 1999), it is relevant to the present study and will be taken as the understanding of the term.

There has been a substantial amount of literature on the term 'desertification' due to its extensive use with a large variety of contradictory meanings (Verstraete, 1986). Within this study the term is understood to refer to the general aridification or degradation of the Karoo with an associated loss of vegetation cover and change in species composition.

2.2. Historical context of the broader Klein Karoo region

The importance of the historical context when considering the extent of land degradation of the Karoo is exemplified by a number of authors (e.g. Dean et al, 1995; Hoffman & Rohde, 2011; O'Farrell et al, 2008) as it offers insight into understanding the current state of the land. In terms of the historical environmental impacts on natural vegetation, Dean et al (1995) argue that the Karoo vegetation is dynamic. They promote the idea that natural historical vegetation change is not uncommon and should be considered when assessing the current and future patterns of change. Prior to anthropogenic influences, quaternary evidence shows variations in climate and weather conditions that would have resulted in vegetation change in the Karoo (Dean et al, 1995).

In their exploration of resilience in the Klein Karoo O'Farrell et al (2008) emphasise the contextual history of the Klein Karoo as a social ecological system (SES). They suggest that internal and external factors such as social, economic and political influences have shaped the current status and land use history of the region. They provide an extensive review of the region's social, economic and political history dating back to early hunter-gatherers and pastoralists, namely the San and Khoi, who used the land on a transhumance basis and didn't cultivate crops (Cupido, 2005). European colonialists first entered the Klein Karoo in order to trade goods for livestock with the Khoi, around 1689, and were followed by colonial hunters and migratory farmers. In 1725 the first permanently settled farmers situated themselves in the Montagu area spreading throughout the Klein Karoo by 1767. Originally the early settlers adopted similar transhumance grazing strategies to the Khoi, whilst also hunting and trading with these indigenous groups of people. However, their main focus was to expand their livestock numbers as much as possible (O'Farrell et al, 2008). Archaeological evidence from 15,000 years of San and Khoi impact suggests that minimal environmental degradation was caused over this period (Hoffman, 1997). However, there is some debate as to whether soil erosion and localized overgrazing may have been present during the pre-colonial period (Boardman et al, 2010; Cupido, 2005).

Following the second British occupation of the Cape in 1806 there was an economic shift from farmers whose trade had previously been controlled by the Dutch East Indian Company to a new free market where taxations on trade were implemented (O'Farrell et al, 2008). Although this allowed farmers to regulate their own prices for their products, it reduced the previous security provided by the guarantee of product sale to the Dutch East Indian Company (O'Farrell et al, 2008).

During the mid to late 1800s the development of more mountain passes and transport routes allowed for greater trade options within South Africa as well as internationally. This also encouraged a greater diversity of agricultural products, resulting in the wool and tobacco boom (O'Farrell et al, 2008). The mid 1800s also saw the establishment of key towns in the Klein Karoo, such as Ladismith, Calitzdorp, Oudtshoorn, Uniondale and Montagu, encouraging a diversity of economic influences in the area as well as local trade (O'Farrell et al, 2008). The economy of South Africa in the 1800s was largely based on extensive rangeland agriculture of the Karoo prior to agricultural development of the more fertile and better watered northern areas of the country in the 1900s (Nel & Hill, 2008).

By the late 1800s the indigenous San and Khoi, in the Klein Karoo region, had either been displaced toward the north or absorbed into colonialist farms as farm workers. From this time transhumance strategies declined as greater private land ownership became more dominant (Downing, 1978; O'Farrell et al, 2008). The introduction of wire fencing and windmills during this period, also allowed for new paddock grazing strategies and a more permanent water supply for livestock in areas where water was previously unavailable. This had severe consequences for land use and natural vegetation due to the extension of grazing within designated paddocks. This historical turning point is explored in depth by Archer (2000) who stresses how the discovery of diamonds in Kimberley drove up mutton market prices providing farmers the incentive and capacity to adopt these technological advances.

The beginning of the 1900s saw political change in South Africa and the establishment of the Union party with a drive to transform South Africa into an independent and self-sufficient country. Agricultural production played a crucial role in this and the agricultural industry gained access to grants and loans to encourage its expansion. The Land Acts of 1913 and 1936 and the Marketing Act 26 of 1937 were promulgated at a similar time strongly favouring and benefitting white farmers. These acts also indirectly forced subsistence farmers to move off their land, resulting in the growth of the surrounding small towns. Specifically the Natives Land Act 27 of 1913 divided land into unequally sized portions assigned to different racial groups which led to the over use of certain areas under communal tenure, accelerated rates of degradation and the forced abandonment of agricultural practices by many marginalized groups (Hoffman, 2014). Although this pattern was not as prominent in the Klein Karoo as other areas of South Africa it is still very much evident within specific areas of the present study.

The growth of commercial farms, demand for cereals and the introduction of railroads had the combined effect of creating greater incentives for dry and fresh agricultural production and the subsequent building of dams for increased irrigation (O'Farrell et al, 2008). The trend in growth of commercial farms and the decline of subsistence farming was later reinforced by the Subdivision of Agricultural Land Act 70 of 1970. This Act prevented farmers subdividing and selling off of portions of their land and is yet to be repealed (Van Zyl et al, 2001).

The early 1900s also saw the beginning of rotational grazing with the Fencing Act 17 of 1912 requiring farms to be fenced (Dean et al, 1995). With the division of farms into camps and the rotation of livestock between camps the Drought Investigation Commission of 1923 proposed that grazing capacities could be increased. The implementation of this recommendation resulted in overstocking and the degradation of veld (Cupido, 2005).

In order to provide greater safety and unity after the crash of the ostrich industry in 1914 farmers organised themselves more effectively. The Kango Tobacco co-operative, established in 1926, was the first of a number of co-operatives established in the first half of the 20th century. Relevant to the present study was the establishment of the Ladismith co-operative in 1939, the remnants of which can still be seen as the dairy factory now owned by Parmalat, a multinational company. Co-operatives provided security for individual farmers where their produce was marketed under the cooperative label (O'Farrell et al, 2008).

By the late 1990s local political shifts reduced market protection for farmers and rising global oil prices pushed up input costs for agricultural production. These two factors caused a further depression in dryland crop production for the Klein Karoo. Along with this, increased transport costs and the unreliability of rainfall led many farmers to introduce game animals due to their hardier nature. This trend is still seen today (O'Farrell et al, 2008), changing the impact of land use on natural vegetation as game roam freely in larger areas of the natural veld.

The 1994 democratic elections saw a major shift in the agricultural sector of South Africa with white farmers no longer having favour or influence in the political realm of the country. The new land reform process, however, did not have a major effect for the Klein Karoo farmers as few land claims were made in this area. The largest influence on agricultural production in the study area was the decrease in cereal production and the freeing up of agricultural markets. According to O'Farrell et al (2008) fruit, wine and vegetable seed production remained fairly stable in the two decades prior to their research.

Another trend that has been witnessed in recent years and explored extensively by Ingle (2010_a; 2010_b; 2013_a; 2013_b) is a migration of a 'creative class' of urban dwellers purchasing land in the Klein Karoo to settle on, to use for vacationing purposes, and/or to begin small tourist or farm-based activities. This has resulted in increased property prices, especially in popular small towns. These trends have significantly impacted the farming industry as farmers may either be attracted to sell their land, thus decreasing the agricultural use of the area, or alternatively be faced with a far more competitive market when wanting to expand (Reed & Kleynhans, 2009).

According to O'Farrell et al (2008) tourists have been visiting the Klein Karoo since the 1700s and have increased in numbers since. The Klein Karoo holds some significant attractions including numerous hot springs, caves and the timeless landscape, all very much dependent upon the natural ecosystems. The trend to take up this opportunity has increased in recent years as land owners, mostly new, have opened up reserves, game farms, lodges, guest houses and farm stalls to cater for this industry. The introduction of wildlife not previously found in the area, or only seasonally, has also occurred, although the ecological consequences of this changed land use have not been extensively explored. It is predicated by some (Ingle, 2010_b) that tourism may become a highly prominent feature for the future of the Klein Karoo. Supporting this prediction, Nel and Hill (2008) and Smith and Wilson (2002) report that substantial amounts of former livestock rangelands have been converted to game farms in recent years.

O'Farrell et al (2008) give an in-depth and incident specific historical context for the Klein Karoo. For the purposes of this study the historical context provided here is assumed to exemplify the complexity of change within this region. The current state of land degradation in the Klein Karoo has a very rich social, economic and political context that cannot be overlooked when assessing the present and planning for the future.

2.3. The Klein Karoo as a biodiversity hotspot

The Klein Karoo supports vegetation from three internationally recognized biodiversity hotspots, namely the Succulent Karoo, the Maputaland-Pondoland-Albany Thicket and the Cape Floristic Region (Myers et al, 2000; O'Farrell et al, 2010; Reyers et al, 2009; Thompson et al, 2009). Furthermore, the Succulent Karoo biome is considered one of only two biodiversity hotspots in semi-arid regions throughout the world (Gil et al, 2004; Hoffman & Rohde, 2011). Milton et al (1997) provide an account of the composition of species in the Succulent Karoo vegetation highlighting some of the major succulent families, such as Aizoaceae and Crassulaceae. Gallo et al (2009) recognize that the protection of global biodiversity is difficult and therefore suggest that global efforts of biodiversity protection be focused on identified biodiversity hotspots (areas of rich and unique species diversity) emphasizing the significance of such areas.

Ecosystems across the world, including those of the Klein Karoo, provide many basic goods and services such as forage production, shade and shelter, erosion prevention, water flow regulation, water provision, carbon sequestration, soil fertility and tourism (O'Farrell et al, 2007; Reyers et al, 2009). The maintenance of biodiversity is recognized as crucial for the ability of ecosystems to provide such services (Simonesen et al, 2014). Where there is intensive water use or grazing, for example, without any form of conservation the likelihood of significant negative effects on the ability of the ecosystem to continue to offer such provisions is extremely high.

Estimates of vegetation degradation are dependent on multiple factors and are assessed relative to the perceived original condition of the vegetation. For this reason varying degradation estimates have been suggested for the Klein Karoo region. The Western Cape Department of Environmental Affairs and Development Planning conducted a biodiversity assessment for the Klein Karoo in 2010. It was reported within this assessment that 15% of the land cover within the Kannaland Municipality was considered degraded (Skowno, Holness & Desmet, 2010). According to Reyers et al (2009) 52% of the Klein Karoo region was considered degraded. They further suggest that these degraded areas largely overlap areas identified as key providers of important services such as forage production, erosion control, carbon storage, tourism and freshwater flow regulation. Thompson et al (2009), suggest that 91% of natural habitat in the Klein Karoo has been degraded to some extent and that 24% of this will require active rehabilitation if it is expected to return to its natural state.

2.4. Climate as a driver of vegetation change

There are contrasting narratives around climate change in the Klein Karoo. The Klein Karoo falls largely in the winter rainfall region of South Africa which is predicted to be one of the most severely affected areas as a result of the impacts of climate change (Hannah et al, 2002; Hannah, Midgley & Millar, 2002; Midgley et al, 2005). Climate models predict the area will become warmer and drier with increases in the incidence of drought (Midgley et al, 2005). Due to the semi-arid nature of this area and the scarcity of water such predictions suggest that the Karoo is likely to face intensive drying in the future and a loss of species richness.

Contrary to these projected trends, however, Hoffman et al (2009) found little change in rainfall and the incidence of drought in the Succulent Karoo over the past 50 years. They did, however, note an increased incidence of drought for the period between 1900 and 1950. Long term climate change is clearly an important feature of the region (Dean et al, 1995; Hoffman & Rohde, 2011) with important implications for vegetation.

In response to projected climate warming, however, several studies have suggested that species will shift southwards in the pursuit of favourable climate (Davis & Shaw, 2001; Hannah et al, 2002; Hannah, Midgley & Millar, 2002). For the Klein Karoo, which lies within a basin of mountain ranges, such a trend is likely to leave vegetation fragmented, thus contributing to a loss of species richness. It is also a significant point of consideration for conservation planning as the positioning of reserves should take these future projections into account (Hannah et al, 2002; Hannah, Midgley & Millar, 2002).

2.5. Land use as a driver of vegetation change

There are a multitude of studies on the impacts of land use on natural vegetation. Specific to the Klein Karoo are studies that focus predominantly on over grazing. This is seen as a strong contributor to land degradation and is one of the main environmental issues in South Africa (Anderson & Hoffman, 2007; Archer, 2004; Darkoh, 2009; Milchunas & Lauenroth, 1993; Reyers et al, 2009; Rutherford & Powrie, 2013; Thompson et al, 2009). Looking back at the historical context of the Klein Karoo it is evident that land use practices have advanced and changed dramatically over the past 200 years. Prior to an increased awareness of land degradation in the area, land use practices were driven by an aim to stock and grow as much as possible. This resulted in periods of heavy over grazing and to a lesser degree intensive crop cultivation.

Reyers et al (2009) and Le Maitre (2007) argued that land use and land cover change significantly impair the ability of ecosystems to offer the provisions such as forage production and water on which these land uses depend. Reyers et al (2009) go so far as to say that over grazing is the main cause of degradation leading to land cover change and biodiversity loss. The importance of the intensity of grazing, however, is highlighted by both Anderson and Hoffman (2007) and Rutherford and Powrie (2013) who recognize that lighter grazing may have a positive effect on natural vegetation.

The range of impacts on vegetation as a result of heavy grazing which have been noted include loss of vegetation cover, composition changes from perennial to annual species and a decrease in general diversity with fewer palatable species. It should be noted that different land form units (e.g. slopes, plains, and ephemeral rivers) are affected to varying degrees relative to their accessibility and use (Anderson & Hoffman, 2007; Rutherford & Powrie, 2013).

Archer (2004) suggests that there are certain stocking and grazing strategies that may have less severe impacts on natural vegetation. Prior to an awareness of grazing induced degradation, most grazing was conducted as a continuous grazing system where camps were grazed until little fodder remained. During the 1960s several alternative grazing systems were developed, such as rotational grazing where animals were moved between camps in order to provide rest for the vegetation to allow its rejuvenation. There is presently, however, still much debate and disagreement about the best practice to use in a particular area (Archer, 2004). Farmers have also attempted to mimic transhumance grazing systems by purchasing two or more farms located in areas with different seasonal rainfall regimes, such as winter and summer rainfall areas, and moving their livestock seasonally between these properties (Hoffman et al, 1999). This strategy, however, requires a large amount of land and is increasingly unaffordable.

There are many variables that influence a farmer's decisions to practice more sustainable and conservation minded techniques, and grazing management approaches should be tailored to specific localities (Dean et al, 1995; Knowler & Bradshaw, 2007). The variables are largely related to the cost benefit ratio perceived by farmers, where it is important that the new techniques do not cost more to farmers than the economic benefits which they provide (Pannell et al, 2006). It has also been highlighted that access to information about land degradation, the vulnerability of land use due to climate change and the potential for viable alternative land use practices is key in the adoption of conservation land use practices (Hannah et al, 2002). The critical role of biodiversity for agricultural sustainability is becoming more evident and thus conservation-minded farming practices are vital for the sustainability of the agricultural system (Thrupp, 2000).

2.6. Policy and strategy for the Kannaland Municipality

2.6.1. Integrated Development Plan

The Kannaland Municipality's Integrated Development Plan (IDP) (2014) has a strong social upliftment focus. However, it also acknowledges the need for sustainable environmental management and highlights the importance for resource use efficiency. It mentions the harsh climate of the region and comments on how droughts pose a threat to the biodiversity and agricultural production of the area.

The IDP repeatedly highlights the importance of the agricultural sector for this municipal area. The agricultural sector is currently the main economic contributor and source of employment within the region. The 2011 census indicated that 37.4% of people in the Kannaland Municipality were employed in the agricultural sector. It also acknowledges that the agricultural sector is disadvantaged by national policies which place high taxation on production which negatively affects this vital industry.

There is a strong promotion of the tourism sector in the IDP to potentially become a large contributor to the economy and employment of the area. The importance of the environment and biodiversity for the tourism sector is rightfully acknowledged and the diversity in natural vegetation is highlighted. The role in balancing the needs of environmental protection and preservation (for biodiversity, tourism and agricultural purposes) versus the need for development (for economic and social upliftment) is also highlighted. The Spatial Development Framework (SDF) is identified as the mechanism by which this balance is to be attained. It is worth noting that the IDP places emphasis on collaborative governance and public participation in decision making and development with indigenous knowledge being identified as a valuable source of information for the enhancement of the area.

2.6.2. Spatial Development Framework (SDF)

The Kannaland Municipality SDF (2013) reiterates the high value of the agricultural industry to the area as well as the importance of promoting tourism in the municipality for job creation and economic stimulation. It again acknowledges the importance of the natural scenery and biodiversity for the tourism industry. The SDF, however, has a strong focus on urban development and housing provision. This is important for the upliftment of people in the area as a whole but has specific relevance to the current research as it strongly advocates that no development should occur outside of the demarcated urban edge, thus minimizing the encroachment into natural veld.

The Kannaland Municipality has a relatively large number of formally protected areas within its boundaries. These include five provincial nature reserves and two local mountain catchment areas. Within the SDF it is recommended that the protection of these areas should be ensured with the active engagement between the municipality and conservation authorities. The SDF goes on to identify relatively large amounts of additional Critical Biodiversity Areas (CBAs) outside of the protected areas for which it strongly encourages conservation. It is recommended that this be done through conservancies and conservation stewardship projects which limit development. Identified river corridors and wetlands are further recommended to have a minimum buffer of 32 m, unless alternative setback lines have already been established, for the protection from urban, agricultural or mining activities. Interestingly, the majority of the surrounding areas to the Kannaland Municipality, within the abutting municipal SDFs, are identified as areas reserved for conservation.

The majority of the remaining area not recognized as formally protected areas, CBAs or river corridor and wetland buffer zones are either identified for intensive agriculture or labelled buffer areas in the SDF. Areas identified for intensive agriculture are relatively small. The remaining buffer areas have been recommended for the use of extensive agriculture. The SDF specifically highlights the promotion of best practice veld management and rotational grazing within the identified extensive agricultural areas in order to improve biodiversity and ensure sustainable stocking rates.

The SDF acknowledges the threat posed by climate change as a result of increased temperatures and shifts in rainfall and precipitation patterns which have the potential to affect water supply. The fragility of water and the importance of the protection of water sources for the sustainability of the natural environment and all industries, particularly agriculture, within the area are also highlighted. Education and conservation of land and water use promotion are identified as strategies for the preparation and minimization of water supply threats and climate change consequences.

It is evident that the natural veld with its rich biodiversity is considered a high conservation priority for the Kannaland Municipality SDF. In order for this to be realized it is acknowledged that collaboration and active engagement is needed between conservation authorities, the local municipality and land owners. Conservation education is also highlighted within the SDF as a potential key contributor to this aim.

The Kannaland SDF makes specific acknowledgement of the interrelated nature of the world and all its components. It therefore adopts a framework of interrelated systems comprised of 26 main layers which characterise the municipality. The diagram which illustrates this framework includes three categories of layers including bio-physical, socio-economic and the built environment. This framework is relevant to the current study as it reiterates the importance of acknowledging the interrelated nature of the components of the system under study.

2.6.3. Gouritz Cluster Biosphere Reserve (GCBR)

Environmental management in a region such as the Kannaland Municipality is challenging because of the numerous land owners and stakeholders involved. In order to manage this complex process, the Gouritz Initiative (GI) was established in 2003. The GI's aim was to assist in the coordination of strategies amongst the stakeholders. It looked to enhance participatory learning in order to ensure the sustainable use of the critically rich biodiversity. The GI has now become the Gouritz Cluster Biosphere Reserve (GCBR), one of the first UNESCO biosphere reserves in Africa. UNESCO biosphere reserves are regions internationally acknowledged and committed to collaborative sustainable development in the 21st century. The GCBR has identified priority corridor areas for conservation within the Klein Karoo with a vision to protect long term ecological shifts (Skowno, Holness & Desmet, 2010).

2.7. Conclusion

The contextual background and history of the Klein Karoo is rich with numerous drivers of land use change. It is important when assessing the current state and predicting the future of natural vegetation and land use that the contextual history of an area is taken into account (O'Farrell et al, 2008). The rich biodiversity of the natural vegetation in the Klein Karoo has been internationally recognized and prioritized for conservation (Gallo et al, 2009; Myers et al, 2000; O'Farrell et al, 2010; Reyers et al, 2009; Thompson et al, 2009). There are contrasting opinions over climate versus land use as the dominant driver of natural vegetation degradation (Anderson & Hoffman, 2007; Archer, 2004; Darkoh, 2009; Hannah et al, 2002; Hannah, Midgley & Millar, 2002; Midgley et al, 2005; Milchunas & Lauenroth, 1993; Reyers et al, 2009; Rutherford & Powrie, 2013; Thompson et al, 2009).

The policies and strategies of the Kannaland Municipality acknowledge the importance of the natural vegetation and biodiversity of the Klein Karoo. The agricultural sector within this area is identified as a key economic driver in the region and important for the creation of jobs and employment. Tourism is prioritised for development and recognized for its potential. Conservation of natural vegetation and the rich biodiversity of the area are identified as critical for both of these sectors. The Kannaland SDF provides recommendations for land use and conservation of the municipal area. Collaboration with private land owners is recognized as vital for conservation. The GCBR has been established to assist in the pursuit of sustainable development within and surrounding the study area.

CHAPTER 3: Methodology

3.1. Conceptual approach: Socio-ecological systems

In response to the debate about whether climate or land use is the dominant driver of vegetation change there are authors who recognize the importance of both (Archer, 2004; Hoffman & Rohde, 2011; Kraaij & Milton, 2006; Milchunas & Lauenroth 1993; Rutherford & Powrie, 2013). Many authors have emphasised the complexity and interdependencies of multiple drivers of land use and land cover change when assessing the state of an area, and making predictions about the future (De Aranzabal et al, 2008; Lambin et al, 2001). A holistic socio-ecological systems (SES) approach has therefore been adopted in order to acknowledge the interrelated nature of all aspects of the Klein Karoo system, its attributes, actors and governing powers. Only once an understanding of this interplay has been attained and a historical perspective of change understood can a trajectory of the system's rate of and susceptibility to change be explored.

The difficulty in analyzing a system with multiple drivers of varying degrees of influence has been acknowledged (Lambin & Meyfroidt, 2010; Young et al, 2006). It is therefore imperative that a clear understanding of SES and their characteristics is grasped. Within the extensive literature on SES and resilience considerable effort is devoted to terminology, explanations and understandings of various theories, frameworks and models. Berkes et al (2013) distinguish three key factors of a SES namely that they have multiple scales, multiple levels and varying degrees of resilience. Scales are largely related to time and space and are a characteristic of the system itself. The SES within the present study has a relatively large scale. The temporal range under consideration spans over 300 years, from the first entrance of colonial Europeans into the area, while the region under consideration encompasses a spatial area of 4,758 km^2. Levels relate to the magnitude of influence an aspect of a system has on the system. For example, the Kannaland Municipality is at a lower level than the Western Cape provincial government, both of which will have influence in the system. Resilience is the ability to maintain the systems function and structure against feedbacks and 'shocks'. Shocks are understood as an internal or external, direct or indirect, influencing factor to a system that requires a level of change or alteration within a system to re-attain a state of sustainability (Berkes et al, 2013).

Berkes et al (2013) describe five other attributes of a SES which have been adopted here. These include drivers, feedbacks, thresholds, transformation and emergent properties. Drivers are factors that bring about change in a system. They may be direct or indirect, natural or anthropogenic. Feedbacks are complex interactions and responses within and between drivers and attributes of a system. Feedbacks can be positive (reinforcing), when they reinforce the current trend of change, or negative (moderating), when they alter or halt the direction of change within a SES. Thresholds are limits to a system's current functionality and structure. The resilience of a system is related to their ability to resist meeting such thresholds. Thresholds are difficult to define prior to their encounter and once reached the system will enter an alternate state. Transformation is the process of establishing such alternate states once a threshold has been crossed. Walker et al (2004) define transformability as the capacity of a system to transform into a new state. Finally, emergent properties are features of a system that come about solely as a result of the interactions between other system attributes. Emergent properties are difficult to predict and may come as a surprise to a system.

An additional term which will be utilized in the present study relating to anthropogenic drivers of a SES is adaptability (Walker et al, 2004). Walker et al (2004) suggest that human actors within a SES have the largest influence on the resilience of that system. They use the term adaptability as the capacity of the collective human actors within a SES to manage the systems' resilience (Walker et al, 2004). Two further recognitions should be made relating to the present understanding of SES. Firstly, SES are often referred to as Complex Adaptive Systems (CAS) reflecting their complex and adaptive nature (Abel, Cumming & Anderies, 2006; Simonesen et al, 2014). Secondly, it is broadly accepted that socio-ecological systems are often cyclical in nature where similarity in patterns of change may be identified (Berkes, Colding & Folke, 2003; Gunderson & Holling, 2002).

Gunderson and Holling (2002) propose a four phased transitional cycle of a SES called the adaptive cycle (Figure 1). The four phases are reorganization, exploration, conservation and release. The diagram shows the pattern and direction of change of the four phases. The reorganization phase (α) is understood to occur after a system has reached a threshold and during the time of transformation. The system undergoes restructuring and establishes new methods of functionality and interaction between new or re-established variables. The system has high resilience during this phase as its state is only just being established according to attributes that are likely in abundance. The exploration phase (r) is understood as a time of accelerated expansion and exploration of the new state of the system. This phase is characterised by rapid growth and resource use and is thus likely to be competitive among system users as they explore new opportunities. The exploration phase has high resilience although this decreases with the expansion of resource use within the system. The conservation phase (K) is understood as a time of plateaued expansion with more conservative resource use. This phase is characterized by low resilience. The release phase (Ω) is understood as a time of system collapse where system thresholds are reached. Resilience in this phase is low but will begin increasing as the system begins to reorganize.

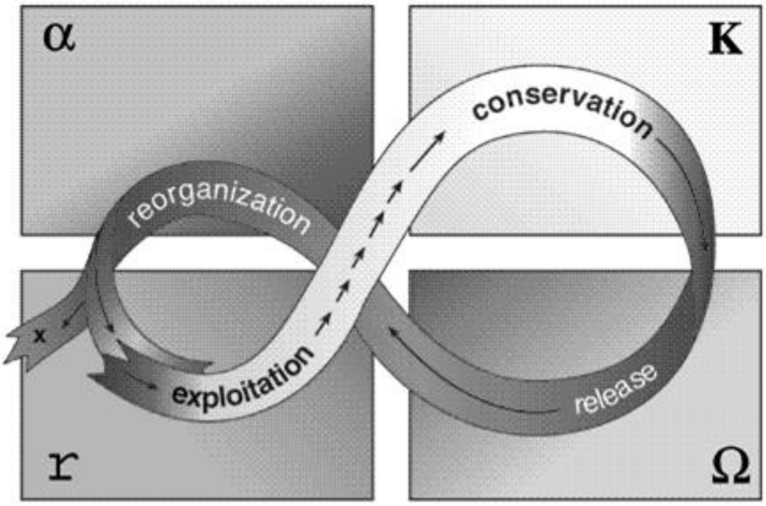

Figure 1 The four phased adaptive cycle of socio-ecological systems (Gunderson & Holling, 2002).

Biggs et al (2012) emphasise the importance of defining both the users and the resilience thresholds of a SES. For the purposes of the present study it is evident that the livelihoods of the majority of people currently living in the study area are dependent on provisions, regulations, cultural uses and the supporting functions of ecosystems and their services (Millennium Ecosystem Assessment (MA), 2003; MA, 2005). These are largely related to the natural vegetation and once again include, but are not limited to, forage production, shade and shelter, erosion prevention, water flow regulation, water provision, carbon sequestration, soil fertility and tourism. In their assessment of specific ecosystem services in the Klein Karoo, such as those mentioned above, Reyers et al (2009) found levels of decline ranging between 18% and 44%. Such rates of decline indicate concern for the sustainability of these service deliveries in the future. In their exploration of principles for building resilience, Simonesen et al (2014) place great emphasis on the importance of maintaining biodiversity within a SES in order to ensure the resilience of the ecosystem and the provisions it offers. This again reiterates the importance of the rich biodiversity found in the SES of the Kannaland Municipality and the Klein Karoo. The present study explores the resilience of the Kannaland Municipality's natural vegetation and biodiversity for the sustainability of the livelihoods of the majority of inhabitants within this SES.

3.2. Study area

The study area covers the majority of the Kannaland Municipality which is located within the Eden District Municipality in the Western Cape Province of South Africa (Figure 2). The Kannaland Municipality falls in the western part of the Klein Karoo and covers 4,758 km^2 including the towns of Ladismith, Calitzdorp, Van Wyksdorp and Zoar (www.localgoverment.co.za). The area lies between four mountain ranges, the Swartberg in the north, Langeberg in the south, Anysberg to the west and Gamkaberg to the east and is drained by both the Groot River and Gouritz River. The Kannaland Municipality area was selected for a number of climatic, social and biological reasons. It falls in a climatic transitional area at the edge of the winter rainfall region with the potential to reflect interesting climatic shifts. The area is also socially diverse. It is occupied by long term generational farmers, local communities and an influx of new farmers and non-farming land owners originating from elsewhere in South Africa and abroad. This has resulted in dynamic land uses with mixed farming practices and an increase in game farm and tourist-related establishments. Finally the study area is located on the western margins of the Albany Thicket biome which allows the potential for vegetation biome shifts to be observed as many species in this region are at the limit of their distribution. The dominant vegetation in this area, particularly in flatter areas with higher land use, is the Succulent Karoo biome (Mucina & Rutherford, 2006). This is an identified global biodiversity hotspot and one of the richest biomes located in an arid landscape anywhere in the world (Hilton-Taylor, 1996).

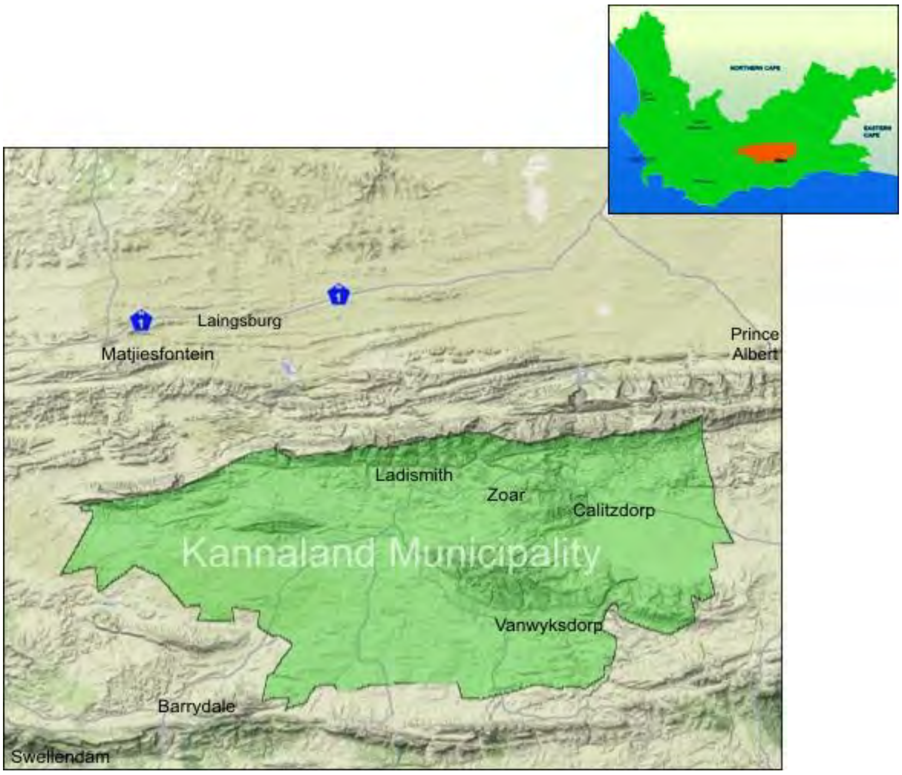

Figure 2 The Kannaland Municipality located within the Klein Karoo area of the Western Cape Province of South Africa (www.westerncape.gov.za).

Figure 3 below provides the distribution of biomes within the study area. It is estimated that around 76.2% of the Kannaland Municipality is still covered with natural vegetation in varying degrees of degradation (Sokowno, Holness & Desmet, 2010). The Kannaland Municipality contains 11 formally protected areas comprising 17.2% of the municipal area. These include five Provincial Nature Reserves including the Anysberg Nature Reserve, Eyerpoort Nature Reserve, Groenfontein Nature Reserve, Gamaka Nature Reserve and the Vaalhoek Nature Reserve; the local Ladismith-Kleinkaroo Nature Reserve; three Forest Act Protected Areas including the Grootswartberg Nature Reserve, the Rooiberg Nature Reserve and the Towerkop Nature Reserve; and two Mountain Catchment Areas (MCA) including the Klein Swartberg MCA and the Rooiberg MCA.

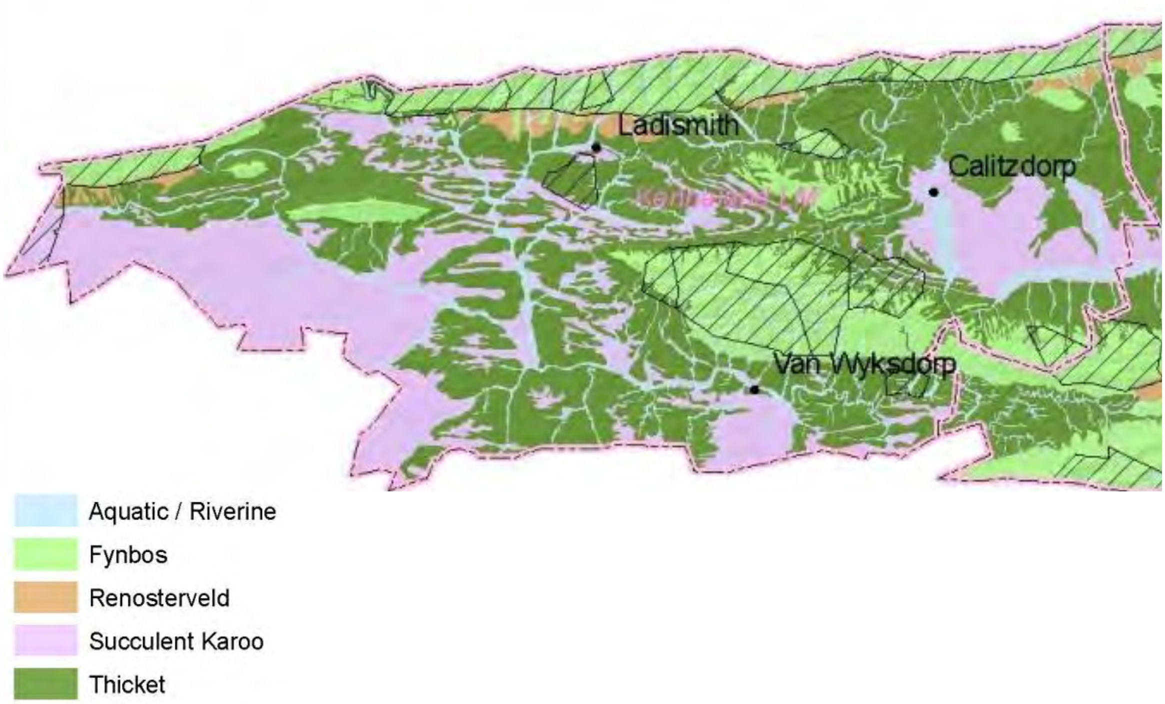

Figure 3 The major biomes of the Kannaland Municipality area. Lined areas represent formally protected areas (Sokowno, Holness & Desmet, 2010 extracted from Vlok et al, 2005).

3.3. Methodology

This study uses a combination of methodologies to produce both quantitative and qualitative data which allowed for a holistic understanding of various drivers of change in natural vegetation and land use. Four methodologies were used in the study including repeat ground photography, an analysis of climate data, an analysis of agricultural census data and in-depth semi-structured interviews with key informants. These will be discussed separately in this order.

3.3.1. Repeat ground photography

Repeat ground photography provides a powerful tool in documenting long term landscape change (Webb, Boyer & Turner, 2010). This study had the unique opportunity to capture a third repeat in a series of 20 repeat photographs sourced from UCT's Plant Conservation Unit's photographic data base. The locations of the 20 sites are provided in Figure 4 below. The original photographs date back to the period ranging from 1919 to 1959, and were repeated during 1993. The third repeats, for the purposes of this study, were taken during June 2014. Finding the exact locations of the sites in 2014 was largely assisted by the GPS coordinates and site descriptions provided in the meta-data created in 1993. Each site was photographed using three camera's including a Canon 5D MK II digital camera, a medium format Mamiya 645 film camera which used Ilford FP4 Plus 125 film, and a Minolta X300 film camera which used 35 mm Fujichrome Superia 400 slide film. At the time the photographs were taken additional meta-data was also recorded. Meta-data included the documentation of present land forms, soil types, dominant species, vegetation cover estimations and weather conditions. Major vegetation changes observed between the original photographs and the repeats were also documented within the meta-data. For the purposes of this study the digital photographs were used for analysis and matched to the previous two original photographs using Adobe Photoshop CS 5.

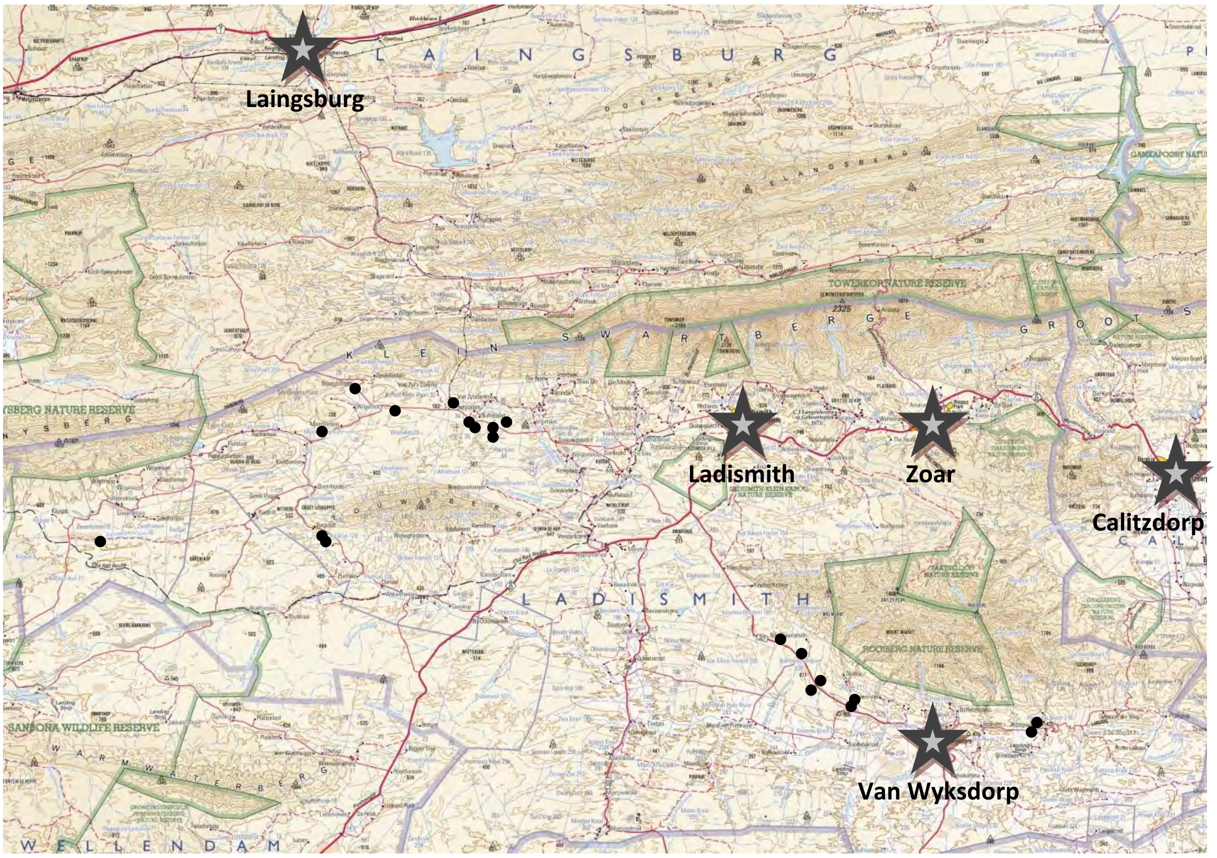

Figure 4 The 20 original photograph sites, represented by black dots, within the study area and the five surrounding towns, represented by stars, Laingsburg in the North, Ladismith in the centre, Zoar to the east of Ladismith, Calitzdorp in the far east and Van Wyksdorp in the South East.

The repeat photograph series with the supporting meta-data was analysed both qualitatively and quantitatively. For the qualitative analysis the observed characteristics of the site were firstly explored including the land form units present, the identified soil types and geology, and the vegetation composition and cover. The major change between the original and the two repeat photographs were then analysed and extended photograph captions developed for each site, see Appendix 2.

The change in vegetation cover was then quantitatively analyzed within two time periods. The first was between the original photograph and the 1993 repeat and the second between the 1993 and the 2014 repeats. Each photograph was divided into three land forms namely slopes, plains and rivers. Some sites included all three land forms whilst in others only one or two were present. The change in cover of three growth forms namely trees, shrubs and grasses within each land form and within each time period was then visually estimated independently by three professionals. The change in cover was estimated using a five point scale where -2 indicated a 25% to 50% loss in cover; -1 indicated a 5% to 24% loss in cover; 0 indicated a range between 5% loss and 5% increase in cover; 1 indicated a 5% to 24% increase in cover; and 2 indicated a 25% to 50% increase in cover (Nyssen et al, 2009). For both time periods cover change values of each growth form within each land form were then averaged, along with the average of the combined total cover of all growth forms within each land form, and placed within a summary cover table for overall vegetation cover analysis.

Statistical analysis of the change in vegetation cover was also conducted using both ordinal logistics and pairwise comparisons. The ordered index of vegetation cover change was the dependent variable and the predictor variables including time, land form and growth form. All possible two way and three way interactions were tested and all tests were run in SPSS version 22.

3.3.2. Climate data

Historical annual rainfall and temperature (mean maximum and minimum) data was obtained from the Agricultural Research Council (ARC). Based on their location within the study area and the length of their climate record, three stations were selected for analysis: Ladismith, Hoeko, and Van Wyksdorp. The earliest records were from 1900 for the Ladismith weather station. Rainfall and temperature data was analysed separately.

Trends in annual rainfall amounts for both Ladismith and Van Wyksdorp weather stations were tested using ANOVA regression statistics. Similarly, trends in annual mean maximum and minimum temperatures for Hoeko weather station, which provided the longest historical temperature record, were tested using ANOVA regression statistics.

3.3.3. Agricultural data

Agricultural census data from the agricultural 'Blue Books', were obtained from UCT's Plant Conservation Unit's archives (www.pcu.ac.uct). The 'Blue Books' contain information on cropping and livestock production from 1911 to 1983. Data for the magisterial districts of Ladismith and Calitzdorp, which overlap exactly with the present-day Kannaland Municipality boundaries, were analysed. Recent data for Kannaland were obtained from the Western Cape Department of Agriculture. Trends in hectares cultivated for grain crops and lucerne from 1911 to 2013 were analysed. Similarly, changes in the number of goats, sheep and cattle within the Kannaland Municipality between 1911 to 2013 were calculated. Ostrich stocking rates were excluded from this study as very little ostrich production occurs in the study area.

3.3.4. Semi-structured interviews

Simonesen et al (2014) acknowledge that in order to understand a SES it is crucial to gain an understanding of how the actors within the system think in order to interpret their actions. In-depth, semi-structured interviews were conducted with different categories of key informants namely farmers, farm workers, non-farming land owners, government officials and/or knowledgeable informants. Government officials included participants from Cape Nature and the Western Cape Department of Agriculture. Knowledgeable informants included botanists, rangeland ecologists and agriculturalists. The interviews were conducted to gain qualitative context on the perceptions and personal accounts of change in natural vegetation and land use in the Klein Karoo in general and the Kannaland Municipality in particular. The meaning of the change experienced by each participant was also explored along with participant's predictions for the future.

At the end of each interview participants were shown the series of 20 repeat ground photographs. During this time the correlation between what their perceptions of vegetation change were and the evidence of change within the repeat photography was discussed. Interviews with farmers and non-farming land owners were supplemented with walks or drives around participant's properties. During this time interview questions relating to natural vegetation change were explored with reference to the physical surroundings.

Participants were initially identified through contact details given by the local Kannaland Municipality office in Ladismith related to the Erf numbers in close proximity to the repeat ground photography sites. In addition to this, a local agricultural extension officer in Ladismith and a knowledgeable informant from the Department of Agriculture's research farm in Worcester were also contacted. The initial participants identified subsequent potential interviewees resulting in a total of 31 semi-structured interviews. Of the 31 interviews 15 were conducted with farmers, 10 with government officials and/or knowledgeable informants, three with non-farming land owners and three with farm workers.

The in-depth semi-structured approach of the interviews permitted flexibility to focus more specifically on issues which individual participants attributed more importance. The open-ended nature of semi-structured interviews allowed for potential issues not previously identified by the study to be explored in the interviews. Four basic interview structures were developed for the four categories of participants. Although all followed the same thematic structure they included varying prompts related to the participant categories. All interviews were recorded, transcribed and supplemented with written notes. The duration of each interview ranged from 30 minutes to over three hours. The interviews were analysed qualitatively and responses were categorized according to the change they related to, either social, economic, political, environmental or land use.

Ethical clearance for this study was received from UCT's Faculty of Science's Research Ethics Committee (Approval code: FSREC 054-2014). All interviewees were contacted prior to the interviews either telephonically, via email or post to determine their willingness to participate. During this time full disclosure about the research aim, objectives, methodology and interview procedure were explained as well as the description of the interviewer and their background. Before the commencement of each interview a consent form was signed by each interviewee confirming their willingness to participate, their understanding of the study's aim and procedure, and their guarantee of anonymity within the study. Participants were free to withdraw from the interview at any stage but none chose to do so.

CHAPTER 4: Environmental drivers of land degradation and land use change

4.1. Change in vegetation cover as reflected in repeat ground photography

Appendix 1 provides detailed extended captions on each repeat photographic series. A descriptive summary of the main changes is provided in Table 1. The first time step covered the period between the original photograph and the 1993 repeat. The second time step covered the period 1993-2014. Changes in total vegetation cover as well as the cover of trees, grasses and shrubs are shown within four land form units, namely rivers, plains, slopes and 'other' (quartz patches and heuweltjies). Analysis of the 20 sets of repeat ground photographic series indicated a significant increase in vegetation cover within the study area across the two time periods (df = 19; χ^2 =64.12; $p < 0.01$) (Table 2).

Table 1 Mean index of change (+stdev) in total vegetation and growth form (trees, shrubs, grasses) cover between two time periods (original-1993 and 1993-2014) within four land form units (rivers, plains, slopes and 'other') in the Ladismith Karoo. N indicates the number of site comparisons available. Blank values indicate the absence of the particular growth form within the relevant land form unit during the given time period.

LAND FORM	GROWTH FORM							
	N	Trees	N	Shrubs	N	Grasses	N	Total
Rivers								
Original-1993	9	**0.2** (1.3)	7	**0.43** (0.98)			10	**0.4** (1.26)
1993-2014	9	**1.1** (0.8)	7	**0.43** (0.98)	3	**1.33** (0.58)	10	**1.1** (0.74)
Plains								
Original-1993	7	**-0.4** (1.1)	16	**0.81** (1.05)	1	**1** (0)	17	**0.65** (0.93)
1993-2014	7	**0.7** (0.5)	16	**0.5** (0.52)	9	**1.33** (0.5)	17	**0.82** (0.53)
Slopes								
Original-1993	15	**-0.1** (0.6)	14	**0.86** (0.53)			15	**0.6** (0.63)
1993-2014	15	**0.1** (0.4)	14	**0.5** (0.65)	3	**1** (0)	15	**0.6** (0.63)
Other								
Original-1993			5	**1.2** (0.84)			5	**1.2** (0.84)
1993-2014			5	**0.8** (0.84)	4	**1.25** (0.5)	5	**1** (0.71)

Table 2 Statistical result of Wald Chi-square analysis of index of change in total vegetation and growth form (trees, shrubs, grasses) cover over two time periods (original-1993 and 1993-2014) within four land form units (rivers, plains, slopes and 'other') in the Ladismith karoo.

Factors	df	Wald Chi-Square	Sig
Time	1	4.66	0.031
Growth form	2	9.83	0.007
Land form	3	2.59	0.459
Time*Growth form	2	16.52	0.001
Time*Land form	3	3.28	0.351
Growth form*Land form	5	10.77	0.056
Time*Growth form*Land form	3	3.17	0.367

The three growth forms, namely trees, shrubs and grasses, also showed a significant change in cover as did the interaction between time period and growth form. There was no significant difference in the index of vegetation change between land forms. The interaction between growth form and land form as well as the interaction between time*growth form*land form was not significant (Table 2).

Tree cover initially declined over the first time period but increased significantly between 1993 and 2014 (Figure 5), especially in the major river courses in the study area. Most of the increase in tree cover within the river courses of the study area can be attributed to the expansion of *Acacia karroo* which is dominant and widespread in the region (Figure 6).

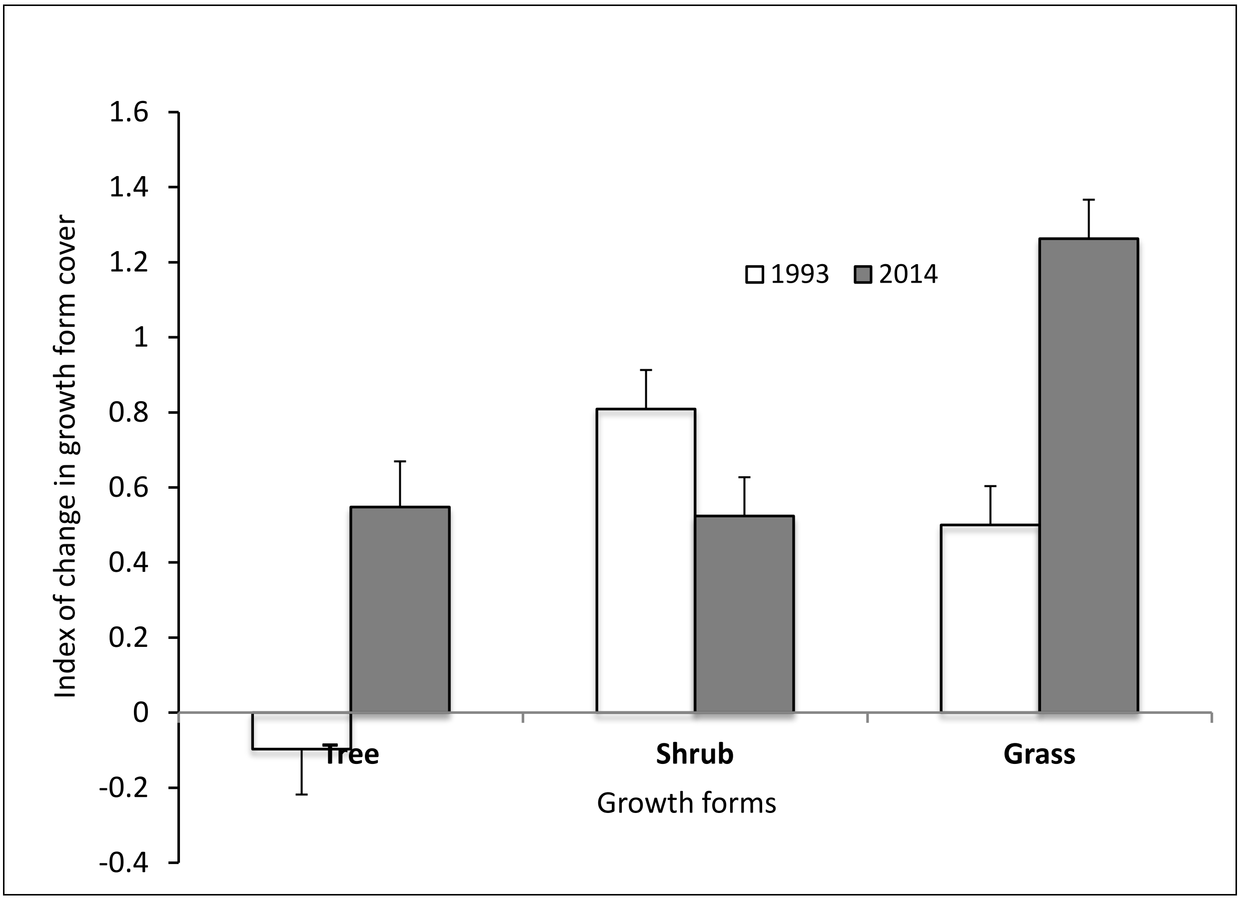

Figure 5 Mean change (+standard error) in cover of trees, shrubs and grasses at 20 locations in the Kannaland Municipality over two time steps (original to 1993 and 1993 to 2014) as determined from an analysis of repeat photographs.

Figure 6 Buffelsvlei_4, Klein Karoo, South Africa.
This view looking north toward the Klein Swartberg shows a riverbed running from the left foreground to the centre mid-ground. Significant increase in tree cover within the river course is evident in the most recent photograph (C), which is now dominated by *Acacia karroo*. Other species in the main river channel include *Schotia afra* and *Euclea undulata,* while *Lycium oxycarpum* occurs primarily on the banks of the ephemeral river.
(A) 1959 J.P.H. Acocks; (B) 1993 M.T. Hoffman; (C) 2014 M.T. Hoffman & A.L. Murray.

Tree cover also declined on the plains and slopes within the first time period. However, between 1993-2014 the cover of trees (e.g. *Pappea capensis* and *Euclea undulata*) appears to have increased within these land forms as well. Distinctive browse lines are evident in the original photographs. By 2014, however, most of the trees exhibited distinctive ‘skirts’ around their bases suggesting that little browsing had occurred in the area in the decades prior to the 2014 photographs (Figure 7).

Figure 7 Witvlakte, Klein Karoo, South Africa
This view looking south across a wide valley, with the Touwsberg in the background, shows a number of tree species on the drainage line running along the centre of the mid-ground. Tree species are dominated by palatable *Pappea capensis* and *Euclea undulata*. An increase in biomass of individual trees in more recent years is evident from the wider canopies and absence of a browse line around the bases of most individuals in photographs (B) and especially (C).
(A) 1937 M. Levyns; (B) 1993 M.T. Hoffman; (C) 2014 M.T. Hoffman & A.L. Murray.

Shrub cover increased in both time periods although to a lesser degree between 1993-2014 (Table 1). The dominant shrub species in the region include *Pteronia pallens*, *Pentzia incana*, *Eriocephalus ericoides*, *Galenia africana*, *Ruschia cymosa* and *Crassula* spp. Comparison with the original photographs suggest that individual shrubs have increased in both height and number over time. This is particularly evident on the exposed quartz patches in the study area where individual shrubs have 'colonized' environments that were previously dominated by dwarf succulent shrubs such as *Gibbaeum shandii* (Figure 8).

Figure 8 Zewenfontein, Klein Karoo, South Africa.
This view looking south shows an east-west trending valley bounded by shale ridges. The mid and foreground is comprised of a complex mix of exposed bedrock in places with sand and extensive quartz patches. Increased shrub cover, dominated by the unpalatable Karoo shrub *Pteronia pallens*, within the mid and foreground is evident in both time periods as seen in photographs (B) and (C).
(A) 1922 I.B. Pole-Evans; (B) 1993 M.T. Hoffman; (C) 2014 M.T. Hoffman & A.L. Murray.

Grass cover is a relatively ephemeral component of the vegetation and was absent from the river courses and slopes in the original -1993 photographic comparisons. Species such as *Cenchrus ciliaris*, *Fingerhuthia africana* and *Digitaria eriantha* were the dominant grasses in the region and were first observed in 2014 in many of the photographs and in the field (Figure 9).

Figure 9 Poortjies, Klein Karoo, South Africa.
This view looking northwest shows a flat plain in the foreground within which an increase in shrub cover is evident between 1959-1993 (B) and an increase in grass cover is evident in the most recent photograph (C).
(A) 1959 I.B. Pole-Evans; (B) 1993 M.T. Hoffman; (C) 2014 M.T. Hoffman & A.L. Murray.

4.2. Perceptions of vegetation degradation

Summary of opinions raised relating to natural vegetation change within the Klein Karoo:
There has been a general increase in vegetation cover. ➢ The rate of vegetation recovery was perceived to be slow. ➢ The veld had improved due to better veld management and the general demise of livestock farming in the region. ➢ Very few farmers were still over grazing their veld and practising poor veld management. ➢ Erosion had declined with improved vegetation cover.
The number of people living on individual farms and utilizing the natural vegetation for their livelihoods declined significantly from the 1950s. ➢ Government schemes introduced in the mid- 20th century played a significant role in reducing stock numbers and improving rangeland management practices in the region.

Most Interviewees indicated that the natural vegetation in the study area had improved in the time that they had known or lived in the area. *"I think the broad general trend if you are saying now within the last 100 years the vegetation definitely improved, I don't have any doubt whatsoever… The main impact on this veld was probably from 1920 probably to 1950 that has been the big impact. And if you look at the veld now compared to what it was like then I think it has improved"* (Respondent 10, knowledgeable informant, 9 January 2015, Oudtshoorn). It was acknowledged, however, that the rate of improvement within the natural vegetation of the Klein Karoo is a slow process. *"The Karoo once it's scarred is just so slow at recovery"* (Respondent 5, farmer, 3 December 2014, Van Wyksdorp). It was further reported that the rate of erosion in the study area had decreased due to the improvement of vegetation. Erosion has *"gradually decreased which is nice to see… recovery has been natural so in other words we have relied on vegetation to do the work"* (Respondent 13, non-farming land owner, 14 January 2015, Van Wyksdorp).

Land use was considered to be the dominant driver of natural vegetation change. *"In the last 100 years a huge amount of degradation happened through unsustainable farming practices and chemical use and just bad grazing, bad management, by most of the farmers, not all of them"* (Respondent 16, farmer, 15 January 2015, Van Wyksdorp). Respondents were largely of the opinion that current land users are more aware of the state of the veld and the value of its management and conservation to maximize current and future productivity. *"I would say that in the past 30 years [the natural vegetation] has not become more degraded, it [has] bec[o]me better [from] good management and better practices, and knowledge"* (Respondent 18, farmer, 3 February 2015, Oudtshoorn). This, along with the drastic decline in stock farming within the study area, was considered the reason for the recent improvement of the veld. *"The [natural] vegetation [has shown] improvement because most of the livestock [has been] taken off the land"* (Respondent 7, farmer, 10 December 2014, Van Wyksdorp). It was however highlighted that on some farms there are still bad land management practices where vegetation has continued to degrade, although these are few and far between. *"There are one or two farmers that we know that are not playing the game, in fact there are two, but the rest of the guys have really made an effort to improve the veld condition"* (Respondent 5, farmer, 3 December 2014, Van Wyksdorp).

The history of land use was repeatedly referred to. Most respondents looked back to the 1950s as the period when over stocking and bad veld management were at their zenith. After this time there was growing realization of veld degradation by farmers which encouraged the increased use of fencing and the change to rotational grazing methods. This meant that farmers no longer required as much labour to manage their herds. As a result, the number of herders and 'bywoners' (described as additional families living and working on farms for the remuneration allowance who were also permitted to own livestock and grow their own crops on the land) declined on most of the farms in the region. This period also saw increased intervention from the Department of Agriculture through the Drought Relief Scheme and the Stock Reduction Scheme amongst others. These interventions contributed to a reduction in stock numbers and better veld management practices. *"At one stage you had… 'bywoners', someone who is also living on the farm…[with] his whole family… so what happened then is there were too many people on the farm and there were too many animals on the farm and due to lack of knowledge the veld was overgrazed I think up to the 50s. And then after the 50s in came the fences… so then you didn't need the shepherd and you didn't need all that lot of people so then those people went off the farm. Then [around] the 70s [government] br[ought] in a system called the Stock Reduction Scheme, 'veer ontrekking skema' [where they] said to the farmer… if your farm can carry x amount of animals we want you to deduct a third of the animals and we will pay you a financial income for that third"* (Respondent 3, knowledgeable informant, 28 November 2014, Laingsburg).

4.3. Climate change

Summary of opinions raised relating to the climate within the Klein Karoo:
There has been little change in the amount of annual rainfall. ➢ An increase in the intensity of rainfall events was observed. ➢ There has been a shift (of 2-3 months) in rainfall seasonality such that rain falls later in the year and after the main winter rainfall period. ➢ Decadal drought cycles were observed where the first years within a decade (e.g. 2011-

2015) are characterized by good rain which then begins to drop around the sixth year and ends in a drought toward the end of a decade. The drought is suggested to be broken often with a flood in the ninth, tenth or first year. ➢ 30 year drought cycles were also observed with extreme droughts lasting up to four or five years.
There has been a general increase in temperatures.

4.3.1. Rainfall

No significant changes in annual rainfall amounts were reported in the interviews or recorded from weather stations in Ladismith and Van Wyksdorp from 1900 to 2014 (Figure 10). The years of highest rainfall recorded within this time period were during 1917 and 1981 with 553.3 and 553 mm of rain respectively. Both of these measurements were from the Ladismith weather station. The lowest recording for Ladismith was in 1978 when only 138 mm of rain was recorded. The lowest annual rainfall total for Van Wyksdorp was 107.5 mm which was recorded in 2010. The longest consecutive period of high rainfall was from 1904 to 1914 with an average annual rainfall of 399 mm. The longest consecutive low rainfall was between 1922 and 1953 with an average annual rainfall of 282.57 mm. Ladismith with a coefficient of variation (CV) of 27.9% and Van Wyksdorp with a CV of 32.0% rainfall is characterized as being variable from year to year.

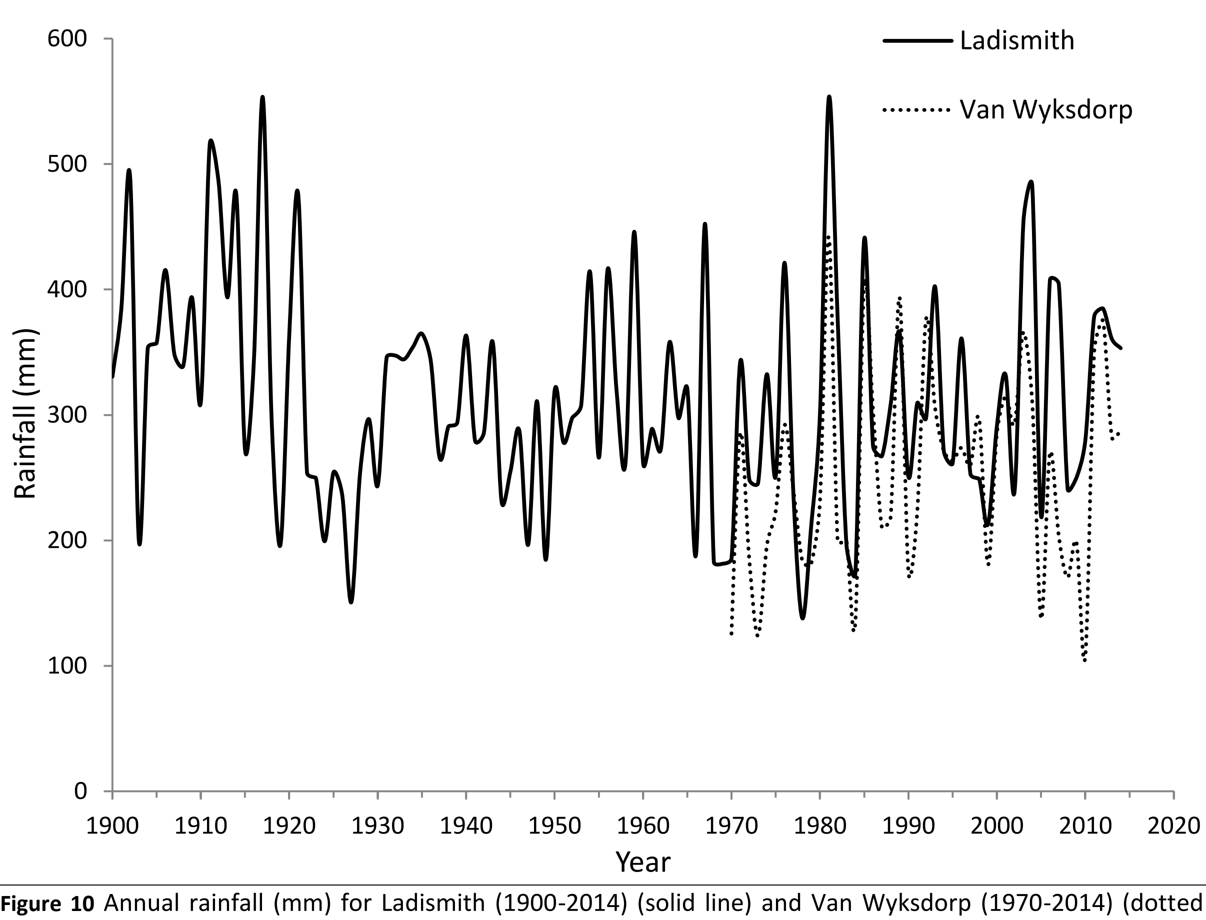

Figure 10 Annual rainfall (mm) for Ladismith (1900-2014) (solid line) and Van Wyksdorp (1970-2014) (dotted line). (Data supplied courtesy of the Agricultural Research Council).

Respondents repeatedly suggested that annual rainfall amounts had remained relatively stable throughout the time they had known or lived in the area, supporting the annual rainfall data. A common assertion, however, was that rainfall had become less consistent with increased intensity of rainfall incidents. *"Our weather pattern is more erratic"* (Respondent 24, farmer, 6 February 2015, Ladismith). *"You get much more dramatic rain so bigger floods, rain in very small short spaces of time"* (Respondent 4, non-farming land owner, 29 November 2014, Ladismith). *"You still get more or less the same [rainfall amount] in a 12 month period but it's 5 mm, 2 mm, 10 mm and then you get an exception where there is 25 or 30 mm… you don't get a good dispersal of rain"* (Respondent 22, farmer, 4 February 2015, Hoeko).

Seasonality shifts in rainfall were also reported with respondents suggesting that the rainy season is coming later on in the year. *"We don't get rain June, August, September we only get rain October, November, December, it moved on totally"* (Respondent 2, government official, 27 November 2014, Ladismith). Interviewees were of the opinion that in recent years there had been an increase in summer rainfall with a decrease in winter rainfall. In the last 30 years there has *"not [been] less rainfall but it seems like less definitely winter rainfall and more summer rainfall"* (Respondent 18, farmer, 3 February 2015, Oudtshoorn).

A number of interviewees further reported cyclical patterns of dry and wet periods. They were of the opinion that there are decadal and 30 year cycles of dry and wet periods. *"Each decade the first three years [are] heavy rainfall years then you got the fourth and the fifth with good rainfall and then usually from the sixth year, that's 1906, 1916, 1926, 1936 … the rainfall starts dropping off until the ninth, tenth year, that is a 10 year cycle. Usually at the tenth year or the first year, for example… 1979, 1980 w[ere] drought stricken year[s] and 1981 was the flood… Then you also have a 30 year cycle, and in the period 1935 to 1939 it was an extreme drought time…Then the second one was from 1965 to 1969/70 that period, extreme drought again, that was 30 years later. Then I realized from 1996 till 2000 was also extremely dry. So there is a 10 year or decade cycle and then there is a three decade cycle"* (Respondent 7, farmer, 10 December 2014, Van Wyksdorp). While quasi rainfall cycles have been suggested for both the winter and summer rainfall regions of South Africa (Tyson, 1986; Malherbe et al, 2014) a more detailed time series analysis is necessary to confirm these patterns in the study area.

4.3.2. Temperature

There has been a significant increase ($Y = 0.0243x - 24.497$; $N = 34$; $p < 0.016$) in mean annual maximum temperature for the period 1980-2013 from the Hoeko weather station (just outside of Ladismith) (Figure 11). No significant change in mean annual minimum temperature has been recorded for this period. 1999 recorded both the highest mean annual maximum and minimum temperatures which were 25.5°C and 12.3°C respectively. The lowest mean annual maximum and minimum temperatures within this time frame were recorded in 1981 and 1982 respectively and measured as 22.5°C and 10.4°C. Responses from interviewees reflected these findings where many respondents reported increases in temperature since the time they have known or lived in the area. *"We can see the temperature is definitely changing… it is definitely rising"* (Respondent 6, farmer, 4 December 2014, Ladismith). Farmers interviewed suggested that crop yields are altered by temperature changes seen in fruit size and flavour intensity, for example *"colder temperatures at night giv[es grapes] more flavour"* (Responsent 6, farmer, 4 December 2014, ladismith). It was also suggested that weeds are more of a problem for farmers with rising temperatures due to the lack of frost in winter known to kill off weeds. *"You have to spray more to get rid of them and you can see they are getting more resistant"* due to the lack of cold winters (Respondent 6, farmer, 4 December 2014, Ladismith).

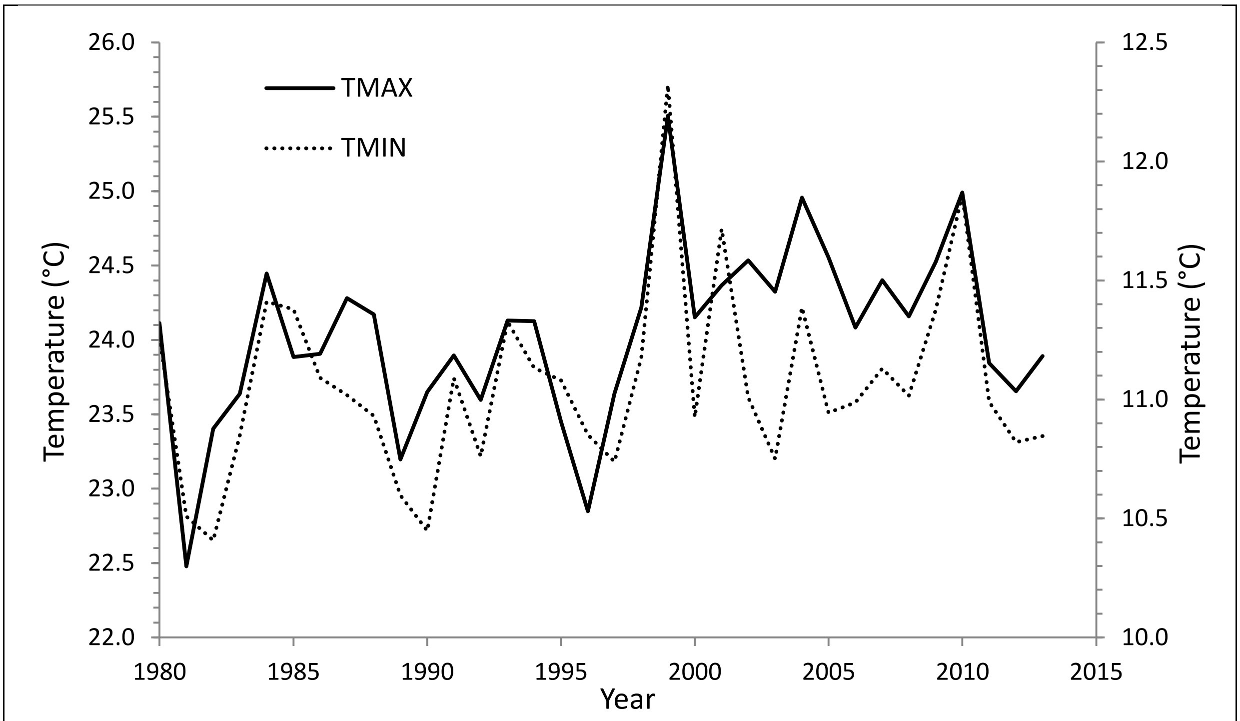

Figure 11 Mean annual maximum (solid line) and minimum (dotted line) temperatures (°C) for the Hoeko weather station, located just outside of Ladismith, for the period 1980-2013. (Data supplied courtesy of the Agricultural Research Council).

4.4. Predators

Summary of opinions raised relating to predators within the Klein Karoo:
Increased loss of livestock loss due to predators had necessitated a return to the old 'kraaling system' of stock management. ➢ Both political and land use related factors were responsible for increased livestock losses due to predators.

Increasing livestock loss due to predators is perceived to be threatening recent improvements in veld management and the use of multi-camp grazing systems. Rotational grazing entails the movement of livestock between camps in a rotational manner ensuring that each camp has the opportunity to rest for a full year in order to build up its seed bank and allow plants time to grow. A number of interviewees brought up this issue which has reportedly encouraged farmers to revert back to the old 'kraal system' where animals are brought back to the farm house at night in order to protect them from predators. This is believed to have had a negative effect on the veld, especially around the house, as the daily pathways used to move the animals are continually grazed and trampled. The camps furthest from the house are also underutilized due to their distance. *"In the last 15 years there is just suddenly an explosion of jackal… [and] farming practices are changing due to the jackal…farmers [are] going back like to predecessor farming practices, around the house with lambs… and what is going to happen, same as before [the 19]70s when camp system was created, around house will be over grazed and further veld not grazed at all"* (Respondent 1, government official, 26 November 2014, Worcester).

Although livestock loss due to predators is not a new occurrence it was suggested that it has been on the increase since the mid to late 1990s. Respondents provided several reasons for why predators may have increased. Some of these reasons related to political change and others to changes in land use practices. *"Since [19]94 a lot of the management systems for predators have been taken away… there was like a 'jackals club' and it was sort of partially subsidized by the government and there was a 'rooikat club', and these clubs were good hey, if they saw a rooikat the farmer would phone them [and] they would get on a spoor and they would catch it"* (Respondent 17, government official, 27 January 2015, Stellenbosch). *"The [current] law says you may not shoot [the jackal but] previously they eradicated the jackal, they said they were pests, today it is seen as pretty for the tourist. So the farmer that still farms with sheep must put them [the sheep] away in a 'kraal' every night and let them out every day"* (Respondent 24, farmer, 6 February 2015, Ladismith). It was also suggested that the removal of subsidies for fencing and the high cost of fence maintenance resulted in the deterioration of jackal proof fencing and thus an increase in predator access into camps. *"In the [19]70s… there was jackal proof fencing around the farms being subsidized and it hasn't been maintained… the farmers are trying to maintain it but it is costing [too much] money"* (Respondent 1, government official, 26 November 2014, Worcester).

The increase in game farming and the decrease in livestock farming, both later discussed in more detail, are land use practices that are perceived to have contributed to the rise in livestock loss due to predators. It was suggested that the increase in impenetrable game fences has reduced the territory in which predators are able to roam causing an increase in local populations. *"What happens with the game farm the fence is two metres [high, so] nothing can come in [and] nothing can come out"* (Respondent 1, government official, 26 November 2014, Worcester). It was also suggested that because sheep are easier prey for predators than game they were more often targeted. *"It's much easier [for a jackal] to catch a lamb than a wild buck"* (Respondent 24, farmer, 6 February 2015, Ladismith). The decrease in livestock farmers was further perceived to have reduced the numbers of prey (livestock) for the growing predator populations as well as resulting in fewer farmers controlling predator numbers. *"What the farmers will tell you [is in the past] say there were 10 [small stock] farms and now five of them have been sold to non-agricultural type of land owners or land use, [so] now there's five farms, now the neighbours aren't controlling predators like they did in the past, so the predator challenge increases"* (Respondent 12, government official, 12 January 2015, Oudtshoorn).

Some solutions to this problem were suggested: first, it was proposed that game fences could allow movement of smaller wild fauna, *"one example is to take a tyre, an old car tyre, and fence that in leaving the hole"* (Respondent 12, government official, 12 January 2015, Oudtshoorn) where animals are able to pass through. Second, Anatolian shepherd dogs were used by a number of farmers interviewed in this study to protect livestock herds. There were contradicting views, however, about the use of Anatolian shepherd dogs. It was suggested by some that they are *"non-selective… they'll keep the sheep safe but they'll kill all sorts of other things from hares to 'bokkies' (buck) to jackals to whatever,"* (Respondent 12, government official, 12 January 2015, Oudtshoorn) which from a conservation perspective is not ideal. Another farmer, however, suggested that *"it depends on how aggressive the dog is"* (Respondent 31, farmer, 12 February 2015, Ladismith) which he suggested was not something you could train. Instead, it depended on the nature of the dog. The change of livestock management to the old 'kraal system' because of increased livestock loss due to predators is of concern for this study. It is therefore vital that an alternative solution to the problem be found.

4.5. Conclusion

The photographic data and responses from interviewees both indicate a growth in natural vegetation cover in the study area, which is particularly evident between 1993 and 2014. Time and growth form, as well as their interaction, were found to be statistically significant factors of vegetation cover change. Although, tree cover declined in the first time period it increased significantly between 1993 and 2014. Of all the growth forms, shrub cover had the most consistent increase over both time periods. Within many of the photographed sites grass cover was first observed in 2014. Interview respondents consistently reported a general increase in natural vegetation cover over the time they had known or lived in the study area. This increase in cover was suggested to be of a slow nature and was attributed to a general improvement in veld management practices and the general demise in extensive agriculture within the study area. Little change in annual rainfall amounts was recorded from the period between 1900 and 2014. A significant increase in mean annual maximum temperature was observed from the period between 1980 and 2013, and which was particularly evident from the late 1990's to 2010. Increased livestock losses due to predators were commonly reported in the interviews, and were particularly evident since the mid 1990s. This was attributed to both political and land use related changes.

CHAPTER 5: Political, economic and social drivers of land degradation and land use change

5.1 Land use change

Summary of opinions raised relating to land use change within the Klein Karoo:
There has been a major decrease in extensive agriculture.
There has been a decrease in the number of intensive agricultural farmers. ➢ The amount of land under cultivation is perceived to have remained relatively consistent.

Land use, specifically relating to agriculture, has undergone dramatic shifts in trends and intensity over the last 100 years. The agricultural data as well as the majority of interviews conducted point toward a declining trend in agriculture in the Klein Karoo. Many of the interviewees were of the opinion that the extent of livestock farming is declining at a far greater rate than that of cultivated lands. *"Our secretary showed me documents [from the early 1990s] of a farmer's day they held here, there was about 30 small stock farmers in this area and now at this moment there are only about five or six"* (Respondent 2, government official, 27 November 2014, Ladismith). It was suggested, however, that the amount of land under cultivation has not changed a great deal although the crop types have varied and the number of farmers involved in this cultivation has decreased. *"If you compare [the present] to about 20 or 25 years ago you still have the same amount of [cultivated] land but in terms of number of farmers there's probably about a quarter left"* (Respondent 23, farmer, 5 February 2015, Ladismith).

Figures 12 and 13 below show the hectares cultivated of grain crops and lucerne from 1911 to the most recent agricultural census in 2013. It is evident that grain crops have declined relatively steadily during this time, with three distinct peaks in hectares cultivated after both world wars and one smaller peak during the 1970s. From 1980 to the present, grain crop cultivation has virtually stopped. Lucerne cultivation appears to have had a more gradual early development with the first distinct peak occurring after the Second World War. Although taking two dips after the Second World War boom in 1950 and in the early 1970s, lucerne production has maintained a relative growth up until 1980 when another decline was recorded. From 1980 to the latest 2013 census there has been a gradual decline in lucerne cultivation. Lucerne, however, remains the dominant cultivated crop within the study area, as indicated in Table 3 below.

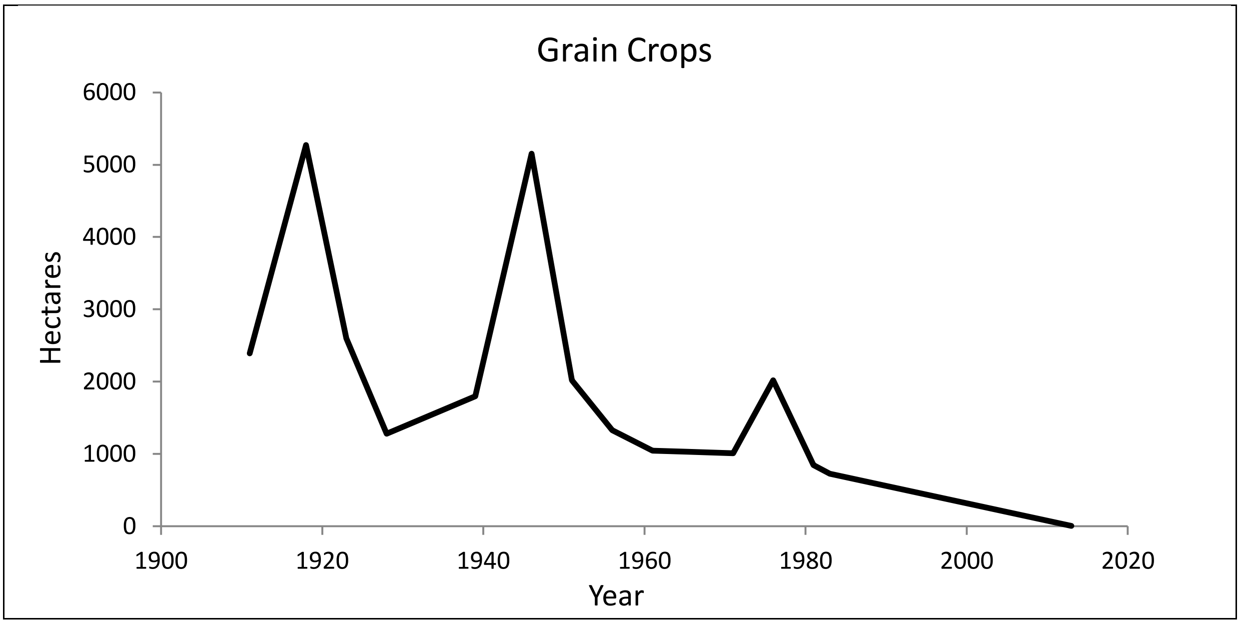

Figure 12 Grain crops (barley, oats, rye, wheat and maize) cultivation (ha) in the Kannaland Municipality from 1911 to 2013 (www.pcu.uct.ac.za; South African Department of Agriculture, Elsenburg).

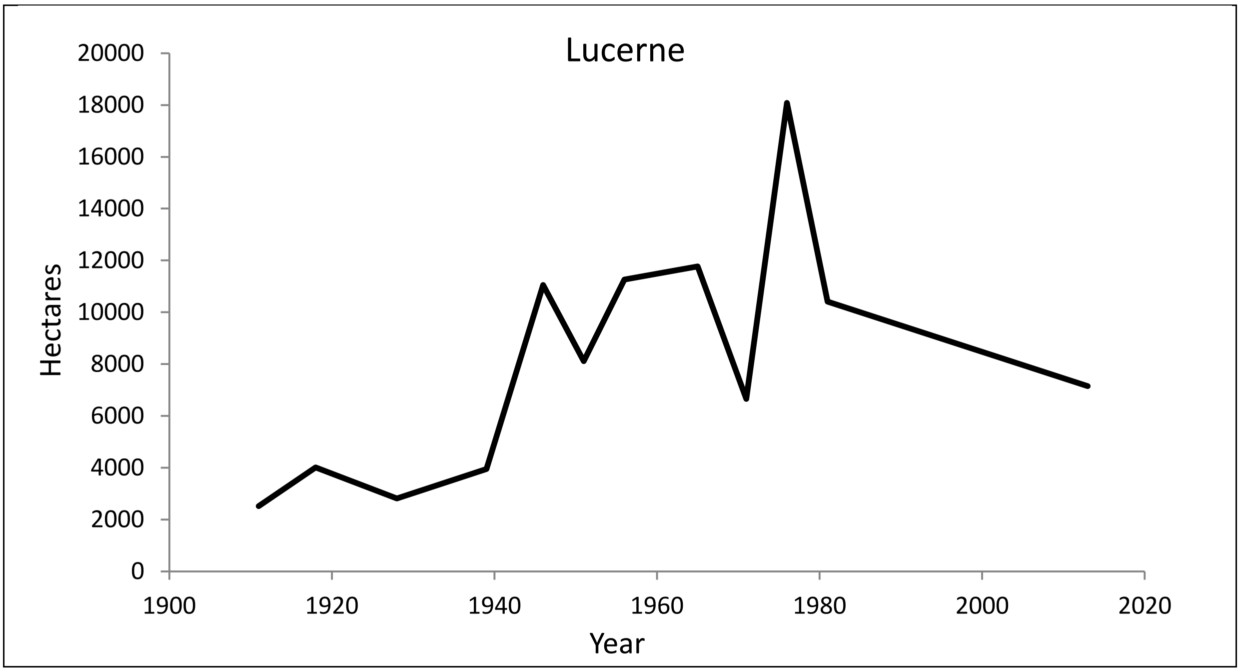

Figure 13 Lucerne cultivation (ha) in the Kannaland Municipality from 1911 to 2013 (www.pcu.uct.ac.za; South African Department of Agriculture, Elsenburg).

Table 3 Top 10 cultivated crops for the Kannaland Municipality in 2013 (South African Department of Agriculture, Elsenburg).

Rank	Area (Ha)	Crop	% of Western Cape
1	7142.7	Lucerne	1.8
2	970.3	Wine Grapes	0.9
3	753.3	Fallow	0.8
4	674.4	Planted Pastures Perennial	0.3
5	643.9	Apricots	20.3
6	556.0	Natural grazing	0.5
7	350.5	Onions	7.4
8	300.8	Small Grain Grazing	0.2
9	296.5	Plums	5.1
10	291.3	Peaches	3.7

Table 3 reflects the 2013 agricultural census data showing the top 10 cultivated crops in the Kannaland Municipality. This table confirms the decline of grain crop cultivation. However, it also suggests that some of the land previously used for grain crop cultivation may now be utilized for other crop types such as wine grapes and stone fruits. This supports perceptions from the interviews claiming that a similar amount of land is still being cultivated despite fewer farmers cultivating a range of alternative crop types. *"Earlier in the 1980s there was double the amount of farmers in this valley then there are today [but] the economic output of the valley has probably doubled in the last 30 years… Farming practices became better and [farmers] started farming products with higher economic value. The ground was always here but it's a case of the strongest will survive"* (Respondent 22, farmer, 4 February 2015, Hoeko).

Figure 14 shows the numbers of cattle, sheep and goat in the Kannaland Municipality from 1911 to 2013. Cattle appear to have maintained relatively stable numbers over the past 100 years. Goats on the other hand show the greatest decline. After the two peaks in goat numbers in 1923 and 1930 there appears to be a relatively consistent decline up to 2013, with one smaller rise in 1983. Sheep numbers on the other hand rose fairly steadily from 1911 to the late 1960s declining in the early 1970s, rising again in the late 1970s to decline once again in 1980. Between 1981 and 1995 sheep numbers gradually increased. However, from 1995 to 2013 sheep numbers have declined substantially. Findings from the interviews are in line with agricultural stocking data as current livestock numbers, particularly small stock, are significantly lower than values reported in the early 1900s. *"The stock numbers have definitely dropped radically over the last 20 years"* (Respondent 10, knowledgeable informant, 9 January 2015, Oudtshoorn).

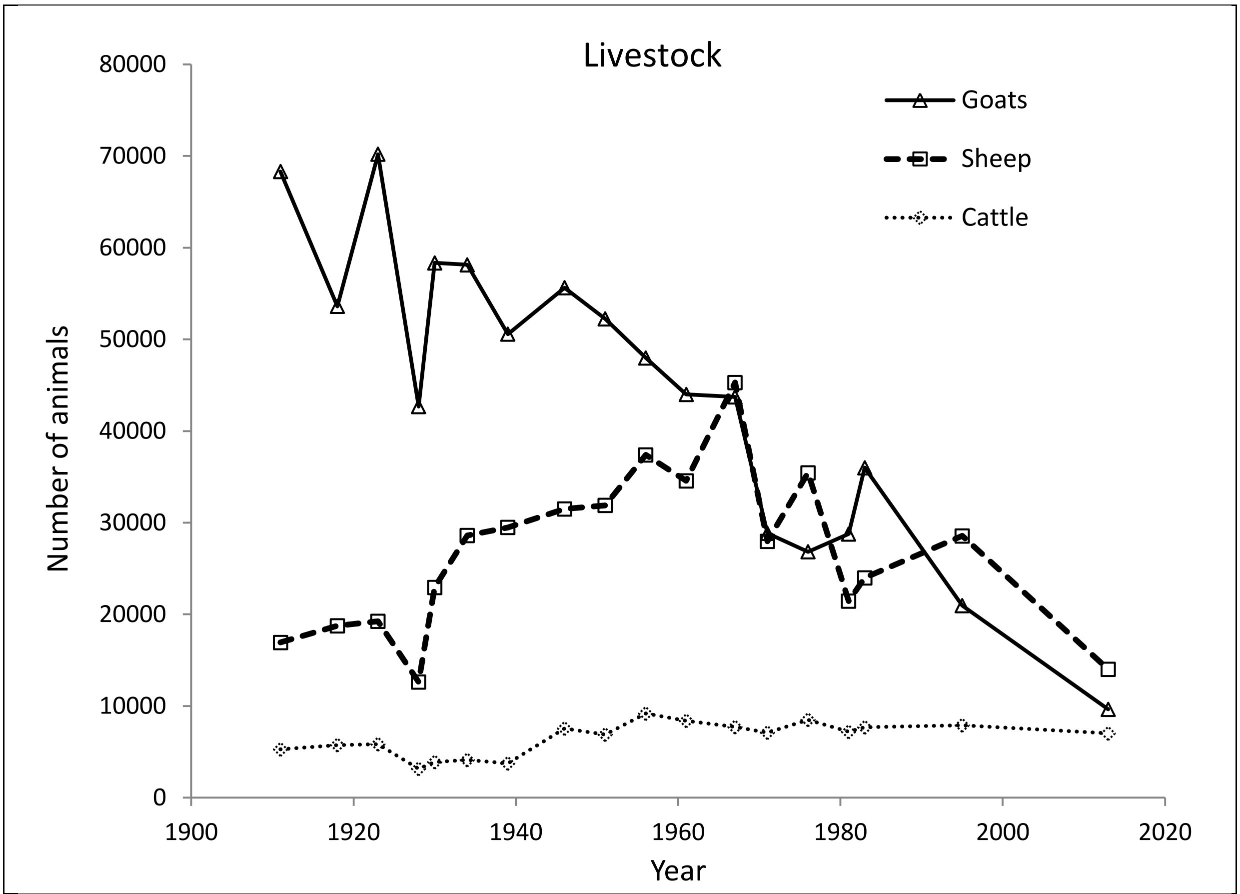

Figure 14 Cattle, sheep and goat livestock numbers in the Kannaland Municipality from 1911 to 2013 (www.pcu.uct.ac.za; South African Department of Agriculture, Elsenburg).

5.2. Political drivers of land use change

Summary of opinions raised relating to political drivers within the Klein Karoo:
There has been a reduction in support to commercial farmers, particularly financial support, since the mid 1990s. ➢ There was reported to be minimal disaster relief support from government largely attributed to bureaucratic complications. ➢ Disparity between local and international access to subsidies was reported to cause difficulty in global competitiveness for commercial farmers.
Raised minimum wage rates were reported to have reduced agricultural labour employment.
There has been a decrease in the capacity and extent of extension services and support.

5.2.1. Legislation

As mentioned in earlier, there are a number of legislative changes which have had a specific influence on land use in the study area. Table 4 lists relevant legislation for land use and agriculture and their implications. Respondents recognized the Conservation of Agricultural Resources Act 43 of 1983 (CARA) as the basis for technical, financial and advisory support to farmers. This support was suggested to have increased the productivity of farms and the standard of veld management as it controlled the utilization of natural agricultural resources. Although financial support is currently no longer as readily available to all farmers, particularly commercial farmers, as when CARA was first introduced, technical and advisory support have remained available to all. The *"Conservation of Agricultural Resources Act 43 of 1983 [provides] regulations that we help with farm planning and so forth… and structures, and fencing, roads, stock [management], watering, drainage, protection works, all that. We give advice and we used to subsidize, but we don't do that anymore [besides] certain farmers but not on this scheme"* (Respondent 17, government official, 27 January 2015, Stellenbosch).

Table 4 Relevant legislation promulgated between 1913 and 1997 and its implications for land use practices within the study area.

Act	Implication
Fencing Act 17 of 1912 with amendment 11 of 1922	Required the fencing of all farm unit boundaries officially segregating land into privately owned units. The amendment to this act further required that all fences be vermin proof further dissecting the land and preventing the free flow of wildlife.
Native Land Act 27 of 1913	Resulted in racially unequal distribution of land strongly favouring white commercial farmers, and facilitating their dominance of land ownership in the study area.
Marketing Act 26 of 1937	Regulated agricultural produce prices to ensure equivalent rural and urban income, ultimately protecting commercial farmers.
Marketing Act 59 of 1968	Replaced the previous 1937 Marketing Act with a largely similar focus of controlling agricultural produce price stability.
Subdivision of Agricultural Lands Act 70 of 1970	Prevented the subdivision of agricultural land into smaller units.
Conservation of Agricultural Resources Act 43 of 1983	Provided the basis of technical, advisory and financial support to farmers in order to control natural agricultural resources and their utilization.
Marketing of Agricultural Products Act 47 of 1996	Replaced the prior 1968 Marketing Act with the aim to open market access to all producers, particularly previously disadvantaged participants.
Extension of Security Tenure Act 62 of 1997	Extended the rights of dwelling tenants against eviction, particularly protecting farm labour against eviction from labour housing on farms.
Basic Conditions of Employment Act 75 of 1997	Provided basic conditions for employment of labour, particularly pertaining to set minimum wage rates and daily work hours.

The most prominent recent legislative influence raised in relation to farming was the Basic Conditions of Employment Act 75 of 1997, amended as Act 11 of 2002, and the minimum wage it requires. Farmers repeatedly remarked that the increasing cost of labour was making it increasingly difficult to maintain a labour force on farms. *"The shepherd costs more in a year than the profit from the goats"* (Respondent 22, farmer, 4 February 2015, Hoeko). Respondents emphasized that it was not that labour did not deserve the wage increases but rather that the income from farming was not increasing according to the rising wage costs. *"We are struggling to pay the minimum wage… not that they don't deserve it or that they shouldn't get it but the prices we get for [our] product[s]… have not gone up accordingly"* (Respondent 30, farmer, 12 February 2015, Ladismith).

Although the Extension of Security Tenure Act 62 of 1997 (ESTA) was not mentioned in the majority of interviews one respondent was of the opinion that this legislation had not affected labour use and labour relations within the study area. *"It is not a new thing, in my grandfathers time if [a farm labourer] retired he remained in his house until he died, the law did not determine this"* (Respondent 24, farmer, 6 February 2015, Ladismith).

5.2.2. Subsidies and support

Government subsidies and support have also had a major influence on land use and agriculture in the study area. The Drought Relief Scheme of the late 1960s to mid 1970s, for example, was recognized as a central support for agriculture from government at the time. This scheme was initiated around the time of a major drought and the coupled realization of growing land degradation from extensive land use. Farmers were given compensation for reducing their stocking rates in order to restore the veld. Around this time short term subsidies for fencing and water were also introduced which reportedly contributed to the improvement in veld management. *"After the 1960/ 1970s there was also a very big drought and after this the government started with the Drought Relief Scheme [where] farmers were paid per sheep to lower stocking rates. That is when fencing and water subsidies came in for five to seven years… and that is what made big change [for the veld] in the area when stock was fenced and managed"* (Respondent 1, government official, 26 November 2014, Worcester).

As noted earlier, the agricultural sector of South Africa was historically viewed as a key mechanism for building independence and economic growth. Commercial farmers therefore received sufficient financial support for farm maintenance, extension and disaster relief. Respondents remarked that since the new government in 1994 the financial support for commercial farmers, or previously advantaged farmers, had been removed almost completely. *"We are not helping commercial farmers anymore, only for advice but no money and no subsidies, maybe for flood damage and those type of things, maybe get a little bit… And then for the small scale farmers [or previously disadvantaged] we give 100%"* (Respondent 2, government official, 27 November 2014, Ladismith). Respondents noted that due to the unstable nature of the agricultural industry the lack of subsidies had made the industry less viable. In times of lower productivity, due to multiple and compounding factors such as lowered annual rainfall or animal disease, farmers struggle to be economically viable whereas in the past subsidies may have helped in this regard. It was suggested that this has contributed to the demise in the number of farmers in the study area.

A number of farmers noted that subsidies for disaster relief, although technically still available to farmers, are hard to come by. It was suggested that this is due to the bureaucratic nature of the procedure for claiming such relief. *"Last year we had… the second biggest flood after [19]81 [but in terms of subsidies for disaster relief] nothing came* *of it. We still in conversation… but now it's been exactly a year, today or yesterday, and its nothing. The farmers gave a lot of support and input, [government] did a lot of surveys, got construction people out to get a realistic figure of what the damage [was], we had a couple of meetings with disaster management and with [the Department of] Agriculture combined… and there is still emails flying around, conversations going on… but they… work on such a backlog of payouts and the things they have to accommodate before they can get to the farmers so I don't think anything will come from that"* (Respondent 8, farmer, 7 January 2015, Ladismith). Disaster costs were reported to reach exceptional amounts, for example the most recent flood in the study area was estimated to have caused R30 million in damage, costs for which farmers are left to cover. *"A [farmer] gave me an estimate of R21 million [in flood] damage if they have to fix the weirs in the river, the channels, all the soil that was lost… [to] bring back soil, pipes, irrigation systems, establishment of lucerne again… and where [must that farmer get the money from?]"* (Respondent 2, government official, 27 November 2014, Ladismith). Farmers emphasized the shock to their business of such unexpected costs and suggested that this sort of instability reduced any incentive to stay in the industry.

In relation to subsidies commercial farmers further stressed the difficulty they experience in competing in the global market with other countries whose agricultural production is subsidized. It was suggested that market prices for global produce are disproportionately low in terms of the input costs they require, due to these subsidies. *"[In] the export market we are fighting a big fight… but we can't really [compete because] they are getting help, we are not, and if they have a drought or something, somebody is going to help them"* (Respondent 6, farmer, 4 December 2014, Ladismith). Furthermore, the export market places stringent regulatory requirement on farmers resulting in increased administrative and regulatory procedures which add cost to farming production for which there is no support.

Finally, it was reiterated that although advisory support is available to all farmers the extent of this provision has drastically declined. Two reasons for this decline were proposed. First, it was suggested that the level of expertise of the extension officers has declined. This was believed to be due to people entering the profession without a background in the area or in the agricultural field and by the motivation of people entering the field not being driven by their desire to remain there. Respondents speculated that people were choosing a career in extension work as a stepping stone for moving into other roles in government. *"The technical support is still available for everybody but I think at this stage we have a problem with people who [are] really having a vision of becoming an extension [officer] in a specific area for a career… You find people [were] working with for instance Health Department and then they are moving to [Department of] Agriculture, so they are just managing a process, and then they are moving from us to Land Reform… So I think at this stage we are losing the* *expertise with quite an extent in the Department of Agriculture"* (Respondent 3, knowledgeable informant, 28 November 2014, Laingsburg).

Second, it was reported that the numbers of extension officers are not sufficient to meet the needs of the agricultural industry in the area. This too was said to be the case in conservation, where there are insufficient numbers of conservation extension officers liaising with land owners. *"I don't think conservation guys are enough. If you look at th[is] area… there's three people for three million hectares doing extension work, and it's not only extension work, they've got to do the policing, the permits and the law enforcement and everything; extension officers for Cape Nature, there's no funding for them, so there is a big gap and I think that's an important thing in terms of going forward. I am not sure what the situation is with the Department of Agriculture but I would assume that that's where the focus needs to be"* (Respondent 12, government official, 12 January 2015, Oudtshoorn).

5.3. Economic drivers of land use change

Summary of opinions raised relating to economic drivers within the Klein Karoo:
There has been a significant increase in farming input costs along with a general increase in the cost of living. ➢ There has been a comparatively slow increase in income from agricultural production. ➢ Input versus income disparity for agricultural production has resulted in the need for larger more efficient production by farmers in order to sustain their involvement in the industry.
Land use, particularly agricultural, was reported to be intrinsically related to the market, thus market fluctuations were reported to regularly result in land use change.
Concerns were expressed over the cost of secondary production processing steps, taking place between the product leaving the farm and arriving at the consumer (for example transport, packaging and butchery), which was said to be resulting in the reduction of income for farmers.
There was reported to have been an increase in alternative land use for income diversification, particularly related to tourism and game farming. ➢ There were opposing opinions around the impacts of game farming on the natural veld.

5.3.1. Inflation, globalization and input versus income

Respondents, particularly older or generational farmers, repeatedly emphasized the increased cost of living and production as a dominant driver behind land use change. Farmers firstly stressed that the input costs of farming alone, including things such as diesel, wire fencing, water and machinery, have increased at a far greater rate than income for farming produce. *"In 1970 we paid something like R100 for 2000 litres of diesel, now last week, after the price reduction, it cost R23 000 for 2000 litres"* (Respondent 22, farmer, 4 February 2015, Hoeko). Then the *"money you are getting for your products doesn't increase as your input costs increase; [for example] in 2007 [farmers were being paid] R28/ R30 a kg for honey [and now] we are still getting R30 a kg"* (Respondent 2, government official, 27 November 2014, Ladismith). This has required farmers to either extend their farming land or look to alternative sources of income. *"You try and go bigger to survive because of the* *economy of scale, you have to do more with less people and they have to be more productive in order to survive"* (Respondent 24, farmer, 6 February 2015, Ladismith).

Respondents expanded on this trend by recognizing the impact of globalization and improved communication and transport routes. They noticed that the standard of living for farmers has substantially increased due to their exposure to growing consumer markets which in turn has raised their living expenses. In addition, many of the children of farmers no longer attend local schools and return to farming but rather receive education at higher levels with larger educational fees. The accumulation of these costs with growing agricultural input costs adds to the inability of farms to maintain viability and to the declining trend of farming. *"Even up to the 1970s, 1980s, early 1980s, 3500 hectare farm was an economical entity whereas now it's not anymore…It will [need to] become bigger mainly because of your, how can I say, your expectations and living conditions are much higher, your standards are much higher, and it's got more expensive"* (Respondent 28, farmer, 10 February 2015, Anysberg).

5.3.2. Market demand variation as a driver of land use change

Agricultural production is intrinsically related to the market. Market changes and fluctuations are driven by multiple factors for which there is little control. Respondents often related market changes to land use changes, such as the wool boom in the early 1950s which drastically raised livestock numbers and brought about a shift to increase Merino sheep as opposed to Dorper sheep. Market demands were also said to place a timing stress on farming as farmers are required to align their harvest time and livestock growth to meet specific peaks in market demand. With the *"case of the animals, now in the market… 60kg sheep [are desired] but my sheep are only lambing now, so the lambs are little, they are 20kg and 30kg, so we have to move [the lambing] to the right period, [consumers] want April and December"* (Respondent 6, farmer, 4 December 2014, Ladismith).

Respondents also expressed concern about the 'middle man' within the progression from production to market. Interviewees stressed that the growing multitude of middlemen in the production process significantly reduced income for farmers. *"The farmer does not get properly compensated because it is the middleman that gets it [although] the farmer takes all the risks"* (Respondent 23, farmer, 5 February 2015, Ladismith). It was stated that *"a farmer is a price taker not a price maker; [a farmer] can do all the right things but end up losing money. Everyone gets paid except [the farmer], the transport gets paid, the commission gets paid and the packaging and the boxing have to get paid"* (Respondent 26, farmer, 9 February 2015, Ladismith). So in the end *"the farmer gets too little for his product, [as an example one farmer stated that he] get[s] R3 for a kilogram of peaches but in the shop they will cost R15"* (Respondent 24, farmer, 6 February 2015, Ladismith). A number of respondents considered assuming some of these processes themselves in order to diminish their loss. *"If I can get a license to chop my own cattle and grade them, do everything* *myself, it will more than double my income"* (Respondent 28, farmer, 10 February 2015, Anysberg). However, this was not seen as an easy option and farmers looked back with nostalgia to the time of cooperatives and collaborative organization of the processing of agricultural produce.

5.3.3. Game farming and tourism

With declining income for agricultural production, many farmers have either left the agricultural industry and have sold their land or have extended their farming practices by increasing their production or diversifying their land use and income sources. Two methods of income diversification have been to build guest houses for tourist accommodation and to introduce game farming. While tourist accommodation has led to little change in overall land use, interviewees were largely of the opinion that the introduction of game had significantly increased the intensity and extent of land use in terms of grazing and trampling.

It was noted, however, that few farmers originating from the study area have made this transition to game farming. It was repeatedly reported that land had been largely bought by foreign investors in order to establish game farms or tourist accommodation rather than to continue farming. *"Many of the traditional livestock farms have changed ownership and the new guys have put up game fences and started game farms"* (Respondent 22, farmer, 4 February 2015, Hoeko). Again in the case of tourist accommodation this was said to have had little impact on land use. Where land had been bought for game farming this had often involved the purchase of numerous farm properties to create one larger entity. All internal fencing within these properties had then been removed with large game fencing placed on the perimeter of the property before game was introduced. Respondents showed concern over the impact of the segregation of land from these impenetrable game fences. *"I think just the movement of natural wildlife, free-ranging wildlife is going to be affected because of these fences... and those fences nothing can get through"* (Respondent 12, government official, 12 January 2015, Oudtshoorn).

Three further concerns were expressed about the increase in game farming in the study area. First, although the type and amount of game introduced onto these farms is regulated, it was suggested that *"there has been so much pressure now on Cape Nature from the game farming industry that they've had to make compromises. And now it seems [game farmers] are getting consulting teams and [they do] a report and it will be assessed, so it depends on how good the report is and who assesses it, it's a problem [there is] a lot of pressure, so there's extralimital* (a species not originally found within a given geographical area) *species coming in all the time"* (Respondent 12, government official, 12 January 2015, Oudtshoorn). Respondents expressed concern over the survival and sustainability of these extralimital species. *"What I have experienced is that the animals adapt. The animals d[on't] die but they grow out smaller in size and their horns decrease in size, [they] become thicker and not as sharp and so the animal is half its size. As far as I am concerned they species are adapting to* *survive in this area, so in my opinion that is not a game farm[,]… it is a place where the people contain the animals like a Zoo and the people can come and see the animals... And… they normally have to feed the animals to survive and then it's easy to see the animals because they come to the areas where they are fed. So in the end it is a zoo where the animals aren't really in the small cages but they are in a cage. That's my experience with game farms here. The only animals that really survive here is the Springbok, Eland at certain stage, Gemsbok and the Rooi Hartebees, they are the animals that were typical in this area"* (Respondent 3, knowledgeable informant, 28 November 2014, Laingsburg).

Second, there were contradicting views about the impact of game farming on natural vegetation. Some interviewees were of the opinion that *"your game is not as heavy on the veld as what your goats and the like are"* (Respondent 5, farmer, 3 December 2014, Van Wyksdorp). Most respondents were more sceptical, one going so far as to state: *"some of the worst damage… seen in this area has been done by game"* (Respondent 30, farmer, 12 February 2015, Ladismith). The difficulty in managing game was also highlighted and it was suggested by one interviewee that *"your threats of game farming are worse than with stock farming… because [game farmers] bring in a whole lot of animals that don't belong in the area and… with game you can't control their numbers that easily and you can't move them from camp to camp."* This same respondent stated that they *"would rather see 'boerbokke' [goats] on the veld then game"* (Respondent 10, knowledgeable informant, 9 January 2015, Oudtshoorn).

Finally, there were opposing opinions relating to veld management on game farms. A number of respondents were of the opinion that the majority of game farmers who are new to farming have no experience in managing veld and detecting veld deterioration and therefore leave veld vulnerable to degradation. *"Nine times out of 10 [new game farmers] have no land management experience, they are doctors and lawyers and accountants"* (Respondent 12, government official, 12 January 2015, Oudtshoorn). Other respondents were of the opinion that the growing game farm trend was positive in terms of veld management because game farmers were likely to *"get a qualified conservationist to look after [their game farm]"* (Respondent 1, government official, 26 November 2014, Worcester).

5.4. Social drivers of land use change

Summary of opinions raised relating to social drivers within the Klein Karoo:
There has been a decrease in the amount of farm labour employment. ➢ A loss in motivation for labour to seek agricultural work was reported, particularly livestock shepherding.
There has been a decrease in motivation for potential farmers to enter the agricultural industry - largely attributed to the economic difficulty of the industry.
There has been an influx of interest and investment from people originating outside of the area. ➢ Due to foreign investment the cost of land was perceived to have increased beyond its

agricultural value.

- Alternative land uses from foreign investment were reported to provide little local employment as well as contributing nothing to local and national food security.
- Concerns were expressed over the lack of attachment, and therefore care, for the veld from foreign investors.

5.4.1. Farm Labour

The declining economic viability of agriculture, coupled with increasing minimum wage rates has resulted in greater mechanisation of agricultural production and decreasing employment of farm labour. *"Farmers are now buying in equipment to replace labour, [in] Prince Albert there [was] a guy using between 250 to 300 labourers every season to harvest his wine grapes and he is now working with three people"* (Respondent 2, government official, 27 November 2014, Ladismith). Growing unreliability of farm labour, particularly related to alcohol abuse, was also suggested to be motivation for farmers to decrease the amount of labour they employ. It was further reported that farmers had began employing foreign labour, particularly people from Malawi and Zimbabwe, due to better reliability, farming skills and work ethic. Farmers were of the opinion that local labour had high *"absenteeism, laziness, slow work ethic and just low productivity"* (Respondent 16, farmer, 15 January 2015, Van wyksdorp) in comparison to foreign labour.

The use of labour in extensive agriculture has undergone a similar decline. It was reported that the common use of shepherds for livestock management has virtually disappeared. Each herd of livestock, particularly smaller stock such as goats and sheep, were historically managed by a single labourer who would live with the herd in the veld for several weeks at a time. One of the farm workers interviewed who used to be a shepherd suggested that the youth of today are no longer interested in such isolated work. *"The [youth] don't know the veld and they are not interested in it"* (Respondent 27, farm labourer, 10 February 2015, Ladismith). They were said to prefer to remain in a more social setting and would ideally like to find work within the towns. It was also suggested that youth no longer showed interest in learning about the natural veld and uses of plants or farming practices; material gain was reported to be of higher priority.

5.4.2. Farmers

Interviewees were of the common opinion that the motivation to pursue or continue a career in farming has significantly declined. It was suggested that the economy of farming was the greatest contributor to this motivational decline. *"The cost of everything is going up so at the end of the day a lot of the farmers must make their calculations and decide that they can't farm anymore"* (Respondent 22, farmer, 4 February 2015, Hoeko). Lack of governmental support and threats of land claims were also said to be contributing factors for declining investment in the agricultural industry. Farmers were reported to no longer encourage youth to continue family farms as historically would have been the norm. Growing investment into the education of youth for alternative professions was reported to allow for their movement away from the agricultural industry. *"The political influence [relating to land claims] makes the farmer negative, farmers tell their children not to come back and farm, they offer to pay for their studies to become something other than a farmer, such as a Doctor"* (Respondent 24, farmer, 6 February 2015, Ladismith). The isolated nature of the agricultural industry was again said to *"not be attractive enough for modern generations"* (Respondent 28, farmer, 10 February 2015, Anysberg) who place greater importance on connectivity and inclusion within social interactions.

Concern was expressed over the demise of the agricultural industry and the knowledge loss associated with this. *"The knowledge of farming in this area is also busy dying because the people who know farming in this area [are] becom[ing] fewer and fewer. And… in Afrikaans they sa[y] you must 'wees vir drink hier', you must be 'born and bred' here and then you can farm here because if you don't know this area then you can burn your fingers here"* (Respondent 7, farmer, 10 December 2015, Van Wyksdorp).

5.4.3. Foreign Influx

Since around 1996 there is said to have been an influx of people from outside the area buying up land within the Klein Karoo. *"There has been an influx of people into the town and into the area since 1996/1997 more or less and they start to buy some so called lifestyle houses and lifestyle farms… and then from about 2004/2005 that increase[d]"* (Respondent 7, famer, 10 December 2014, Van Wyksdorp). It was suggested that this was due to a number of factors. First, it was said that the vast areas of open space were attractive to people due to the picturesque landscape and the contrast to crowded cities. The proximity to Cape Town was also suggested to be a large motivational factor for people to invest in the area as it is accessible for weekend get-aways. The Klein Karoo is also said to be perceived by many as safer than many other parts of South Africa due to its remoteness and low population levels. *"What you find in this area is people who come from Cape Town, Johannesburg, Pretoria, even overseas and just want to buy some vacant land either to get away from [the city] for a weekend or for an investment… [and this trend started] 10, 15 years ago.. This is [also] a very safe area for the moment… there's minimal theft, there's no farm murders [and] there's no land claims"* (Respondent 23, farmer, 5 February 2015, Ladismith). It was also suggested that there has been a growing change in perception and interest in the Klein Karoo which has become more trendy and artistic resulting in the opening of numerous arts, crafts and coffee shops within small towns. One farmer stated the Klein Karoo has *"become vogue, you can see in little towns like Barrydale, even Robertson, Montagu and so on having become a little more hip and being over taken by arty types. So its losing its hard core agricultural flavour, you know the small stock and large stock farming. We've seen an influx and turn around, instead of urbanization we have ruralisation happening in these little towns"* (Respondent 5, farmer, 3 December 2015, Van Wyksdorp).

Due to the majority of land transactions in the Klein Karoo going to people who have made their money outside of the agricultural industry the cost of land in the area has substantially increased. Farmers have found it difficult to extend their farming land, in order to maintain their business, as property values have increased beyond the farming potential of the land. *"To buy a piece of land now and the interest on that money you must borrow [in order to make the purchase] there is no way you can produce enough product on that land to pay the interest, so land is unaffordable [for agricultural purposes] at the moment"* (Respondent 2, government official, 27 November 2014, Ladismith). As noted few people from outside the area buy land for commercial farming but rather use it for game farming, tourist accommodation or 'weekend farming'. Weekend farming was understood as small farm units characterized by low or subsistence production utilized on a part time basis by the owner. These farms were reported to be unsustainable in isolation requiring input from other sources of income.

Interviewees expressed concern over the lack of stimulation to the local economy brought in from foreign investment for weekend farming and other alternative land uses which are not permanently inhabited. *"The typical weekend farmer brings nothing to your community, he does not attend your church, he doesn't create work, he does not contribute to the community. If he comes for the weekend he brings his food from Pick and Pay in Cape Town. But if he lives here he buys his diesel at the co-operatives and he buys his tyres from the tyre place and if his child gets sick then he goes to the Doctor here… If you and I fight then we go to the lawyer and if the lawyer's child also lives in the town then the hospital can also stay, the school can also stay. But these new people that have come in have made it that we almost have no schools left, they have made it that only two Doctors can make a living here when there was always three, they have made it that the hospital is no longer productive. So there are many losses for the small town due to the lowered purchasing power"* (Respondent 24, farmer, 6 February 2015, Ladismith).

Alternative land users such as tourist accommodation, game farming and weekend farming also require, and therefore employ, less labour than commercial farms. *"[Game farmers] are not giving anybody a job… maybe one or two just to check the fences, but not much"* (Respondent 30, farmer, 12 February 2015, Ladismith). One respondent suggested that *"what happens is a lawyer or a doctor or a minister or someone comes and buys a farm, he pulls out the trees and gets 10 sheep or 20 cattle and he lays off most of his employees and maybe keeps two who he asks to look after the farm and he goes and works in the city, and there are a lot of these 'holiday farms'. Financially he can manage because he has alternative work but he only creates work for two people, he only provides for two families. If you count the heads on my farm then everyday a 170/180 people are fed from this farm"* (Respondent 24, farmer, 6 February 2015, Ladismith).

Respondents observed that the lack of productivity of these land uses contributed little to national and global food security as opposed to commercial farming. *"The money is only being pumped into those [alternatively utilized] farms, there's no money coming out of them in terms of even job creation and food production, which is a concern"* (Respondent 12, government official, 12 January 2015, Oudtshoorn). *"If rural areas like the Karoo die out… then the markets will feel the effects of it because… farmers… are producing a lot of food, sending out tons of meat here per week, so if that would just stop, for example all the mutton and lamb that gets produced here goes to George and… if Laingsburg would just crash, George would have less than half the meat they currently consume"* (Respondent 28, farmer, 10 February 2015, Laingsburg).

Finally, many respondents believed that foreign investors had reduced attachment to the land in comparison to long term commercial farmers. It was said that generational farmers know the vegetation and are cautiously aware of signs of stress as the veld is their current and future source of income. *"Farmers … know that this is their family inheritance, they've got to look after the land. And if it has been dry years they're going to reduce their numbers of stock, because their children are going to farm this land. Now the guys coming in, they've got no real connection with the land. They buy it up and they put up fences and they put in game. And if it doesn't look like a great thing after a year they'll just flog it, and that's the concern"* (Respondent 12, government official, 12 January 2015, Oudtshoorn).

5.5. Conclusion

It is evident that there are multiple political, economic and social factors that influence land use change and therefore the degradation of natural vegetation. Within the study area there has been a decline in extensive agriculture as well as a decline in the number of intensive agricultural farmers. However, it was reported that the amount of land under cultivation has remained relatively consistent. Although there has been substantial legislation relating to the agricultural industry the decline in support to commercial farmers, the increases in minimum wage rates and the decrease in the extent and capacity of extension support and services were considered the major political drivers of land use change. Increases in living and agricultural production costs with comparatively slow increases in income from agricultural production were reported to result in the need to produce more with less economic input, ultimately altering land use practice. The decrease in the number and extent of agricultural production was commonly attributed to the decreasing economic viability of the industry leading to the sale of agricultural land and the diversification of land use. Decreased use of farm labour and decreased motivation to enter or remain in the agricultural industry were also largely attributed to economic strain. There has been an increase in foreign investment and purchase of agricultural land for alternative land use. This has reportedly increased the cost of land beyond its agricultural value. Respondents expressed concern over the reduced attachment and, therefore, care for the veld from foreign investors and the potential negative impact from increased introduction of game to the area. Growing alternative land use was also reported to provide little local employment and contribute nothing to local and global food security.

CHAPTER 6: Discussion

6.1. The Kannaland Municipality as a cyclical socio-ecological system

It is evident that since the early 1900s the Kannaland Municipality of the Klein Karoo has seen substantial land use and environmental change for which there have been multiple contributing drivers. The interrelated nature of environmental, political, economic and social factors which have influenced natural vegetation and land use change emphasises the need to discuss these themes together. This section provides a narrative account of change within the Kannaland Municipality with consideration of all of these factors.

The SES theoretical conceptual diagram presented in Chapter 3 (Figure 1) provides the framework for this discussion. The four phases within the cycle include the reorganization phase (α) which occurs after a system threshold has been reached and during a time of transformation. The system must restructure itself and develop new interactions and connections between new and existing system attributes. The exploration phase (r) is characterized by a growth of spatial extent, interactions and resource use within the system as the new reorganized state is developed. The conservation phase (K) occurs when the awareness of a system's limitations become exposed. This phase is characterized by plateau in expansion and greater conservation of resource use. Finally, the release phase (Ω) occurs when the threshold of a system is reached and the system begins to depart from its 'usual' manner of functioning. Figure 15 represents the study area as interpreted within this SES diagram. As Berkes et al (2003) and Gunderson and Holling (2002) have shown, change within a SES is of a cyclical nature. Figure 15 illustrates such cyclical phase changes in the study area. It explores the prior phases of the SES, the characteristics of the system's current phase, and projects for possible future phases of the system. Estimations of time frames have been allocated to each phase in order to guide the transition of change within the SES. The phases have been labelled 1 to 10 for ease of discussion. Phases will be discussed respectively with an exploration of relevant environmental, social, economic and political drivers of change within each phase.

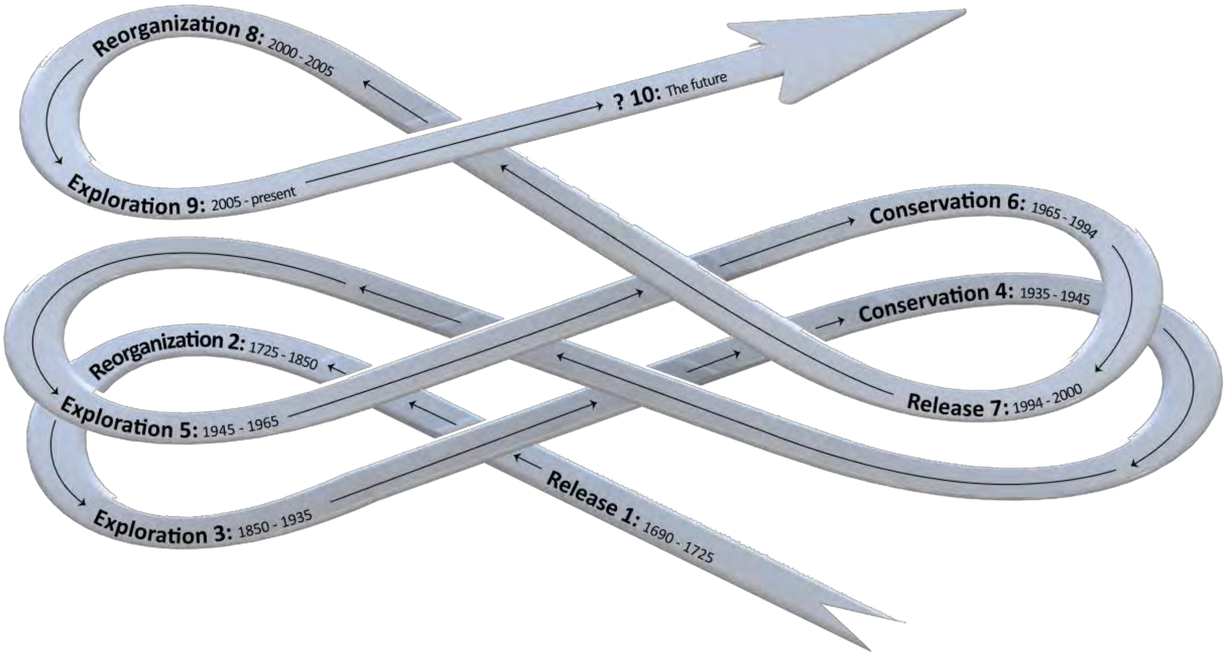

Figure 15 Changes in the Kannaland Municipality area as interpreted within a cyclical socio-ecological system (SES) conceptual framework. Each phase, labelled 1 to 10, represents a change within the SES brought about by varying external and internal drivers of change. Explanations for each phase and the main drivers are discussed in the text below.

6.1.1. Phase 1. Release, 1690 to 1725

Phase 1, marks the end of the transhumance land use of the Klein Karoo by the indigenous San and Khoi (O'Farrell et al, 2008). This phase began with the first entrance of colonial settlers into the Klein Karoo around 1689 (O'Farrell et al, 2008) and ended in 1725 around the time of the first settled farms in the region. During this time the remaining Khoi were either displaced further north of the Klein Karoo or recruited as farm workers on settler farms. The threshold reached within this phase was one of space, relating to the scale of the system. The system reached a point, or threshold, where there was no longer enough space for the combined transhumance use of the area by Khoi as well as the settler farmers who had become more reliant on intensive agriculture (Cupido, 2005). This phase was largely brought about by the growing number of resource users.

6.1.2. Phase 2. Reorganization, 1725 to 1850

Phase 2, from 1725 to 1850, marked the permanent establishment of settlers into the Klein Karoo and their progression of developing permanently settled farms throughout the area by 1767 (O'Farrell et al, 2008) and establishing the first towns within the region towards the end of this phase starting with the town of Montagu in 1725 (O'Farrell et al, 2008). This phase represents the transformation of land use within the Klein Karoo and a shift in both the number of resource users and the way in which the resource was used. This phase was driven primarily by the influx of Europeans into the area in pursuit of livelihoods and potential economic gain.

6.1.3. Phase 3. Exploration, 1850 to 1935

This exploration phase, from 1850 to 1935, saw a progression from the expansion of small town establishments to the development of an entire agricultural industry in the area. The phase was marked by widespread growth in land and resource use within the SES and a consistent increase in system users. This included the development and expansion of major transport routes throughout the area allowing for greater accessibility within the SES, and between the surrounding towns and major centres such as Cape Town. Greater accessibility enabled the transportation of agricultural produce incentivizing expansion in agricultural production and the potential for greater economic gain for system users. Similarly the establishment of major towns in the Klein Karoo facilitated the social and economic use of the wider region.

The Fencing Act 17 of 1912, which required all farm boundaries to be fenced, was also introduced during this period. A 1922 amendment required that all fences be vermin proof. This formalised the segregation of land and encouraged, with the introduction of windmills, the extensive use of land for livestock grazing. The Drought Investigation Commission of 1923 promoted the further division of land into camps. This purportedly allowed for more animals to be kept on the land thus significantly increasing stocking rates (Cupido, 2005).

The Native Lands Act 27 of 1913, which formally assigned unequal portions of land to different race groups, was a political driver during this phase. This act favoured white commercial farmers and although it did not have as large an effect on the Klein Karoo as in other areas in South Africa, it did force a number of subsistence farmers off their land.

Seven of the original photographs from the repeat photographic series were taken towards the end of this phase. These sites consist predominantly of plains vegetation and the original photographs show consistently less shrub cover than in the 1993 and 2014 repeats. The lack of shrub cover supports the evidence of a growth in extensive livestock production during this time as the plains would have been commonly used for livestock grazing.

6.1.4. Phase 4. Conservation, 1935 to 1945

The earliest environmental influence recalled within the interviews conducted for this study was the major drought which occurred between 1935 and 1939. This extensive drought provided a shock to the SES which had seen rapid agricultural expansion within the prior exploration phase. The drought brought about the realization that natural resources had become depleted and that water supplies and grazing were in limited supply. Livestock numbers were reduced, water use became more conservative and the expansion of agricultural production declined over this period as system users attempted to maintain the system state.

Many people were unable to survive during the extended drought of the late 1930s and left the region at this time. The drought also encouraged people to sign up for the war (WWII) in order to get money to buy bread and food. *"Then lots of people… young men and young women, they went to the war, and in Afrikaans they said…they signed on 'ondenbrooder', they signed on to get money to buy bread"* (Respondent 7, farmer, 10 December 2014, Van Wyksdorp). The movement of people out of the area at this time released some of the pressure that had been exerted on the land by an increasing number of land users.

6.1.5. Phase 5. Exploration, 1945 to 1965

Phase 5 represented a time of return to the prior exploration phase, phase 3, of the SES. It began at the end of WWII and was characterised by an influx of people either returning or entering the area after the war and the end of the major drought. The depopulation of the area in phase 4was believed to have significantly lowered the cost of land which added incentive for people returning to or entering the area during this time.

The phase saw a boom in agricultural production, as evident in the agricultural data analysed in this study. Both grain crops and lucerne saw major peaks in production after the war. Livestock numbers, particularity sheep and cattle, also maintained relatively steady growth within this phase. A social trend within this phase was the adoption of 'bywoners' on farms which contributed to the rise in livestock numbers.

During this phase nine of the original photographs of the repeat photographic series were taken. The majority of these photographs included both slopes and plains, with five of the nine also containing views of river courses. There was consistently less shrub cover on both the slopes and plains within these photographs than what was found in the later 1993 and 2014 repeats. This was likely to have been the result of extensive use of these areas for livestock grazing during this time. Three of the five sites which contained river courses also showed substantially less tree cover than what was found in the 1993 and 2014 repeats. This again supports the idea that there were large numbers of livestock during this phase as livestock were commonly kept in river courses due to greater forage supply and the desire of land users to maintain clear river courses for flood damage control.

6.1.6. Phase 6. Conservation, 1965 to 1994

The influx of people into the area during the previous expansion phase, coupled with the social 'bywoner' trend, and the resultant peaks in agricultural production reportedly caused growing land degradation due to over stocking and over use. The realization of this degradation and the beginning of another drought from 1965 to 1969/70 saw the start of efforts to improve veld management and reduce stocking numbers in order to maintain the system status qou. At this time the government introduced the Drought Relief Scheme, giving farmers an incentive to further reduce stock numbers. The decline in grain crops, lucerne and livestock numbers in the 1971 census reflects this reduction in agricultural production. It was suggested that many people, particularly 'bywoners' and smaller farmers, who were unable to survive the drought, were forced to leave the area during this time. The Subdivision of Agricultural Land Act 70 of 1970 was then introduced to prevent farmers subdividing their property in order to sell off portions of their land. This led to lowering of the population within the study area.

The Conservation of Agricultural Resources Act 43 of 1983 (CARA) was introduced within this period. This Act formed the basis of subsidies and support to the agricultural industry in South Africa. CARA favoured white commercial farmers due to the strong economic contribution the agricultural industry provided for the country and supported agricultural production within this sector of the population for the remainder of this period.

The 1993 repeat photographs were all taken at the end of this conservation phase marking the end of the first time period of natural vegetation cover change within the repeat photographic series. The 30 year length of this conservation phase and its associated reduction in extensive agriculture may potentially explain the increase in shrub cover across all land forms seen in the 1993 images. However, it may not have been sufficient time for the significant growth in tree species as seen in the 1993-2014 time period.

6.1.7. Phase 7. Release, 1994 to 2000

This relatively short phase reflects the major political shift of government priorities within South Africa and the demise of the agricultural industry of the Klein Karoo. Amendments were made to CARA in 1994 which mostly reduced the subsidies provided for commercial farmers. The phase also saw the introduction of the Basic Conditions of Employment Act 75 of 1997 which introduced a minimum wage rate for farm labour, diminishing the use of cheap labour for commercial farmers. This lack of financial support, the increase in labour costs and growing inflation of agricultural input costs, such as fuel and fencing, began a decline in extensive farming in the Klein Karoo and a significant drop in the number of intensive agricultural farmers.

This finding is supported by Shackleton et al (2013) who noted a significant decline of the agricultural industry in South Africa during the 1990s at the time of political transition in the country and noticeable increases in farming input costs. These factors required farmers to increase their farm size and the amount they produce in order to maintain economical viability. This was not always financially possible and led to many larger farmers buying out smaller farms or alternatively the sale of farm units to willing buyers from outside the Klein Karoo (Nel & Hill, 2008). The Extension of Security Tenure Act 62 of 1997 (ESTA) was also introduced during this phase to protect labour from unfair eviction from their homes located within the farms on which they worked.

6.1.8. Phase 8. Reorganization, 2000 to 2005

The recent reorganization phase of the Klein Karoo SES is characterized by the social trend of foreign (outside of the Klein Karoo) influx into the area. The change in perception of the Karoo from a barren desert like agricultural landscape to a trendy spacious getaway destination, as suggested by the findings of this study and supported by Ingle (2010_a; 2010_b), has accelerated such foreign investment.

Ingle (2013_a) expands on this social trend and highlights how technological advances in communication and connectivity have allowed for professionals who derive income from urban related sources to either relocate to or spend more time in the rural Karoo. Ingle (2013_a) refers to this group of people as the 'creative class' and explores the concept of the 'post-productivist countryside'. The decline of the agricultural industry has facilitated this reorganization with growing numbers of property on the market. The growing popularity of foreign investment into the area, for non-agricultural purposes, has in turn increased the cost of land beyond its agricultural value. This economic trend has impacted the ability of farmers to extend their property in order to maintain the economic viability of their farms, incentivizing them to sell their land and leave the study area, leading to the demise of extensive agriculture.

6.1.9. Phase 9. Exploration, 2005 to present

The current exploration phase is characterised by an expansion of foreign investment in the Klein Karoo and the exploration of alternative sources of income and land uses. Findings reveal that not much change in land use and natural vegetation can be associated with small town development from the opening of arts, crafts, coffee shops and restaurants as well as the establishment of tourist accommodation and guest houses. However, it is worth noting that these developments have encouraged tourism which in turn has brought some economic upliftment and small scale employment. Weekend farming although not seen as detrimental to the environment and natural vegetation was viewed by most respondents interviewed as being unproductive and not contributing to the local economy.

Game farms and the impact that they had on vegetation were more controversial and elicited a number of different and conflicting opinions. Some saw the growing trend in game farms as positive for the area and the natural vegetation. Similarly Smith and Wilson (2002) in their study of the growing trend in game farming in the Eastern Cape of South Africa were of the opinion that well managed game farming has a higher potential ecological sustainability than stock farming. They, however, acknowledge the need for further research into the impacts of game on natural vegetation and the estimated stocking rates for game grazing for this growing industry in the future.

Several people interviewed were of the opinion that game was far more detrimental to the natural vegetation than well managed livestock. The risk of bad veld management due to lack of experience and knowledge of the veld by many of the new game farmers was also highlighted. Concerns were further expressed over the growing introduction of extralimital game species to the study area. As Smith and Wilson (2002) suggest the growing game farming trend is largely market-driven and is based on eco-tourism and hunting. Satisfying these two demands is largely dependent on the diversity of species. Game farms, therefore, commonly introduce extralimital species in order to attain this species diversity.

Changes in land use within the current exploration phase have not only been due to foreign investment into the area. A small number of farmers have also looked to diversify their income sources through the development of tourist accommodation and the introduction of game farming in order to sustain their farming practices. Simonesen et al (2014), in their exploration of principles for resilience in SES, highlight the trend for farmers in dry areas of South Africa to diversify their land use practices, particularly in relation to ecotourism. They further highlight the importance of natural biodiversity for such land use practices.

Although game are reportedly less selective grazers than domestic livestock and graze a wider variety of plants this study suggests that permanently grazed game camps will inevitably become over grazed if game numbers are not strictly managed. Skilled game management, however, requires a rich knowledge of the veld and a keen eye for initial signs of veld degradation. The introduction of extralimital game species or species which came to the area on a seasonal basis are also perceived to leave the veld vulnerable to degradation if permanently left in the area. For example, the introduction of elephants to the area have been observed to push down tree species such as *Euclea undulata* and *Pappea capensis* which have taken decades and centuries to reach maturity and recruit only intermittently. Extralimital game species may themselves be negatively affected by their introduction to the area as their nutritional requirements may not always be met by the natural vegetation of the area.

Phase 9 marks the end of the second time period of natural vegetation change within the repeat photographic series, as the 2014 repeat photographs were all taken during this time. The photographic series and interview responses consistently suggest that natural vegetation had increased in cover in the study area particularly in the last 20 to 25 years since the early 1990s. This finding may suggest an alternative trajectory to previous degradation estimates of the Klein Karoo (Reyers et al, 2009; Thompson et al, 2009). The transformation of the SES in terms of shifts in land use and system users between the end of the conservation phase 6, with the 1993 photograph repeats, and the present phase, with the 2014 repeats, may explain the significant change in natural vegetation cover within this time period. For example the demise in extensive agriculture in the last two decades may account for the significant growth in tree species within river courses. Extensive livestock farmers commonly utilized river areas for livestock grazing, thus maintaining lower vegetation density. *"In the river bed we had cattle grazing there, going up and down…*

cleaning that river, now the river is getting overgrown" (Respondent 8, farmer, 7 January 2015, Ladismith). It was suggested that the clearance of river areas by grazing livestock was purposely carried out as it also supported flood damage control, preventing large amounts of plant and tree debris from being uprooted and washed down the river.

However, in relation to the increase in the cover and abundance of *Acacia karroo* in the river courses, Kgope, Bond and Midgley (2010) have reported noticeable growth in thorn size of *Acacia karroo* with increased CO_2 levels. One informant suggested that global rising CO_2 levels may be partly accountable for the recent significant growth of this species in river land forms. *"The Acacia karroo likes this increase in CO_2 and that may be part of the reason they are now becoming more abundant"* (Respondent 10, knowledgeable informant, 9 January 2015, Oudtshoorn).

It was also suggested that the significant increase in grass species observed between 1993 and 2014, was *"probably [due to] a summer rain event that brought out the grasses"* (Respondent 10, knowledgeable informant, 9 January 2015, Oudtshoorn). Consistent with this suggestion high rainfall was recorded in January (87 mm) and March (74.8 mm) of 2014. The sudden emergence of grass species suggests that although grasses are not always present in the vegetation cover of the study area, their seed is evidently present within the soil and able to respond when conditions are favourable.

It is evident that the demise in extensive livestock within the area as well as changes in climate and anthropogenic effects such as increased CO_2 has resulted in an increase in natural vegetation cover. Whether natural vegetation cover will continue to increase with current land use practices is, however, questionable.

6.1.10. Phase 10. The future?

The rise of game farming coupled with climate changes such as increasing rainfall intensity and rising temperatures, suggests that the limitations of the current system are becoming exposed and that increased conservation of the system state or a reorganization of the system function is likely in the future. Concerns over the uncertainty of the impacts of game were repeatedly expressed within the interviews conducted for this study. *"There's a big risk now in terms of going forward with regards to the management of game, how it is going to be managed, and we won't know now, we'll only know 10 or 15 years time [what the impact of game on the veld will be]"* (Respondent 12, government official, 12 January 2015, Oudtshoorn).

Both the climate data and interviews suggest that long term annual rainfall amounts have not significantly changed since the early 1900s. Interviewees were of the opinion, however, that the intensity of rain events had increased and that the rainy season had commenced two to three months later in the year. Although this study did not assess such claims, the climate predictions reported by Midgley et al (2005) are consistent with these suggestions and project a reduction in winter rainfall with a slight growth in summer rainfall. Boardman et al (2010) and Midgley et al (2005) also report on the feasibility of more irregular rainfall of a more intense nature, again consistent with the respondents' suggestions. If the intensity of rainfall incidents has increased, as suggested, there are negative implications for vegetation and land use. First periods of intense rain are more likely to cause soil erosion and nutrient loss from top soil run off, particularly in bare or degraded land, due to larger quantities of water running off the land. *"Flash floods… just remove anything in [the] way… they just strip your land and wash it away"* (Respondent 26, farmer, 9 February 2015, Ladismith). Rain water is also not as easily absorbed into the soil during intense rain events, as opposed to lighter more consistent rain, and less moisture is subsequently available for vegetation. Seasonal shifts in rainfall also have important implications for the scheduling of different land use practices due to the timing of seed sowing, crop harvesting and lambing periods.

The significant increases in mean maximum temperatures are again consistent with findings presented by Midgley et al (2005) who report that in the past three decades temperature trends have shown considerable warming. However, the implications of rising temperatures for natural vegetation in the area are dependent on the largely unknown tolerance of plant species and are thus hard to predict (Midgley et al, 2005).

6.2. Interpretation and projection of the SES trajectory

The SES framework interpretation of change in the Kannaland Municipality was a useful tool which allowed for a broad synopsis of long term change and a visual guide to assist in comprehending the pattern of long-term change in this region of the Klein Karoo. With the use of this framework the current system state and the likely trajectory of change within the system have been interpreted within the historical context of the system itself.

6.2.1. Deagrarianization

As suggested in phase 8 and 9 of the proposed SES the decline of the agricultural industry and the lowered motivation and incentive for its revival has led to the deagrarianization of the Klein Karoo. This trend is similar to what has occurred in other parts of South Africa (Shackleton et al, 2013).

It has been repeatedly suggested and confirmed that the agricultural industry of the Klein Karoo, particularly extensive agriculture, has dramatically declined since around the mid 1990s (Nel & Hill, 2008; Shackleton et al, 2013). *"I don't think there are more than four or five remaining sheep or stock farmers left in this area. I can name them on one hand. And 20, 30 years ago when I came farming, the whole area, we had a stock fair here in town every month, where a number of sheep, goats, and cattle and stuff were sold. That's gone* *long ago, because there's nothing left to sell."* (Respondent 30, farmer, 12 February 2015, Ladismith). As already explored there are numerous contributing factors to this decline.

In his discussion of deagrarianization Klimanek (2013) refers to Musial's (2007) exploration of four dimensions of deagrarianization which will be adopted for the understanding of the concept within this study. This understanding of deagrarianization recognizes the complexity and multiplicity of drivers. The four dimensions proposed by Musial (2007) and Klimanek (2013) are related to production, economic, social-cultural as well as ecological and landscape factors. The *production dimension* is related to the decrease in production quantity and productive land. The *economic dimension* is related to the decrease in contribution from the agricultural sector to the national economy, a decrease of household agricultural income, a decrease in agriculturally-related employment and a drop in financial support to the industry. The *social-cultural dimension* is related to the reduction of people involved in the agricultural industry, greater diversification of income sources in rural areas and a decrease in agricultural-based education. Finally, the *ecological and landscape dimension* is related to increasing cover of natural vegetation and fallow lands.

Findings from the current study area indicate evidence of each dimension of this phenomenon. Whether the perception of deagrarianization is a positive or negative trend is, however, a broad debate (Benayas et al, 2007; Dethier & Effenberger, 2012; Klimanek, 2013; Manyevere et al, 2014; Shackleton et al, 2013). The common negative perception of deagrarianization is related to local and national food security whereas the dominant positive perception relates to increases in natural vegetation and the reverse of biodiversity loss (Shackleton et al, 2013).

The growing cover in natural vegetation as evident in the repeat photographic analysis and interviewee responses indicate the positive aspect of the deagrarianization trend. The correlation between stocking number decline and veld rejuvenation is undeniable, however growing alternative land uses such as game farming or veld that is underutilized or left 'un-pruned' from lack of grazing on unproductive farms requires further research in terms of the long term effects of this on biodiversity and associated ecosystem processes. It is possible that improved grazing and veld management practices may be most beneficial for the vegetation of the Klein Karoo.

6.2.2. Collaborative conservation and land use diversification

The future of the SES, as explored in phase 10, has the potential to facilitate long term sustainability through collaborative conservation and land use diversification. It is widely suggested that conservation efforts require investment from private land owners in order to reach desired conservation goals (Gallo et al, 2009; Pasquini et al, 2009; Reyers et al, 2009; Smith and Wilson, 2002). The Kannaland Municipality Spatial Development Framework (SDF) in its identification of CBAs also recommends that the conservation of these areas be largely dependent on conservancies and conservation stewardship projects which in turn rely on private land owners. It is therefore emphasised that communication and knowledge sharing between land owners and conservationists is vital in this pursuit, thus emphasising the importance of conservation extension services (Pasquini et al, 2009). Pasquini et al (2009) also highlight the importance of increasing public recognition received by private landowners for their conservation efforts. In a similar vein the importance of shared value and common conservation motivations between system users is emphasised by Ostrom (2009) in relation to the success within SES to self-organize and build resilience to be more sustainable. Furthermore, within the Kannaland Municipality IDP emphasis is placed on the importance of participation from stakeholders with regard to the governance and development of the Kannaland Municipality.

Such collaborative conservation efforts would require a diversification of land uses in the region. The vision of the Kannaland Municipality SDF as well as the Gouritz Cluster Biosphere Reserve (GCBR) is in line with this as they suggest that both conservation and development are required for the sustainability of the area and that education in both of these pursuits is vital. The consideration of conservation corridors is prioritized in conservation activities but farming and productive land use is not compromised. The local SDF further promotes the development of the tourism sector within the municipality and acknowledges the importance of a healthy eco-system and the preservation of the rich biodiversity within the area.

With the current diversification of land uses in the Kannaland Municipality the ideal of balanced agricultural production, biodiversity conservation and development is possible. Caution however is required, first, to ensure that the agricultural sectors demise within this area is stabilised. This is likely to be achieved with a growth in governmental and local support to the agricultural industry. Second, the game farming industry requires stringent monitoring and research concerning its long term impacts to ensure that veld degradation does not occur.

CHAPTER 7: Conclusion

Contrary to many degradation predictions of the Klein Karoo this study found that natural vegetation cover within the Kannaland Municipality of the Klein Karoo had generally increased since the early 1900s across all land forms. Although tree cover showed a slight decline between the original photographs and 1993, tree cover increased significantly between 1993 and 2014. Shrub cover increased consistently over both time periods. A significant increase in grass cover was first observed in 2014. However, due to the ephemeral nature of grasses this is probably linked to increased summer rain immediately prior to the 2014 photographs.

Climatic changes within the Kannaland Municipality during this period appeared minimal. However, in recent years an increase in annual mean maximum temperatures was evident. A perception of increased rainfall intensity within rainfall events was also reported. Land use and therefore land cover within the Kannaland Municipality has undergone substantial change since the early 1900s. There has been a major decline in extensive livestock farming. This decline started in the late 1960s but has intensified from the mid-1990s. Although the amount of land under cultivation has remained relatively consistent, the number of intensive farmers has decreased. This is due to the need for increased production quantities, and therefore larger farm properties, in order to sustain economic viability. Alternative land uses have increased since the mid 1990s, particularly the introduction of game farming.

It is evident that a multitude of interrelated factors have contributed to change in land use within the Kannaland Municipality. There are contrasting opinions about the respective roles of climate and land use as drivers of natural vegetation degradation. Based on the evidence presented in this thesis, I conclude that change in vegetation is driven by a combination of changes in climate, land use and other environmental, political, economic and social factors.

The implications of land use change within the study area, particularly the decline in livestock farming and the growth in game farming, are perceived by this study to have been both positive and negative. Natural vegetation cover and the accompanying potential increase in biodiversity, due to better veld management and a decrease in livestock farming are positive factors which have resulted from changes in land use. Reduced employment and agricultural productivity are both negative implications of this land use change. Growth in the game farm industry is considered negative in terms of the increase in the extent of unproductive land. There are also questions about the ecological impacts of game farming for natural vegetation, many of which require further long term research.

Finally, this study wishes to promote three recommendations for land use authorities and land owners and stakeholders in the Kannaland Municipality and the broader Klein Karoo. First, it encourages collaborative conservation, where conservation targets are met through private land as well as identified national, provincial and local conservation areas, as this is perceived to be an effective and inclusive strategy for long term conservation targets. It is evident from the study that land use change and the associated change in natural vegetation has occurred predominantly on private land. For this reason private land should be targeted in conservation pursuits. Second, in line with a vision of the local SDF and GCBR, the study views the diversification of land use as optimal for the sustainability of the area. Such diversification would include agricultural production, conservation of natural ecosystem biodiversity, and development, particularly in the tourism sector. The encouragement for diverse land use in the area would balance conservation, economic and development needs in the area allowing for greater sustainability of land use. Third, the study recommends capacity building of agricultural and conservation extension services in the broader Klein Karoo region. It is evident from the study that extension services are not currently meeting the needs of the area. Such capacity building would increase collaboration, recognition, knowledge sharing and education for and among land owners, stakeholders and land management authorities within the area. Increased knowledge and communication would encourage co-operative governance over land use, management and conservation targets as well as collaborative conservation.

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APPENDIX 1

Details of repeat photography

Table 5 List of photographs used in the repeat photograph study of long-term vegetation change in the Kannaland Municipality. The 1993 photographs were taken by M.T. Hoffman while the 2014 photographs were taken by M.T. Hoffman and A.L. Murray.

Site No.	Site name	GPS co-ordinates	Original Photographer	Date of original image	Date of 1993 image	Date of 2014 image
50	Zewenfontein	S 33° 58524 E 20° 66550	I.B. Pole-Evans	18.03.1922	17.03.1993	24.06.2014
53	Miere Fontein	S 33° 50498 E 20° 87769	I.B. Pole-Evans	24.05.1919	24.05.1993	24.06.2014
54	Zorg Vliet_1	S 33° 34590 E 20° 52276	I.B. Pole-Evans	24.05.1919	24.05.1993	23.06.2014
55	Zorg Vliet_2	S 33° 34590 E 20° 52276	I.B. Pole-Evans	24.05.1919	24.05.1993	23.06.2014
56	Poortjies	S 33° 49987 E 21° 03997	I.B. Pole-Evans	23.05.1919	26.05.1993	23.06.2014
65	Witvlakte	S 33° 48345 E 20° 94298	M. Levyns	07.1937	28.05.1993	23.06.2014
68	Van Zylsdamme	S 33° 48379 E 20° 99820	M. Levyns	07.1937	28.05.1993	24.06.2014
69	Buffelsvlei_1	S 33° 50032 E 21° 03386	M. Levyns	07.1937	29.05.1993	24.06.2014
70	Buffelsvlei_2	S 33° 49844 E 21° 03556	M. Levyns	07.1937	29.05.1993	24.06.2014
83	Biljetsfontein	S 33° 46570 E 20° 90529	J.P.H. Acocks	20.10.1959	25.10.1993	25.06.2014
84	Buffelsvlei_3	S 33° 50008 E 21° 03674	J.P.H. Acocks	20.10.1959	26.10.1993	25.06.2014
85	Buffelsvlei_4	S 33° 50008 E 21° 03674	J.P.H. Acocks	20.10.1959	26.10.1993	25.06.2014
87	Boerbone Fontein_1	S 33° 67490 E 21° 31730	J.P.H. Acocks	20.10.1959	27.10.1993	27.06.2014
88	Boerbone Fontein_2	S 33° 69178 E 21° 33545	J.P.H. Acocks	20.10.1959	27.10.1993	27.06.2014
89	Opzoek_1	S 33° 72566 E 21° 38070	J.P.H. Acocks	20.10.1959	27.10.1993	27.06.2014
90	Opzoek_2	S 33° 72544 E 21° 38121	J.P.H. Acocks	20.10.1959	27.10.1993	27.06.2014
91	Assegaay Bosch_1	S 33° 74087 E 21° 54335	J.P.H. Acocks	20.10.1959	28.10.1993	27.06.2014
92	Assegaay Bosch_2	S 33° 73903 E 21° 57846	J.P.H. Acocks	20.10.1959	28.10.1993	27.06.2014
93	Keurboschfontein_1	S 33° 68708 E 21° 33053	M. Levyns	1927	28.10.1993	27.06.2014
94	Keurboschfontein_2	S 33° 68653 E 21° 33281	M. Levyns	1927	28.10.1993	27.06.2014

APPENDIX 2

Repeat ground photograph series, with detailed extended captions, used in the study of long-term vegetation change in the Kannaland Municipality.

Site 50. Zevenfontein

A

B

C

Figure 2.1 Zewenfontein, Klein Karoo, South Africa.

A. (1922). This view shows an east-west trending valley about 3 kilometres wide bounded by shale ridges on both north (behind the camera location) and south sides. The north facing background ridge is Bokkeveld shale with the bottom valley comprising of a complex mix of exposed bedrock in places and sand with extensive quartz patches on the plains throughout the region. Considerable west to east water movement is evident in the centre of the valley where sheet wash erosion and exposed sand patches are clearly visible. The foreground and rest of the valley plains has a relatively low cover of vegetation. Common species include *Felicia filifolia* and *Gibbaeum shandii* which dominate the quartz patches. The background ridge also has a sparse vegetation cover with a few scattered *Euclea undulata* individuals. The region appears to have been utilized extensively for livestock farming with additional trampling due to the location of a major watering dam visible in the left mid-ground. (Pole-Evans).

B. (1993). The unpalatable Karoo shrub *Pteronia pallens* appears to have increased in density and cover particularly on the quartz patch in the foreground. Another dwarf shrub *Felicia filifolia* has also increased significantly in cover on the quartz patch in the foreground while *Gibbaeum shandii* appears to be unchanged. A number of *Acacia karroo* and *Searsia lancea* individuals have become established just above the dam and along the drainage line on the right. The shale ridge in the background shows a slight increase in the size of some individual trees. (Hoffman).

C. (2014). This view shows an increase in cover of *Pteronia pallens* and *Felicia filifolia* on the quartz patch in the foreground while the abundance of *Gibbaeum shandii* has remained relatively unchanged. There has been an increase in *Acacia karroo* and *Searsia lancea* individuals around the dam and along the drainage line in the left mid-ground. There has been a slight increase in low trees and shrubs on the ridge in the distance. (Hoffman & Murray).

This series suggests that the decline in extensive stock farming in this region which is evident in Pole-Evans' 1922 photograph has resulted in an increase on cover of dwarf shrubs such *as Pteronia pallens* and *Felicia filifolia* on the plains. Palatable tree species such as *Acacia karroo* and *Searsia lancea* have also been able to increase in abundance. Species present in the original photograph have also increased in size which suggests a general improvement in vegetation condition.

Site 53. Meire Fontein

A

B

C

Figure 2.2 Miere Fontein, Klein Karoo, South Africa.

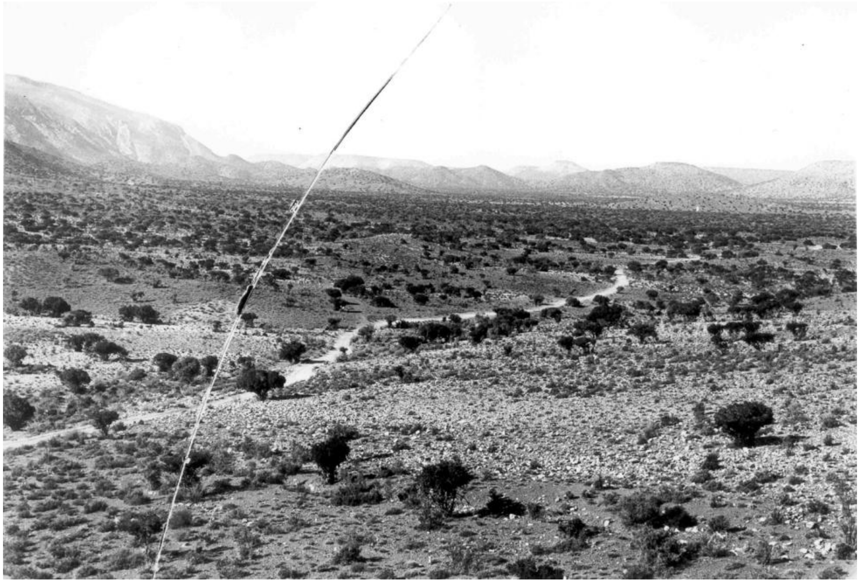
A. (1919). This view looking north shows a steep south-east facing ridge in the background comprised of shale. There is much debris of large stone upslope, especially on the right, and smaller shale-derived angular stones mixed with quartz lower down. The foreground is comprised of alluvium and varying amounts of rock cover. Heuweljies are also present. The ridge has a scattered cover of various tall shrub and tree species including *Pappea capensis*, *Searsia lancea*, *Dodonea anaustifolia*, *Euclea undulata*, *Carissa haematocarpa*, and *Nymania capensis*. The foreground has a low cover of vegetation dominated by *Pteronia pallens*. (Pole-Evans).

B. (1993). There is a decrease in *Pappea capensis* individuals on the ridge with many of the carcasses still remaining in place, some of which still had living tissue when the slope was surveyed in 1993. These appear to have been blown over as no cut stumps were visible on the slope. *Searsia lancea* appear to have increased in cover, especially where the crest joins the upper slope. *Dodonea anaustifolia* individuals also appear to have increased in cover on the lower slopes. *Euclea undulata* shows signs of limited recruitment and very little if any signs of mortality. The position of hueweljies in the right mid-ground is the same. The low quartz ridge in the foreground appears not as well defined as in 1919 suggesting a slight increase in *Pteronia pallens* cover and density. (Hoffman).

C. (2014). There appears to be an increase in the density of the majority of individual tall shrub and tree species on the ridge. *Dodonea anaustifolia* on the lower western slopes and *Searia lancea* on the upper western slopes appear to have increased in cover. The cover of *Pteronia pallens* appears unchanged in the foreground. An introduction of grass species (e.g. *Finerghuthia Africana* and *Digitaria eriantha)* appears throughout the mid and foreground, which may be due to good summer rain. (Hoffman & Murray).

This series suggests that between 1919 and 1993 many of the large and palatable trees on the distant slope such as *Pappea capensis* had died either as a result of an extended drought or very strong winds which blew the adult trees over. Death as a result of windthrow has been recorded elsewhere for a tall desert succulent tree, *Aloe ditchotoma* (Jack et al, 2014). The presence of grass in the foreground and absence of any signs of animal presence (e.g. hoof damage, dung, grazed plants) suggests few herbivores are currently present on the landscape.

Site 54. Zorg Vliet_1



A

B

C

Figure 2.3 Zorg Vliet_1, Klein Karoo, South Africa.

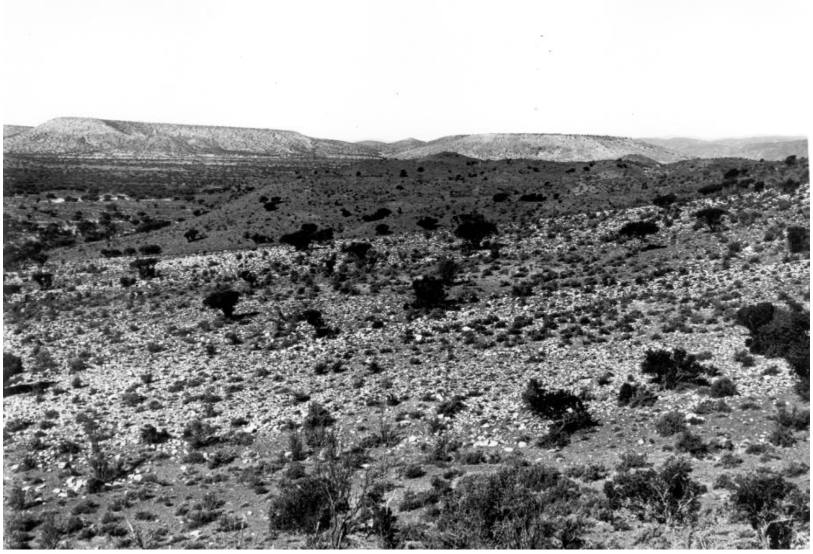
A. (1919). This view looking east through a wide valley shows Touwsberg to the left. Touwsberg is a sandstone mountain surrounded by low shale and quartzitic ridges. A very complex soil results with hard red clayey soils adjacent to exposed bedrock in the right mid-ground or deeper sandy soil as seen in the lower foreground strip. The valley has a high tree cover of trees dominated by *Pappea capensis* and *Euclea undulata* with a number of other tall shrubs such as *Carissa haematocarpa* and *Rhigozum obovatum*. The remaining ground cover is low and is dominated by *Pteronia pallens*. (Pole-Evans).

B. (1993). Large tree elements including *Pappea capensis* and *Euclea undulata* appear to have increased in abundance and certainly increased in size. Three young *Pappea capensis* and two *Euclea undulata* seedlings are located within either *Rhigozum obovatum* or *Carissa haematocarpa* bush clumps. The protection provided by these other shrubs may be a pre-requisite for recruitment. Generally *Pteronia pallens* appear to have thickened, although the boundaries between soil types remain stable with clay soils dominated by *Mesembryanthemum sp.* (Hoffman).

C. (2014). Very little change appears to have taken place among the tree elements and larger shrubs. The density of *Pteronia pallens* appears to have increased slightly. (Hoffman & Murray).

This region probably receives considerably more rain as well as run-off from the adjacent Touwsberg than many other areas in the Ladismith region of the Klein Karoo. This is evident in the great subtropical tree biomass present in the valley. The umbrella shape of the majority of tree elements in Pole-Evans' 1919 photograph suggest that the area was heavily used for livestock grazing during this time. However, the considerable thickening of these elements in 1993 suggests that the land had been left ungrazed for a number of years prior to 1993.

Site 55. Zorg Vliet_2


A


B


C

Figure 2.4 Zorg Vliet_2, Klein Karoo, South Africa.

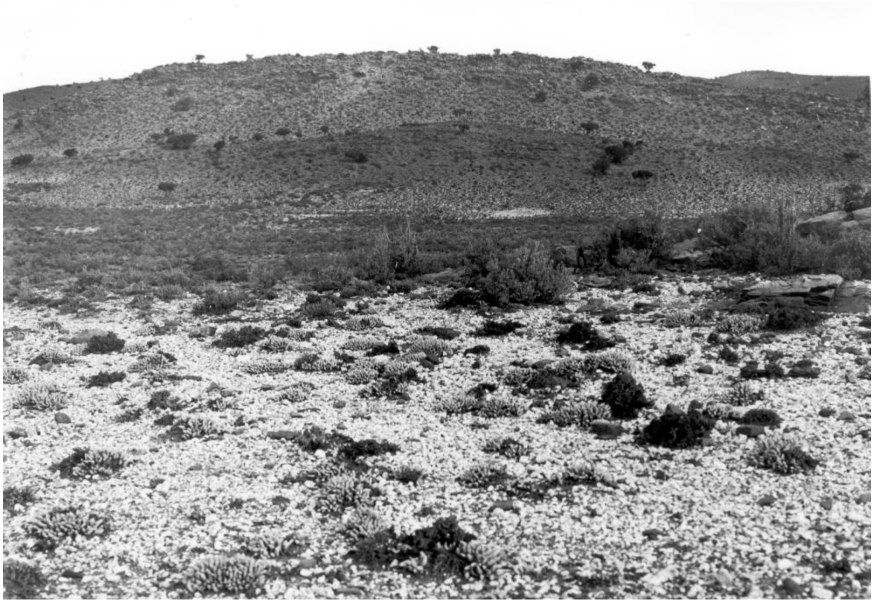
A. (1919). This view looking east, with Touwsberg out of view to the left of the photograph shows the extent of vegetation change on a low shale and quartz-dominated ridge-line and in the wide valley below the Touwsberg. A very complex soil results on the ridge with hard red clayey soil adjacent to exposed bedrock, as seen across the mid-ground, or deeper sandy soil as seen in the lower foreground strip. The valley on the left of the photograph has a relatively high tree cover dominated by *Pappea capensis* and *Euclea undulata*. The cover in the foreground and the majority of the mid-ground is low and dominated by *Pteronia pallens* with scattered taller shrubs and trees such as *Pappea capensis* and *Euclea undulata*. (Pole-Evans).

B. (1993). The vegetation in the valley in the distance appears little changed. The tree elements in the fore and mid-ground including *Pappea capensis* and *Euclea undulata* appear to have increased in size. Generally *Pteronia pallens* appears to have thickened, however boundaries between soil types remain stable with clay soils dominated by *Mesembryanthemum sp*. (Hoffman).

C. (2014). There appears to have been a very slight thickening of the tree and taller shrub elements and a very slight increase in the density of the *Pteronia pallens*, although very little change appears to have taken place. (Hoffman & Murray).

The umbrella shape of the majority of tree elements and sparse ground cover in Pole-Evans' 1919 photograph suggest that the area was used for livestock grazing during this time. However the considerable thickening of these elements in 1993 and 2014 suggests the land has not been heavily grazed for decades.

Site56. Poortjies



A

B

C

Figure 2.5 Poortjies, Klein Karoo, South Africa.

A. (1919). This view looking south shows a complex mix of skeletal soils on a shale ridge with much rock debris just below the crest of the main ridge in the background. The mid-ground valley bottom is eroded and sandy, with numerous 'heuweltjies' dotted across the plain. The quartz patches scattered along the lower slopes of the two ridges support their own fairly unique assemblage of plants such as *Dicoma fruticosa*. Present on the ridges are *Portulacaria afra*, *Searsia lancea*, *Pappea capensis* and *Euclea undulata* along with lower shrubby vegetation. The sandy valley bottom is dominated by *Pteronia pallens*, *Eberlanzia ferox*, *Psilocaulon utile*, *Salsola glabrescens* and *Euphorbia karooica*. The quartz outcrop in the foreground is dominated by *Eberlanzia ferox*, *Dicoma fruticosa*, *Gibbaeum pubesens*, *Salsola tuberculata* and *Ruschia cymosa*. (Pole-Evans).

B. (1993). The patches of *Portulacaria afra* and *Searsia lancea* appear to have increased on the ridge with a small decline in the *Papea capensis* population. There appears to have been little recruitment of *Euclea undulata* although the individuals present on the slope have grown in size. There has been a general increase in shrubby vegetation on the front ridge. The sandy valley bottom has changes little between the original photograph and 1993. The numbers of individuals of *Gibbaeum pubesens* have decreased substantially on the quartz patch in the foreground. There has also been a large increase in *Eberlanzia ferox* and a smaller increase in *Salsola tuberculata* and *Dicoma fruticosa*. The composition of the quartz patch has changed considerably with an increase in the abundance of non-succulent woody shrubs and a decrease in dwarf succulents. (Hoffman).

C. (2014). This view shows a large increase in *Portulacaria afra* on the top of the main ridge with a smaller increase in *Searsia lancea*. The sandy valley bottom shows little change although overall vegetative cover appears to have increased. Grass cover is noticeable for the first time in the mid and foreground areas of the image. (Hoffman & Murray).

The change throughout this series appears to be characterised by a slow general growth in individual species with an increase of general cover. The main decline in species is mostly present in the *Pappea capensis* on the ridge and the *Gibbaeum pubesens* in the foreground. The introduction of grasses in the most recent picture suggests that this area is currently not utilized for grazing and that there has recently been good summer rain.

Site 65. Witvlakte


A


B


C

Figure 2.6 Witvlakte, Klein Karoo, South Africa

A. (1937). This view looking south across a wide valley shows the Touwsberg in the background. Touwsberg is a sandstone mountain surrounded by lower shale and quartzitic ridges. The mid-ground south of the road has a fairly high cover of low shrub species dominated by *Pteronia pallens*. There are a number of tree species on the drainage line along the centre of the mid-ground. These are predominantly *Pappea capensis* and *Euclea undulata*. (Levyns).

B. (1993). The foreground vegetation hasn't changed much in terms of cover. The subtropical thicket trees along the drainage line have far less distinct browse lines and appear to have thickened from the base. The same appears to be the case with the tall shrub and tree species present on the base of the three lower hills in the distance. (Hoffman).

C. (2014). Again there appears to be little change in the low shrubs in the foreground. The subtropical thicket trees, *Pappea capensis* and *Euclea undulata,* have continued to thicken around the base so that the main stems are no longer visible in the photograph. Several individual trees have expanded and coalesced with neighbouring trees to form islands of thicket vegetation. The tall shrubs and trees on the lower hills in the distance appear to have continued to thicken which gives the appearance of greater cover on the hill slopes. (Hoffman & Murray).

The Increase in biomass of individual trees in more recent years is evident from the wider canopies and absence of browse lines around the bases of most individuals in the 1993 and 2014 photographs suggests that this area has not been heavily grazed for decades.

Site 68. Van Zylsdamme


A


B


C

Figure 2.7 Van Zylsdamme, Klein Karoo, South Africa

A. (1937). This view looking east shows the Grootriver in a west-east trending valley just below the Klein Swartberg mountain range. The river banks are characterized by thick tree cover which thins thinning out in the immediate foreground where sandy soils are exposed. The gently sloping plain between the lower foothills on the left and the river bank appear to have been cropped but not on a regular basis. The same appears to be the case on the right fore- and mid-ground. (Levyns).

B. (1993). The original river course has been altered as the result of several major flood events that have occurred since the original photograph was taken. The tall shrub and tree vegetation along the river bed appears to have been thinned out quite substantially, possibly due to a more recent flood prior to 1993. Many small shrub species now cover much of the foreground. There has also been a noticeable increase in the expansion of cultivated fields. These cultivated fields have expanded into what was once relatively dense riverine vegetation. (Hoffman).

C. (2014). The river has been partially canalized and the channel can be seen going from bottom left to mid way on the right. The riverine vegetation to the left of the river channel has thickened since the 1993 photograph. There has been little change in the small shrubs in the foreground. There appears to have been growth in taller shrubs in the immediate foreground. The cultivated fields have remained relatively the same size. (Hoffman & Murray).

It is evident that the river course has been substantially altered since the original photograph in 1937 due to major flood events as well as an encroachment of cultivated fields. The cultivated fields appear to have changed from less regular use in the original photograph to a more permanent, irrigated and fertilized system showing the shift from subsistence to commercial farming.

Site 69. Buffelsvlei_1

A

B

C

Figure 2.8 Buffelsvlei_1, Klein Karoo, South Africa.

A. (1937). This view looking east with the Klein Swartberg mountain range in the distant background is taken from a point of elevation on a small rocky ridge. Just below the ridge and to the left is a thin drainage line beyond which is a relatively flat valley broken by a low rising mound in the mid-ground. The left background shows a steep ridge. The foreground rocky ridge contains a single *Pappea capensis*, in which Levyns's husband sits. This individual has a significant browse line which makes the plant top heavy and is probably the reason why it has toppled over in subsequent photographs. The left foreground has a relatively sparse cover of low shrub species. The drainage line is dominated by *Acacia karroo* and *Schotia afra*. The flat mid-ground to the left also contains a sparse cover of low shrubs. A similar cover is seen on the low rising mound with a number of taller shrub and tree species seen at the base of the mound. (Levyns).

B. (1993). The *Pappea capensis* on the rocky outcrop appears to have been blown down as it is still rooted in some places. The low shrub species on the out crop have increased in cover and include species within the following genera: *Crassula, Euphorbia, Sarcocaulon, Monechma* among others. The low shrubs on either side of the drainage line and on the risen mound appear to have increased in cover. The trees on the drainage line have thickened although one or two individuals to the far left of the drainage line have disappeared.

C. (2014). The rocky foreground has far greater cover in succulent and non-succulent species. Also present are palatable grasses including *Fingerhuthia africana* and *Eragrostis sp*. Grasses are also now present in the flat plains on either side of the drainage line. The drainage line is more heavily vegetated as well as the mound just beyond the drainage line. Still dominant in the drainage line are *Acacia Karroo* and *Schotia afra* but a number of other species are also present including *Euclea undulata, Pappea capensis, Nymannia capanesis, Rhus sp*. and *Lycium oxycarpum*. *Agave mexicana* individuals, located along the western border of the drainage line are also new.

The photograph series suggests that this area has not been heavily utilized since around the time of the original photograph by Levyns in 1937. However, the presence of a significant browse line on the *Pappea capensis* in the foreground in 1937 suggests that the area was heavily grazed at this time. The presence of palatable grasses in the most recent photograph suggests that this area is not grazed by livestock and indicates recent good summer rain.

Site 70. Buffelsvlei_2


A


B


C

Figure 2.9 Buffelsvlei_2, Klein Karoo, South Africa.

A. (1937). This view looking north north-east shows the Klein Swatberg in the background with low rolling hills behind the old road in the mid-ground. A drainage line runs through the middle of the photograph and is dissected by the road. It receives run-off from the road and from upstream to the right. Shrub species are abundant along the drainage line and show greater density in this photograph than in subsequent images, especially behind the car. Dominant species here appear to be *Acacia karroo* and *Lycium oxycarpum*. The immediate foreground has low cover. (Levyns).

B. (1993). The road has moved a few meters to the north removing the taller shrub and tree species on the far side of the original road. The foreground appears to have increased in cover particularly along the drainage line where some taller shrub species appear to be growing.

C. (2014). The foreground cover has increased and is now dominated by *Stipagrostis obtusa* which has increased in abundance toward the drainage line. Other dominants in the foreground include the palatable shrubs *Pentzia incana* and *Rosenia humilus* while the palatable grass *Fingerhuthia africana* is also common in places. The drainage line is dominated by *Cenchrus ciliaris* and *Eragrostis sp*. The large shrub which has grown up on the left is *Lycium oxycarpum*. The drainage line on the other side of the road is dominated by *Acacia karroo* and *Schotia afra* while other trees and shrubs include *Euclea undulata, Nymannia capensis* and *Pappea capensis*.

The major change between Levyns' 1937 photograph and the 1993 image is the move of the road to the north and a very slight increase in ground cover. There has been a substantial increase in overall vegetation cover between 1993 and 2014 as well an increase in the number of trees and tall shrubs along the drainage line. The presence of grasses in the most recent photograph suggests recent good summer rains.

Site 83. Biljetsfontein

A

B

C

Figure 2.10 Biljetsfontein, Klein Karoo, South Africa.

A. (1959). This view looking east shows a flat foreground of washed and eroded sands and silts from the sandstone ridge just north of the site. The broken hill in the background is comprised of Bokkeveld shale. At the base of this hill is a narrow watercourse in front of which is the road. A second dirt road cuts up the mid ground from right to left. The foreground is dominated by *Pteronia pallens*, *Galenia africana* and numerous leaf succulent shrubs within the family Aizoaceae, as well as several *Aloe striata* individuals. *Euphorbia mauritanica* and *Salsola aphylla* are present in the mid ground. The river course is dominated by Acacia karroo while the hill is dominated by *Euclea undulata*, *Searsia lancea* and *Nymannia capensis*. (Acocks).

B. (1993). The foreground appears to have few changes although *Tylecodon wallichii* appears more abundant than in the 1959 image. *Aloe striata* is now only present as seedlings. *Euphorbia mauritanica* appears to have disappeared from the mid-ground while *Salsola aphylla* appears to have increased in abundance, especially in the silty saline soils. The river course appears not to have changed significantly. There appears to be a very slight increase in tree cover and individual tree growth on the hill. (Hoffman).

C. (2014). The foreground appears to be relatively unchanged. However, the mid-ground shows a growth in cover and an increase in grass cover. *Aloe striata* are no longer present at this site. Growth and cover of *Acacia karroo* has increased significantly within the river course. There appears to be little change in the hillside vegetation although several individual tree species appear to have grown in size.

Generally this series shows a gradual growth in vegetation cover and recruitment especially along the drainage line. It is possible that the foreground and the access road were utilized for grazing and movement around the time of the 1959 photograph but have since been left unutilized. The trees on the hill in the background appear to have been grazed in previous years resulting in their umbrella-shaped appearance. However, in the most recent photograph it is apparent that they are no longer grazed and have subsequently regrown from their base.

Site 84. Buffelsvlei_3


A


B


C

Figure 2.11 Buffelsvlei_3, Klein Karoo, South Africa.

A. (1959). This view facing north-east shows a Bokkeveld shale outcrop in the foreground with quartz stones on the lower slopes grading into silty colluvial deposits on the valley bottom. The landscape is broken with skeletal shale soils on koppies which form the foothills of the Klein Swartberg mountain range lying a few kilometres north as seen in the background. The foreground is dominated by *Ruschia cymosa* and *Monechma sp*. with a small *Carissa bispinosa* clump in the centre foreground. The tree to the left of the mid-ground is a *Schotia afra*. The vegetation on the plains below the ridge varies between the quartz patches and areas without quartz. The quartz patches have darker green *Pteronia sp*. individuals with a mix of a relatively complex flora associated with quartzitic soil. The areas without quartz appear to be saline due to the dominance of *Pteronia pallens, Salsola aphylla*, *Blackiella inflata* and *Zygophyllum microphyllum*. (Acocks).

B. (1993). There appears to be little major change in the foreground and the *Monechma* individuals *Ruschia cymosa* are still present. The *Carissa bispinosa* clump appears to have had slight growth as do the *Euclea undulata* behind the clump in the mid-ground. The *Schotia afra* appears to have remained unchanged. The plains below the ridge appear to have had little change with a possible slight growth in cover and one new *Acacia karroo* on the fence line of the road. The west-facing bare rocky hillock shrubs, in the centre of the background, have increased in size and number. (Hoffman).

C. (2014). The rocky foreground slope has had a slight decrease in *Ruschia cymosa* and an increase in *Monechma*. The presence of grasses in the foreground is new. The *Carissa bispinosa* clump has again grown in size and now has an *Acacia karoo* growing out of it. The *Euclea undulata* individuals at the bottom of the slope have stayed much the same. However there is evidence of a previous drought due to an old dead stem in the centre with new shoots growing off it. A *Pappea capensis* individual behind the *Euclea undulata* is now visible. The *Schotia afra* tree has remained unchanged. The lower plains also show an introduction of grass species. For example, the palatable *Digitaria eriantha* is associated with the quartz patches and *Fingerhuthia africana* in the areas without quartz. The background ridges appear to have had little change. (Hoffman & Murray).

In general there appears to have been steady growth in cover of this region with an introduction of *Acacia karroo* trees and palatable grass species in the most recent photograph. This may suggest good summer rains prior in the last year and the removal of grazing within this region between Acocks' 1959 picture and the 1993 picture.

Site 85. Buffelsvlie_4

A

B

C

Figure 2.12 Buffelsvlei_4, Klein Karoo, South Africa.

A. (1959). This view looking north toward the Klein Swartberg in the background is taken from a small rocky ridge with quartz pebbles scattered on the lower slopes. A riverbed runs from the left foreground to the centre mid-ground and is characterized by deeper soils derived from Bokkeveld shale with sand deposits on the river banks. The Klein Swartberg mountain range is in the background over a drainage line and river terrace below the south facing foot slopes of rocky Bokkeveld shale. The foreground outcrop is dominated by *Monechma sp*. and *Ruschia cymosa* with a *Euclea undulata* on the bottom right edge. The river bank before the main river channel is very bare. The lower plain to the right of the river bed is dominated by *Pteronia pallens*. The river course is dominated by *Acacia karroo*, *Galenia africana*, *Nicotiana glauca*, *Pentzia incana*, *Fingerhuthia africana*, *Argemone mexicana*, *Eriocephalus ericoides* and *Melianthus major*. Also present in the river course are *Schotia afra* and *Euclea undulata*. The south facing slopes are dominated by a wide variety of low shrubs both succulent and non-succulent. Also present on the slopes are trees including *Euclea undulata*, *Carissa haematocarpa*, *Putterlickia pyracantha*, *Nymannia capensis* and *Pappea capensis*. (Acocks).

B. (1993). There appears to have been a very slight thickening of vegetation in the foreground, the lower plain and the river bank but no major changes can be seen. The flat plains north of the road to the right appear to have had an increase in *Pteronia pallens* which now dominates this area. Some of the trees in the river bed have disappeared and there appears to be a growth in *Galenia africana*. The south facing slopes appear to have had little change apart from a slight thickening of individual trees. (Hoffman).

C. (2014). There is again little change in the foreground besides a slight thickening of the *Euclea undulata* on the right with the emergence of a new individual. New *Rhigozum obovatum* individuals have also emerged on the edge of the quartz-dominated patch. The river bank, although still quite bare, has seen a definite increase in vegetation including *Salsola sp.*, *Acacia karroo*, *Galenia africana*, *Cenchrus ciliaris*, *Lycium oxycarpum* and *Pteronia pallens*. The most significant change in the river course has been the increase in *Acacia karroo*. Many of the original *Schotia afra* and *Euclea undulata* individuals appear to be present. The river course north of the road also shows a slight widening and increase in tree cover. The south facing slopes have again thickened up and in places coalesced into small bush clumps. (Hoffman & Murray).

From this series it is evident that this region has had some time to rest from grazing since Acocks' original photograph in 1959 as the vegetation cover appears to have increased steadily. The river course has seen the most significant change with the increase in *Acacia karroo*. The introduction of grasses on the plains, river course and river bank suggest both good recent summer rains and the absence of grazing as these grasses are highly palatable.

Site 87. Boerbone Fontein_1


A


B


C

Figure 2.13 Boerbone Fontein_1, Klein Karoo, South Africa.

A. (1959). This view facing north shows the southern foothills of the Rooiberg with very broken typography. The foreground is comprised of eroded silty flats, the mid ground of deeper soils, while the ridge beyond is comprised of Bokkeveld shale. Purple flowering *Mesembryanthemum* sp. are prominent in the foreground and are surrounded by a basic mix of species including *Pteronia pallens*, *Salsola sp.* and *Galenia africana*. The mid ground, with a small gully, is comprised of thicket species such as *Lycium austrinum*, *Nymannia capensis*, *Euclea undulata*, *Searsia lancea*, *Pappea capensis* and many lower shrubs. The rocky west south-west facing ridge is dominated *Pteronia incana*, *Euclea undulata*, *Pappea capensis* and *Searsia lancea*. The top slope is dominated by *Elytropappus rhinocerotis*. (Acocks).

B. (1993). There appears to be a slight thickening of all vegetation throughout this view however little significant change is apparent. The purple *Mesembryanthemum* flowering in 1959 is no longer visible although this may just be due to seasonal variation in the timing of each photograph. (Hoffman).

C. (2014). Once again the vegetation in this view appears to have increased in density. This is particularly apparent in the mid-ground gully where a significant increase in *Lycium austrinum* and *Nymannia capensis* is evident. (Hoffman & Murray).

The steady increase in cover of all vegetation in this view suggests little use of this region has occurred since the original photograph in 1959.

Site 88. Boerbone Fontein_2


A


B


C

Figure 2.14 Boerbone Fontein_2, Klein Karoo, South Africa.

A. (1959). This view shows an east north east facing Bokkeveld slope with shallow skeletal soils. The immediate foreground looks to be the site of the old road and is dominated by *Pteronia pallens* and a variety of succulents. The lower slopes are also dominated by *Pteronia pallens* with strong signs of soil slip and erosion with many of the plant species standing on elevated mounds. The upper slopes are comprised of mixed karroid broken veld, rich in species with much co-dominance. The top right centre of the koppie has a very steep east facing slope dominated by *Pentzia incana* and *Fingerhuthia africana*. (Acocks).

B. (1993). There appears to be a very little change in vegetation in the immediate foreground. The lower slopes appear to have had a slight growth in general cover with a number of the taller shrubs having been removed from this area. The upper slopes also appear to have had a general growth in cover. However, there appears to be a decrease in *Crassula portulacacea* which have moved further upslope. (Hoffman).

C. (2014). The vegetation in the foreground appears to have increased with new *Salsola sp*. in the immediate foreground. The dominant *Pteronia pallens* on the lower slopes appear to have increased along with a number of new lower shrubs. The vegetation on the upper slopes, particularly to the left has increased in density with a number of new taller shrubs. (Hoffman & Murray).

The continued growth in vegetation cover on this slope and the closing up of bare areas by vegetation suggests that there has been little use of this area since Acocks' photograph in 1959.

Site 89. Opzoek_1


A


B


C

Figure 2.15 Opzoek_1, Klein Karoo, South Africa.

A. (1959). This view facing north shows a large heuweltjie in the mid-ground situated between a river course in the foreground and a shale ridge in the background. The Rooiberg can be seen just behind the shale ridge. The river course has low cover with a few scattered *Acacia karroo*. The heuweltjie is dominated by *Drosanthemum* sp. and is in full purple bloom. Also present on the heuweltjie is *Psilocaulon sp*. The shale ridge is comprised of a very complex phyto-geographic mix of Little Karoo and renosterveld elements along with some subtropical thicket over-storey elements such as *Searsia longispina, Carissa haematocarpa*, *Euclea undulata*, and *Pappea capensis*. The steep west facing ridge on the right is comprised of open Portulacaria afraveld and subtropical thicket with renosterveld on the gentler south facing slopes. (Acocks).

B. (1993). This view shows a significant increase in *Acacia karroo* within the river course with two dead trees that appear to have been killed by *Viscum rotundifolium*. Of concern is the presence of *Tamarisk* with a number of new seedlings visible. The heuweltjie appears to be relatively unchanged and is still dominated by *Drosanthemum sp*. The shale ridge appears to have had a slight increase in general cover however both ridges, the shale and west facing ridge, appear relatively unchanged in composition. (Hoffman).

C. (2014). This view again shows a significant increase in *Acacia karroo* in the river course and a new individual can even be seen to the left of the heuweltjie. The (lime green- *Drosanthemum*?) on the heuweltjie appear to have increased slightly in density. There are also new grasses to the lower right corner of the heuweltjie. The shale ridge again appears to have had a general increase in cover with the west facing ridge again appearing to have had little change. (Hoffman & Murray).

The most significant change in this series has been the dramatic growth in number and size of the *Acacia karroo* within the river course and in the most recent photograph the new individual to the left of the heuweltjie just below the shale ridge. The general growth in cover since Acocks' 1959 photograph also suggests that this area has not been utilized since this time.

Site 90. Opzoek_2

A

B

C

Figure 2.16 Opzoek_2, Klein Karoo, South Africa.

A. (1959). This view facing north west shows a large heuweltjie in the mid-ground situated between a river course in the foreground and a shale ridge in the background. The river course is bare with only a few short shrubs that have established from the gentle heuweltjie slope. The heuweltjie, on silty soils, is dominated by *Drosanthemum* sp. and *Psilocaulon sp*. The shale ridge is comprised of a very complex phytogeographic mix of Little Karoo and renosterveld elements along with some subtropical thicket over-storey elements such as *Searsia* longispina, *Carissa haematocarpa*, *Euclea undulata*, and *Pappea capensis*. (Acocks).

B. (1993). There has been a significant increase in *Acacia karroo* in the river course which is no longer bare. Of concern within the river course is the presence of *Tamarisk* with many seedlings of this species present. The heuweltjie is still dominated by the purple blooming *Drosanthemum* sp. and *Psilocaulon sp*. There appears to be little change on the shale ridge with a possible slight increase in general cover. (Hoffman).

C. (2014). In this view a significant increase in the cover of *Acacia karroo* within the river bed can again be seen. There is also a new individual just below the shale ridge to the left of the heuweltjie. Both the heuweltjie and ridge appear to have had little change in composition although there appears to have been a slight increase in general cover. (Hoffman & Murray).

The significant increase in *Acacia karroo* appears to be the most significant change in this photograph series. There also appears to be a consistent increase in cover since Acocks' 1959 photograph suggesting that this area has not been utilized since that time.

Site 91. Assegaay Bosch_1


A


B


C

Figure 2.17 Assegaay Bosch_1, Klein Karoo, South Africa.

A. (1959). This view facing north west with the Rooiberg in the far background shows a slightly eroded valley with deep red, and now mixed, soils in the foreground which was once a ploughed field. The background hills are steep south facing shale slopes. The foreground heuweltjie is dominated by the purple flowering *Drosanthemum hispidum*. Also present in the foreground is *Salsola aphylla* and *Euphorbia mauritanica*. The mid-ground has a good cover of succulent karoo shrubs and two *Euclea undulata* present on either side of the mid-ground. The background south facing shale slopes are comprised of renosterveld communities. (Acocks).

B. (1993). This view was taken further east along the road to Acocks' 1959 picture due to a change in both road and fence locations. The foreground is still dominated by *Drosanthemum hyspidum* although they appear to be less than before. The unpalatable *Pteronia pallens* appear to have increase on the heuweltjie and in the foreground in general. The *Salsola aphylla* still occupies the same position. *Euphorbia mauritanica* now appear absent from this view. The mid-ground appears to have changed little despite the disappearance of the *Euclea undulata* on the left. There has also been an introduction of *Aloe ferox* in the mid-ground although the height of the tall individual to the right suggests that there may have been younger individuals not visible in the 1959 photograph. The renosterveld community in the background doesn't appear to have changed much at all. (Hoffman).

C. (2014). In this view the foreground appears to have had a slight increase in diversity (grasses on the left and a grey green shrub on the right) and possibly a very slight increase in cover. There has been an increase in *Aloe ferox* in the mid-ground and some growth in the remaining *Euclea undulata* which has filled out from its base. There has again been very little change in the background, south facing shale slopes. (Hoffman & Murray).

The increase in diversity and grasses as well as the growth in foliage around the base of the *Euclea undulata* between the 1993 and 2014 photographs suggests that this area had previously been utilized for grazing but that this had stopped sometime before the 1993 picture.

Site 92. Assegaay Bosch_2

A

B

C

Figure 2.18 Assegaay Bosch_2, Klein Karoo, South Africa

A. (1959). This view looking west shows narrow valley between two low ridges. The shale slopes have very eroded skeletal soils on the valley sides with deep erosion in the valley bottom. The north facing slope, to the left, is dominated by *Portulacaria afra* and to a lesser degree by *Euclea undulata*. The river bank on the south side of the main channel is dominated by typical hueweltjie species and *Pentzia incana*. This area has high cover particularly of succulent shrubs. The valley bottom is dominated by *Pteronia pallens* with a number of *Salsola* species on very skeletal soils. The south facing slope to the right is characterized by renosterveld. (Acocks).

B. (1993). The *Portulacaria afra* veld on the north facing slope appears to have change little with a possible slight increase in the height of *Portulacaria afra*. The south river bank has also change little. The valley bottom in the foreground of the photograph appears to have had a slight increase in cover. However, the *Pteronia pallens* and *Salsola* species occupy the same position in the landscape. The south-facing slope appears to also have changed little. (Hoffman).

C. (2014). This photograph location had to be moved about 12 meters closer to the road from the previous two pictures due to a tall fence, approximately 2,3 meters high, which had been recently erected. There again appears to be little change in the north and south facing slopes on either side of the valley. The river bank appears to have lost a number of *Euclea undulata* which may be related to the establishment of the new fence. The disturbed foreground is still relatively bare. However, with the new site location it is difficult to determine whether a slight increase in cover has occurred. (Hoffman & Murray).

The small amount of change that has occurred in this series of images suggests that the steep north and south facing slopes have had little use since before Acocks' original photograph in 1959. The valley bottom has seen a slight increase in cover which suggests that this area may not have been utilized since the time of the original picture. However, it also suggests that once vegetation and land in this area has been heavily eroded and is in a bare state it takes decades to recover.

Site 93. Keurboschfontein_1


A


B


C

Figure 2.19 Keurboschfontein_1, Klein Karoo, South Africa

A. (1927). This view looking north shows heavily eroded deep red soils of what used to be a river bank terrace leading to a river course. The surrounding landscape is dominated by Bokkeveld shale. (Levyns).

B. (1993). There is evidence of some soil movement within this view. However, the same small hillock is still present. (Hoffman).

C. (2014). Again there appears to have been some soil movement since the 1993 image. However, this is very slight and the same small hillocks are still present. (Hoffman & Murray).

It is highly interesting to see that the soil movement process in this eroded river course may not have been as dramatic as one would expect. The area about 300 meters east north east (i.e. above) of this station has had a long history of having been ploughed since the middle of the last century which may have something to do with the deep gullies cut into this surface. Therefore events that happened over a century earlier may have extremely long-term repercussions.

Site 94. Keurboschfontein_2

A

B

C

Figure 2.20 Keurboschfontein_2, Klein Karoo, South Africa

A.(1927). This view looking north shows the lowlands dominated by Bokkeveld shale with the sandstone Rooiberg Mountain in the distant background. The foreground to the left appears to be an old ploughed field with the old road cutting between the mid and foreground region. The foreground is relatively sparsely covered with vegetation and isdominated by *Galenia africana*. The mid-ground has a variety of small Karoo shrubs and a number of *Euclea undulata* to the right. (Levyns).

B. (1993). There appears to be a general increase in small shrub cover throughout the mid and foreground region. *Galenia africana* is still dominant in the foreground. The *Euclea undulata* individuals appear to have grown taller and thicker. There appears to also be a number of new tall shrubs in the mid-ground. (Hoffman).

C.(2014). Once again there appears to be a general growth in cover and density of the shrub species in this view. The *Euclea undulata* and tall shrub species have also grown more dense. (Hoffman & Murray).

The growth in general cover seen in this series suggests that this area has not been utilized since the original photograph in 1927. The long dominance of *Galenia africana* in the foreground exemplifies the extent of time old ploughed fields take to recover from disturbance and regain plant diversity.