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January 2009

An environmental history of the Cederberg: changing climate, land use and vegetation patterns

Daniela Vincenza Bonora

Supervisors: Prof. Timm Hoffman (Botany, UCT), Dr. Rick Rohde (Centre of African Studies, University of Edinburgh) and Dr. Edmund February (Botany, UCT)

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BNRDAN001

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- ABSTRACT -

This thesis documents how climate and land use practices have changed in the Cederberg over the last century and how these changes have affected vegetation patterns. Along with a description of the major geological, climatic and vegetation gradients in the study area, changes in rainfall, temperature, A-pan evaporation and fire regimes over the 20th century are analysed from official records. While rainfall has not changed significantly from 1900-2007, the last 30 years have been drier than the mean value. The temperature records show an increase of 1°C since the 1960s; however, A-pan evaporation values have declined significantly over the last 30 years. The fire records suggest an increase in area burnt and in frequency since the mid 1940s. Changes in land use and its impacts on Cederberg landscapes are then assessed through a combination of archival sources, repeat photography and oral history. A zonal theme was adopted to analyse the environment of the Cederberg, and land use and landscape changes of the lowlands, midlands and uplands are examined independently. Results show that the Cederberg lowlands have experienced the largest degree of transformation over the course of the 20th century, primarily as a result of the intensification of agriculture, specifically fruit, vine and potato cultivation. Large areas of the midlands have also been transformed, although to a lesser extent than the lowlands. The midlands have experienced a complex history with changes differing between the northern and southern parts of the Cederberg. Evidence from 17 repeat photograph pairs suggests that the natural vegetation of the northern midlands has witnessed a recovery, with a contraction of traditional forms of farming and an increase in tourism and wine making. The southern midlands, on the other hand, have seen an expansion in agricultural production similar to the trends recorded in the lowlands. In contrast to the lowlands and midlands, human-induced transformation of the Cederberg uplands has been minimal. In this region, the impacts of a changing climate and fire regime are most clearly observed, and best explain the declining populations of the endemic Clanwilliam cedar tree (*Widdringtonia cedarbergensis*). Evidence from 15 repeat photographs shows that there has been a rapid decline (average of 2.5% per annum) over the last 70 years, and if current rates of decline continue, the species will be extinct in the region within 300 years. An increase in fire frequency is the best explanation for the demise of the cedar, although changes in rainfall, temperature and the impacts of disease deserve further investigation. The results of this thesis are relevant for land owners, agriculturalists, conservationists and the tourism industry, and by using repeat photograph pairs, it provides a richly illustrated account of changes in the region over the last 100 years.

CHAPTER 1: GENERAL INTRODUCTION

1.1 BACKGROUND AND MOTIVATION FOR RESEARCH

The broader aim of this research was to detail the extent and rate of change to the Cederberg landscape over the last 100 years. These changes were investigated in terms of both changes in the climate regime as well as anthropogenic impacts. The ultimate goal was to use this information to inform conservation management options for the Cederberg Wilderness Area (CWA) and its surrounds as a whole. The study investigated the primary drivers of change to this area, which is situated within a local biodiversity hotspot – the Cape Floristic Region (CFR). It was guided by current principles of conservation biology, which focus on the relations between anthropogenic actions, environmental condition and biodiversity (Sarkar, 1999).

An in-depth look at the environmental history of the Cederberg Wilderness Area and its surrounds is important for a number of reasons. Firstly, at more than 71,000 hectares (ha), the Cederberg is an area of significant regional conservation importance. It is home to a variety of important and unique plants and animals, with more than 1,700 fynbos and succulent plants, including the rare and endemic Snow Protea (*Protea cryophilla*) and the threatened Clanwilliam cedar tree (*Widdringtonia cedarbergensis*) (Van Rooyen and Steyn, 2004). It also forms an important catchment in the more arid northern portion of the Western Cape (Taylor, 1996), and in terms of vegetation dynamics, the Cederberg is an area of interest as its flora not only has associations with the fynbos[1] of the Cape Floristic Region, but also with the Namaqualand and western Karoo[2] shrublands. A checklist of the vascular plants of the Cederberg Wilderness and Mountain Catchment Area compiled by Taylor in 1996, revealed there to be a total of 1,778 species (Taylor, 1996).

From about 1903 to 1973, exploitation of the Cederberg's natural resources was widespread and highly problematic, with extensive harvesting of cedar wood, rooibos

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[1] Fynbos, meaning "fine bush" in Afrikaans, is the natural shrubland or heathland vegetation that occurs in a narrow belt of the Western Cape of South Africa.
[2] The Karoo is a semi-desert region of South Africa, which has two main sub-regions: the Great Karoo in the north and the Little Karoo in the south.

tea and buchu, while mountainous land was being used by farmers for livestock grazing. During this period, some 7,200 cedar trees were used as telephone poles between Piketberg and Calvinia (Taylor, 1996). Since being declared a wilderness area in 1973, the removal of cedar trees and other forms of exploitation have come to an end, and today there is a voluntary agreement among landowners in the area to manage the environment sustainably.

The Cederberg also forms part of the Greater Cederberg Biodiversity Corridor (GCBC), which is a conservation partnership stretching across the landscape from Verlorenvlei River on the northern West Coast and the Tanqua Karoo in the East, and between the Baviaansberg in the South to Nieuwoudtville in the North (Low *et al.*, 2004). This is an area of approximately 1.2 million ha, and is one of the largest, broad scale conservation initiatives ever undertaken in the Western Cape. The main aim of the GCBC is to maintain or repair connectivity across the landscape, so as to improve protected area management for the benefit of biodiversity and the reduction of habitat loss and species extinction.

A second reason for an environmental history focus on the Cederberg is that it is a major agricultural region of South Africa and represents a node of significant tourism expansion. In fact it is the agriculture and tourism sectors in the Cederberg Local Municipality (CLM) that are the main contributors to the Gross Domestic Product (GDP) in the region. These two sectors also contribute greatly to employment and social development and they are also now driving secondary economic growth through the development of small, medium and micro enterprises (SMMEs). In terms of agriculture, citrus farming and the cultivation of Rooibos tea are the main products of the region and there is a constant demand for these products, both locally and internationally (http://www.tradeinvestsa.co.za/investment_opportunities/983583.htm).

Thirdly, the broader Cederberg is also an area of major historical significance as this region was for a time the Cape Frontier, which saw the advancement of the Dutch colonists and the confrontation with the indigenous Khoisan peoples in the eighteenth century (Penn, 2005). Intertwined with this is the significance of the pre-colonial and archaeological heritage of the region. There have been numerous archaeological

findings in the area, and the Cederberg has one of the richest rock art collections in Southern Africa, if not the world. The ages of rock paintings in the Cederberg vary, with the paintings of colonial farmers less than two hundred years old, and other paintings, such as those of handprints, range between 1,000 and 1,500 years of age (Parkington, 2003). However, the oldest paintings in the Cederberg are said to date as far back as 4,000 years (Parkington, 2003).

Finally, in addition to the influences of land use to the environment, it has become widely accepted that increased levels of atmospheric CO2 are expected to raise both global and regional temperatures – producing a knock-on effect of change in other climatic variables such as precipitation and evaporation (New, 2002; Christensen *et al.*, 2007). A study conducted by Hewitson (1999), on regional climate change scenarios, showed the consequences of increases in atmospheric CO2. It revealed that during summer, we can expect an increased occurrence of days with a stronger and more southerly South Atlantic high pressure system, as well as enhanced high pressure ridging – the implications of which can have the following effects: increased aridity in the south-western Cape, and the possibility of more pollution; as well as the chance of increased orographic rainfall on the southern coastline (Hewitson, 1999). In winter, it is indicated that in the southwest portion of Africa there could be a greater number of frontal systems, leading to greater frontal passage in the western Cape (Hewitson, 1999). In general, the implications of climate change are expected to cause mean temperature increases of between 1°C and 3°C by the mid 21st century, with the highest increases in the most arid parts of the country. These altered temperatures may lead to changes in biogeographic distributions and the loss of biodiversity (DEAT, 2000). Climatic scenarios such as these suggest that areas such as the Cederberg will become hotter and drier (Hewitson, 1999; New, 2002; Christensen *et al.*, 2007), resulting in increased plant water stress (Midgley *et al.*, 2003). This has important implications for future land use practices and impacts as well as for the long term dynamics of the vegetation of the region.

The effects of climate change on biodiversity are uncertain, however Rutherford *et al.* (1999), predict a combined 50% area reduction of all South African Biomes. The results of regional biome-level modelling assessments of climate change impacts on biodiversity in the Cape Floristic Region, have revealed that the fynbos biome is at

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risk of losing large areas towards its northerly boundaries, particularly along the west coast (Midgley *et al.*, 2003). Furthermore, it is suggested that the fynbos biome will contract southwards in the future, within the mountains of the Cape Fold Belt (Midgley *et al.*, 2003). In terms of species-level responses to a changing climate, it has been said that an altering of the species' composition of protected areas is likely with future climate change (Hannah *et al.*, 2005). Bioclimatic models have shown that a significant number of species could lose all suitable range and representation in protected areas, and it is emphasised that the spatial composition and division of protected areas, especially between lowlands and uplands, is an essential determinant of the possible outcomes of climate change. Modelling has revealed that lowland species and species of minimal range are the most vulnerable to local extinction and the first to lose protection (Hannah *et al.*, 2005).

The Cederberg has been heavily utilized by people for millennia, by both the San and Khoi clans and by European settlers. However, human impact has not been uniform across the landscape. Land use has been heavily influenced by the relatively steep topographic and climatic gradients in the region, and historical and political influences have also changed over time having effects on land use practices in the area. In addition, climate change impacts are already considered an important driver of environmental change in the region.

This thesis investigates a number of aspects of climate and land use change in order to present a sound environmental history of the Cederberg. It uses a wide range of tools and focuses on the climatic and anthropogenic impacts within three distinct regions of the Cederberg: (1) a low-lying river valley and coastal plain (below 500 m above sea level) with access to irrigable lands; (2) a middle zone (between 500 and 1,000 m above sea level) with variable access to markets and agricultural and tourism opportunities and (3) a high-lying, relatively inaccessible wilderness area dominated by adventure hiking trails and spectacular scenery (between 1,000 and 2,027 m above sea level) (Taylor, 1996). It must be noted that these are broad classes only and are not precise, bounded units. The thesis discusses the rate of change in each of these three regions and identifies the main drivers of change, and it also shows how changing land use practices have influenced the vegetation and general landscape

patterns within each region. Finally, the implications of these changes for ongoing management and policy issues are discussed.

1.2 OBJECTIVES

1.2.1 Project Aims

The project aims to document the extent and rate of landscape change in the Cederberg Wilderness Area (CWA) and its surrounds over the last 100 years, and to identify the main drivers of this change. The relative influence of climatic and anthropogenic factors will be assessed within three broad geographic regions.

1.2.2 Key Questions

- What has been the extent and rate of landscape change in the Cederberg Wilderness Area (CWA) and its surrounds over the last 100 years in relation to altitudinal, moisture and disturbance gradients?
- What are the fundamental drivers of change to this system – climatic (e.g. temperature, rainfall seasonality and amount) or anthropogenic (e.g. fire, grazing, cultivation)?
- What additional information do indicator species (e.g. the Clanwilliam cedar or species within the Proteaceae) reveal about environmental change within the Cederberg over the twentieth century?

1.3 LIMITATIONS OF RESEARCH

There were various limitations encountered whilst conducting this research. Firstly, in terms of data availability – agricultural census records were difficult to obtain, and they ceased to exist from the mid 1990's. There were also gaps in the available agricultural data records, with many years missing. In addition, recent citrus and deciduous fruit data for the region were not compatible with the area covered by previous censuses.

Climate data (temperature and rainfall) for the Cederberg was also somewhat restricted with there being insufficient points at high altitude for a very good set of measurements. Algeria Forest Station is the only rainfall station within the Cederberg Wilderness Area (CWA) itself, with the available data dating between 1910 and 2007. Kromrivier, on the perimeter of the CWA had rainfall records from 1957 to 2007. Outside of the mountain range there are a number of climate stations, which record both rainfall and temperature information. The climate stations in the Clanwilliam area, other than the town of Clanwilliam itself, are: Lorraine, HLS Augsburg and Middeltuin. And in the Citrusdal area, the climate stations are: Citrusdal, Citrusdal Noord and Stagmanskop.

Another difficulty encountered in conducting the field research for the project was the extremely tough terrain of the Cederberg mountain range, which resulted in the inaccessibility of high altitude sites.

In terms of the photographic component of the research, it was recognized that due to the reliance on a single collection of historical photographs, the analysis is confined to original and repeat images, and therefore a time series element is unfortunately lacking. Furthermore, the photographs sometimes presented a limited number of sites – this was specifically so with regards to the cedar component of this thesis.

1.4 THESIS STRUCTURE

Chapter 2 looks at the study area in more detail, providing background information on the fynbos biome and its vegetation, as well as the geology, climate and history of human occupation of the Cederberg.

Chapter 3 is an examination of the land-use history of the Cederberg and the changes observed over the 20th century. This chapter will be investigating the low-lying areas of the Cederberg where agricultural production has been most intense. Here there will be a thorough examination of the agricultural data in terms of the deciduous and citrus fruit industries, wine production and livestock farming.

Chapter 4 assesses general landscape change in the Cederberg Wilderness Area over the 20th century and investigates changes in vegetation structure in response to changing land use practices in the region. In this chapter the focus falls on the mid-altitude division of the Cederberg, and incorporates interviews with land owners as well as an analysis of eight repeat photographs to document the changes that have occurred in this region.

Chapter 5 considers the collapse of the Clanwilliam Cedar in the high-lying areas of the Cederberg. Fifteen repeat photographs of cedar populations from the northern section of the Cederberg are examined in this chapter - illustrating the decline of the cedar tree by way of repeat matched photography and statistical analyses.

Chaper 6 concludes this study with a discussion on the links between land-use practices, landscape change and biodiversity conservation across the lowland, midland and upland ranges of the Cederberg. It summarises the spatial and temporal patterns of change observed throughout the Wilderness Area and its surrounds, and outlines the varying degrees of anthropogenic influence. An attempt is made here to identify the fundamental drivers of change to this system, and its implications for management practices in the region.

CHAPTER 2: THE CEDERBERG ENVIRONMENT IN SPACE AND TIME

2.1 INTRODUCTION

This study focuses on the area broadly defined as the greater Cederberg region, which stretches from the town of Clanwilliam in the North to the town of Citrusdal further south in the Olifants River valley (see Figure 1). The Olifants River, which originates in the rocky altitudes of the Cederberg mountains, carves a valley through this mountain range. The Cederberg itself, which is a proclaimed Wilderness Area, encompasses some 162,000 hectares of mountainous terrain extending north from the Pakhuis Pass to Grootrivier in the south. The geology, soils, climate and major vegetation units of the study area are described in detail below, as well as the fire history of the Cederberg and the chronology of human occupation of the region.

2.2 THE GEOLOGY AND GEOMORPHOLOGY OF THE CEDERBERG

The Cederberg forms the northern limit of the Cape Fold Belt of mountains that dominate the Cape Floristic Region (Mucina and Rutherford, 2006). Upthrust and folding of the sedimentary rocks and subsequent extensive faulting formed the mountains of this region, which follow a northwesterly direction. The rocks consist of a mixture of shales, siltstones, sandstones, quartzites and conglomerates, and are differentiated according to the origin of the sedimentary materials which comprise them, as well as by their chemical transformation through time (Theron, 1984; Parkington, 2003).

An arenaceous sedimentary sequence known as the Table Mountain Group (within the Ordovician to Devonian Cape Supergroup) make up the majority of the Cederberg, with some fragments of the older 560 MYA Malmesbury shales near the Olifants River in the west and a sudden transition to the younger 350 MYA Bokkeveld[3] formations to the east (Taylor, 1996).

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[3] The term veld, literally meaning 'field', refers to the wide open rural spaces of South Africa, and in particular, areas covered in grass or low scrub.

There are four formations of the Table Mountain group of the Cape Supergroup found in the Cederberg, they are from bottom to top:

1. The Peninsula Formation (450 MY), which is similar to the Nardouw and is a very thick deposit of course-grained quartzitic sandstones with occasional white quartz pebble deposits. (Taylor, 1996).
2. The Pakhuis Formation (420 MY) - found immediately below the shale band, is a thin layer of tillite and other rocks (Taylor, 1996; van Rooyen and Steyn, 2004).
3. The Cederberg Formation (410 MY), which is made up of the shale band (a prominent feature of the landscape), is set between the Pakhuis and Nardouw Formations and forms a narrow green band that varies sharply with the bare rocky quartzites below. (Taylor, 1996; van Rooyen and Steyn, 2004).
4. The Nardouw Formation (400 MY), which is common in the plateau-like summits north of Pakhuis Peak and on Sneeukop and Tafelberg (Taylor, 1996).

Two other formations – the Graafwater and Piekenier Formations (480 MY) are the lowermost strata of the Table Mountain Group and do not appear in the Cederberg.

This mountainous region of the Western Cape was initially a low-lying land between mountain ranges, which is now covered by the Atlantic Ocean to the west and the Karoo region to the east. At some stage between 440 and 420 million years ago when Africa straddled the South Pole, a large glacier travelled from the north and smoothed the accumulating Cederberg surface (McCarthy and Rubidge, 2005). Signs of this glacial event are evident in glacial scouring and drop stones at the bottom of the Pakhuis Pass in the northern Cederberg. Once the glacier melted, it deposited millions of tons of fine-grained sediment taken from the landscapes to the north. Gradually sediment amassed on sediment and both land and sea rose and fell – initiating the processes of consolidation and metamorphosis (Theron, 1984; Parkington, 2003).

Further sediments accumulated within the shallow seas and extensive river deltas, which deposited hundreds of meters of material into shallow waters in the region of Clanwilliam, approximately 350 million years ago (Parkington, 2003). Large cobbles and gravels and lesser sized silt and clay particles were alternatively transported and

deposited in shifting cycles. Over time, the deposited sediments were separated out into conglomerates, sandstones, siltstones and clayey shales (Theron, 1984; Parkington, 2003). Through forces of pressure and heat, unconsolidated sands turned into sandstones or were converted into quartzites. Folding and warping of the sediments of the earth's crust emerged with the drifting of the continental plates – twisting into the peaks, troughs, ridges and valleys that we see in the Cederberg landscape today.

The Olifants River Valley that exists at present is a synclinal fold, set between two upthrust sets of ridges known as the Cederberg and Olifantsrivierberg ranges (Parkington, 2003). The sediments that were deposited became vertically fissured and ruptured from intense faulting. A typical angular pattern is displayed in the sandstone beds, arising from the drainage which follows fault lines and angular lines of weakness. The quartzitic sandstones are fairly resistant to weathering, but the shales and mudstones of the shale bands are less resistant (Taylor, 1996).

On the western boundary of the Cederberg Wilderness Area, the mountains ascend steeply from the Olifants River valley. Sneeuberg forms the highest peak in the range at 2,027 m and the difference in altitude between the summit of Krakadouw Peak (1,744 m) further north and the Jan Dissels River, 4 km to the west, is 1,450 m (Taylor, 1996) – illustrating the swift change in elevation that is experienced in this mountain range.

The topography, as Taylor (1996) notes, is distinctive of regions where an arid climate with marked seasonal differences in temperature and rainfall controls the erosion cycle. Flat mountain tops, like that of Tafelberg, are a result of the limited folding of the Table Mountain Group. This produces a typical weathering pattern of large rock groups sculptured by wind and weather into unique shapes (Taylor, 1996).

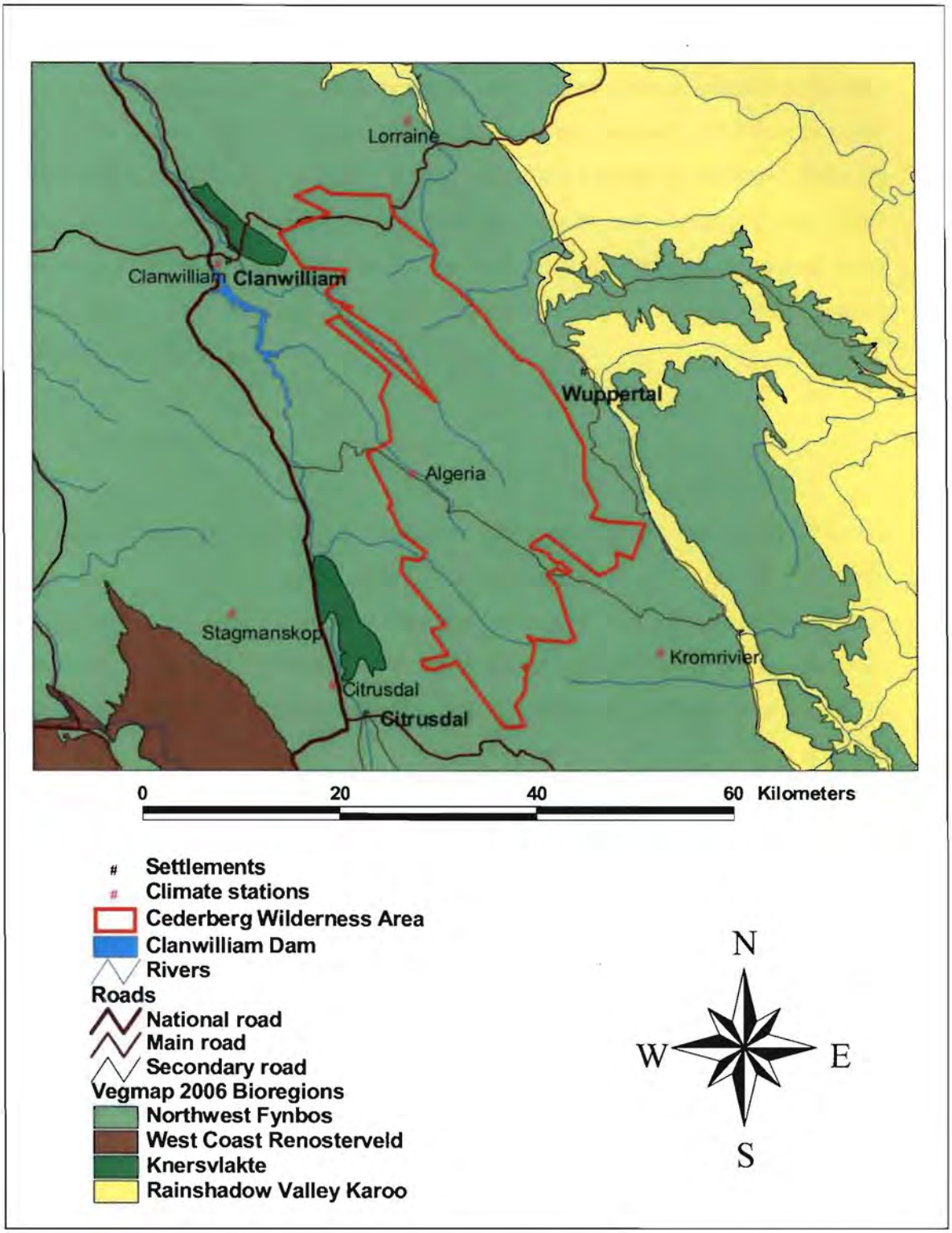

Figure 1: Outline of the study area within the broadly-defined Cederberg region. The map shows rivers, roads, major place names (including climate stations), bioregions (after Mucina and Rutherford, 2006) and the boundary of the Cederberg Wilderness Area.

2.3 SOILS

The western mountains of the Cederberg are made up of coarser textured soils than those in the eastern parts (Taylor, 1996). The soils are generally well leached acid sands, lacking in nutrients and with a limited capacity for retaining moisture. Soils are skeletal on rocky slopes and are primarily of the Mispah and Glenrosa Forms. They are porous and free-draining (Taylor, 1996), making them resistant to normal water erosion. Little mass wastage is observed, however accelerated sheet erosion is sometimes seen after fires.

2.4 CLIMATE

The fynbos biome is located in a transition zone between two noticeably different meteorological systems (Fuggle, 1981). The extreme summer aridity of the south-western cape and indeed the length of the west coast of South Africa and Namibia, is largely the result of the South Atlantic anticyclone, whose southern and landward movements bring this portion of Southern Africa under the influence of the stable eastern part of this high pressure cell. It is this phenomenon which ultimately accounts for the relatively dry, summer conditions of the south-western Cape by preventing major vertical air movements (Fuggle, 1981) (Figure 2).

Winter rain is proportionately highest in the west of the fynbos biome and decreases northwards. The Cederberg – among the most westerly and northerly of fynbos mountains, receives around 80% of its rain in the three winter months of June, July and August, but has an annual total that is lower than most other Cape mountains (Taylor, 1996). The west also receives greater seasonal temperature ranges and higher annual pan evaporation.

The Cederberg experiences a Mediterranean type climate, characterized by cold, wet winters and hot, dry summers (Cowling *et al.*, 1992). The area has local gradients in precipitation determined by altitude and proximity to the Atlantic Ocean (Taylor, 1996). Generally, areas within the higher mountainous regions (such as Algeria) receive more rain than the valleys. North and south aspects also differ significantly in their radiation loads and hence their aridity (Taylor, 1996). All of these factors result

in significant variations in the local climates of the Cederberg, with corresponding differences in vegetation.

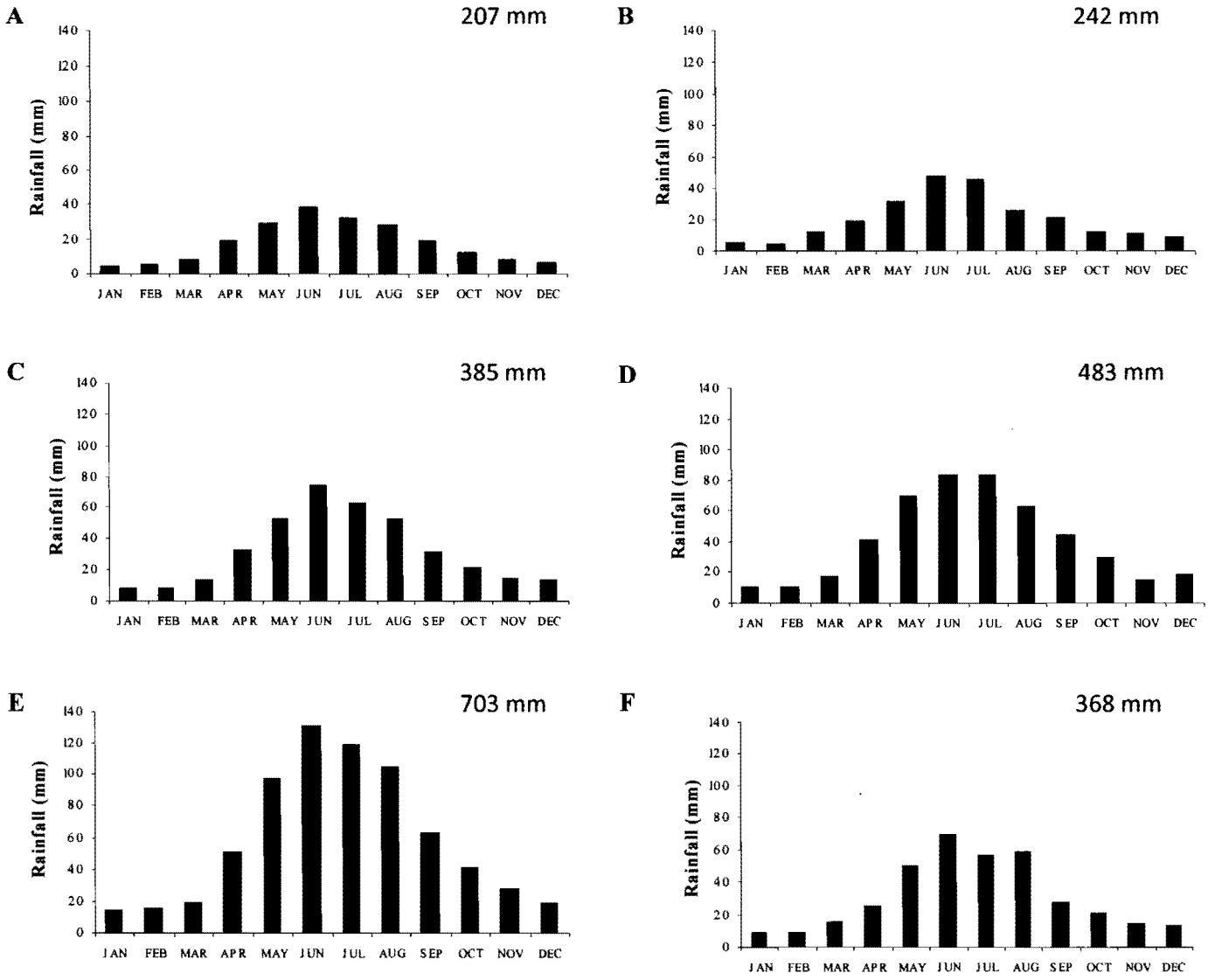

Figure 2: Average monthly rainfall totals for six climate stations in the Cederberg area: (A) Clanwilliam (1875-2007), (B) Lorraine (1983-2007), (C) Citrusdal (1965-2006), (D) Stagmanskop (1983-2007), (E) Algeria (1910-2007), (F) Kromrivier (1957-2007). The long-term mean annual rainfall is also provided in the top right-hand corner of each graph.

2.4.1 Palaeoclimates of the Cederberg and South Western Cape

The Cenozoic Era - a noteworthy time period of significant climatic trends, covers the last 65 million years, and includes the two most recent epochs: the Pleistocene and the Holocene, which together comprise the Quaternary - the last 2 million years. The

Holocene – the current interglacial, represents the last 11,500 years (Deacon, 1983; Deacon and Lancaster, 1988). Deacon (1983) notes that the contemporary climatic trends of the Fynbos region are the result of a pattern of lowering temperatures throughout the Cenozoic Era. These current climatic trends were initiated in the Pliocene epoch, which saw the inception of Mediterranean type climates. A striking aspect of the modern climatic systems, which commenced during this epoch and which continued through the Pleistocene, is the 100,000 year cycling of cooler, glacial climates; disrupted by short periods of warmer interglacials (Deacon, 1983; Deacon and Lancaster, 1988). In the fynbos region, the coldest recorded period of the late Pleistocene was between 30,000 and 16,000 BP, with the most severe episode apparently occurring between 16,000 and 18,000 BP (Deacon, 1983; Deacon and Lancaster, 1988).

Chase and Meadows (2007) comment that in terms of studying large-scale environmental change over glacial-interglacial cycles, Southern Africa assumes a significant location within the Southern Hemisphere. Key time periods in terms of past Quaternary climates, include the Last Glacial Maximum (LGM), the lateglacial, the Holocene and the Holocene Altithermal (HA).

The LGM, the period of greatest global ice content approximately 21,000 years ago, was a time characteristic of the most developed glacial environmental conditions. The lateglacial (18,000-11,500 yrs BP), was transitional between the LGM and the Holocene – the present interglacial age. The Holocene then covers the last 11,500 years, and includes the HA – the warmest period of the Holocene, more or less between 8,000-4,000 cal yr BP (Chase and Meadows, 2007).

At present, the westerlies only affect the aforementioned margins of Southern Africa. However, it has been speculated that during glacial periods, with the expansion of the Antarctic sea ice, westerlies would have a greater influence on the subcontinent, increasing the humidity and the amount of winter rainfall (Chase and Meadows, 2007). From the palaeoclimatic records it appears that during the LGM in the mountains of the Western Cape, winter temperatures may have been as much as 10 degrees C colder than at present (Chase and Meadows, 2007).

2.4.2 Historical Trends in Climate

Climate stations are noticeably lacking in the mountainous parts of the biome, and even though there are a range of climate stations in fynbos areas, many only record rainfall. Fuggle and Ashton (1979) estimated that of all the stations in the fynbos biome recording various climatic elements, approximately 546 stations record rainfall, as oppose to a mere 120 temperature recording stations.

Below are graphs of temperature, rainfall and A-pan evaporation data for areas in and around the Cederberg Wilderness Area (CWA). Algeria Forest Station is the only rainfall station within the CWA and possesses a relatively long record from 1910-2007. Outside of the mountain range there are a number of climate stations, which record both rainfall and temperature information. The rainfall data for Algeria and Kromrivier were obtained from the South African Weather Service (SAWS) and all the remaining temperature and rainfall data was acquired from Infrutec (Agricultural Research Centre). The A-pan evaporation data was procured from the Department of Water Affairs and Forestry (DWAF) website. Any missing data points were identified and filled in with the mean.

2.4.2.1 Rainfall

Figure 3 illustrates the total annual, summer and winter rainfall for six stations within the study area. Clanwilliam has the longest continuous rainfall and shows no significant change during the 20th century. The trend line for total annual rainfall for Algeria is positive but appears to demonstrate increased inter-annual variability in the recent past. In both Clanwilliam and Algeria, however, the last 25 years exhibit a downward trend which is supported by the rainfall trends for those stations with shorter records. Lorraine and Stagmanskop have the shortest time series and both show a downward trend in total rainfall as well as winter and summer rainfall amounts.

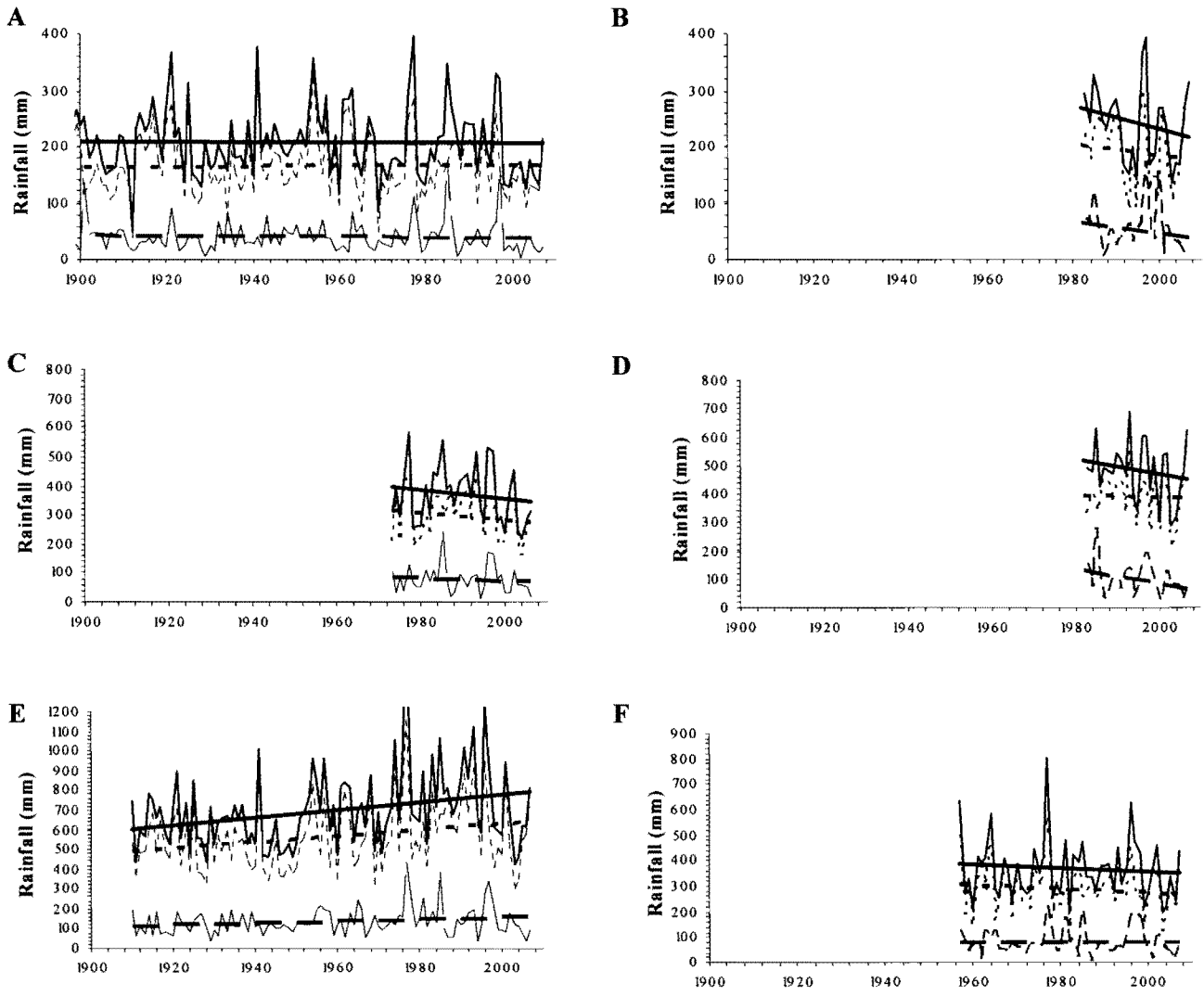

Figure 3: Annual rainfall (Oct-Sep) (top, solid line), winter rainfall (Apr-Sep) (middle, dotted line) and summer rainfall (Oct-Mar) (lower, dashed line) in mm for six climate stations in the Cederberg area: (A) Clanwilliam (1900-2007), (B) Lorraine (1983-2007), (C) Citrusdal (1965-2007), (D) Stagmanskop (1983-2007), (E) Algeria (1910-2007) and (F) Kromrivier (1957-2007).

2.4.2.2 Temperature

Although there is considerable inter-annual variability in mean annual temperature, all four stations analysed in the region have a trend of increasing temperature (Figure 4). Temperatures at Clanwilliam, which has the longest record (1963-2005), have increased by about 1 degree Celsius over the last 42 years. Data for Lorraine and Stagmanskop, which only cover the last 25 years, have the strongest increasing trends. The trend for Citrusdal is also positive although only weakly so.

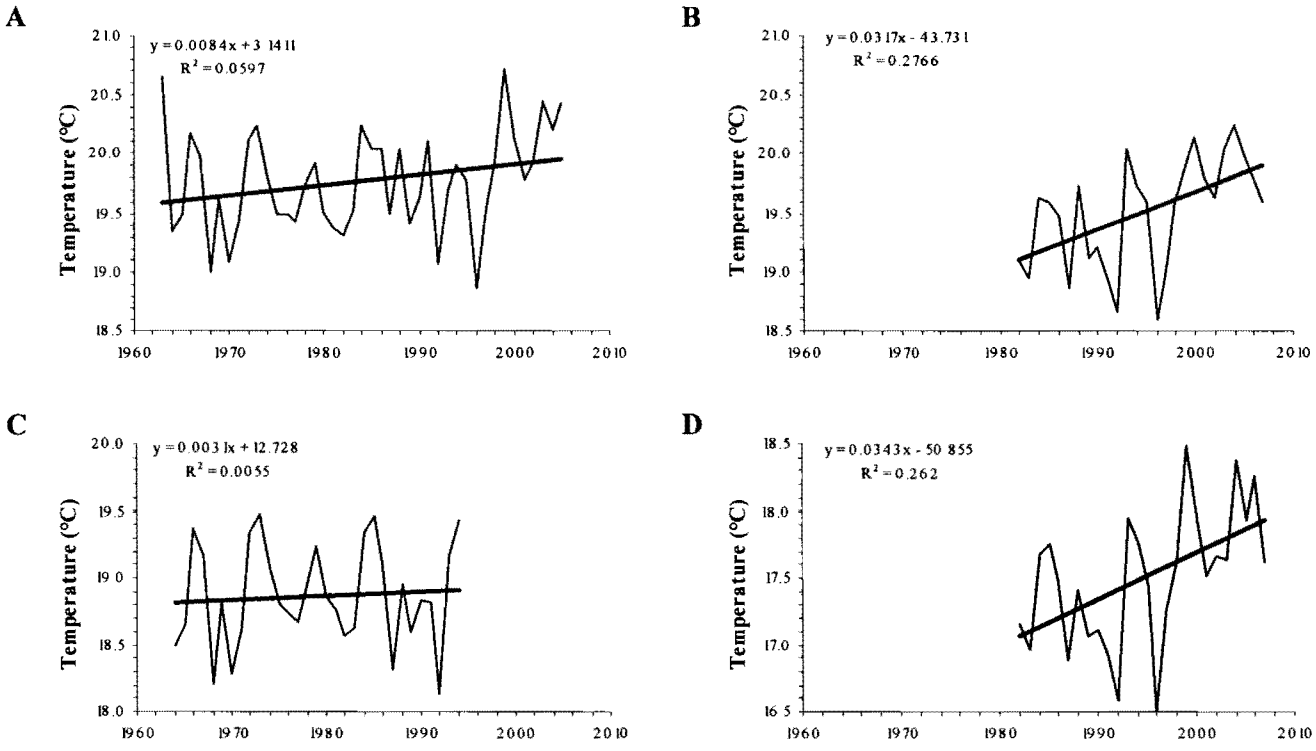

Figure 4: Annual average temperature (°C) for (A) Clanwilliam (1963-2005), (B) Lorraine (1982-2007), (C) Citrusdal (1964-1994) and (D) Stagmanskop (1982-2007).

2.4.2.3 Evaporation

Pan evaporation measures the amount of water evaporated from an open pan and is influenced by several climate variables including temperature, wind, solar radiation and humidity. It is only over the past 50 years or so that pan evaporation has been carefully monitored and measured. Recent studies have noticed that over this period of time the rate of evaporation has been falling (Roderick and Farquhar, 2004; Jovanovic *et al.*, 2008). This downward trend of pan evaporation has been associated with global dimming, a phenomenon describing the gradual decline in the amount of global direct irradiance at the Earth's surface (Stanhill and Cohen, 2001). However, since the 1990's, some studies have noticed that the trend has reversed, with a switch from dimming to brightening (Roderick and Farquhar, 2004) perhaps in response to a decline in global aerosol levels and increased solar irradiance. There is considerable (unresolved) debate on the impact of declining evaporation levels on the hydrological cycle (Jovanovic *et al.*, 2008).

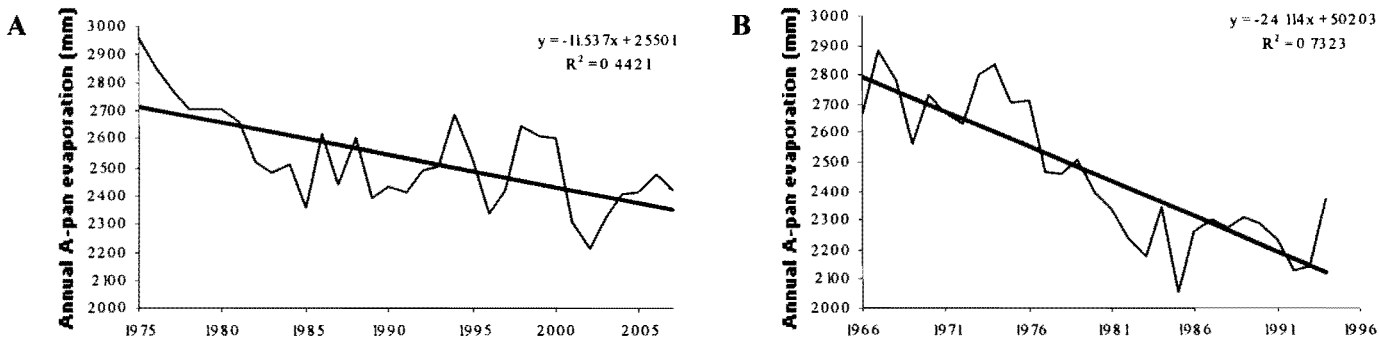

Figure 5: (A) Clanwilliam annual A-pan evaporation (mm) 1975-2007 and (B) Citrusdal A-pan evaporation (mm) 1966-1994.

Annual A-pan evaporation trends for climate stations at Clanwilliam and Citrusdal are shown in Figure 5. Both stations show a significant decrease in evaporation although there is considerable inter-annual variation at both sites. The Clanwilliam graph covers a 32 year period from 1975 to 2007 and shows an overall reduction in A-pan evaporation of 534 mm. At Citrusdal the data cover a 28 year period from 1966 to 1994 and shows an overall reduction of 300 mm over the period on record.

2.5 FIRE

Fire is a fundamental driver of dynamics within the fynbos biome. The frequency, season and intensity of burn and the extent of the area burnt all influence the biodiversity and ecosystem processes of the biome (Cowling and Holmes, 1992). Fire records for the Cederberg Wilderness Area (CWA) are maintained by CapeNature and were downloaded from their website. These records are summarized in Figure 6 and illustrate the temporal history of fire in the CWA for the period 1945 to 2007. The results show that a greater proportion of the Cederberg is burnt during the hot, dry summer months (October to March, with a noticeable peak in December) than in the cool, wet winter months (April to September). The 62 year fire history shows several noticeable peaks when large fires occurred in the region. The greatest burn occurred in 1988 when a fire burnt 59,179 hectares of land. The average area burnt between 1945 and 2007 in the Cederberg was 7,590 hectares.

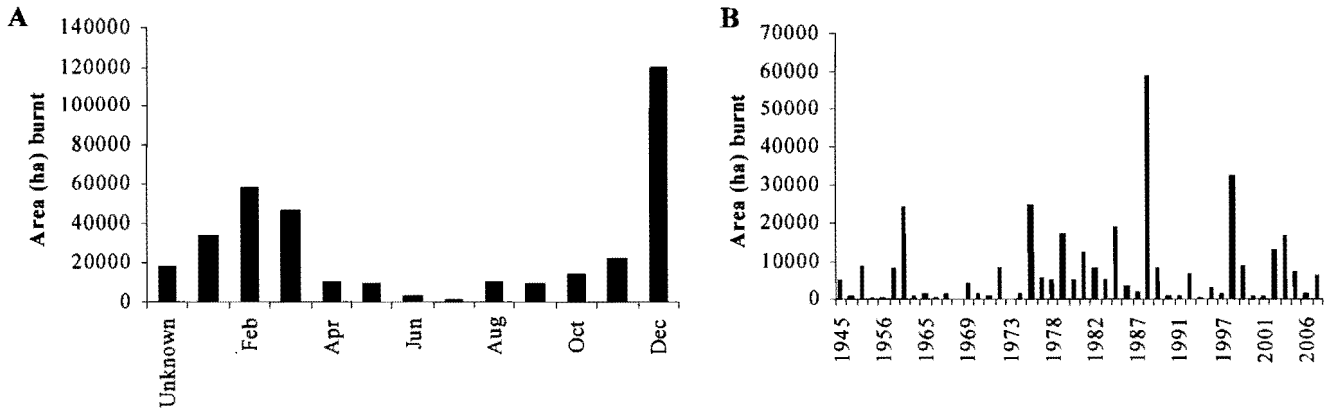

Figure 6: Fire history of the Cederberg Wilderness Area: (A) the average area (ha) burnt per month (including an 'unknown' category) and (B) the area (ha) burnt per year for the period 1945-2007.

2.6 VEGETATION: BIOMES AND BIOREGIONS

The study area is comprised of two main biomes (Fynbos and Succulent Karoo). Mucina and Rutherford (2006) further delimit two bioregions within the fynbos biome (Northwest Fynbos and West Coast Renosterveld) and two within the succulent Karoo biome (Knersvlakte and Rainshadow Valley Karoo). The Cederberg Wilderness Area (CWA) is located entirely within the Northwest Fynbos bioregion between 32° 00' and 32° 45' south and 18° 50' and 19° 25' east, and is 90 km long and 25 km wide (Taylor, 1996) (Figure 1).

2.6.1 The Fynbos Biome

The Fynbos Biome can be subdivided into two broad vegetation units in the study area: fynbos and the renosterveld (Van Rooyen and Steyn, 2004).

Fynbos vegetation

Fynbos vegetation is mostly restricted to well-leached, sandstone derived soils, which are typically infertile (Van Rooyen and Steyn, 2004). There are three characteristic elements of the Fynbos vegetation: (1) The restioid component - Restios belong to the *Restionaceae* or Cape reed family, which replace grasses on nutrient-poor soils in winter rainfall regions; (2) The ericoid or heath component, which generally possess

small, rolled leaves and (3) The proteoid component, comprised of the family *Proteaceae.* One of the key environmental parameters within the Fynbos is fire, which acts as both a destroyer and a regenerator (Moll and Jarman, 1984; Moll and Bossi, 1984).

Renosterveld

Renosterveld vegetation, in contrast to Fynbos vegetation, is dominated by members of the *Asteraceae* (daisy) family, particularly *Elytropappus rhinocerotis* or renosterbos, from which the vegetation gets its name. The shrub *Eriocephalus purpureus*, and the grass *Merxmuellera stricta*, are two other examples of dominant elements of the renosterveld vegetation (O'Farrell, 2005). Most renosterveld shrubs have small, leathery, grey leaves and the vegetation is rich in geophytes within the *Iridaceae*, *Liliaceae* and *Orchidaceae* families. Renosterveld vegetation is mainly associated with fine-grained soils (clays and silts), derived from shales and has much higher soil fertility than fynbos vegetation. Within the Cederberg, this vegetation type is represented by Central Mountain Renosterveld and can be found on the Cederberg shale band as well as in the Pakhuis Pass area (Van Rooyen and Steyn, 2004). The shale band can be easily recognized as it forms a distinct break in the general slope and has a different species composition when compared to fynbos vegetation (Van Rooyen and Steyn, 2004). Central Mountain Renosterveld is often found between fynbos vegetation and succulent karoo vegetation.

2.6.2 The Succulent Karoo Biome

Two primary factors determine the occurrence of the succulent Karoo biome in this area, namely: the low winter rainfall (20 to 290 mm/year) and the severe summer aridity (Van Rooyen and Steyn, 2004). Dwarf, succulent shrubs dominate the vegetation, of which, *Mesembryanthemaceae* and *Crassulaceae*, are particularly prominent. *Asteraceae* also form a major constituent of the vegetation. In spring-time, one can witness mass displays of annuals (mainly daisies) within this biome. These often occur on degraded or fallow parts of the land. The absence of grasses within this biome is attributed to the lack of summer rain (Van Rooyen and Steyn, 2004). In this area,

Lowland Succulent Karoo is represented – occurring in the Rainshadow of the Cederberg in the valleys to the east, such as the Biedouw and Olifants River Valleys.

2.6.3 The Vegetation and Flora of the Cederberg

The vegetation of the Cederberg mountain range does not appear much different from that of other mountainous areas in the south-western Cape. There is the Waboom (*Protea nitida*), which commonly appears throughout the south-western Cape and is found amongst a mixture of restios, sedges and grasses (Taylor, 1976). Distinctive features of Cederberg vegetation are species of *Pelargonium,* which come in a variety of forms from low-growing fleshy plants to tall woody shrubs. In addition, there are species of *Phylica* and *Serruria*, which are also typical of the Cederberg. The Clanwilliam cedar (*Widdringtonia cedarbergensis*) is also distinctive. It is endemic to these mountains and is found almost exclusively on high rocky outcrops. Other species and genera which are common in the Cederberg are *Stoebe plumosa*, *Leucospermum* spp. (e.g. *L. reflexum*) and *Protea* species, (e.g. *P. cedromontana*) (Taylor, 1976).

The distinctive shale band is mostly covered by dwarf-like vegetation of *Restionaceae* and low-growing shrubs, which have become adapted to withstanding extreme ranges in climate. Another endemic species, the SnowProtea (*Protea cryophila*) a prostrate shrub, is found exclusively on the highest Cederberg peaks such as Sneeuberg, where snow cover is the norm throughout winter (Taylor, 1976). The Cederberg also possesses two plants of economic importance, namely Buchu (*Agathosma betulina*), which is primarily utilized for pharmaceutical purposes and Rooibos (*Aspalathus linearis*), which is cultivated for use as a tea.

The central Cederberg mountains contain about 1,800 plant species (Taylor, 1996), and the Cederberg-Tanqua area has close to 1,200 species, making this region extremely rich in terms of its flora and vegetation. In addition, there appear to be major species turnovers along the sharp environmental gradients of the ecotone between the Cederberg and Tanqua Karoo.

There are 13 vegetation types within and surrounding the study area (see Figure 7). Nine of these vegetation types fall within the fynbos biome and four fall within the

succulent Karoo biome. Tables 1 and 2 below look characterize these vegetation types in more detail, outlining their altitudinal and rainfall ranges, the geology of the area in which they are found, as well as each vegetation types' conservation status and transformation status.

Figure 8 below, shows the relationship between the mean altitude in meters of all the vegetation types and the degree to which they have been transformed, primarily by cultivation and settlement. The lower altitude vegetation types show a higher percentage of transformation, whereas at higher altitudes transformation appears almost non-existent. The mountainous upland areas are in general adequately conserved. Negative impacts within the broad Cederberg region include unscheduled fires, overgrazing and intensified land use, especially in the lowland areas.

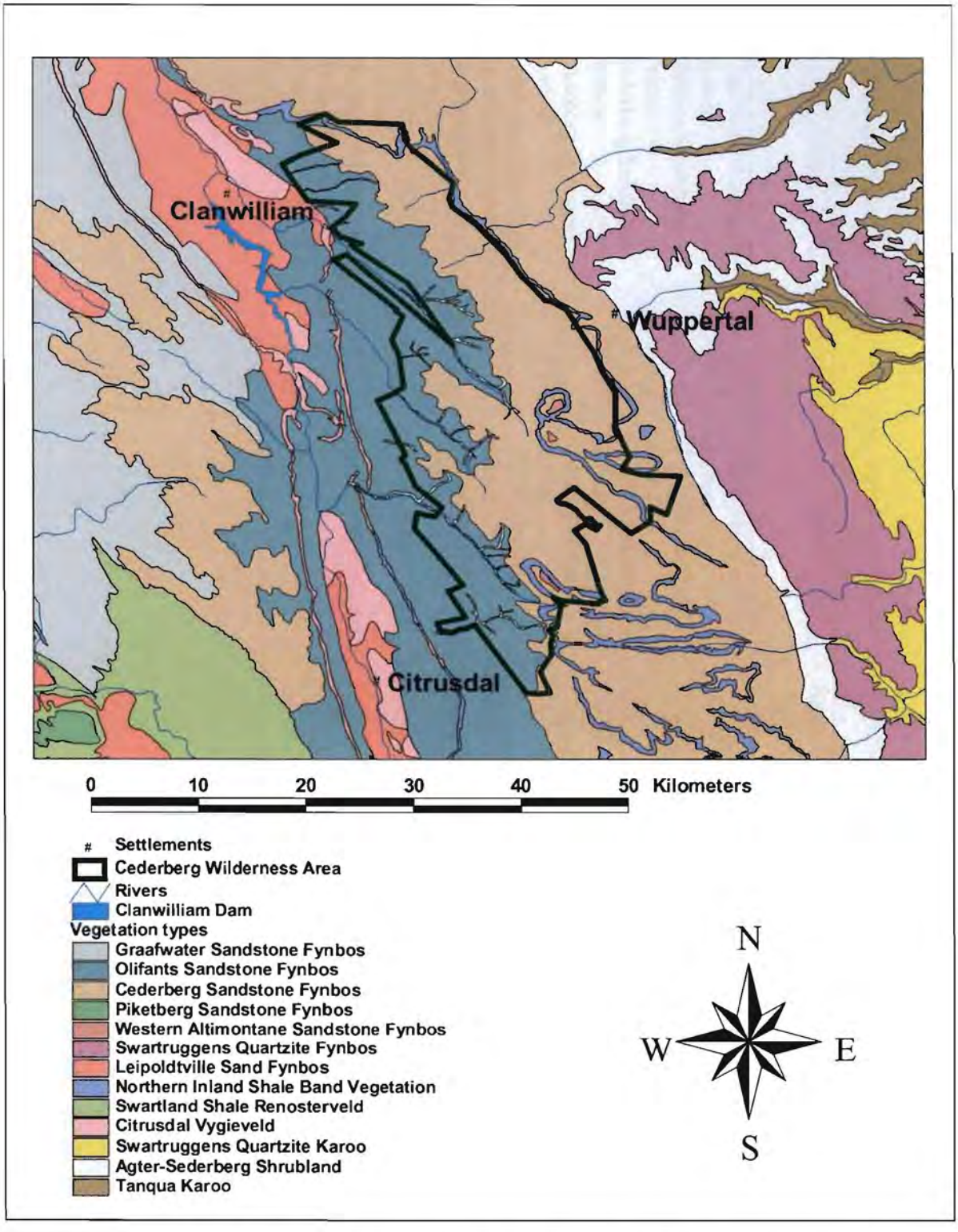

Figure 7: The 13 vegetation types which occur in the study area and the location of the Cederberg Wilderness Area (Mucina and Rutherford, 2006)

Table 1. Key characteristics of the nine fynbos biome vegetation types within the study area (from Rebelo *et al.*, 2006 in Mucina and Rutherford, 2006)

Code	Name	Altitudinal Range (m)	Geology	Rainfall Range (mm) (MAP)	% transformed	% conserved (statutory)	% conserved (private)	Conservation status
FFs2	Graafwater Sandstone Fynbos	100-650	Table Mountain Group	200-499	28	0	0	Vulnerable
FFs3	Olifants Sandstone Fynbos	200-1200	Table Mountain Group	250-700	8	23	44	Least threatened
FFs4	Cederberg Sandstone Fynbos	300-1800	Table Mountain Group	180-600	15	17	29	Least threatened
FFs6	Piketberg Sandstone Fynbos	100-1458	Table Mountain Group	320-860	17	0	4	Least threatened
FFs30	Western Altimontane Sandstone Fynbos	1800-2249	Table Mountain Group	450-3140	0	35	65	Least threatened
FFq2	Swartruggens Quartzite Fynbos	800-1800	Witteberg Group Quartzite	200-620	2	4	5	Least threatened
FFd2	Leipoldtville Sand Fynbos	50-350	Deep, acid, tertiary sands	130-450	55	0	0	Endangered
FFb1	Northern Inland Shale Band Vegetation	400-1650	Cederberg Formation	250-1360	4	80	0	Least threatened
FRs9	Swartland Shale Renosterveld	50-350	Malmesbury Group Shales	270-670	91.4	0.1	0.8	Critically endangered

Table 2. Key characteristics of the four succulent Karoo biome vegetation types within the study area (after Mucina *et al.*, 2006 in Mucina and Rutherford, 2006).

Code	Name	Altitudinal Range (m)	Geology	Rainfall Range (mm) (MAP)	% transformed	% conserved (statutory)	% conserved (private)	Conservation status
SKk7	Citrusdal Vygieveld	180-700	Table Mountain Group	316	34	0	4.2	Vulnerable
SKv2	Swartruggens Quartzite Karoo	300-1180	Witteberg Group (Cape Supergroup)	200	1.4	5.3	0	Least threatened
SKv3	Agter-Sederberg Shrubland	220-1320	Bokkeveld Group & Table Mountain group	250	2.5	0.9	0	Least threatened
SKv5	Tanqua Karoo	240-960	Bokkeveld Group	72-112	0.7	7.2	3.7	Least threatened

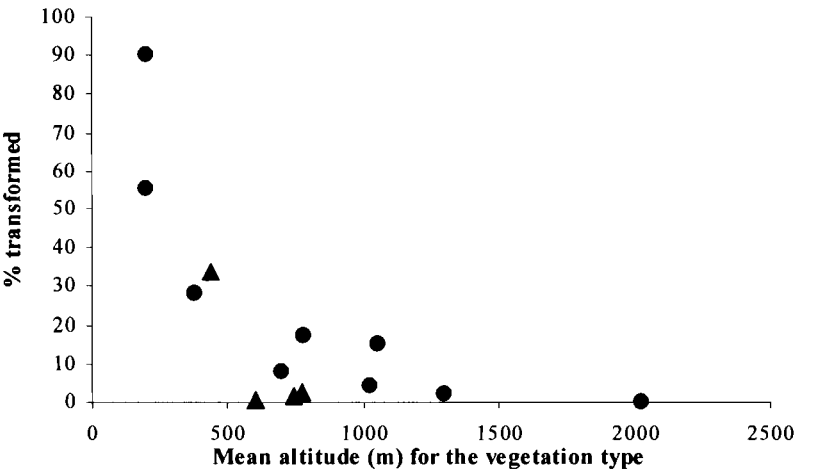

Figure 8: Relationship between mean altitude (m) and the percent of the vegetation type that has been transformed ▲ indicate the Succulent Karoo species and • indicate the Fynbos species. ($n = 13$; $y = 0.00000.5x^2 - 0.1314x + 84.243$; $r^2=0.7233$; $p<0.01$) (Mucina and Rutherford, 2006).

2.7 A CHRONOLOGY OF OCCUPATION

The habitation of the Cederberg area will be analysed in terms of three distinct phases: the pre-colonial era, which describes a time series from the pre-pastoralist hunter-gatherers to the introduction of the transhumant pastoralist Khoikhoi society; the early colonial era, which saw the arrival of the European settlers and the beginning of land appropriation and ownership; and the post-colonial era or twentieth century.

2.7.1 Pre-colonial History

The Cederberg region has accommodated human settlement for at least 30,000 years, but probably for as much as 280,000 years (Jacobs *et al.*, 2008). It is generally accepted that the hunting populations, known as San or Bushmen were the original indigenous inhabitants of the Cape region, and were followed about 2,000 years ago by the Khoikhoi (Penn, 1986; Mitchell, 2002). These different populations used the land and its resources in different ways – the San were hunter-gatherers and the Khoi a nomadic pastoralist society, who moved seasonally with their sheep to ensure year round access to water and grazing (O'Farrell, 2005). The production activities of the Khoi included herding, hunting and gathering.

The indigenous populations had a sound system of movement through regular ranges, which was influenced by climatic and economic stimuli. They also had a strong sense of territoriality and there was open hostility and struggle for particular territories among the indigenous people in the pre-colonial eras (Elphick, 1977). Antagonism over specific areas was common, but it was only with the arrival of the European settlers that notions of individual land claims and land ownership began to take root. Despite this, Mitchell (2002) notes that the Dutch were far from the first catalyst for changing human settlement patterns at the Cape. Changes in the distributions of populations have been ongoing over the last 30,000 years (Parkington, 1988; 1999) – influenced by environmental transformations. Over this long period of time, people have altered their actions, territorial ranges and food strategies in response to differing environmental conditions, and from about 2,000 years ago – the advent of pastoralism in the Western Cape saw a new series of changes (Mitchell, 2002).The arrival of herders at the Cape from this time displaced many of the hunter-gatherer populations and put increasing pressure on San society. Furthermore, the gradual replacement of wild game by domestic herders forced the movement of the San to less productive, more remote areas.

Smith (1983) notes that the boundary situation that existed between the indigenous San hunters and the immigrant Khoi herders can be explained in terms of "adaptive strategies" and the triumph of the Khoi can be accredited to increased exploitation efficiency of grasslands and their larger population densities.

Smith (1983) notes that the Khoi pastoralists are notoriously absent in the archaeological record as a result of their transhumant way of life and exceedingly unpreserved material culture. The transhumant life-style is one that follows climatic changes and seasonal fluctuations in resources. The timing of movement revolves around the availability of resources such as water and pasture for animals and humans alike. Today, traditional forms of pastoralism have all but disappeared, apart from a few extant and isolated Nama-speaking communities in Namaqualand and the Richtersveld (Hendricks *et al.*, 2007). In the Southwestern Cape – a winter rainfall zone where indigenous African grains such as sorghum and millet are not able to be exploited due to their being summer rainfall crops, agriculture had to await the arrival of the Europeans who introduced crops such as wheat and barley, which are well adapted to winter rainfall conditions.

Both the San and the Khoi populations left little permanent trace on the landscape and it is possible that the land looked devoid of habitation when first encountered by the settlers. This false impression however was short lived, and the advancing colonial frontier soon brought competition. The Trekboere, who shortly preceded the colonials, brought with them unparalleled rivalry for land and resources and their arrival brought permanent settlement with permanent physical structures in the landscapes (Penn, 2005; Mitchell, 2002). They introduced new technologies and ideas, as well as the concept of individual claims to the land and fixed permanent boundaries (Mitchell, 2002).

2.7.2 Early Colonial History

The Europeans first arrived in the Olifants River Valley in 1660 (Mitchell, 2001), when Jan Danckaart saw herds of elephants after which he named the river (Penn, 1995; Hoffman and Rohde, 2007). However, it was not until approximately 1725 that the expansionary trends of the Dutch East India Company began to impinge on the region in full. It was from this time on that stock farmers began using the region on a regular basis.

The Olifants River has played an undeniably important part in the history of human occupation and settlement in the Cederberg region, and without it the Cederberg would not have been an attractive place for human settlement. There is evidence of the aggregation of human activity along the river in both pre-colonial and colonial times. Also, it was understandably a point of orientation among Europeans from the earliest days of colonial penetration in the region. The river valley and its surrounds was thus an important area of interaction between the settlers and the indigenous hunting and herding populations in the eighteenth century.

The Olifants River Valley abounds with flat stretches of land – ideal for farming. The mountainous landscape adjoining both sides of the valley is covered with thick, scrubby vegetation – allowing for the support of wildlife and domestic sheep and cattle. In general however, the land of this region has a relatively low carrying capacity, and it is unlikely that large herds of ungulates existed in the region in the pre-colonial Olifants River Valley (Hoffman and Rohde, 2007). The low rainfall and subsequent low water availability would have restricted the spread of animals in the Cederberg and it is reasonable to assume that their numbers would have been limited in the past. Despite the tough terrain and lack of readily available water, there is clear evidence of human habitation in the area for at least the last 10,000 years. Clearly, the Olifants River region was used both extensively and intensively before European arrival and settlement.

The Khoikhoi and San populations that inhabited the region prior to the European settler's arrival, were nomadic and did not establish permanent settlements. Even the first colonial farmers to claim land in the Olifants River Valley did not build permanent dwellings – its was not until the early nineteenth century that the first signs of concentrated settlement began emerging in what used to be known as the *Jan Dissel's Vlei* – renamed Clanwilliam in 1814 (Mitchell, 2001).

Colonial land claims under the rule of the Dutch East India Company at the Cape were founded on a two-tiered system of permanent grants (freehold property) and permits (loan farms) (Mitchell, 2001). In the Cederberg, settlement was based on the system of loan farms, which gave a settler exclusive rights to a fixed tract of land in exchange for rent. This was an annual permit granted by the VOC and was renewable for an indefinite period of time. The Burghers, to whom the permits were granted, were able to farm, graze, hunt and build on

their loan farms without limitations. The introduction of the VOC loan farms, however, brought greater competition for the land and its resources (Mitchell, 2001). Furthermore, settler loan farms signified the commencement of a new land tenure regime centred around notions of private ownership that were fundamentally detrimental to Khoisan seasonal migration.

The response of Khoisan to the colonial intrusion was irregular – consisting of different degrees of engagement and resistance. The first Khoisan resistance when white farmers settled in the Tulbagh area in the early 18th century (Penn, 2005). By the end of the 1730's, violent resistance predominated, concluding with the brutal frontier war of 1739, which as Penn (1987) notes, affectively crushed and saw the end of Khoisan resistance – opening up this part of the frontier to more intensive colonial expansion.

2.7.3 The Twentieth Century

The Olifants River Basin today remains home to many farms and supports an intensive agricultural industry. Along with a well developed network of private irrigation schemes that abstract water, the main system of irrigation includes the Clanwilliam and Bulshoek dams, with a 126 km of main canals and 60 km of distribution canals (Low *et al.*, 2004). The agricultural sector is a major contributor to employment and GDP in the region. The main products of the area are citrus and deciduous fruit, as well as wine and Rooibos tea. The region has also experienced an increase in potato production in recent decades. These different types of agriculture will be expanded upon in greater detail in the following chapter, which looks at agricultural expansion in the Cederberg lowlands during the 20th century.

The success of the agricultural sector in this region is heavily reliant on the adequate supply of water, and awareness is growing around the negative effects of intensive agriculture. Over the course of the 20th century there has been a gradual reduction in extensive agriculture, which has given way to more intensive crop production and ec0-tourism. These changes are also evident in the middle altitude reaches of the Cederberg and will be dealt with in chapter 4.

CHAPTER 3: THE INTENSIFICATION OF LAND USE IN THE LOWLANDS OF THE CEDERBERG DURING THE 20TH CENTURY.

3.1 INTRODUCTION

Changing land use practices over the last 100 years have had a significant impact on the environment (IPCC, 2007) and some of the most obvious and pronounced changes that we see today have been caused by human manipulation of the land. However, land-use is influenced by culture as well as by a range of inter-related environmental, social and economic factors (Mortimore, 1989). Studies linking human activity and environmental change require comprehensive analyses of land use history so as to identify the primary factors responsible for changes to the environment of the area under study (Foster, 1992). Understanding the extent of historical land use change and particularly the main drivers of change is important for sustainable future land use management (Sisk, 2003).

Investigations of land use history provide a background for understanding the development of an area's current landscape and events of the past play a decisive role in determining the attributes of current environments (Christensen 1989). Studies of past land use practices also offer perspectives that may be useful for the sustainable management and preservation of unique landscapes such as the greater Cederberg region (Foster, 1992).

There are a number of reasons why an in-depth investigation of the land use of the Cederberg lowlands is important. Firstly, the region's exceptionally rich biodiversity is of global importance and an appreciation and awareness of the threats presented by different land use practices is important for its future sustainable management. Secondly, the Cederberg area has been occupied by humans for thousands of years, and during the course of the 20th century the landscape has undergone several transformations in response to changes in land use practices. Therefore, a more robust understanding of the region's land-use history is of immediate relevance for future planning decisions.

Addressing the issue of sustainable agricultural development requires an understanding of the processes and phases of intensification (Erenstein *et al.*, 2006). Agricultural activities have played a dominant role throughout the Cederberg lowland's history – shaping the landscape and providing essential livelihoods to its inhabitants. The 17th century European settlers

brought with them the beginnings of settled agriculture, which quickly replaced the nomadic practices of the indigenous Khoi pastoralists. It was with these events that the transformation of the Cederberg lowlands began in earnest (Smith, 1983). As a result of these transformations, the natural habitat of the lowlands has been left vastly fragmented (von Hase *et al.*, 2003), with substantial parts of the natural landscape having been replaced by cultivated fields. Agricultural expansion and intensification then is one of the most critical pressures to the environment of this region, especially as in recent years this area has seen the shift from traditional forms of cultivation to more intensively grown, higher value crops such as fruit, vegetables and grape vines (von Hase *et al.*, 2003).

In this chapter I first contextualise the contribution made by agriculture to the economy of the region at provincial, district and municipal levels of scale. Then I use several long-term data sets to reconstruct the land use history for the Cederberg Local Municipality (CLM) with a particular focus on human population growth, livestock production and cultivation. In terms of cultivation, it needs to be noted that an analysis of Rooibos as an increasingly significant cash crop in this region has been left out as there are no readily-available, reliable data on Rooibos cultivation and relative to the other crops, such as grains, fruit, vegetables and vines, it has historically (i.e. prior to 1990) not been cultivated as extensively in the lowlands. The main drivers of land use change are identified and explained in terms of local, regional, national and global influences over the course of the 20th century.

3.2 AGRICULTURE AT A PROVINCIAL, DISTRICT AND MUNICIPAL SCALE

3.2.1 The Western Cape Province

According to the 2005 Western Cape Provincial Spatial Development Framework (WCPSDF) report, the Western Cape Province's contribution to the country's Gross Domestic Product (GDP) is approximately 14.5%, and of the total gross income of the agricultural sector, the Province generates about 23% (Capegateway, 2005). The Western Cape Province is the country's largest producer of deciduous fruit, and responsible for 85% of all deciduous fruit exports (Capegateway, 2005). Two of the main industries of the agricultural sector in the Western Cape are fruit and vegetables (Capegateway, 2005). Agriculture is the principal user of land in the Province with about 13 million hectares being used for agricultural production (Capegateway, 2005). Extensive livestock production

particularly cattle and sheep, occurs on about 43% of the land in the Province, and about 36% is used for crop production especially wheat, citrus and deciduous fruit, vines, and vegetables (Capegateway, 2005). About 2.5 million hectares of land in the Province is under cultivation, with about 270,000 hectares under irrigation (Capegateway, 2005). Since the late 1980's, the area of land in the Province used for grazing by domestic livestock, has decreased, with a subsequent increase in croplands, especially in the western districts (Capegateway, 2005). Vineyards have also increased in recent years, and this increase has occurred predominantly in the West Coast District (DEADP, 2004). In general, the lowland coastal plains support most of the *intensive* agriculture, while *extensive* agriculture takes place in the drier, semi-arid interior of the Province.

The Province is subdivided into five district municipalities, one of which is the West Coast District Municipality (Figure 1). This district municipality includes the Cederberg Local Municipality which forms part of the northern limits of the winter rainfall region. It is comprised predominantly of pastoral land with irrigated vegetable and wine production along the Olifants River, and irrigated seed potato farming in the Sandveld area.

Figure 1: Map of the five municipalities within the West Coast District Municipality, with the Cederberg Municipality in the middle and the Cederberg Wilderness Area shown in grey checks (source: Department of Land Affairs, chief directorate: surveys and mapping).

3.2.2 West Coast District Municipality

The West Coast District Municipality (WCDM) includes five local municipalities, one of which is the Cederberg Local Municipality (CLM) (Figure 1). The contribution of the largest economic sectors to the economy of the West Coast District is as follows: Manufacturing (20.6%), Agriculture, Forestry and Fishing (19.4%), Wholesale and Retail Trade, Catering and Accommodation (16.1%), Finance and Business Services (13.3%) (Capegateway, 2007). The WCDM is a semi-arid area, which uses its inland regions for commercial agriculture such as wheat and citrus farming. Agriculture, however also inflicts major pressure on the natural environment, especially in terms of water use and loss of natural habitat, and for a water-scarce region such as the West Coast, agricultural expansion could be problematic (Capegateway, 2007).

3.2.3 Cederberg Local Municipality

The area covered by the Cederberg Local Municipality (CLM) was demarcated after the 1994 democratic elections in South Africa and includes the following six Wards: Clanwilliam, Citrusdal, Lamberts Bay, Graafwater, Elands Bay and Wupperthal (Capegateway, 2007). The boundaries of the CLM are broadly consistent with the boundaries of the Clanwilliam Magisterial District which was relatively stable for the period 1910-1996. In 2004, the CLM contributed just 9.9% to the West Coast District's Gross Domestic Product per Region (GDPR) although considerable room for improvement in this performance has been noted (Capegateway, 2007). The main sectors which contribute to the economy of the CLM are Agriculture, Forestry and Fishing (27.7%), Wholesale and Retail Trade, Catering and Accommodation (23%), Manufacturing (12.4%), Financial and Business Services (11.6%). The Olifants River Valley, which is situated within the CLM, is extensively cultivated. The agriculture sector includes a variety of farming enterprises such as citrus and deciduous fruit, wine and rooibos tea production and is strongly reliant on a labour force of mostly seasonal workers. The agricultural production sector relies on a sophisticated irrigation system of canals, which channel water to a sprawling, inter-connected network of surrounding farms. The area between Citrusdal and Clanwilliam is the third largest citrus producing district in South Africa (National Department of Agriculture, 2000). A detailed analysis of land use changes in the CLM follows. The main question which is addressed in this chapter is: How

have human populations, livestock numbers and the area used for agricultural production changed in the CLM in the 20th century?

3.3 METHODS

The total population and ratio of urban to rural inhabitants in the Cederberg Local Municipality at roughly ten year time intervals from 1911-1991 was assembled from published government census records (Hoffman *et al.*, 1999; www.sanbi.org/landdeg). This was augmented with data from StatsSA for the years 1996 and 2001 (http://www.statssa.gov.za). An annualized population growth rate for the period 1911-2001 was calculated as follows:

$$g = \{(X_t/X_0)^{1/t} - 1\}*100, \text{ where:}$$

g = annualized population growth rate
X_t = population at end of census period
X_0 = population at start of census period
t = number of years between census period

Agricultural production data for the Cederberg Local Municipality was sourced from the agricultural census records of Government Gazettes which were collated either from archives in the University of Cape Town or from Hoffman *et al.* (1999) (see www.sanbi.org/landdeg). The last official agricultural production census at magisterial district level occurred in 1988. There are considerable difficulties in obtaining more recent agricultural census data, partly as a result of problems with reconciling boundary differences between agricultural census records and industry records. For example, the deregulation of the Deciduous Fruit Board and Citrus Board in the early 1990s saw the collapse of government-orchestrated data collection in these industries and available records do not conform to previous magisterial district boundaries. Furthermore, lengthy time series for the last decade are seldom presented in easily-available repositories such as industry publications or websites.

The number of cattle, sheep and goats in the Cederberg Local Municipality over the period 1891-1996 was determined from published government census records (Hoffman *et al.*, 1999; www.sanbi.org/landdeg). The number of Large Stock Units (LSU) was calculated according

to Anonymous (1984) where one head of cattle = 1.1 LSU, and a sheep and a goat = 0.17 LSU each. Changes in the area (ha) used for different agricultural crops were also derived from published government census records. These included cereal crops (wheat, oats, barley and rye) for the period 1911-1988, fruit data (citrus and deciduous fruit) from 1946-1988, vegetable crops (potatoes 1934-2002 and onions 1950-2002) and grape vines for the period 1936-1988. The length of the time series differed for different crops and values for some crops were incomplete (e.g. there were no data for rye for the years 1956, 1961, 1965 and 1988). A trend line was fitted to each of the time series and the strength of the relationship was calculated. In order to calculate the total area used for the cultivation of all crops in the Cederberg Local Municipality, values for all cereal crops (wheat, oats, barley and rye), fruit (citrus and deciduous fruit), vegetables (potatoes and onions) and vines were added together for the period 1939-1988.

3.4 RESULTS

3.4.1 Population

The population of the Cederberg Local Municipality increased linearly during the 20th century from 11,307 people in 1911 to 39,328 people in 2001 at an average annualized growth rate of 2.5% (Figure 2). Population growth has been greater from 1985-2001 than during the 70 years which preceded this time period. At the start of the census period in 1911 only 10% of the population lived in urban centres. This increased to a third by 1946 and doubled to more than 70% in 1951. The ratio of urban to rural inhabitants remained relatively constant until 1991, after which this comparison was no longer available in the census record.

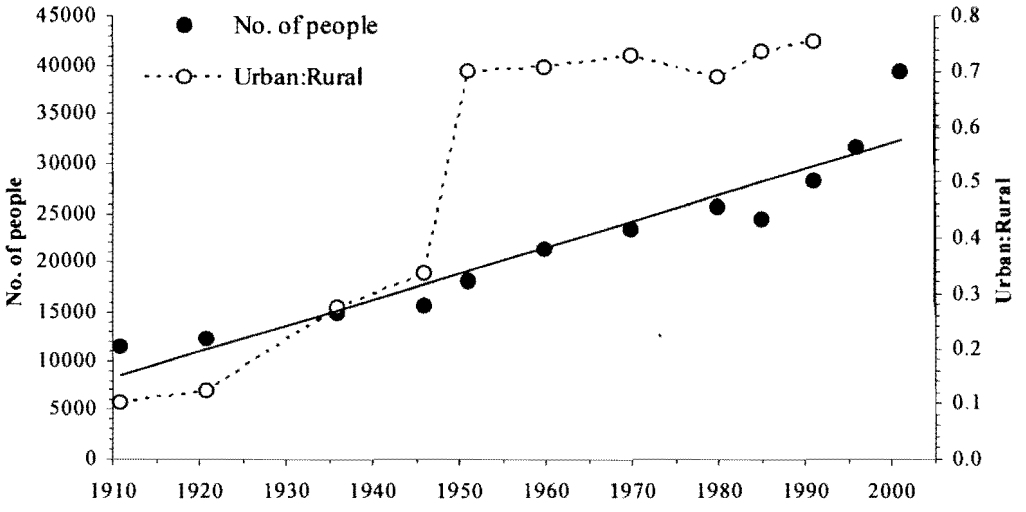

Figure 2: The number of people and ratio of urban to rural inhabitants in the Cederberg Local Municipality for the period 1911-2001 as determined from official census records. The linear trend line in the total population trend is: $y = 265.3x - 498494$, $R^2 = 0.8917$, $p<0.001$.

3.4.2 Livestock

In 1891 there were 21,777 cattle, 84,437 sheep and 125,945 goats in the Cederberg Local Municipality (Figure 3). Cattle numbers remained relatively high between 1891 and 1923 but declined thereafter. In 1995 there were fewer cattle (5,220 animals) in Clanwilliam than at any other time in the census period. Goat numbers showed a similar pattern and declined steadily after 1930 to reach their lowest numbers in the later part of the 20th century. Conversely, the number of sheep increased steadily until 1967 although they declined steeply thereafter. By the mid-1990s the number of sheep was similar to levels of the 1930s and 1940s. Stocking rates, as measured in Large Stock Units (LSU), increased from the early 1930's to the early 1970's, but declined steadily after that, influenced, no doubt by the significant decrease of sheep in the district at this time.

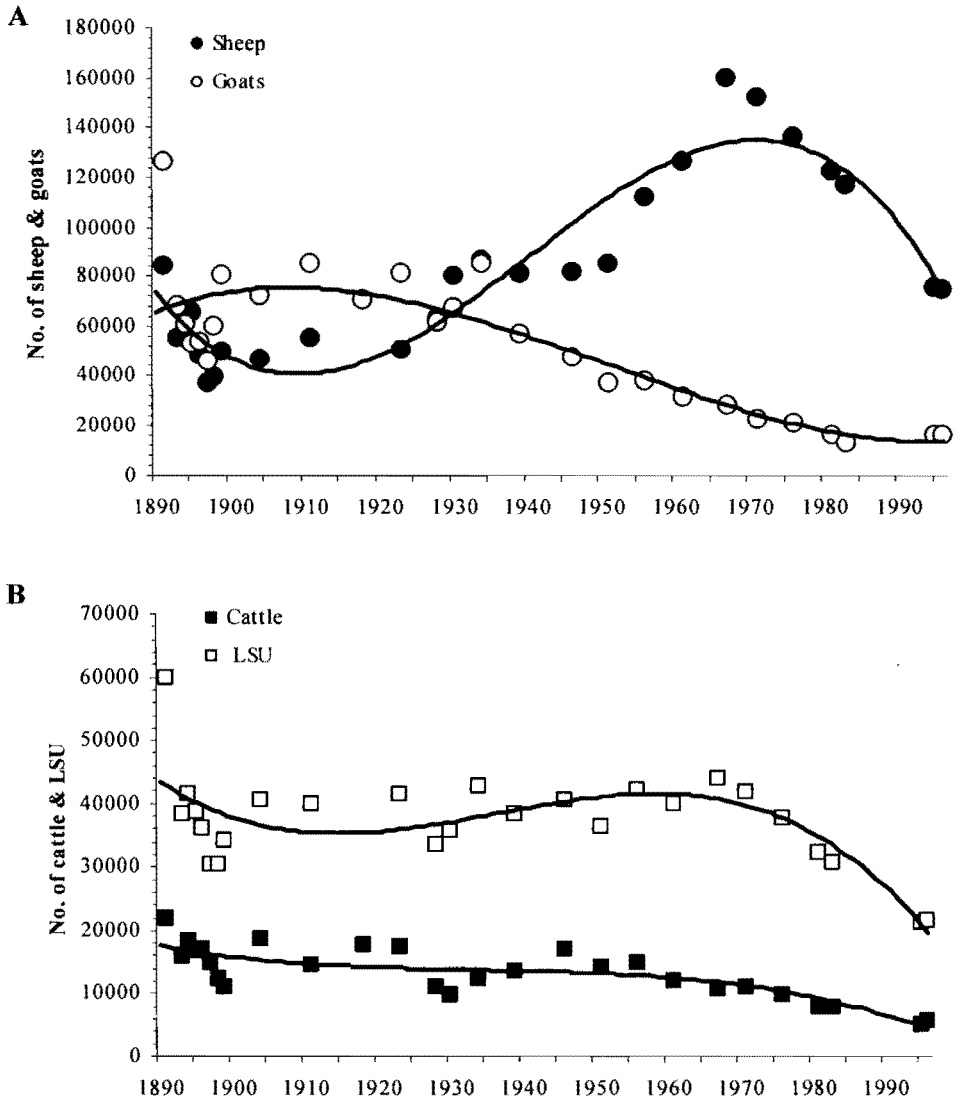

Figure 3: Livestock numbers for the Cederberg Local Municipality for the period 1891-1996 for (A) sheep and goats and (B) cattle and Large Stock Units (LSU). Equations for the lines are as follows: Sheep: $y = -0.8087x^3 + 121.3x^2 - 3767x + 73908$, $R^2 = 0.8778$; Goats: $y = 0.1962x^3 - 35.896x^2 + 1106.3x + 66181$, $R^2 = 0.6947$; Cattle: $y = -0.0333x^3 + 4.3997x^2 - 216.07x + 17641$, $R^2 = 0.6676$ and LSU: $y = -0.1488x^3 + 20.737x^2 - 749.94x + 43453$, $R^2 = 0.5448$, and all equations explain a significant proportion of the variance in the data ($p<0.001$).

3.4.3 Cultivation

Wheat has been the dominant crop in the Cederberg Local Municipality (CLM) during the course of the 20th century although smaller quantities of oats, barley and rye have also been cultivated (Figure 4). The total area within the CLM used for the cultivation of these four crops, peaked at 30,795 ha in 1971. It declined steadily thereafter, to 20,386 ha in 1988 when

the last available agricultural census of the district occurred. This decline in total ha cultivated to grain crops mirrors and is influenced strongly by the decline in wheat production.

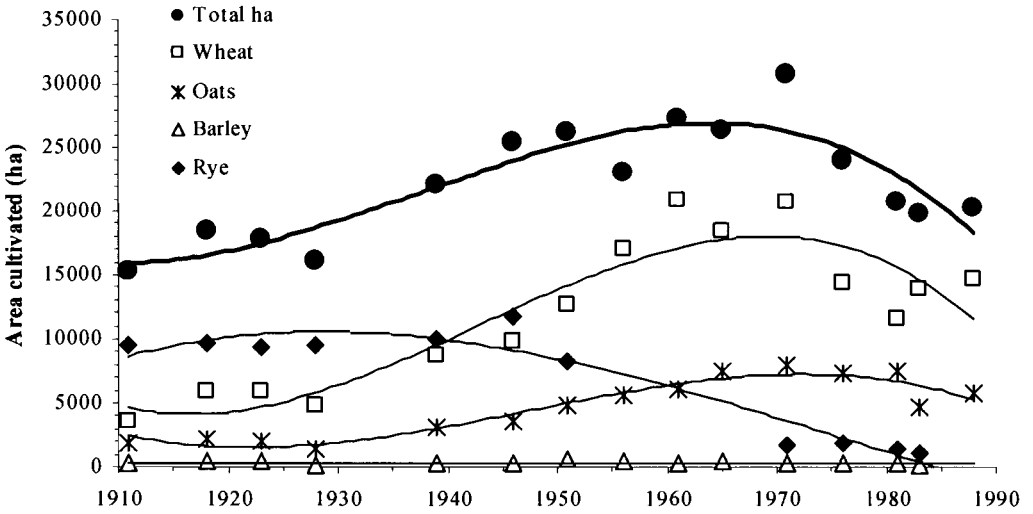

Figure 4: The area in hectares of land used for the cultivation of wheat, oats, barley and rye in the Cederberg Local Municipality for the period 1911-1988, as well as the total ha cultivated for the four crops. Equations for the lines are as follows: Total ha: $y = -0.1457x3 + 847.04x2 - 2E+06x + 1E+09$, $R^2 = 0.7914$, $p<0.001$; Wheat: $y = -0.1908x3 + 1112.3x2 - 2E+06x + 1E+09$, $R^2 = 0.8335$, $p<0.001$; Oats: $y = -0.0898x3 + 524.71x2 - 1E+06x + 7E+08$, $R^2 = 0.909$, $p<0.001$; Barley: $y = -0.0278x2 + 107.45x - 103367$, $R^2 = 0.0397$, $p>0.05$ and Rye: $y = 0.0364x3 - 215.83x2 + 426761x - 3E+08$, $R^2 = 0.925$, $p<0.001$.

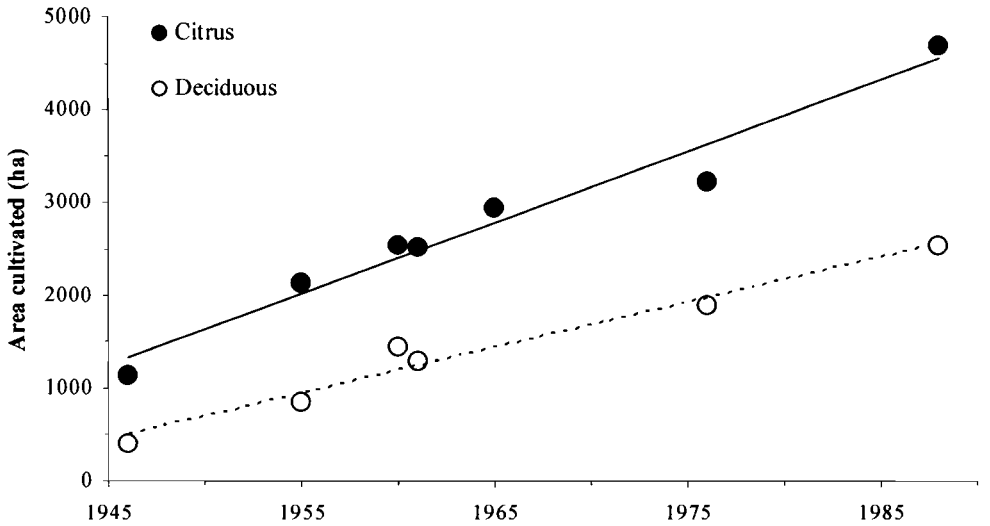

Figure 5: The area in hectares of land used for the cultivation of Citrus and Deciduous fruit in the Cederberg Local Municipality for the period 1946-1988. Equations for the lines are as follows: Citrus: $y = 77.439x - 149382$, $R^2 = 0.9608$, $p<0.001$ and Deciduous fruit: $y = 48.847x - 94556$, $R^2 = 0.9666$, $p<0.001$.

Citrus and deciduous fruit production in the Cederberg Local Municipality comprised 7,200 ha in 1988 and increased nearly five fold between 1946 and 1988 (Figure 5). The area planted to citrus grew at a slightly higher rate than the area planted to deciduous fruit. In 1988 the area planted to citrus was 1.8 times the area planted to deciduous fruit.

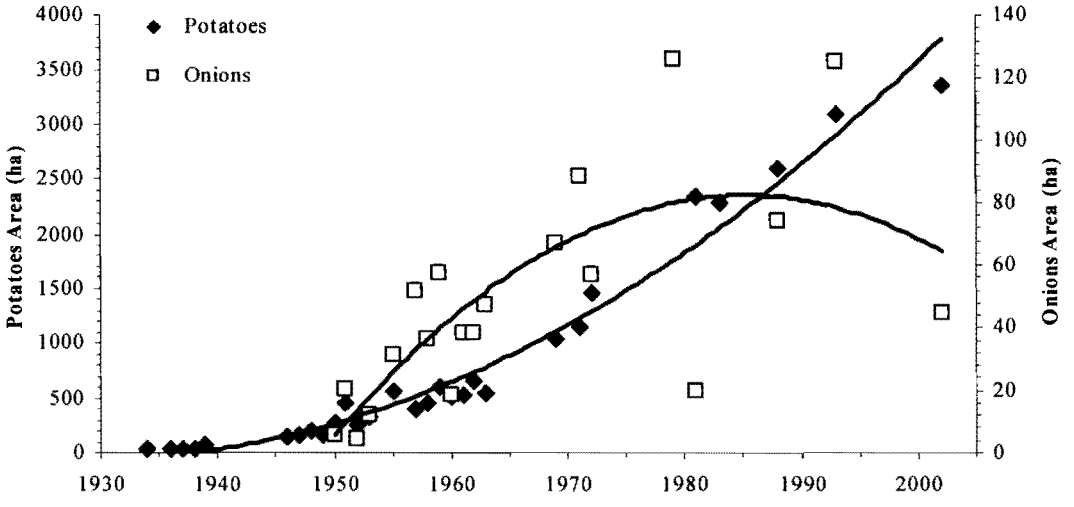

Figure 6: The area in hectares of land used for the cultivation of potatoes (1934-2002) and Onions (1950-2002) in the Cederberg Local Municipality. Equations for the lines are as follows: Potatoes: $y = 0.7085x^2 - 2732.3x + 3E+06$, $R^2 = 0.9723$, $p<0.001$ and Onions: $y = -0.062x^2 + 246.31x - 244405$, $R^2 = 0.5287$, $p<0.001$.

Potato production in the Cederberg Local Municipality increased exponentially between 1934 and 2002 (Figure 6), increasing from 29.8 ha in 1934 to 3,356 ha in 2002 (see Figure 7). The area cultivated to onions, however, was considerably more variable over this period and fluctuated widely between 1979 and 2002 presumably in response to market prices. The area planted to onions peaked in 1979 but in 2002 dropped to levels last seen in the early 1960s.

The area of land under vines in the Cederberg Local Municipality (Figure 8) increased more than five fold between 1936 and 1988, from 243 ha to 1,319 ha. Between 1936 and 1955 there was a nominal expansion of the area cultivated to vines. After this, however, the rate increased considerably, particularly during the decade from 1955-1965 (see Figure 10)

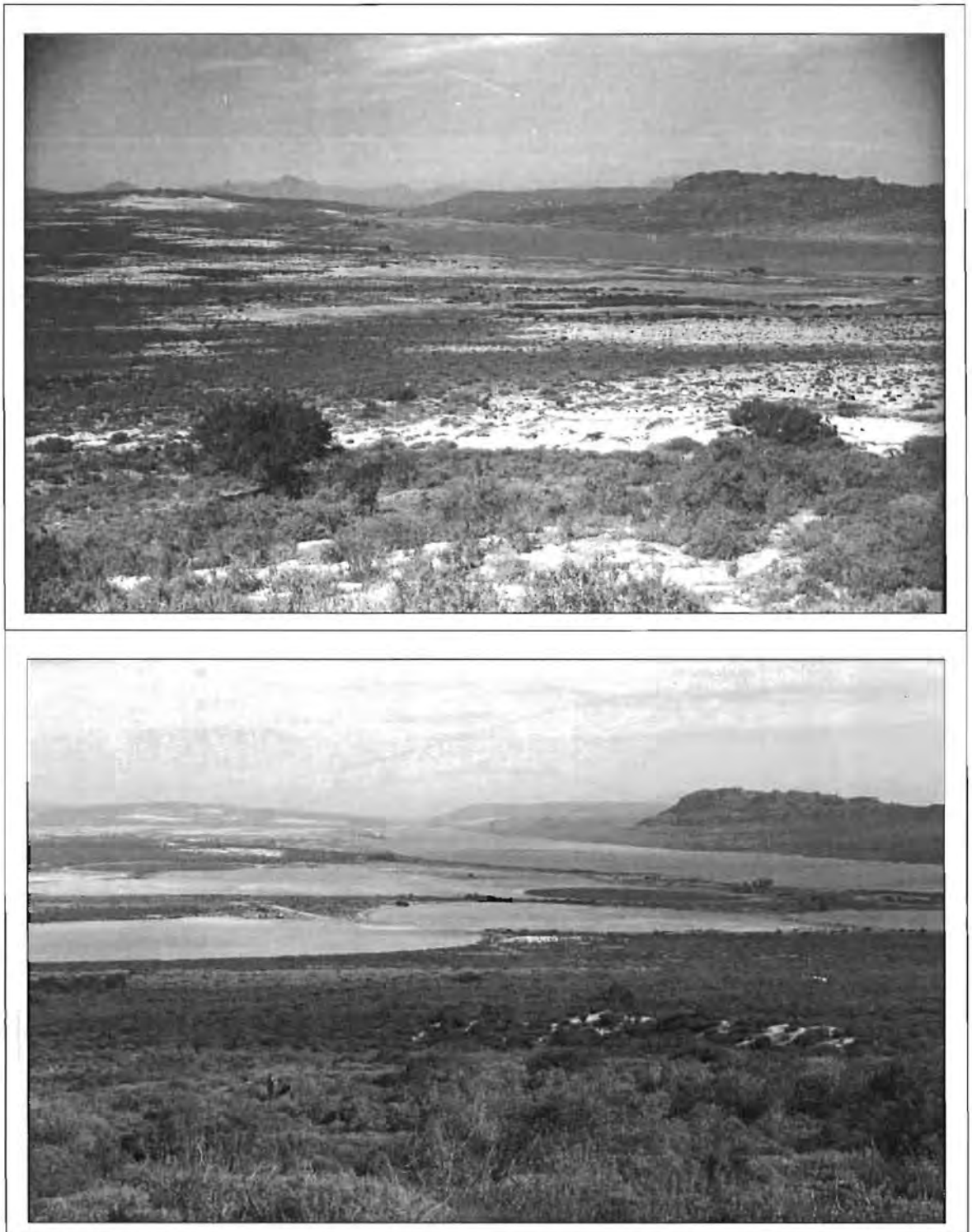

Figure 7: Acocks's original 1958 photograph (top) near Elands Bay (Verlorenvlei in distance) and re-photographed (bottom) in 2008 showing the conversion of Sandveld vegetation to centre-pivot irrigation primarily for potato production.

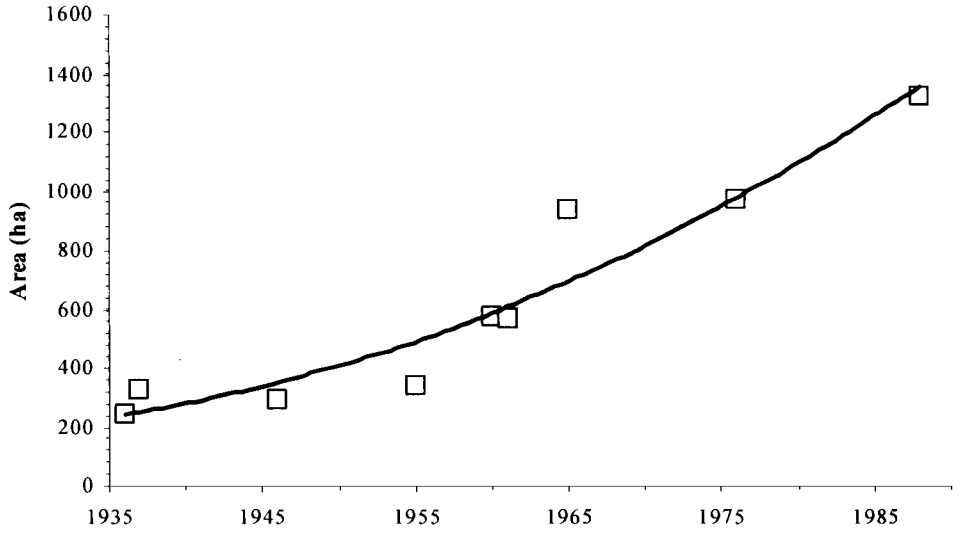

Figure 8: The area in hectares of land used for the cultivation of vines (1936-1988) in the Cederberg Local Municipality, $y = 0.2492x^2 - 956.53x + 918027$, $R^2 = 0.917$, $p<0.001$.

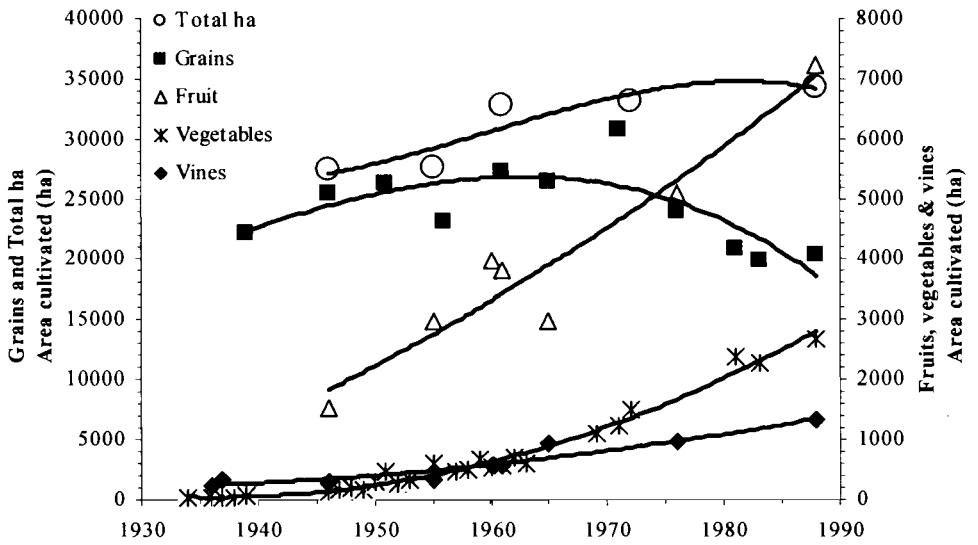

Figure 9: The area in hectares of land used for the cultivation of grains (1939-1988), fruit (1946-1988), vegetables (1934-1988) and vines (1936-1988) in the Cederberg Local Municipality, as well as the total ha cultivated for all crops (1946-1988). The equation for the total ha cultivated is: $y = -0.2059x^3 + 1210.9x^2 - 2E+06x + 2E+09$, $R^2 = 0.8424$, $p<0.05$.

The total area within the Cederberg Local Municipality used for the cultivation of all the crops evaluated in this study (grains, fruit, vegetables and vines) increased by 25% between 1946 and 1988 (from 27,506 ha to 34,274 ha) (Figure 9). However, there has been a significant switch in the dominant crops produced in the district. While the area used for the production of grains, such as wheat, oats, barley and rye has decreased over the course of the

20th century, the area of land cultivated for citrus and deciduous fruits, vegetables and vines has increased. Of these, the expansion of the citrus and deciduous fruit industries in the Clanwilliam valley has been the most significant.

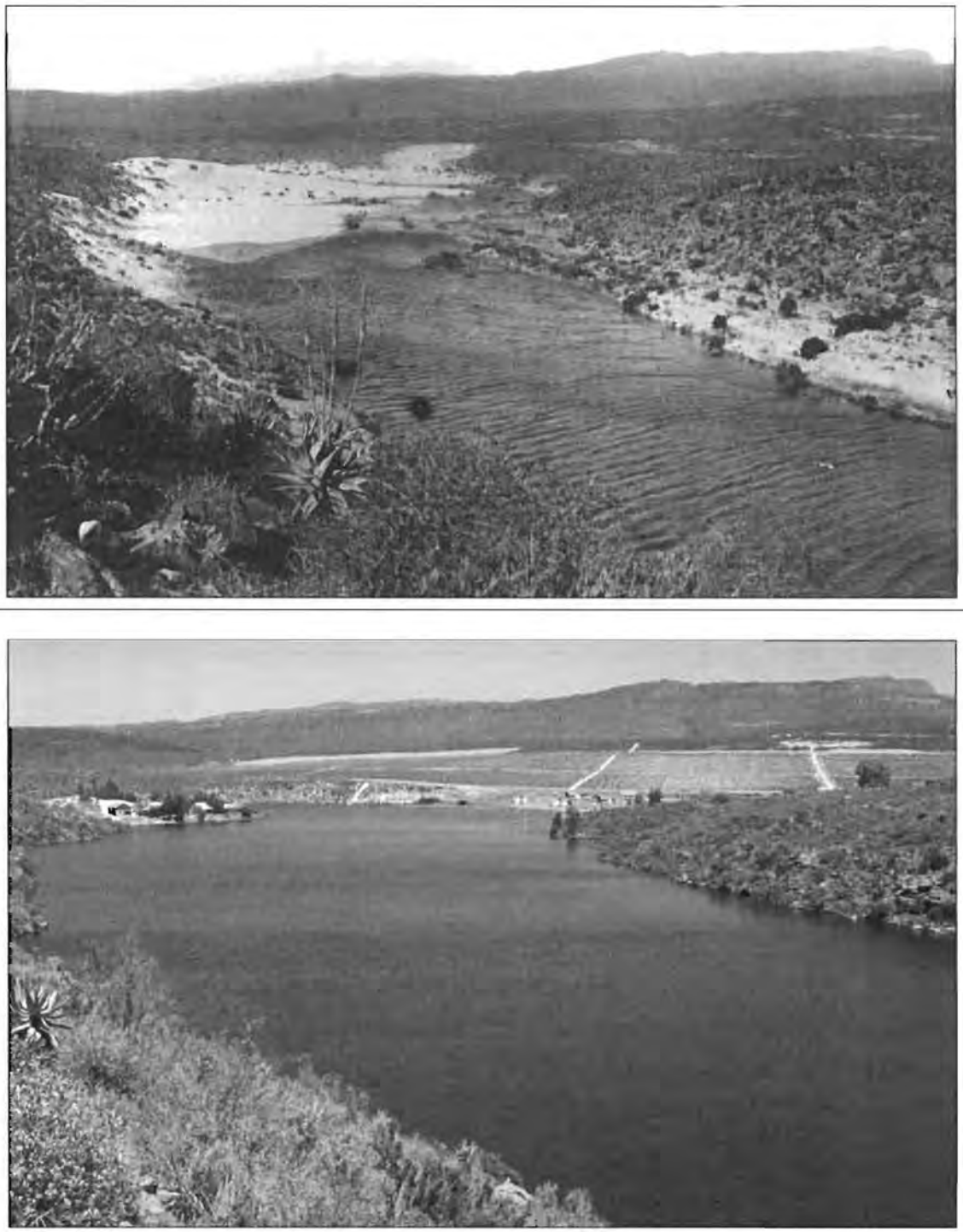

Figure 10: Pole Evans's original 1915 photograph (top) at site 444 (Olifants River) and re-photographed (bottom) in 2007 showing the increase in water volume as a result of the Bulshoek Dam (immediately downstream) and the land conversion to vines in the middle distance and the presence of holiday houses on the left bank of the river.

3.5 DISCUSSION

There has been a linear increase in the population of the Cederberg Local Municipality (CLM) during the course of the 20th century with a marked acceleration between 1985 and 2001. This is in contrast with other districts in the region such as Namaqualand, which have seen a moderate decline in total population in the latter part of the 20th century (Hoffman and Rohde, 2007). In addition, most people lived in the rural areas of the CLM before 1946 but this changed dramatically thereafter, and by 1951 more than two thirds of the population was living in urban centres such as Clanwilliam and Citrusdal. Reasons for these trends are complex and in many respects, population trends as well agricultural production in the region have been influenced by local and global political, technological and socio-economic circumstances. For example, the Land Acts (1913, 1936), and the Marketing Act (1937), which promoted white access to land, also forced subsistence farmers off their land (O'Farrell *et al.* 2008). The general rise in mechanised agriculture in South Africa in the immediate post-World War II (WWII) period (Vink and Kirsten, 2000) might also account for the loss of labour from farms and the dramatic increase in urban populations at this time. Urbanisation was undoubtedly also influenced by global political trends such as the post-WWII movement of people away from marginal environments and into lively agricultural centres such as Clanwilliam, where education and employment opportunities were more available (see Chapter 5).

Livestock production in the Cederberg Local Municipality (CLM) was relatively stable until about 1970 but declined significantly after this period. However, the overall stability in LSUs during the first part of the 20th century is characterised by a switch from goats to sheep, particularly after WWII. This reflects the shift from subsistence livestock production with a heavy reliance on goats, to the commercialisation of the small stock industry and the use of new sheep breeds such as Dorpers. The 51% decline in livestock production in the CLM in the last 30 years of the 20th century mirrors the general reduction in livestock in most magisterial districts of the Karoo (e.g. Dean and Macdonald, 1994; Hoffman *et al.* 1999; Hoffman and Rohde, 2007; O'Farrell *et al.* 2008). Dean and Macdonald (1994) found that in semi-arid and arid regions of the pre-1994 'Cape Province', over a 70 year period from 1911 to 1981, there was an almost 50% reduction in the stocking rates of domestic livestock. Hoffman *et al.* (1999) note that livestock numbers in the Karoo increased steadily from the late 19th century until the late 1960s, when state intervention schemes such as the Stock

Reduction Scheme (1969-1978) and shifts in management practices and stock breeds resulted in a reduction in animal numbers. Undoubtedly the reduction in grain crop production also influenced the livestock production sector. Since much of the CLM is comprised of vegetation of poor grazing value (e.g. Graafwater, Cederberg and Olifants Sandstone Fynbos vegetation types all occur on nutrient-poor acid sands) there are only limited opportunities for the expansion of the livestock industry if it is based on the extensive production of animals on natural veld.

The 20th century history of crop production in the Cederberg Local Municipality is characterised by a 25% increase in the area cultivated and a shift in the types of crops grown. Most noticeable has been a switch from grain crop farming to more intensively farmed and irrigated produce such as citrus, grapes and potatoes. This trend began as far back as the 1950's, when the agricultural industry first experienced a decline in the production of the more traditional cereal or grain type crops, and a switch to increasing fruit and vegetable production. In relation to this, O'Farrell *et al.* (2008) note that in the 1950's, farmers in the Little Karoo began in earnest to produce vegetable seed for export to USA and Europe, suggesting that this switch was influenced by market demands and global trends. The 1973 global oil price shocks further impacted the agricultural industry, and could also be related to the continuing decline in grain production at this time, especially wheat production since input and transport costs would have increased significantly.

The Cederberg Local Municipality (CLM) is not alone in this pattern of change, as most parts of the Karoo (Dean and Macdonald, 1994) including Namaqualand (Hoffman and Rohde, 2007), have shown a decline in 'traditional' grain crops in the 20th century. The switch to more intensively grown and higher value crops is also consistent with developments in other parts of the Western Cape and South Africa where this expansion has often been accompanied by significant levels of foreign investment, particularly after the democratic elections in 1994 and the deregulation of the agricultural industry in South Africa (Vink and Kirsten, 2000). Increased access to export markets in the post-1994 period, as well as the introduction of policy instruments such as the 1996 Marketing of Agricultural Products Act, have also influenced the shift to more intensively-cultivated crops. The region is in many respects following global and economic trends. The decline in grain crop cultivation, as well as the decline in livestock production, suggests a trend of the general decrease in *subsistence* farming in the region, which has been taken over by the more profitable, commercial farming

of citrus and deciduous fruits along with vegetables and wine and a diversification of investments into activities such as eco-tourism (Vink and Kirsten, 2000).

Special mention needs to be made of the expansion of the potato industry in the study area. Between 1995 and 2000, country-wide potato production showed an annual average growth rate of two per cent (National Department of Agriculture, 2000) and the Western Cape is one of the major potato-producing areas in the country (National Department of Agriculture, 2000). The Sandveld is the largest potato-producing area in the Western Cape and with 6,442 ha planted in 2005; it contributed more than 75% of all potatoes marketed in the Province (Potatoes SA 2006, www.potatoes.co.za). The 25% increase in the area of cultivated lands in the Cederberg Local Municipality over the course of the 20th century has occurred primarily as a result of the expansion of the potato industry in the Sandveld. Although the Sandveld was historically used primarily for grazing cattle, large areas of 'virgin land' (Anonymous, 1984) began to be ploughed and centre-pivot irrigation systems installed (Duncan, 2004), once it was discovered that the area was fit for potato farming from about the 1970s onwards.

The potato industry has been operating under free market conditions for many years, and the deregulation processes of the agriculture sector during the 1990's had very little impact on its operations (http://www.nda.agric.za/docs/fpmc/Vol4_Chap8.pdf). However, there are concerns that the expansion of the potato industry has degraded indigenous fynbos vegetation of the area. In the Sandveld, nearly 2.7 ha are cleared for potato production daily (SANBI, 2006) and the natural vegetation is rapidly being transformed. Provincial records show that between 1989 and 2004, 80% of all natural veld cleared for agriculture, was along the west coast. Finally, the irrigation requirements for potato cultivation, have resulted in a lowering of the water table (SANBI, 2006) and there are concerns about increasing salinity levels in the available groundwater (Duncan, 2004). This is concerning particularly in the light of future climate change scenarios for the region which suggest that the western parts of the country will become progressively drier during the course of the 21st century (Midgley *et al.* 2008).

The key question posed at the beginning of this chapter was: How have human populations, livestock numbers and the area used for agricultural production changed in the Cederberg Local Municipality (CLM) in the 20th century? Evidence suggests that lowlands have been transformed substantially, particularly as a result of the expansion of cultivation in the region.

Similar to the rest of the country (Vink and Kirsten, 2000) there has been a switch from extensive to more intensive crop production in the CLM with high-value products and a diversification of on-farm activities. However, livestock production has declined in the region and assumes less importance today than it did in the first 70 years of the 20th century. Many of these changes have been driven by socio-economic, legislative, political and global influences rather than by local environmental or climatic fluctuations and are testament to the ever-increasing intensity of human impact on landscapes (Meadows, 2001).

CHAPTER 4: PHOTOGRAPHIC EVIDENCE AND LOCAL INTERPRETATIONS OF 20TH CENTURY LANDSCAPE CHANGE IN THE CEDERBERG WILDERNESS AREA (CWA)

4.1 INTRODUCTION

The previous chapter illustrated how historical land use practices have changed in the low-lying areas of the Cederberg Local Municipality (CLM) and documented how large-scale, intensive commercial agriculture has expanded over the course of the 20th century. The focus of this chapter addresses the history of land use change in the middle altitude range (primarily between 500 and 1,000 m above sea level) of the Cederberg Wilderness Area (CWA). This type of approach has been termed "applied historical ecology" (Swetnam *et al.*, 1999: 1189), and it uses knowledge of the past in the management of ecosystems for the future. It has become increasingly recognised that historical perspectives enhance our comprehension of the dynamic quality of landscapes and present a context for gauging contemporary situations and practices (Swetnam *et al.*, 1999). The objectives were not to try and assess how the present day environment of the Cederberg would be had it remained unused, but rather to consider the role played by anthropogenic influences on the landscape, in comparison to non-anthropogenic, climatic factors.

Changes in the composition of landforms and vegetation, collectively identified as land cover change, occur primarily in response to human activities and climate. In many instances, human actions have become the dominant driver of environmental change. During the course of the twentieth century, the human population has increased by 4.4 billion people and over this period the impacts and pressures of humans on the environment have increased rapidly (Hughes, 2000; Walther *et al.*, 2002). Human impacts in the Cederberg have changed significantly over the last few millennia as hunter-gatherer lifestyles have been replaced firstly by herder and later by settled agriculture (Chapter 2). In addition, short-term (e.g. seasonal) and longer-term (e.g. annual or decadal) changes in climate have the potential to influence landscape composition through its influence on growth, reproduction and recruitment. Global warming also has strong implications for biodiversity since it influences the physiology and distribution of many species and affects community structure and

ecosystem dynamics (Hannah *et al.*, 2005). Although such impacts are difficult to measure, many consider them largely irreversible (Kappelle et al., 1999). The distribution patterns of both plants and animals are heavily influenced by patterns of temperature and moisture gradients (Walther *et al*, 2002; Hannah *et al.*, 2002), and studies of fossil pollen records have shown that some species are sensitive to changes in climate (Grimm and Jacobson, 1992; Davis and Shaw, 2001). It has been suggested (Midgley *et al.*, 2002) that the first signs of climatically induced effects on plants in the south-western Cape, will be in the Cederberg Mountains (February *et al.*, 2007).

Using repeat photographs and oral testimony the aim of this chapter is to understand how landscapes in the Cederberg midlands have responded to 20th century changes in settlement, cultivation, livestock grazing and fire. The midlands are divided into the northern portion where agricultural activity has never been significant and the southern portion where agricultural activity has increased in recent decades. The chapter assesses the main drivers of change to the natural environment of the region, and investigates transformations in vegetation structure in response to changing land use practices in the region.

4.2 METHODS

The impact of land use on the landscapes of the Cederberg midlands was assessed through the use of repeat photography and interviews with local farmers who live in the region. Historic and repeat landscape photographs of the area were used as visual evidence of changes to the environment through time. Two collections of photographs were used. The first set comprised of 14 original images taken by the late Kenneth Howes-Howell who visited the Cederberg between 1931 and 1955. His collection is currently housed in the University of Cape Town's Manuscripts and Archives Department. The second set of photographs, comprised of three original images, was in the personal collection of Interviewee A who currently owns the property Suikerbossie in the southern portion of the Cederberg. A total of 17 photographs spanning the north-south divide of the Cederberg midlands was relocated. Eight of these are presented in this chapter and the remainder in Appendix 1. The eight landscape photographs used in this chapter cover an average period of 59 years, with the oldest of these dating back to 1934 and the most recent to 1976. Repeat

photographs were taken at each of the original photograph sites, and the repeat photographs along with the original images were digitized and used to assess landscape changes. Adobe Photoshop version 7.0 was used to match the original and repeat photographs, by rescaling each until the permanent features of the images had exactly the same dimensions. Where appropriate the photographs were divided into different zones according to characteristic landforms (e.g. sandy lowlands, rocky footslope, grassy mountain slope) and the main changes in each landform described in the field.

For the purpose of developing a detailed understanding of the environment and history of the Cederberg midlands, interviews were conducted with five residents in the area. The five interviewees were chosen for one or more of the following three reasons: (1) the repeat photographs were located on their property; (2) they were landowners with some history in the area and (3) they were available and willing to talk openly to us about the history of their farms and their future aspirations. A semi-structured interview technique (Patton, 1990), which is based on a loose framework and uses open-ended questions, was employed. This approach maintains a certain amount of structure, but also allows for opportunities to investigate matters that arise (O'Farrell *et al.*, 2008). From the interviews, information was gathered on the social environment, land-use trends and ecological conditions in the Cederberg midlands, both past and present, and local perspectives regarding the current and possible future state of the environment of the area were recorded. The interviews provided an understanding of the farming methods and land use practices employed by land owners as well as perceptions surrounding the management of the CWA by conservation officials, specifically in terms of disturbances to the land, the use of natural resources and the management of veld burning regimes.

While doing field work, four land owners and a farm manager were approached and asked if they would agree to be interviewed. The first interview was conducted on the 21 August 2007, at the farm house of Interviewee A, on their farm 'Suikerbossie' in the Citrusdal area. The second interview took place on the 22 August 2007 on the farm of Interviewee B in the Sandfontein area. The foreman of the farm, Interviewee C, was interviewed briefly on the same day. The fourth interview was with Interviewee D on their farm on the 23 August 2007 and the fifth interview took place

on the 23 October 2007 on Interviewee E's farm in the Ceres District. All of the interviewees were located within the CWA. Each interview lasted about two hours except for Interviewee C who was interviewed for about half an hour. The four main interviewees all came from families which have been farming in the area for several generations.

4.3 RESULTS

Figure 1 is from a location immediately below the Sneeuberg looking towards the shale band. Although the camera station is at 1,462 m many high altitude sites in the region were used for livestock grazing and cultivation in the past (see Figure 2). The vegetation of the footslope in the immediate foreground (Zone A) appears taller in the original photograph of 1937, as a result of a recent fire which occurred in the region about four years before. The lightening of the vegetation in the flat plain beyond the line of rocks in the middle distance (Zone B) is as a result of a substantial increase in grass cover (see also Appendix 1, Figure 1). The east-facing, boulder-strewn slope of the shale band below the Sneeuberg (Zone C) has less cover in 2007. The abundance of black shrub skeletons is evidence of a recent fire.

Figure 2 shows the matched images at a site near de Riff in the Cederberg, of the now abandoned farm of the Visser family located at about 1,160 m above sea level (asl). Four zones are described for analysing this site: A: foreground ridge; B: farmstead, valley bottom; C: rocky ridge behind farmstead and D: the Eikerboom valley at 900 m above sea level. Zone A has experienced a recent fire, estimated to have occurred about 4 or 5 years before the repeat photo was taken. A lot of young growth is evident in this region in the repeat image, with many old *Protea laurifolia* skeletons. The patch of trees (probably *Populus* sp.) which intrudes into the 1937 image in the right foreground is no longer evident although a large stand of cedar trees (*Widdringtonia cedarbergensis*) is present (out of view on the right) in 2007. The farmstead in zone B is now demolished, although there are still signs of disturbance, especially evidenced by patches of *Stoebe plumosa*. The rocky ridge (Zone C) has not experienced much change while the valley bottom (Zone D) has seen the abandonment of cultivated fields.

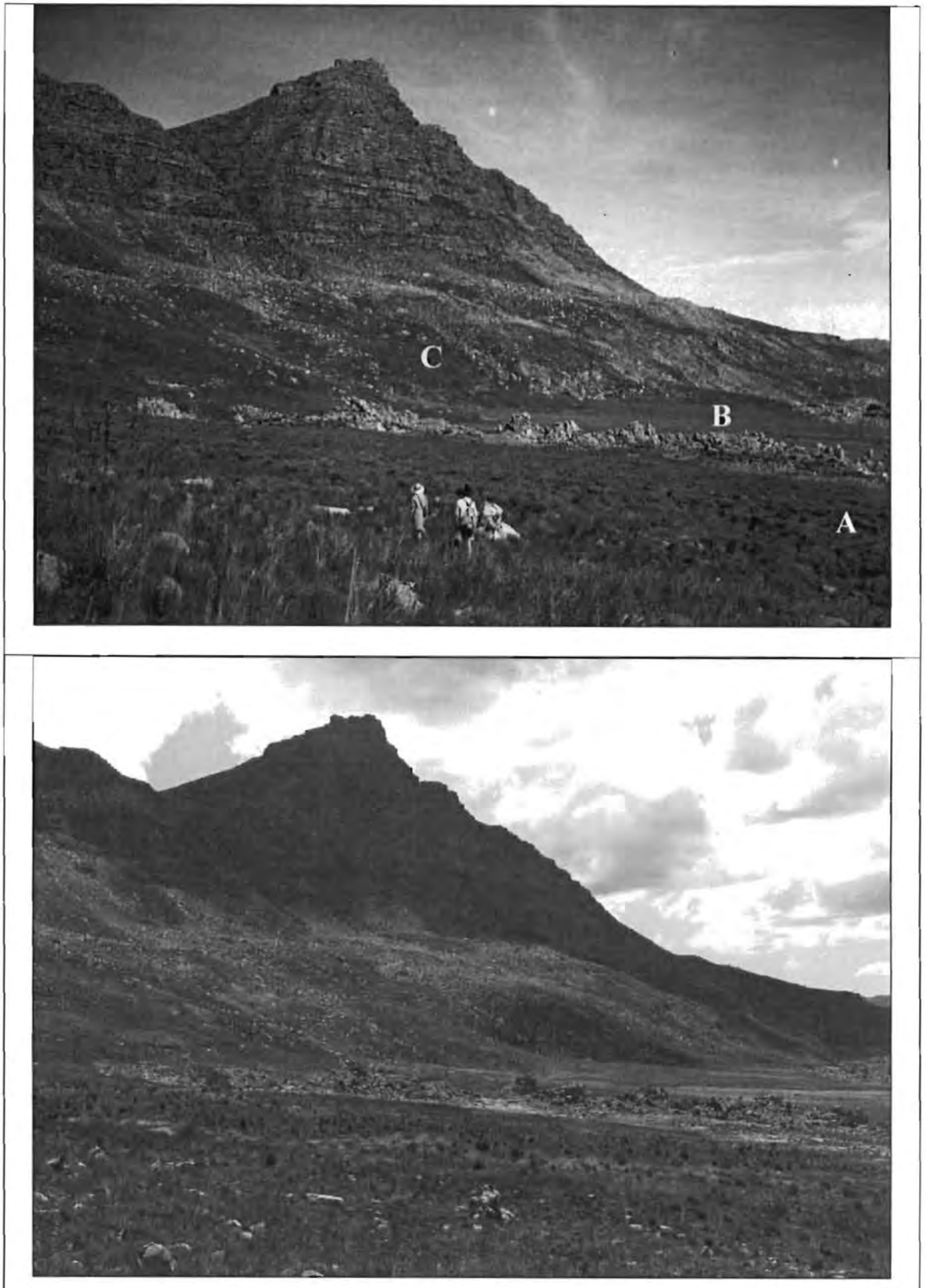

Figure 1: Kenneth Howes-Howell's original 1937 photograph (top) at site 422 (Sneeuberg shale band 1) and re-photographed (bottom) in 2007.

Figure 2: Kenneth Howes-Howell's original 1934 photograph (top) at site 436 (Vissers farm: de Riff) and re-photographed (bottom) in 2007.

Figure 3 was taken from Uitkyk Pass, looking towards Cederhout Kloof, at an altitude of 1,017 m. The foreground was heavily burnt at the time of the original photo as evidenced by the skeletons of plants. The foreground vegetation of the repeat photo is very dense, with *Leucodendron* sp., *Stoebe plumosa* and *Merxmuellera* sp. common. On the left foreground, amongst the rocks, *Protea nitida* now occurs. The valley bottom looks cultivated in the original photo as seen from the presence of white patches in the image.

In analyzing Figure 4 at Eikerboom, three landforms were identified, namely: A: foreground comprised of wind-blown sand; B: valley plain comprised of darker humic, organically-rich soils and C: the ridge called Rondeheuwel comprised of sandstone-derived rocky outcrops. The dune fields and exposed dunes of zone A are now stabilized and vegetated by tussocks of *Wildenowia incurvata* in the foreground with an associated dense stand of emergent *Protea laurifolia* shrubs on the NE edge of the dunefield, as it dips to the valley plain below. Hummocky dunes alternate with wind-blown deflations, which usually are associated with small surface pebbles and rocks. Some dunes to the right of the photo station are still weakly vegetated and appear to be mobile and losing sand. *Stoebe plumosa* is interspersed with *Protea laurifolia*.

In August 2007, when this site was visited for a second time, there were patches of standing water in the dunes with restios growing around the edges. At the time of the original photo (1934) there was probably very little water, and a general absence of restios. At least two cohorts of *Protea laurifolia* were recorded at this site. Living individuals were estimated (from stem node counts) at 15-16 years of age. The 24 dead individuals within the field of view died in a fire when they were approximately 30 years of age. In the valley plain (zone B), few changes are evident between 1934 and 2007. Light patches could reflect *Stoebe plumosa* dominance, which is still a feature of this region today. This zone starts with a 15 – 20 m wide line of *Erica* and then grades to a moist *Cyperaceae*-dominated zone before opening out to a *Stoebe plumosa* zone and finally a *Restio* bottomland, which is quite wet and marshy. The trees on the ridge in zone C, which were visible in the original photo, are a mixture of *Protea nitida* and *Maytenus oleoides* and have decreased in abundance since 1934.

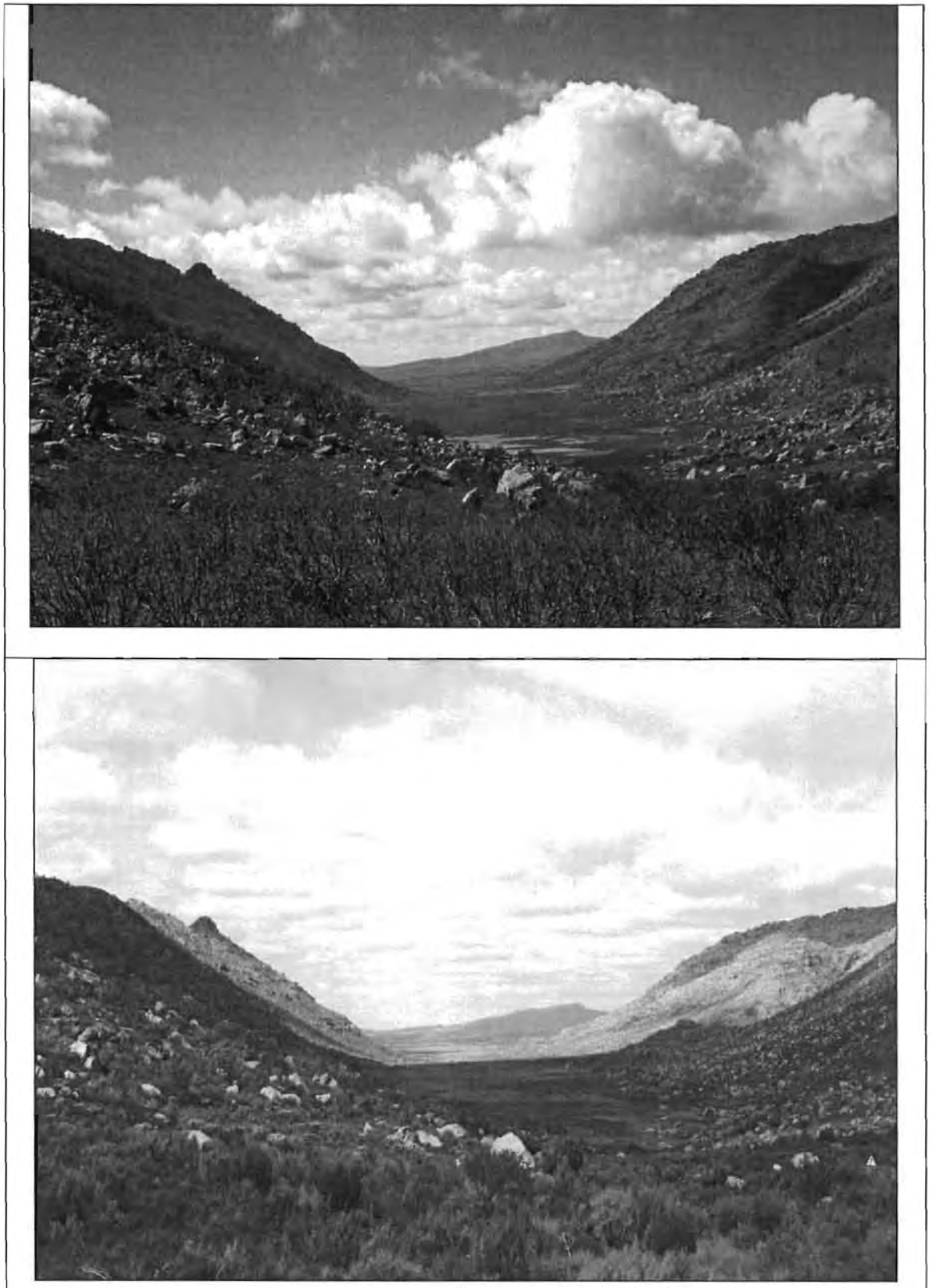

Figure 3: Kenneth Howes-Howell's original 1949 photograph (top) at site 438 (Uitkyk Pass 2: looking to Cederhout Kloof) and re-photographed (bottom) in 2007.

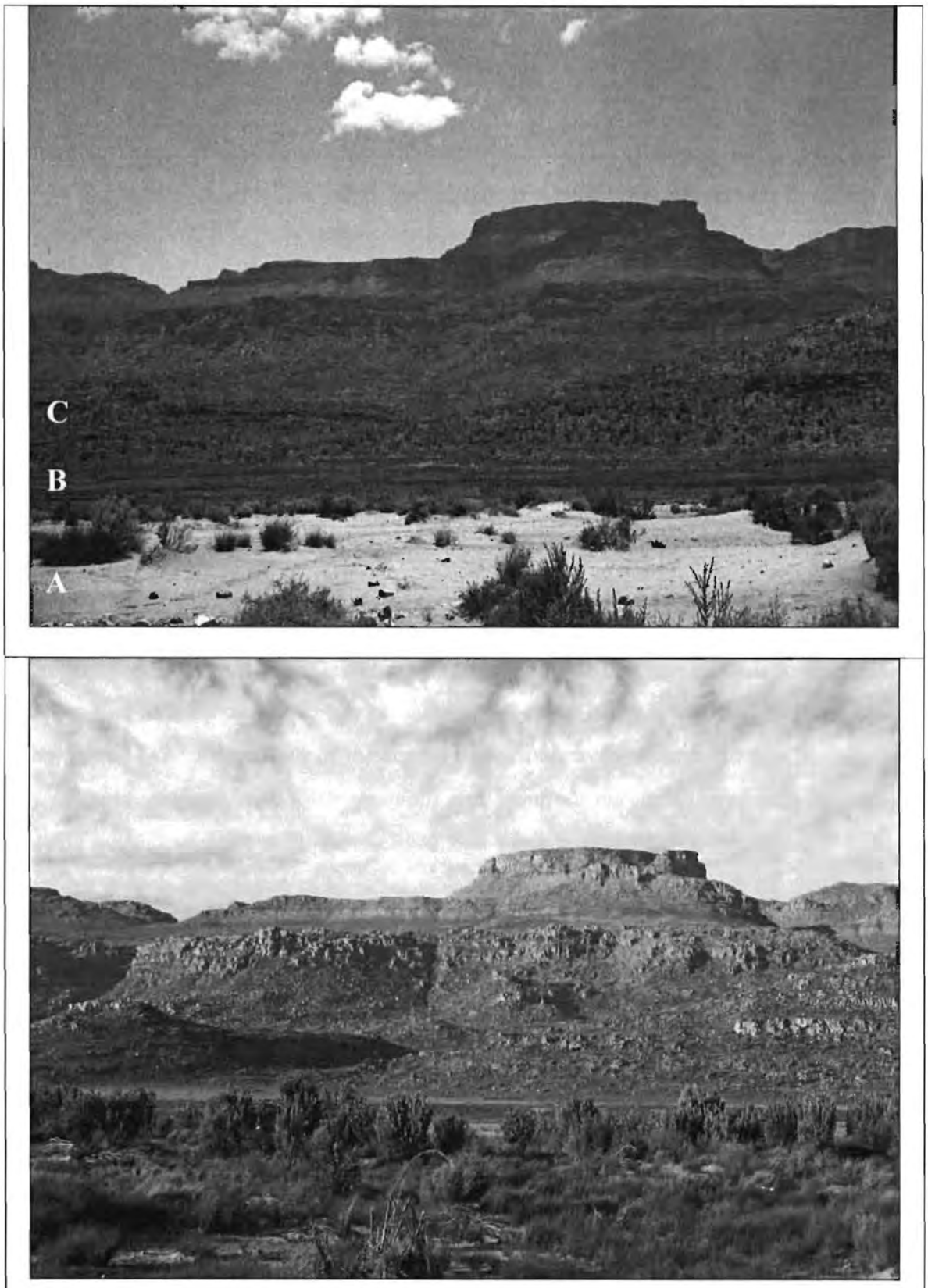

Figure 4: Kenneth Howes-Howell's original 1934 photograph (top) at site 421 (Tafelberg as seen from road near Eikerboom) and re-photographed (bottom) in 2007.

Figure 5 is situated at the site Krom Rivier on the edge of the Cederberg Wilderness Area (CWA). The altitude of this site is 890 m, and two zones or landforms were demarcated for description purposes. The sandy bottomland in the immediate foreground is identified as zone A, while the rocky mountain slope to the left is zone B. A fire has transformed the landscape, although not all *Protea laurifolia* have been burnt. Several individuals in the repeat image, particularly around the rocky outcrops, were only slightly burnt. *Protea laurifolia* appears more dominant in the repeat image than in the original, and individuals were aged to be approximately 10-12 years old. The dominant grass in the understory is *Ehrharta villosa* and has not changed significantly in cover. An interpretation of changes on the rocky mountain slope (zone B) undertaken in the field suggests that *Protea nitida* has increased in numbers since 1955.

The photographs in Figure 6 were taken in an area called Sandfontein, near Groot Rivier at an altitude of 653 m. Two zones are described, A: the immediate foreground comprised of rocks and boulders along the road verge and which extends to the base of the first slope and B: the large east-facing slope on the left-hand side of the photograph. The foreground in the repeat image is heavily disturbed and dominated by *Galenia africana* with *Rhus undulata* and *Montinia caryophyllacea* also present. At the bottom of zone A it was noticed that there was a small population of *Aloe comosa*, which appear not to be present in the original image. Very little change in plant density is apparent in the distant part of this zone. The east-facing slope (zone B) has also changed very little in terms of vegetation cover between the original and repeat photographs. Clumps of *Rhus undulata* and associated shrubs appear to be much the same.

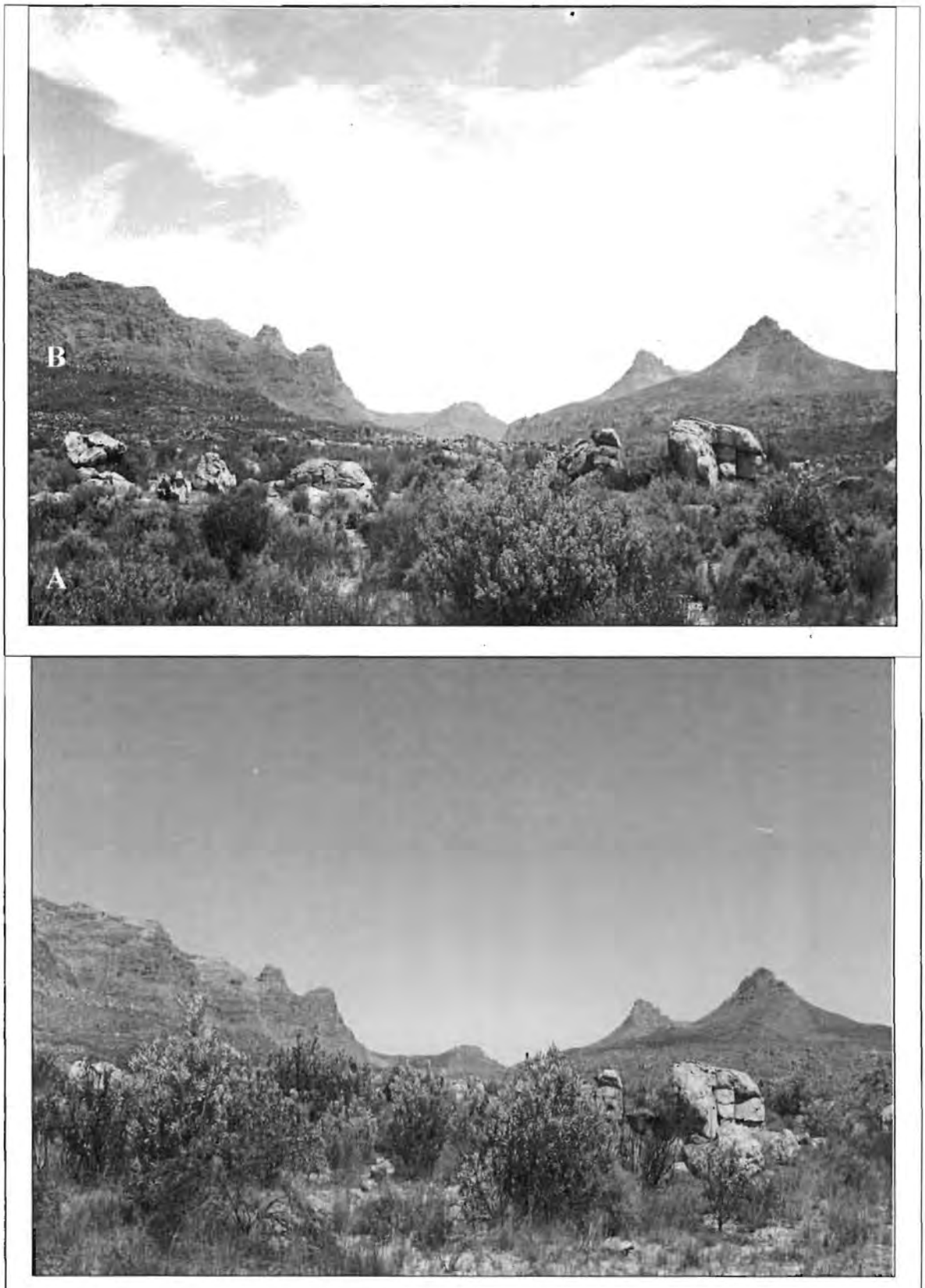

Figure 5: Kenneth Howes-Howell's original 1955 photograph (top) at site 427 (Krom Rivier 2) and re-photographed (bottom) in 2007.

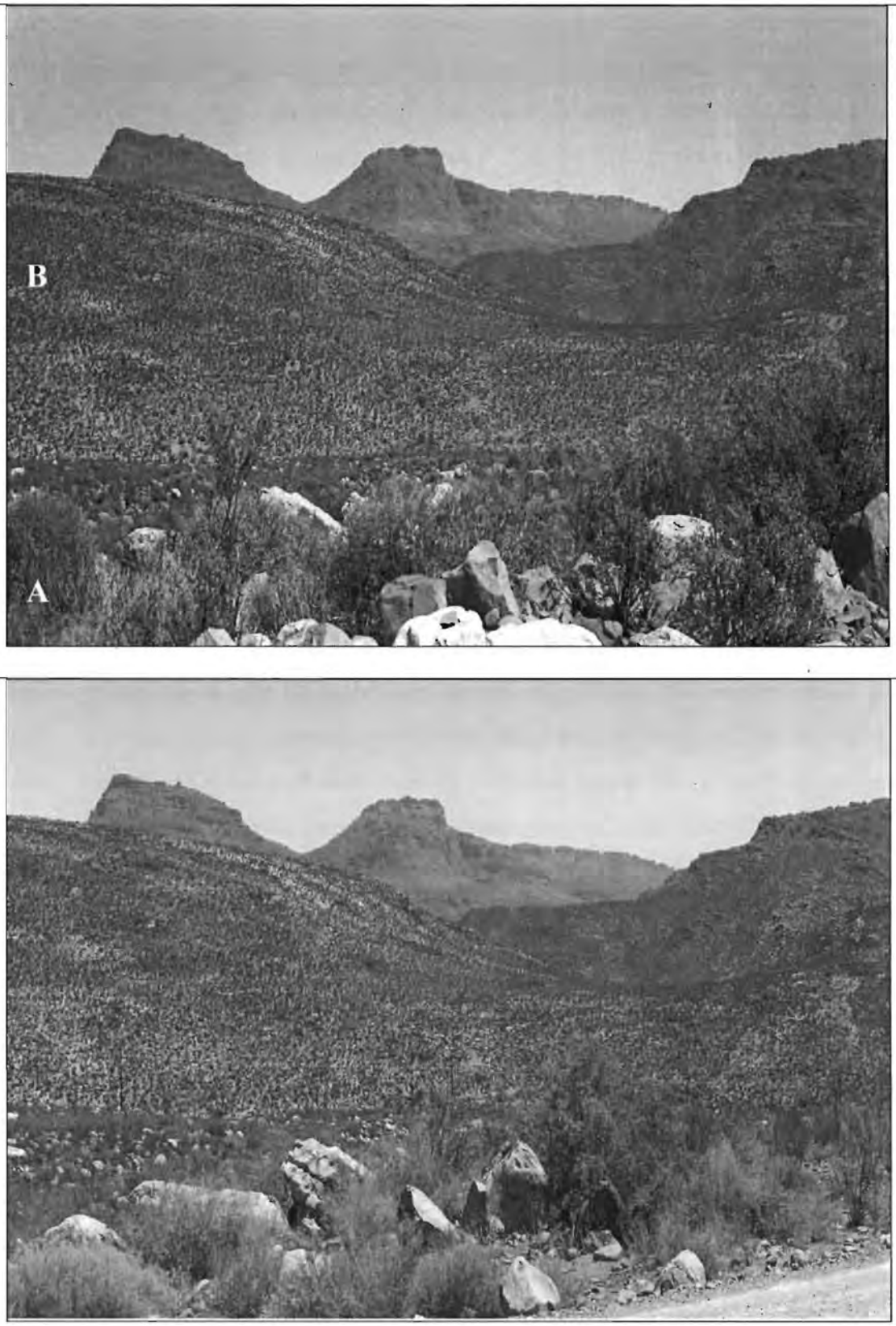

Figure 6: Kenneth Howes-Howell's original 1949 photograph (top) at site 428 (Sandfontein – near Groot rivier) and re-photographed (bottom) in 2007.

Figure 7 was taken from the top of Sandfontein Peak (1,610 m asl) in the southern portion of the Cederberg midlands. The view is looking down over the farm Zandfontein in the foreground and Suikerbossie Farm at about 750 m asl in the valley immediately beyond. In the distance, to the south, lies the Bokkeveld mountain range. There has been a significant increase in agricultural activity on the two farms below Sandfontein Peak. The dam in the foreground of the repeat image is new, and there are new lands in the bottom left of the photo. The major changes however, are in the second valley, where there has been a significant increase in agricultural development including the construction of a new dam.

Figure 8 is a panorama of Suikerbossie Farm, which is also located within the southern portion of the Cederberg midlands at an altitude of 741 m. Three zones were allocated to this site, the second of which has been further divided into two parts. Zone A is the rocky ridge immediately in front of the camera station. This area is made up of shallow soils with large stones. The dominant species include *Stoebe plumosa*, *Passerina* sp. and *Eriocephalus ericoides* with *Protea laurifolia* common in places. Little change has occurred in this zone and it is still dominated by the same species. Zone B (1) is the undisturbed sandy pediment below the rocky ridge on the right of the image. This area has deeper sandstone-derived soils. Immediately below the rocky ridge the undisturbed vegetation has seen an increase in *Protea laurifolia*. The bare patches between *P. laurifolia* seen in the original panorama have closed up but are still evident in places. Zone B (2) is the open stretch of land to the base of the mountains on the left of the image. The once open patches of veld, which were previously planted to wheat, are now planted with onions and oats. The sandy pediment to the right of the original panorama is zone C. This area is now covered by a range of different fruit orchards such as peaches, pears and minolas. *Cassuarina* sp. (Dogwood) trees have been planted around the orchards as wind breaks. An agricultural patchwork exists on the sandy pediments above the river course, which bisects the valley. Sandstone mountains and ridges surround the valley. The landscape is surprisingly broken when viewed in detail and several tourist dwellings are evident in the area today.

Figure 7: Kenneth Howes-Howell's original 1949 photograph (top) at site 434 (Sandfontein Peak) and re-photographed (bottom) in 2007.

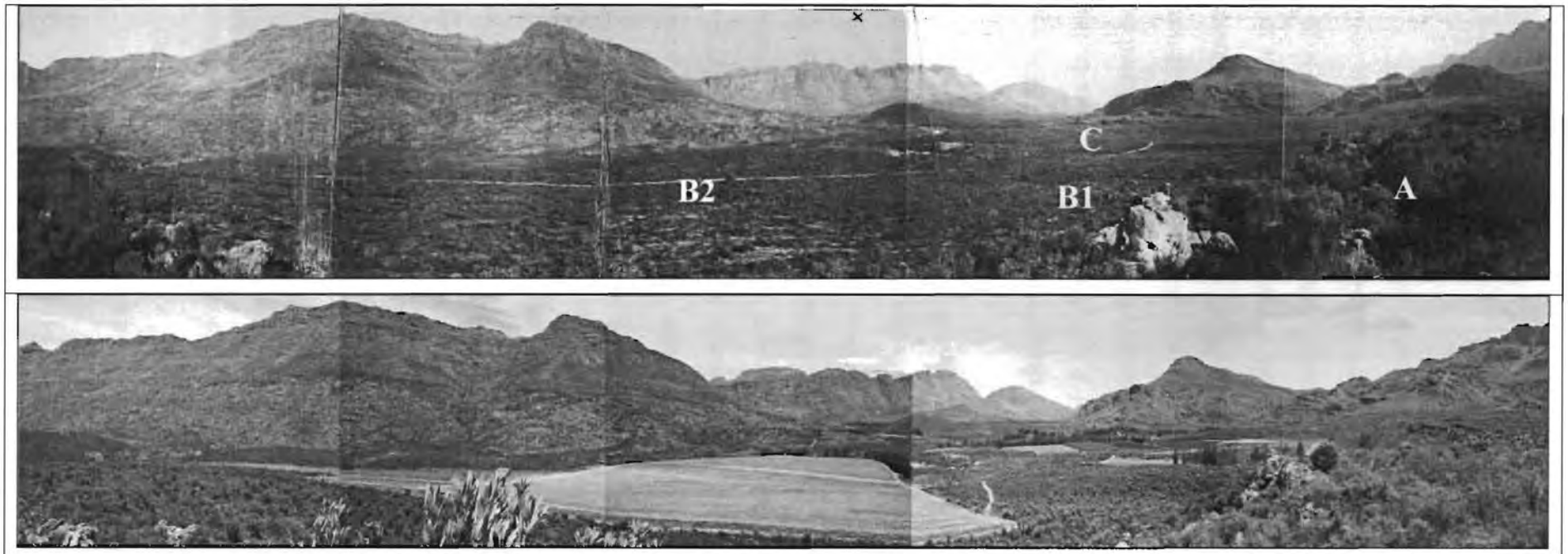

Figure 8: Interviewee A's original 1976 photograph (top) at site 440 (Suikerbossie Farm 1. Panorama) and re-photographed (bottom) in 2007.

4.4 DISCUSSION

4.4.1 Changes in Plant Cover and Species Composition

This chapter analysed pairs of matched photographs and documented the changes that have occurred at each of the sites, which span the north-south reaches of the Cederberg midlands. The eight matched photographs as well as the images in Appendix 1 provide a visual documentation of 20th century landscape change in the Cederberg Wilderness Area in response to anthropogenic and climatic influences. Several important observations can be drawn from these images. Firstly, there is no evidence of extensive reductions in plant cover or shifts to weedier, drought-adapted flora as would be expected under a drier, hotter climate. Some of the repeat images show an increase in vegetative cover, while others show a decrease. These differences can best be explained by either the presence or absence of recent fires, or the reduction in grazing, which has led to an increase in woody vegetation, particularly evident along the river courses. Not all landowners perceive this positively. Some are of the view that animals keep the veld young and without grazing by livestock, the veld becomes too rank and old. The vegetation then gets so thick that wild fires are needed to germinate seeds. "It is a good practice to graze the veld." (Interviewee A, 2007). With a general reduction in livestock in the region however, the trend for an increase in woody elements is likely to increase.

A few of the repeat photograph pairs show changes in the abundance of two species within the genus *Protea* (*P. laurifolia* and *P. nitida*). *P. laurifolia* has increased in cover at all sites where it occurs, while the response of *P. nitida* has varied between sites. At sites where anthropogenic impacts (as a result of wood harvesting) were high in the past, *P. nitida* has decreased, while at others, where impacts by humans have been minimal or non-existent, it has increased in cover. However, in order to gain a more robust generalization of changes in species such as these and other large iconic types, the analysis of more sites is needed. An example of this approach is outlined in considerable detail in Chapter 5 for *Widdringtonia cedarbergensis*.

4.4.2 Anthropogenic Impacts

A second important finding from this study is that most of the observed changes seen in the repeat images can best be explained through an understanding of anthropogenic influences. What is also clear is that twentieth century changes in settlement, cultivation, livestock grazing and fire have happened on a different scale in the different parts of the Cederberg midlands. Agricultural activities, particularly cultivation and livestock production, have given way to a mixture of wine production and tourism in the north, whilst the southern portions have become more intensively cultivated although tourism has also started to grow in the region. The following sections will contextualize and discuss the observed changes using information gathered from interviews with local farmers and landowners in the area.

4.4.2.1 Settlement

In the northern midlands after the Second World War, many poor whites were in search of land on which to settle. Because these people did not own land, they rented land on large farms in the area, and they became known as "bywoners" (adjacent farmers or squatters). The Visser's were one such family who worked as bywoners on many of the larger farms in the area, and their original and abandoned farmstead called 'de Riff' is shown in Figure 2. This farm was abandoned in 1947, when the family moved down to Welbedacht to school their children (Interviewee D, 2007). The area around Eikerboom (Figure 4) was also utilized by a bywoner family in the past (Interviewee D, 2007). Many people, from both white and mixed-race ancestry, used to live and farm in the mountains of the northern parts of the Cederberg midlands. However, after the declaration of the wilderness area in 1973, they were forced off these lands and "they had to break down their buildings. Nature Conservation broke everything down and removed the oak trees" (Interviewee D, 2007).

Bywoners were less common in the southern portions of the midlands. Most of the farms in this area have been farmed by the same families for generations. For example, the broader farm Ysterplaat from which Suikerbossie farm was established, has been in Interviewee A's family for 250 years. The last 15 years, however, have

seen an influx of people from cities in the Cape Province, as well as from overseas. "These people are buying farms in the region especially wine farms and fruits farms" (Interviewee A, 2007). There is a general consensus amongst local farmers that the urbanites moving into the area do not buy land to farm: "A lot of people just buy land for speculation for tourism or guest houses or change the agricultural land for nature conservation and ecotourism" (Interviewee A, 2007). This is supported by Interviewee E (2007) who suggests that "Most come just to enjoy the environment, a lot come and get ownership of the small holdings for holiday houses".

4.4.2.2 Cultivation

The northern midlands have seen a transition from traditional methods of farming to wine making and tourism. For example, "at de Riff (Figure 2) the Visser's sowed wheat, 'op die ou tyd se manier' (in the old, traditional way) using sickles. They also separated the wheat from the chaff using clay 'vloere' (threshing floors). They planted mostly fruit trees along the edges of the lands and these trees included peaches, quince and pears. They also had pigs in a pen and goats, sheep and cattle. Donkeys used to do the ploughing and pull the wagon" (Interviewee D, 2007).

Interviewee D and their family have themselves abandoned fruit farming to enter the tourist trade by building cottages and by developing a camp site. "Last year we started planting vineyards and we hope to grow wine. At the moment about 60% of our income comes out of tourism" (Interviewee D, 2007). One of the main reasons why they abandoned fruit farming was because of transport problems: "we have stopped farming deciduous fruits because the roads are so bad and the costs are too high to get fruit to the market" (Interviewee D, 2007).

In contrast, the southern midlands have witnessed an intensification in cultivation, particularly with the production of fruits and vegetables. "At the moment, the most important crops grown are peaches, pears and citrus fruit. It was the same when I was a youngster, although not at the same scale" (Interviewee E, 2007). "Croplands have almost doubled in size over the last 15 years because of deciduous fruit and vegetables in the Sandfontein area" (Interviewee A, 2007) (see Figures 7 and 8). The once open patches of veld in the original image of Figure 8 are now planted by onions

and oats and were previously planted to wheat. This suggests that this farm has undergone market-driven land use change. Improved transport routes have further aided the expansion in cultivation in the region. Superior roads have made the transportation of fruit a lot safer, which has made marketing much easier.

4.4.2.3 Livestock

Unlike cultivation, livestock farming has declined in the Cederberg midlands over the course of the 20th century. In the past people kept animals to be self-sufficient and many of the farmers interviewed said that they grew up with cattle and sheep. The land was in many instances overgrazed in the past as "in those days people's wealth was measured by the number of animals they had. Some farmers still farm a little with sheep but not many" (Interviewee E, 2007).

Today in the southern midlands, the main land use practices are the farming of citrus, and deciduous fruit, and vegetables. "Livestock farming is no longer profitable – a farmer can make R150, 000 per ha producing fruit, but can only get R12-15, 000 per ha farming sheep" (Interviewee E, 2007). "There used to be around 100, 000 sheep in the Ceres District, but today there are no more than 10, 000. People used to be traditional skaapboere (sheep farmers) and would hold onto the culture of their fathers, but today sheep farming is contracting and fruit farming is expanding" (Interviewee E, 2007).

The reduction of livestock numbers, usually leads to an increase in the cover of natural vegetation. An example of this is seen in Figure 7, where numerous bare patches are evident in the valley where the Suikerbossie farm is now located in the original 1949 photograph. These open patches of land are not as evident in the 2007 image. While fires and early 20th century mining excavations are the cause of some of these bare areas of land, grazing by livestock also had an impact: "Cattle used to graze in this area. The bare patches in the valley could perhaps have been as a result of 'kolbrand' (patch burning). In the rivers you get flat open areas, which were burnt for grazing in the past. This part of the family farm was called the 'veepos' (stock post) where the cattle used to graze during the day. Rooi Afrikaner oxen were like 'creepy crawlies' and they ate the reeds in the river and the river was not so overgrown in the

past. It would not be a bad thing to graze the area as heavily again. One thing I can assure you of is the fact that the river has grown closed tremendously in the last 23 years. Palmiet (*Prionium serratum*) and Wilde Amandel (*Brabejum stellatifoium*), were not as common in the past. The area was 'mooi oop' (nice and open) and is now so much more overgrown that 'hy spoel nie so veel as tevore nie' (it doesn't flood as much as before)" (Interviewee A, 2007).

The change in plant cover at Eikerboom (Figure 4) may also be as a result of a reduction in livestock numbers in this area. The exposed dunes, evident in 1934, are today covered with *Wildenowia incurvata* and several shrubs such as *Protea laurifolia*. This increase in cover could have occurred in response to decreased grazing pressure.

4.4.2.4 Fire

Fire regimes have also changed in the region during the 20th century. "In the past we used to use the 'kolbrand' method" (a patch burning system which was started intentionally) (Interviewee A, 2007). Patch-burning enabled farmers to open up the veld allowing animals access to land further away from the homestead. "It is difficult to implement this practice today because Nature Conservation doesn't like it" (Interviewee A, 2007). A 'Brand Bestrydings Forum' (Fire-Fighting Forum) was established by Nature Conservation and you now need to get permission before burning. This is also to prevent runaway fires and fires being set at the wrong time of the year. Livestock farmers used to burn "lappieskombers" (small patches or literally 'patch quilt') for their animals to graze. They burnt very frequently, and this prevented large run away fires (Interviewee E, 2007). "In 1989 a large fire burnt from Citrusdal for 60 km in length and 25 km in width and nothing escaped" (Interviewee E, 2007). There is a perception amongst farmers that 'kolbrand' is very similar to the natural fire regime, justified they say since fires usually start by lightening and an hour or so after a lightening event it rains and puts out the fire (Interviewee C, 2007).

Most of the local farmers interviewed expressed displeasure with no longer being allowed to use the 'kolbrand' method: "Today we are told what to do and we have to pay money to belong to the Brand Bestrydings Forum. Within the forum they just talk

and talk and they don't get anywhere" (Interviewee B, 2007). Patch-burning (kolbrand) is not allowed by Nature Conservation but the local farmers believe it is necessary for preventing fires from getting out of control. "...people used to burn small pieces of veld in the beginning of winter when there had been a bit a rain. We burnt a small patch so that when fires started in between it wasn't so bad that fires got out of control" (Interviewee B, 2007). Farmers link the recent increase in large fires with the suppression of patch-burning: "Since kolbrand was stopped in the 1980s there have been three big fires in the region 1986, 1992 and 2000" (Interviewee C, 2007).

4.4.3 Climate Change and Land Use Impacts

The effects of climate change on the landscape of the Cederberg midlands are difficult to identify from the repeat photographs and will probably only be evident in several decades. While some land owners believe that the climate has changed in recent years, others do not share this view, and so perceptions of climate change vary. "The previous three years were the worst in my 23 years on the farm. 2003 and 2004 were the first time I saw the river standing (not flowing). This winter was like normal" (Interviewee A, 2007). "We have had poor winters in the last 10 years. This winter we have had the 'outydse' (old-time) winter. We usually had our rains in the Easter months but in the last 10 years this has been getting worse. This year has been the best we have had for a long time. The future of this area is bleak" (Interviewee B, 2007). "My rainfall records go back to 1961. I have not really seen a decline in rainfall. I am not worried about climate change. My data show two or three years (of good rainfall) followed by a few dry years" (Interviewee E, 2007).

Land owners in the region are further concerned about the impact of agriculture on water resources. "One trend you see is an enlargement of dams or the lifting or deepening of dams." (Interviewee A, 2007). This testimony is illustrated in Figure 7, where an increase in the number of dams is shown. "I still have to build myself a (bigger) dam. I am using the river as a reservoir at this stage but when people upriver irrigate they just take the water and that is a problem for me" (Interviewee A, 2007).

A positive outcome from the increase in tourism in the region, is that less water is used for irrigation. "The other positive side (of an increase in tourism) is the water. If land is taken out of agriculture then there is more water available because not as much is used for irrigation. On the other hand, people buying land for agricultural purposes just run it like commercial farming and they use more and more water. Tourism is saving water but on the other side (when the land is used for agriculture) water is disappearing. If you love the land you try to keep a balance between plantings and water sources. Water wasn't a scarcity but it has become a scarcity because of agriculture" (Interviewee A, 2007).

Aside from climate change there is also the possibility that elevated partial pressures of carbon dioxide may have influenced the vegetation of the Cederberg midlands, however there is no data to support this observation and so this point is rather speculative.

4.4.4 Future Land Use

Evidence from land owners in the region suggests that there is likely to be an increase in the intensification of agricultural production combined with a mixed livelihood strategy, which involves primarily the expansion of the tourism industry. "I would also like to be in harmony with nature and farming and develop tourism. We have three camping areas that we would like to enlarge and develop. I am trying to mix it (tourism) with farming so that they (people from the cities) get a bit of an experience of farming. There are so many people who have not experienced picking a peach from a peach tree, for example. We have lots of education to do around farming. I would like to give people from the city the experience of farming" (Interviewee A, 2007).

The role of the Cederberg Wilderness Area (CWA) is also perceived as important for this expansion. When asked whether the development of the CWA has had an influence on the region in terms of land use practices, profitability and impact on the landscape, responses by land owners included: "From my point of view everything is more organized and there is more discipline in doing more things. In the future, all these things will come together - conservation, plants, fire and water – there will come a time when things will be-more organized" (Interviewee A, 2007).

4.4.5 Synthesis

Repeat photographs and oral testimony have illustrated how landscape changes have occurred differently in the northern and southern portions of the Cederberg midlands over the course of the 20th century. Much like the Cederberg lowlands, the main drivers of change experienced in both geographic segments of the midlands, have been influenced by anthropogenic factors rather than climatic factors. Political and economic influences have been responsible for the changes in settlement patterns, land use, and land management. The post-WWII displacement of people led to the occurrence of bywoners in the northern midlands, while the declaration of the Wilderness Area in 1973 and the resultant management principles saw the dissolution of this culture and the recovery of the lands occupied by the bywoners. Market-driven land use changes occurred in both sectors of the midlands, with agriculture largely giving way to the tourism and wine industries in the northern midlands, and traditional forms of agriculture, especially livestock production, being displaced by fruit and vegetable farming in the southern midlands. It needs to be acknowledged however, that there are limitations in the methods engaged in attempting to identify the relative importance of various changes in explaining landscape-scale changes. Such an assessment is very difficult to make, given the size of the area under study and its complexity in terms of land use and history. The next chapter concludes the zonal theme of the thesis, and turns its attention to the Cederberg uplands where an analysis of the decline of the endemic Clanwilliam cedar tree is undertaken.

CHAPTER 5: THE DECLINE OF THE ENDEMIC CLANWILLIAM CEDAR (*WIDDRINGTONIA CEDARBERGENSIS*) OVER THE LAST 75 YEARS AS REVEALED BY HISTORICAL PHOTOGRAPHS

5.1 INTRODUCTION

The distribution patterns of plants and animals are heavily influenced by gradients of temperature and moisture. There have been several studies mostly from the Northern hemisphere, which have suggested climate-related range shifts for several species (Walther *et* al., 2002; Parmesan and Yohe, 2003; Thomas *et al.*, 2004; Duncan *et al.*, 2006). In the context of ecological response to climate change, it is the regional changes as opposed to the approximated global averages that are of significance (Walther *et al.*, 2002). In mountainous areas, climate changes more swiftly with elevation and so it is expected that there will be rapid changes in montane communities as climate continues to change (McCarty and Markham, 2001).

The Clanwilliam cedar, *Widdringtonia cedarbergensis* is an endangered species in the family *Cupressaceae*, endemic to the Cederberg Mountains in the Western Cape Province of South Africa. It is one of only two coniferous tree genera indigenous to Southern Africa (Manders, 1986). Confined to the rocky areas between 900 and 1, 400 meters above sea level (February *et al.*, 2007), *Widdringtonia cedarbergensis* is normally around 5 to 7 m tall, but occasionally attains a height of around 20 m with a stem diameter of 2 m. The species has a relatively long life span, often surviving for several hundreds of years (Dunwiddie and La Marche, 1980). It does not resprout after fire, but germinates every winter with the highest regeneration occurring after fires. Anecdotal evidence for declining numbers of this charismatic species has made its conservation a topic of concern since as far back as 1805 (Smith 1955). These early observations however, did not provide precise descriptions of the cedar trees' distribution and status, and thus the first reliable records pertaining to these matters are relatively recent (Manders, 1986).

The primary hypotheses for the decline in cedar populations include (1) the adverse effects of human exploitation, (2) disease, (3) a change in the frequency and intensity of fire and (4) climate change.

Human exploitation

Many believe that human exploitation of the tree during the 18th and 19th centuries was a major cause of the present day plight of the cedar (Mustart and Bond, 1994). As cedars grow in a vegetation type (fynbos) in which there are few trees, their wood was in demand for furniture, telephone poles and other building materials. The 1805 agricultural commission report found that people had been making a living in the Cederberg for many years – selling timber to surrounding districts. The early settlers in this area, harvested trees in such great quantities that within a decade of the first settlement, it was found necessary, by the Governor of the Cape, to enforce restrictions on harvesting (Manders, 1986).

Disease

Wingfield *et al.* (1988) investigated the occurrence and threat of pests and diseases in mature *Widdringtonia cedarbergensis* found in natural stands and plantations in parts of the Cederberg (natural stands north of Sneeuberg Hut and plantations at Algeria Forest Station). Examinations of healthy, dying and dead trees were performed in February 1984 and March 1985. The study analysed root diseases, leaf diseases and stem diseases and found that there were no severe diseases or insect problems and that only minimal tree death could be attributed to disease (Wingfield *et al.*, 1988). However, it was discovered that the general health of cedars was lower in the plantations than in natural stands, evidenced by the fact that in plantations of *W. cedarbergensis,* groups of aging trees were found with apparently weak root systems; whereas in natural stands, only single dying trees were occasionally found (Wingfield *et al.*, 1988). Wingfield *et al.* (1988) only examined the health status of *mature* cedar trees, meaning that the question of the effect of pests and diseases on the reproductive capacity of *W. cedarbergensis* remains unanswered.

Fire

One of the leading hypotheses regarding the cedar's decline is the impact of fire (van Wilgen, 1980; Manders, 1986; Manders and Botha, 1987). Although the Clanwilliam cedar is only found in fire-adapted fynbos vegetation individuals are easily killed by

fire (Manders, 1986). The kolbrand system, which was characterised by lots of small, frequent fires has been replaced by less-frequent, but more intense fires in the Cederberg Wilderness Area over the last 50 years (Mustart and Bond, 1994; Manders, 1986) (also see Chapter 2), which has negative implications for the cedars as it prevents seedlings and saplings from developing into mature trees. This poses the question as to whether the large numbers of cedars reported by early travelers, which may have been several hundreds or even thousands of years old, did not develop during a climatic period that was more beneficial to its survival (Lückhoff, 1971).

Fynbos vegetation naturally burns at a cyclical interval ranging from anything between five and 30 years (Rebelo *et al.*, 2006). Fynbos plants generally mature quickly and establish sufficient seed stores within 10 to 15 years. The cedar however, only begins its seed production approximately 15 years after a fire (Mustart and Bond, 1994). Consecutive fires after 15 year intervals will therefore seriously hinder the cedar as seedling numbers will become fewer and fewer after such a succession of fires. It has been said that mature cedar populations do not burn out, as these populations, which include many large trees, are able to stifle the under-storey fynbos plants, thereby lessening the flammable load that would sustain intense fires (Mustart and Bond, 1994). It is possible then that the more extensive stands suggested by early travelers may have withstood fires more effectively. Because of their sensitivity to fire, the cedars have adapted to growing between large boulders on rocky outcrops, where they are well protected.

Climate change

The human impact on the environment has led to significant changes in climate. Such change over the last 50 years could also explain the decline of the cedar particularly when viewed in combination with changes in fire frequency and intensity. Over longer time frames, the palaeoecological record indicates that the drying trend within the Holocene has had a detrimental impact on the cedar, and is in stark contrast to the past glacial era 12,000 years ago when the cedar thrived (Sugden and Meadows, 1990). Climate change has strong implications for biodiversity – causing changes in physiology, distribution, community structure and ecosystem dynamics (Midgley *et al.*, 2002, 2003). *Widdringtonia cedarbergensis* is dependent on reliable access to

available water (February *et al.*, 2007). Future climate change predictions for the south-western Cape are for drier, hotter conditions (Midgley *et al.*, 2002), which it is suggested, will lead to a constriction of the fynbos biome, resulting in the extinction of species. It is further noted that the first signs of these climatically related species losses will be in the Cederberg (February *et al.*, 2007), specifically with the extinction of *W. cedarbergensis*, as if these predictions are realised, the species reliance on regular rainfall for available water will lead to its demise. As noted earlier, the impacts of climate change are often more easily evident along altitudinal gradients (McCarty and Markam, 2001). This leads to the consideration that this could be what we are seeing in the Cederberg, where the Clanwilliam cedar tree's lower range has shifted upwards in altitude over the last one hundred or so years, from being around 900 – 1,000 m above sea level in the past (van Wilgen, 1980), to now being found almost exclusively between 900 and 1,400 m above sea level (February *et al.*, 2007).

This study of *Widdringtonia cedarbergensis* was undertaken in the northern parts of the Cederberg Wilderness Area (CWA) and follows on the work of Manders (1986), Mustart *et al.* (1995) and Fox (2003). Using the technique of repeat photography, this study documents the population dynamics and current status of the Clanwilliam cedar and records the annual mortality rates of populations of cedar trees from 15 sites over an average of 69 years. It addresses the following questions: (1) What was the age and size class structure of cedar populations in the first half of the 20th century; (2) How has this changed over time; (3) What factors best explain this change? One of the key objectives of this chapter is to explore the decline in cedar populations over the course of the twentieth century.

5.2 METHODS

5.2.1 Field Sampling

The sites of 15 historical photographs taken by Kenneth Howes-Howell between 1931 and 1951 were re-visited in December 2007. These sites are situated in the northern parts of the Cederberg in the areas of Crystal Pools, Skerpioensberg and Vogelsangvallei (Figure 1). A 2003 1: 50 000 map was used along with the Howes-Howell photographic collection's index and a GPS to track and locate the sites. Two

cameras (one digital the other colour slide film) and a tripod were taken into the field, along with detailed fieldwork sheets – on which each site's information in terms of GPS coordinates, altitude, general ecological description and description of major changes was explicitly noted. Repeat photographs were taken at each of the 15 locations, and the digitised repeats together with the digitised originals were used to analyse mortality rates within the populations (see Appendix 3).

5.2.2 Photographic and Statistical Analyses

Image analysis was performed on each of the repeat photographs using Adobe Photoshop version 7.0. The original and repeat images were rescaled in Photoshop to achieve equal dimensions. This was done by arranging both the original and repeat photographs in Photoshop, selecting two permanent features (e.g. mountain peaks or rocks), which appeared in both images and measuring the distance between the two, using the measuring tool. Any differences in size were corrected so that both images were of equal proportions. Thereafter, the repeat image was overlaid on the original so that both images were combined into one window on the screen. The opacity of the repeat image was then reduced – making it possible to align the permanent features of the two images perfectly on top of each other.

Once the original and repeat photographs were perfectly matched, statistical analyses were performed so as to quantify changes in populations of cedar trees in these specific locations. For each site and time period, the trees were numbered (Appendix 3) and the following information obtained: present/absent (where absent = 0 and present = 1); dead/alive (where dead = 0 and alive = 1); size class (small (<2 m) = 1, medium (2-4 m) = 2 and large (>4 m) = 3) and foliage density (where sparse = 1 and dense = 2). For the populations where there was at least one cedar surviving in the repeat photograph, annual mortality was calculated as: (Nt-Nn/No)^1/y – 1, where Nt = the number of cedar trees in the repeat photograph, Nn = the number of new cedar trees in the repeat photograph, No = the number of cedars in the original photograph and y = the number of years between photographs.

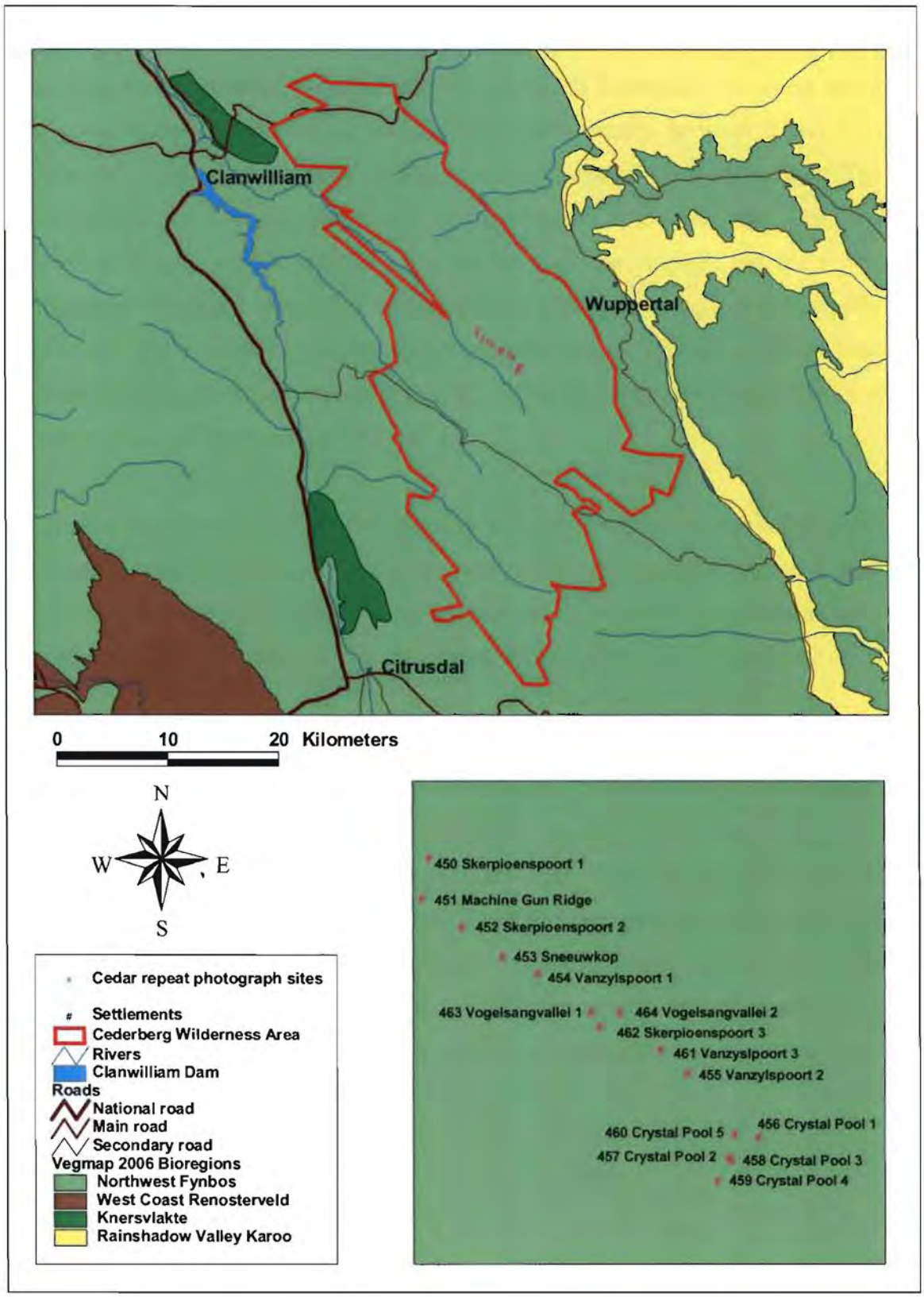

Figure 1: Map of all 15 cedar repeat photograph sites in relation to the Cederberg Wilderness Area and surrounding landmarks. The box in the bottom right provides the relative location, number and name of each of the repeat photograph sites (see Appendix 3 for all matched images).

For the three sites where there were no live cedars in the repeat photograph, we used an individual based simulation approach. For each year, the number of surviving individuals was determined by identifying whether each individual was dying based on a given mortality rate, which was changed automatically between 0 and 1 to identify the point at which 95% of the simulated populations went extinct. The surviving individuals formed the number of trees present in the next year. This was repeated iteratively for the number of years between the original and the repeat photographs. The entire simulation was performed 1,000 times (as it is a stochastic process) and the number of populations which were extinct after the observed time was counted. The simulation was written in R 2.6.2 (R Development Team, 2008) and the source code can be found in Appendix 4.

The relationship between annual tree mortality and altitude, slope and aspect was also determined from an analysis of the repeat photographs. The specific location of sub-populations of cedar trees within 12 of the repeat photograph sites were mapped on a 1:50 000 topographic map of the Cederberg and digitised. The remaining three photograph pairs (454, 458, and 460) were not used because of the low number of identifiable trees in the original image. A Digital Elevation Model (DEM) with 70 m contour intervals was draped over the sub-population location map and the mean altitude, slope and aspect values were determined for each of the sub-populations. Aspects were grouped into three classes: NW-NE, ENE-SE and SSW-WNW. Differences in mortality between sub-populations growing on different aspects were tested using one-way analysis of variance. Annual mortality within each sub-population was also plotted against altitude, slope and aspect. Aspect values, which were initially calculated in degrees, were transformed to radians and the cosine value used in the regression analysis.

5.2.3 Fire

The fire history for each of the 15 sites was acquired as an ArcView shapefile from CapeNature's Scientific Services website, from the section 'Ecological Fire Downloads' and a subfolder called 'AllFiresUpdate'. ArcView GIS Version 3.1 was used to compile the fire histories for each site.

5.3 RESULTS

Two of the 15 repeat photographs are shown for illustrative purposes and the remainder are detailed in Appendix 3). Changes at site 452 (Skerpioenspoort 2) (Figure 2) show the large number of deaths that have occurred in the cedar population at this site in the 66 year period since the original photograph was taken in 1941. Mortality has been widespread at this site but was especially evident on the left-hand, south-west-facing slope, where there has been approximately 90% mortality of the original 130 individuals. There were many healthy, young cedars in the right mid-ground, beyond the large boulders in 1941 but most were recorded as dead in 2007. It is also evident from the original 1941 photograph that the population of 130 cedar trees at this site was comprised of different size classes while the present day population of only 10 surviving trees consists solely of the largest size class (>4 m) with no young trees evident in the 2007 image.

The decline in cedar trees is further illustrated by the two images in Figure 3, which shows an east-facing slope at site 464 (Vogelsangvallei 2). A total of 28 trees was counted on this slope, 19 of which were alive in 1941 and only six of which survived in 2007, providing an annual mortality rate of 2%. Of the nine dead trees in the original photograph, eight of these skeletons were still evident in 2007. Table 1 illustrates the percentage of annual mortality of each of the 15 sites visited. The results show that since the original photographs were taken there has been a rapid decline of cedar populations at each of the sites, with an average annual mortality rate of 2.48 %. No new trees were observed in the recent photographs.

Figure 4 shows the mortality of cedar trees according to size class for five of the 15 sites, namely: 450, 451, 456, 463 and 464. These five sites were chosen as they were the only sites for which it was possible to identify the size of trees reasonably accurately. In general there were more live individuals than dead individuals in all size classes in the original photographs. In the repeat photographs there were generally higher numbers of dead trees than alive trees in all of the size classes. Young trees were not at all prevalent at any of the sites. There were no individuals <2 m in height at four out of the five sites. On average there has been a 3.78% annual mortality rate at these five sites over the last 68 years.

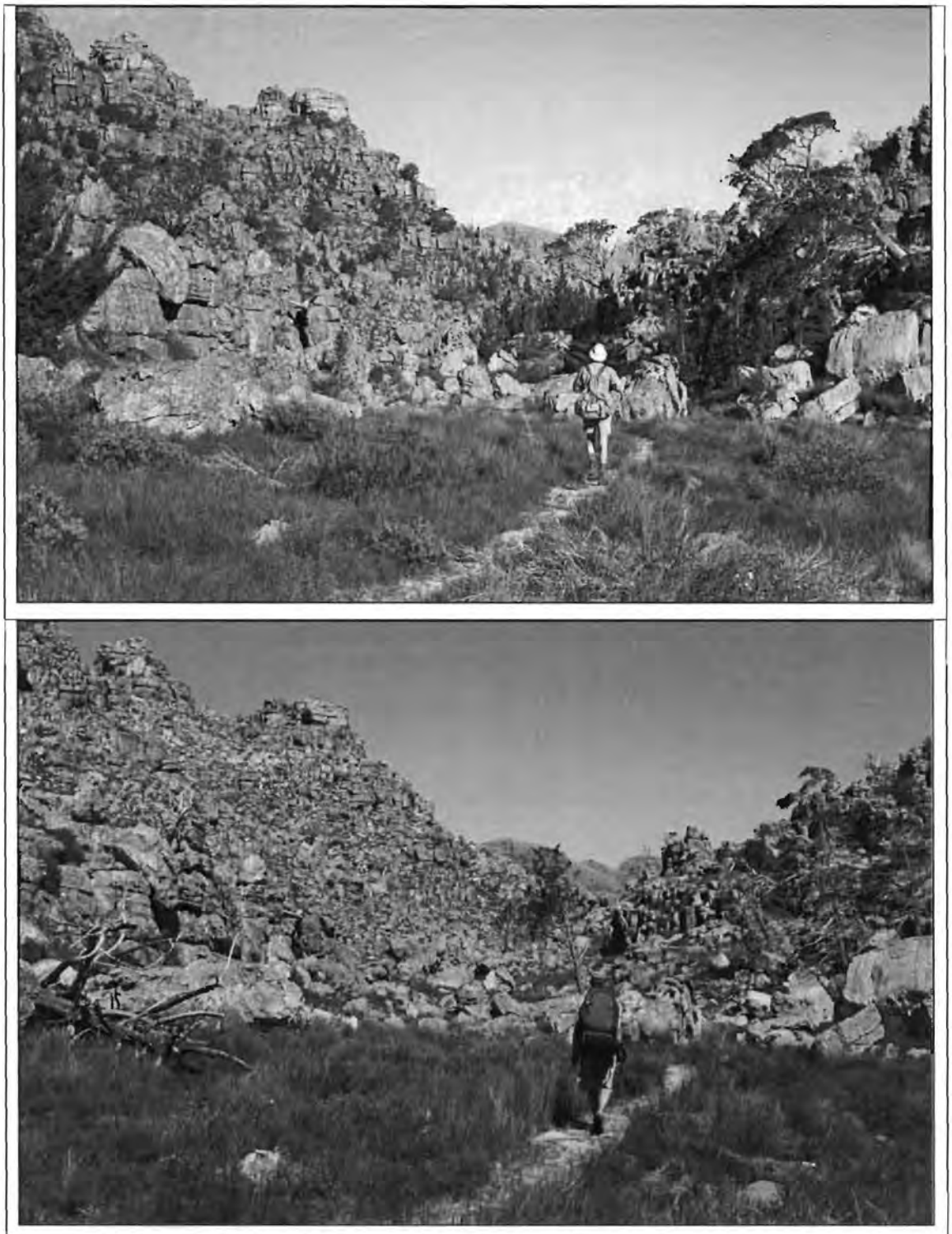

Figure 2: Kenneth Howes-Howell's original 1941 photograph (top) at site 452 (Skerpioenspoort 2) looking ESE towards Sneeukop, and re-photographed (bottom) in December 2007.

Figure3: Kenneth Howes-Howell's original 1941 photograph (top) at site 464 (Vogelsangvallei 2) and re-photographed (bottom) in December 2007.

Table 1. The number of individual cedar trees (*Widdringtonia cedarbergensis*) in original and repeat photograph pairs, counts of individuals not surviving, new recruits and % annual mortality at 15 repeat photograph sites in the Cederberg Wilderness Area.

Site No.	Site name	No. of years between photo's	No. of (live) trees in original photo's	No. of (live) trees in repeat photo's	No. of trees not surviving	No. of new trees in repeat photo's	% Annual mortality
		[y]	[No]	[Nt]	[Nd]	[Nn]	(Nt-Nn/No)^1/y - 1
450	Skerpioenspoort (1)	66	6	0	6	0	7.05
451	Machine Gun Ridge	76	28	0	28	0	8.02
452	Skerpioenspoort (2)	66	130	10	120	0	3.81
453	Sneeukop	76	47	10	37	0	2.02
454	Vanzylspoort (1)	73	6	4	2	0	0.55
455	Vanzylspoort (2)	63	26	6	20	0	2.30
456	Crystal Pool (1)	76	9	5	4	0	0.77
457	Crystal Pool (2)	73	6	4	2	0	0.55
458	Crystal Pool (3)	76	1	0	1	0	3.81
459	Crystal Pool (4)	73	6	2	4	0	1.49
460	Crystal Pool (5)	73	4	2	2	0	0.95
461	Vanzyslpoort (3)	63	38	13	25	0	1.69
462	Skerpioenspoort (3)	63	21	10	11	0	1.17
463	Vogelsangvallei (1)	56	19	9	10	0	1.33
464	Vogelsangvallei (2)	66	19	6	13	0	1.73
	Average	**69**	**24**	**5**	**19**	**0**	**2.48**
	Stdev	**6**	**32**	**4**	**30**	**0**	**2.29**
	Min	**56**	**1**	**0**	**1**	**0**	**0.55**
	Max	**76**	**130**	**13**	**120**	**0**	**8.02**

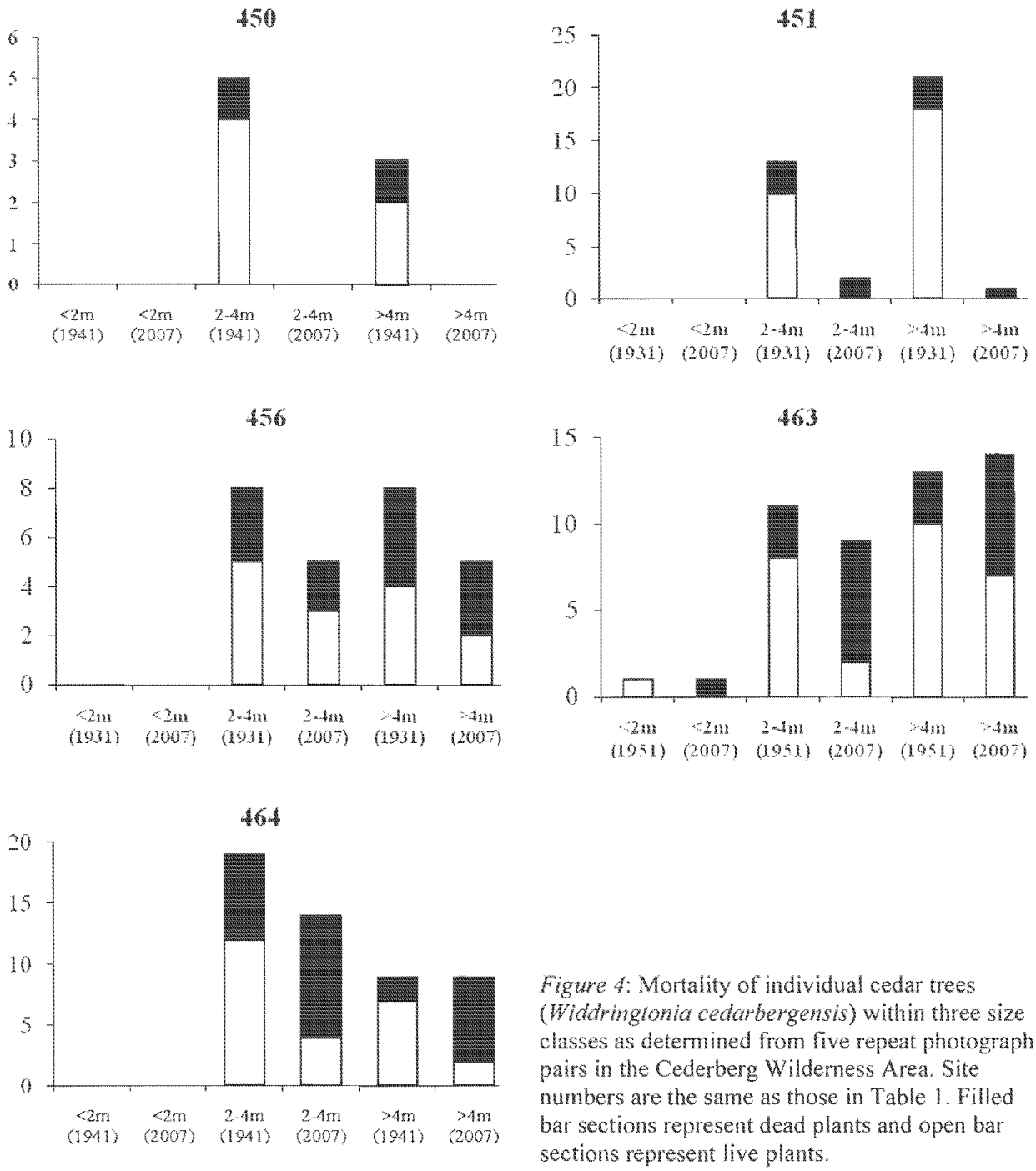

Figure 4: Mortality of individual cedar trees (*Widdringtonia cedarbergensis*) within three size classes as determined from five repeat photograph pairs in the Cederberg Wilderness Area. Site numbers are the same as those in Table 1. Filled bar sections represent dead plants and open bar sections represent live plants.

Table 2 identifies the difference in the ratio of trees with sparse foliage between the original and repeat photographs at seven of the 15 sites. The proportion of trees with sparse foliage cover increased by nearly 25% over the 67-year period.

Table 2. Change in foliage density of cedar trees (*Widdringtonia cedarbergensis*) at seven locations in the Cederberg Wilderness Area over an average 67 years.

Site No.	Time interval	Total No. of trees in original photograph	Ratio of trees with sparse foliage	Total number of trees in repeat photograph	Ratio of trees with sparse foliage	% change
454	73	7	0.00	4	0.75	75.0
455	63	26	0.62	6	0.83	21.8
456	76	9	0.89	5	1.00	11.1
457	73	6	0.67	4	0.75	8.3
461	63	39	0.87	13	0.92	5.1
463	56	19	0.47	9	0.78	30.4
464	66	20	0.30	6	0.50	20.0
Average	67	18	0.55	7	0.79	24.5
Stdev	7.2	11	0.29	3	0.15	22.1

The annual mortality of cedar trees was not significantly different for populations growing on different aspects or slopes (Table 3, Figure 5) ($p>0.05$). Although mortality was significantly greater for lower altitude sites than higher altitude sites ($p<0.05$) the relationship was strongly influenced by just two localities (450 and 451).

Table 3. The relationship between % annual mortality of cedar trees (*Widdringtonia cedarbergensis*) and microhabitat variables for 12 of the 15 sites grouped into three aspect classes: WNW-NNE, NE-SE and SSW-W. Every site where the original photograph contained six or more living individuals was used in the analysis. Some sites were divided into separate zones (a, b, c) according to aspect.

Site No.	Aspect	Aspect	Slope	Altitude	No. of yrs between photos	No. of (live) trees in original photo	No. of (live) trees in repeat photo	% annual mortality
		(°)	(°)	m	yrs	No	Nt	(Nt/No)^1/y - 1
452b	WNW	284	9	1292	66	10	4	1.4
450	WNW	299	24	1099	66	6	0	7.1
457	NW	308	12	1451	73	6	4	1.5
451	NW	319	9	1215	76	28	0	8.0
456b	NNW	328	21	1356	76	9	5	0.8
459b	NNW	348	17	1308	73	6	2	1.5
456a	N	1	7	1330	76	7	3	1.1
452c	N	1	13	1297	66	17	4	2.2
461b	NNE	16	20	1297	63	38	13	1.7
Average			**14.6**	**1294.0**	**70.6**	**14.1**	**3.9**	**2.8**
Stdev			**6.1**	**96.3**	**5.2**	**11.5**	**3.9**	**2.7**
453b	NE	46	14	1318	76	13	8	0.6
455a	ENE	62	12	1284	63	6	0	7.0
461a	ENE	67	7	1280	63	32	10	1.8
459a	ENE	70	3	1295	73	4	0	5.9
64	E	99	6	1273	66	19	5	2.0
462	SE	130	5	1259	63	15	7	1.2
Average			7.7	**1284.7**	**67.3**	**14.8**	**5.0**	**3.1**
Stdev			**4.4**	**20.1**	**5.8**	**10.1**	**4.2**	**2.7**
453a	SSW	201	23	1319	76	48	8	2.3
452a	SW	219	22	1318	66	130	10	3.8
455b	WSW	256	33	1309	63	26	6	2.3
463	W	274	5	1275	56	19	9	1.3
Average			**20.8**	**1305.4**	**65.3**	**55.8**	**8.3**	**2.4**
Stdev			**11.8**	**20.8**	**8.3**	**51.0**	**1.7**	**1.0**

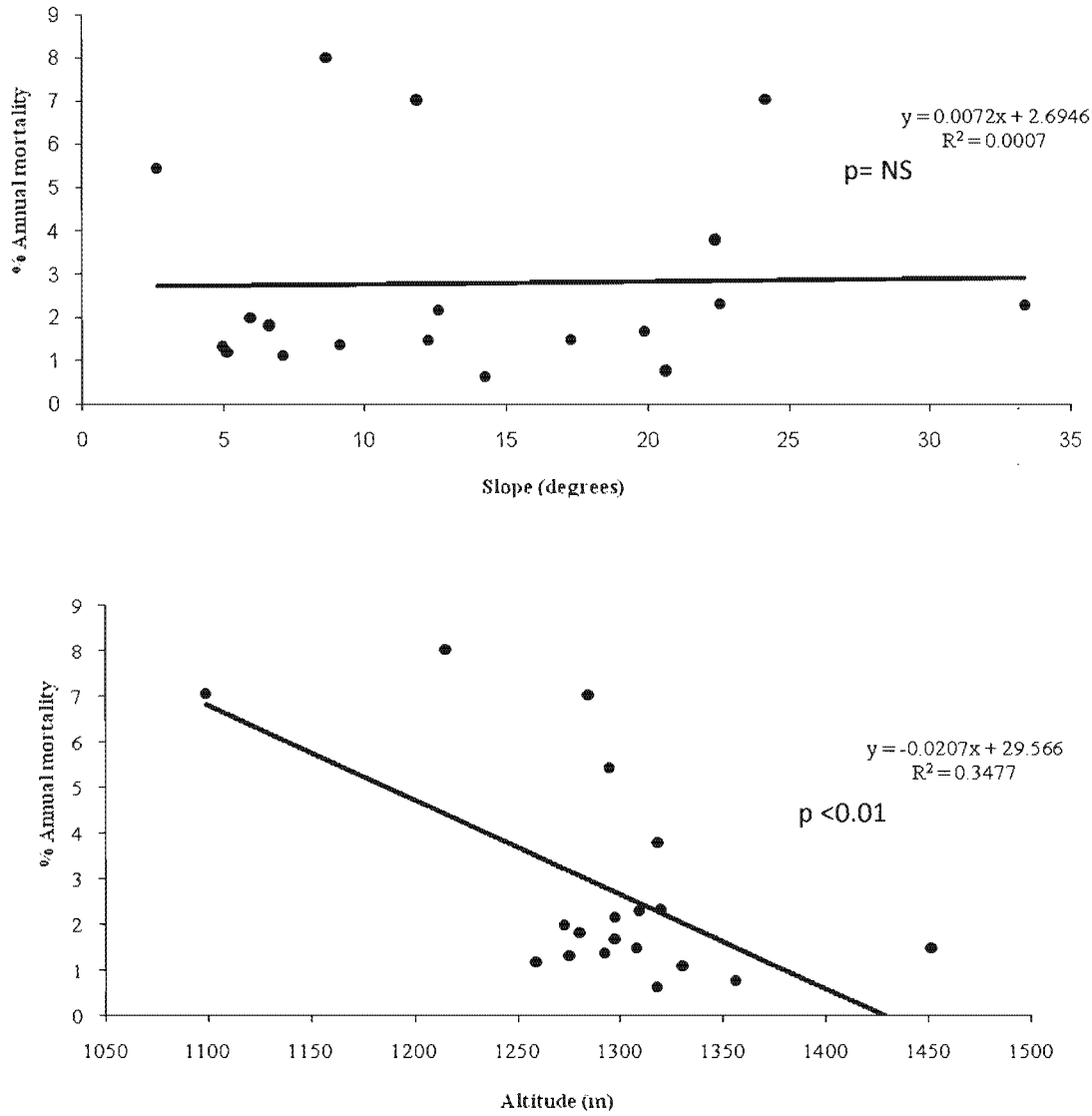

Figure 5: The relationship between slope (top), altitude (bottom) and % annual mortality of *Widdringtonia cedarbergensis* within the 19 sub-sites listed in Table 3.

Table 4 shows the fire history record for each of the 15 cedar study sites between 1959 and 1999. Eight fires were recorded in the study site and the years 1959, 1979 and 1985 stand out as prominent fire years in the Cederberg with total areas burnt of 18,415, 11,090 and 18,504 ha respectively. Although the fire in 1976 was recorded at 10 of the 15 photographic stations it was localized and the total area burnt by this fire was only 353 ha.

Table 4. The fire history record (1959-1999) for the 15 photographic stations derived from CapeNature's spatially-explicit database of fire records in the Cederberg.

Site No	Site Name	1959	1967	1970	1975	1976	1979	1985	1999	Average fire return interval (yrs)
450	Skerpioenspoort (1)	X			X		X	X	X	10
451	Machine Gun Ridge		X				X	X	X	11
452	Skerpioenspoort (2)	X					X	X	X	13
453	Sneeukop	X					X	X	X	13
454	Vanzylspoort (1)	X					X	X	X	13
455	Vanzylspoort (2)	X				X		X		13
456	Crystal Pool (1)	X				X		X		13
457	Crystal Pool (2)	X				X	X	X		9
458	Crystal Pool (3)	X				X	X	X		9
459	Crystal Pool (4)	X		X		X	X	X		7
460	Crystal Pool (5)	X				X		X		13
461	Vanzylspoort (3)	X				X		X		13
462	Skerpioenspoort (3)	X				X	X	X	X	10
463	Vogelsangvallei (1)	X				X	X	X	X	10
464	Vogelsangvallei (2)	X				X	X	X	X	10

5.4 DISCUSSION

The principal aim of this study was to assess the current status of *Widdringtonia cedarbergensis* and the reasons for its marked decline. This was done by comparing cedar population dynamics of 15 sites in the northern reaches of the Cederberg Wilderness Area over the last 69 years. The results show a rapid decline in cedar numbers at all of the sites with an average annual mortality rate of nearly 2.5%. The most striking result, however, is that there has been no recruitment at any of the 15 sites during the period of study. If current mortality and recruitment patterns persist, all trees will have disappeared from the study area within the next 300 years. Evidence from other studies (Lückhoff, 1971; Manders 1986; Sugden and Meadows 1990; Mustart and Bond 1994) suggests that this pattern is widespread across the full range of *W. cedarbergensi* and the species is facing a high risk of extinction in the wild. The critically endangered status given to this species in the recent Red Data

Book interim listing (http://www.sanbi.org/biodiversity/reddata.htm) appears justified.

Photographic evidence suggests that cedar populations in the first half of the 20th century were healthy with several populations skewed towards a predominance of young individuals. Analyses from the 15 repeat photograph sites revealed that it was only after the 1950s that large scale mortality occurred. It needs to be taken into consideration however, that there are limitations with using repeat photographs to identify population-level changes in cedars, particularly when the images are all of such different scales. Nonetheless, this observation of healthy populations, skewed towards juveniles at the beginning of the last century, has relevance for two prevailing points of view about the demise of cedars. Firstly, it suggests that despite the alleged heavy logging pressure exerted on this species in the 19th century (Mustart and Bond, 1994), this 'orgy of destruction' (Hubbard, 1937: 573) did not remove all populations. Some areas within the Cederberg possessed large numbers of cedars within a range of age classes. In some cases, whole mountain slopes were covered by young cedar trees before 1950.

Secondly, Sugden and Meadows (1990) argue that the decline of cedars in the region is part of a long-term process and that the species has "...long since had its day". Meadows and Sugden (1991) suggest that the cedar has not been dominant in the Cederberg landscape at any time during the last 14,500 years, and that both pre-colonial and early colonial burning practices would have impacted on cedar populations. Palynological evidence (Meadows and Sugden, 1991) suggests that the cedar was more successful during the Last Glacial Maximum (LGM), partly because the cooler temperatures and increased precipitation during this time (Chase and Meadows, 2007) would have favoured the recruitment and survival of cedars. However, photographic evidence for large populations of cedars in the first half of the 20th century, suggests that despite an overall decline in abundance of cedars over time, as revealed in the set of 15 repeat photographs, there have been periods when the cedar has been relatively common in some areas. This implies that conditions for recruitment of cedars were probably more favourable during the latter part of the 19th century, perhaps in relation to cooler temperatures and higher rainfall during the Little Ice Age which extended from AD 1300 to 1800 (Tyson *et al.*, 2000). Although

speculative, the original photographs taken before 1950 probably document the 'ghost of climate's past' and reflect a residual or lag-effect from events that occurred several decades before the images were captured on film. The photographs might portray the last stages of this cooler climate phase at the end of the 19th century which would have favoured the recruitment and establishment of cedars (Sugden and Meadows, 1990; Meadows and Sugden, 1991).

Although the Clanwillam cedar has been extensively studied (Manders, 1986, 1987; Manders and Botha, 1989; Sugden and Meadows, 1990; February and Stock, 1999), the exact reason behind its declining status has not been established. Besides the impact of logging on cedar populations, which has been discussed earlier, there are three additional explanations which could account for the decline of the species. The first involves the impact of disease. Although studies by Lückhoff (1971) and Wingfield *et al.* (1988) revealed no evidence that trees were being killed by fungal diseases or insect pests it is acknowledged that the role of pathogens hasn't been explored thoroughly enough and there is merit in looking into this in more detail. This is further recognised in light of the example from the southwestern parts of the United States, where there is evidence that pinyon pines have been devastated by disease in combination with drought and fire (Breshears *et al.*, 2005).

A second explanation for the decline in cedar populations in the study area includes the role of climate. Over the course of the 20th century, there has been a measured increase in temperatures in the Cederberg region, which has been particularly marked over the last 30 years (see chapter 2). There is also some evidence that rainfall has been lower, on average, over the last two-and-a-half decades at several stations in the region. A conundrum exists, however, in that the A-pan evaporation data suggests that overall water balance might not have changed, particularly since CO_2 has increased resulting in a concomitant increase in the water use efficiency of most plants (Körner, 2000). However, support for the climate change related decline of cedars comes firstly from the change in foliage density, which suggests a physiological response to drought stress. The proportion of trees with dense foliage cover has substantially decreased suggesting that the surviving trees have experienced a slow reduction of photosynthetically active material. The second support for the climate change link is from the relationship reported between mortality and altitude. Although data at a

wider range of altitudes is needed, there is evidence from this study that populations at lower altitudes have experienced significantly higher levels of mortality than those at higher altitudes. A confounding result, however, is that no differences were found in mortality between populations growing on northern versus southern aspects. If aridification was a factor, there should have been differences in mortality between cooler southern versus hotter northern slopes. Clearly, more work is needed to examine the impact of climate change on cedar population dynamics.

A final, and possibly the most plausible explanation for the decline in cedars is a change in the fire regime over the last fifty years. Cedars are particularly susceptible to fire damage (Hubbard, 1937; Lückhoff, 1971) in part because the nature of the trees' essential oils make it highly flammable (Hubbard, 1937). Cedars also do not resprout after fire and unlike the dominant fire-prone Fynbos vegetation they also take a long time to reach reproductive maturity (Manders, 1986). No vegetative regeneration occurs and no seed pool is established for about 12 years after a fire (Manders, 1986). Furthermore, a period of 36 months is required between fertilisation and release of the ripe seed (Manders, 1986). A reduction in the fire-return interval, as evidenced from the CapeNature fire record for the study area, could have devastating impacts on the regeneration of cedars. Also, the impact of wide-spread, intense fires such as those of 1927, 1959 (Lückhoff, 1971), 1975 and 1985 (Manders, 1986) have also had a significant impact on populations of cedars. The complete lack of recruitment at any of the 15 sites examined in this study suggests that an increase in the fire frequency might be the best explanation for the decline in cedar populations in the study area.

There have been numerous attempts to protect the vulnerable tree from the harmful effects of large, intense fires. In 1956 a policy of a four year burning cycle of cedar areas was implemented (Manders, 1986) so as to reduce fuel loads and thereby reduce fire intensity. In 1972, a different burning policy was introduced, which prescribed burning on a 12 year planning cycle (Manders, 1986). No positive effects of these burning policies have been realised. Furthermore, because fire velocity increases as it moves upslope; even those cedars on high rocky outcrops are not escaping fire. Finally, future climate change scenarios all suggest that the Western Cape will become hotter and drier (Midgley *et al.*, 2002; 2003; 2008; Ragab and Prudhomme,

2002; February *et al.*, 2007) over the next 100 years. If this is the case then pressures on existing cedar populations will only intensify.

CHAPTER 6: CONCLUSIONS

6.1 INTRODUCTION

The overall objective of this thesis was to document how the Cederberg landscape has changed over the last century. It used a combination of archival sources, repeat photography and oral history and investigated how climate has changed in the region and how different anthropogenic impacts have influenced the environment. The thesis presented a comprehensive environmental history of the broader Cederberg region, by analyzing the area in terms of three distinct 'zones': (1) the lowlands, where changes in land use over the course of the 20th century were described, (2) the midlands, where the changes in the general state of the physical landscape were assessed, and (3) the uplands of the northern parts of the Cederberg Wilderness Area (CWA), where changes over the last 70 years in populations of the endemic Clanwilliam cedar tree were documented and the reasons for their decline discussed. In so doing, the question of how land use and changes in climate and fire regimes have affected the landscapes within each of these three zones was addressed.

6.2 CLIMATE AND VEGETATION OF THE CEDERBERG REGION

The local climate of the Cederberg varies significantly across steep gradients. For instance, there are gradients in precipitation determined by altitude, with higher altitude sites receiving more rain than the low-lying valleys (Taylor, 1996). Temperature differences between north and south aspects are also noticeably dissimilar – with different aspects receiving different radiation loads. These local disparities in climate have led to analogous differences in vegetation. An examination of long-term rainfall trends revealed that there has been no significant decrease over the 20th century when the data are assessed from 1900 to 2007. However, for most climate stations the trend over the last 30 years has been downwards and this decline is apparent in both summer and winter rainfall totals. For all stations which were analysed temperature has increased and for Clanwilliam which has the longest record, this increase has been by 1 degree Celsius over the last 42 years. Despite this increase in temperature, however, A-pan evaporation data have shown a downward trend. This so-called 'evaporation paradox' is similar to the findings of other researchers (e.g.

Roderick and Farquhar, 2004) and is thought to be in response to 'global dimming' (Stanhill and Cohen, 2001). More research is needed to determine what the effect of reduced rainfall, increased temperature and reduced evaporation rates are likely to be on the hydrological balance of Cederberg environments. The fire history records (1945 to 2007) gathered from CapeNature, revealed that the interval between fires has declined over the past 50 years. However, some caution is recommended when examining these records, as the Cederberg was only declared a wilderness area in 1973 and fire records may have been more rigorously maintained from this time onwards. Nevertheless, if the data are correct then there has been an increase in fire frequency as well as an increase in the area burnt each year although the official fire records probably do not document the small-scale patch burns favoured by local land owners and herders particularly in the period prior to 1973 when the Cederberg Wilderness Area was declared.

The study area is comprised of four bioregions two of which are associated with the fynbos biome and two with the succulent karoo biome. There are 13 vegetation types (Mucina and Rutherford, 2006) nine of which are associated with the fynbos biome and four with the succulent karoo biome. There is a significant negative relationship between altitude and the percent of the vegetation type that has been transformed, primarily by agriculture. A greater proportion of the high altitude vegetation types are also conserved in either statutory or private conservation areas. This study confirms that it is the relatively low-lying Leipoldtville Sand Fynbos, Swartland Shale Renosterveld and Citrusdal Vygieveld which are the most threatened vegetation types in the region (Mucina and Rutherford, 2006).

6.3 LANDUSE IN THE CEDERBERG LOWLANDS

The lowlands of the Cederberg are used primarily for agriculture which is strongly dependant on the limited surface and ground water supplies for irrigation. A variety of crops are grown in the area, and at present the dominant yields are citrus and deciduous fruit, vegetables and grape vines. This has not always been the case, as the area has gone through phases of differing agricultural activity, influenced largely by a wide range of social and economic factors operating at local to global scales.

Investigations into the 20th century land use history of the Cederberg lowlands started with an analysis of the changes in human population in the region. Results showed that there was a positive trend of increasing population size in the area during the course of the 20th century. There were also shifts in the ratio of rural to urban inhabitants, with greater numbers of the population constituted as rural inhabitants prior to the 1950's, after which time urban population numbers steadily rose to make up 75% of the population by the early 1990's.

In terms of agricultural production, livestock numbers were reasonably constant until 1970, after which time they declined steadily. The 20th century history of crop production in the Cederberg Local Municipality on the other hand, showed an increase of nearly 25% in the area cultivated and a change in the type of crops grown. The main change was reflected as a switch from grain crop farming to the farming of 'higher-value', more intensively irrigated produce such as fruit, grapes and vegetables. This switch in the types of crops cultivated has been strongly influenced by socio-economic factors which can be explained by global market trends, the accessibility of international markets to South African fruit producers after the decline of apartheid in 1994 and improved access to transport networks and irrigation infrastructure. Farmers have also switched to these more profitable farming strategies in a bid to maximise their income, as the most profitable agricultural yields in this region are derived from fruit, vegetable and wine production. In addition to the switch in the types of produce being farmed, farmers in the region have also begun to diversify by starting other non-farming activities such as eco-tourism ventures.

6.4 LANDSCAPE CHANGE OF THE CEDERBERG MIDLANDS

Landscape change in the midland region of the Cederberg Wilderness Area (CWA) was assessed in terms of a northern region and a more southerly region. Twentieth century changes in settlement, cultivation, livestock grazing and fire have occurred differently in these areas. Repeat photography and oral testimony were the primary tools used in this chapter to illustrate and document the landscape changes of the Cederberg midlands. The chapter identified the variable differences between anthropogenic and climatic influences and it was recognised that most of the changes observed in the repeat photograph pairs, were best explained through an

understanding of human-induced pressures. The results showed no clear evidence of a widespread reduction in plant cover or adaptive shifts in flora, which would be expected in response to a warming climate. On the contrary, many sites showed an increase in cover primarily in response to a reduction in stocking rates in the region.

The changes in land use practices across the Cederberg midlands were also investigated. It was found that land use practices in the northern portions of the midlands have seen a decline in agricultural traditions and an increase in tourism and wine making. The southern portions on the other hand have experienced intensification in agricultural practices. However, this has involved the transition from 'traditional' farming practices such as sheep farming and subsistence agriculture, to the production of high profit goods such as fruit and vegetables. The trends in the southern parts of the Cederberg midlands then are much like those of the Cederberg lowlands.

In addition to the effects of changing land use practices, transformation of the Cederberg midlands could also be explained by 20th century changes in the fire regime. The declaration of the Cederberg as a Wilderness Area in 1973 and the simultaneous management of the area by Nature Conservation saw the dissolution of the local people's customary 'patch-burn' system of fire management. Many farmers in the area expressed the belief that the increase in the occurrence of large fires since the 1980s, is linked to the suppression of patch burning which they maintain best simulates a natural fire regime.

Much like the Cederberg lowlands then, the main drivers of change experienced in both geographic segments of the midlands, have been influenced by anthropogenic rather than climatic factors. It was difficult to identify the effects of climate change on the landscape of the region, however, it was recognised that the consequences of a changing climate may only appear several decades from now.

6.5 ENVIRONMENTAL CHANGES OF THE CEDERBERG UPLANDS AND THE DECLINE OF THE CLANWILLIAM CEDAR TREE

There has been a well documented decline in Clanwilliam cedar (*Widdringtonia cedarbergensis*) populations attributed to, amongst other causal factors, disease, wood cutting, fire and climate change. The timing and rate of decline, however, has not been well described over time periods of 50-100 years. An analysis of repeat photographs taken approximately 70 years apart at 15 sites in the northern parts of the Cederberg Mountains was used to document the % change in separate cedar populations. We tested the hypothesis that changes in climate should be reflected by higher mortality rates at lower altitudes and on steeper, north-facing (hotter) slopes. The results showed that many cedar populations were healthy and skewed towards juveniles prior to the 1950s and it was only after this period that large scale mortality occurred. Since the early photographs were taken there has been a rapid decline (average of 2.48% per annum) in all size classes. Furthermore no recruitment has occurred at any of the sites. The proportion of trees with sparse foliage cover also increased by 25% suggesting that a slow reduction of photosynthetically-active material has occurred on many of the surviving trees. Although plant mortality is significantly greater within populations occurring at lower altitudes it is not related to either slope steepness or aspect. In reviewing the main hypotheses behind the cedars declining status, it was concluded that the cause is likely the combined result of a changing climate and an increase in fire frequency and potentially also, a change in fire management practices from small-scale, local fires to wide-spread and intense hot fires after the creation of the Cederberg Wilderness Area. It was acknowledged, however, that disease is not a cause that can be ruled out at this stage and more research is required. This rather equivocal result suggests that more effort is needed to differentiate between the impact of climate change, fire and disease on cedar mortality. In addition, the relative impact of slow incremental processes such as temperature increase versus catastrophic events such as large-scale, intense fires, droughts and disease eruptions need to be better understood. Results from this study suggest that if current processes continue or intensify then *Widdringtonia cedarbergensis* is likely to become extinct in the region in the next 300 years.

6.6 SYNTHESIS OF FINDINGS

The results show that the environments of the Cederberg lowlands and midlands have predominantly been influenced and shaped by anthropogenic impacts to the natural landscape. These impacts were observed on a greater scale in the lowlands, primarily as a result of the intensification of agriculture and the production of high-value cultivated crops. The availability of good transport networks and irrigation infrastructure has helped to intensify agriculture and transform the low-lying regions of the Cederberg. It is here that the greatest conservation efforts should be placed to prevent the complete transformation of critically endangered vegetation types such as the Swartland Shale Renosterveld.

The midland regions of the Cederberg have experienced a complex history which has differed substantially between areas in the north and south. In the northern parts there has been a recovery of land in response to the establishment of the CWA and the removal of the bywoners and traditional forms of agriculture. Even though signs of their occupation are still evident in the landscape today, the cessation of cultivation and the removal of domestic livestock have resulted in an increase in indigenous plant cover in most parts of this region. The southern midlands, however, have experienced similar trends to those observed in the lowlands, perhaps because of its closer proximity to Cape Town, better transport routes and market opportunities. In this part of the midlands there has been an intensification of land use with largely irreversible transformation. There has also been an increase in the growth of tourism although this is not as important for farm income as it is in the northern parts of the Cederberg midlands.

In the high-lying regions of the Cederberg, generally above 1,000 m there has been less transformation, primarily because of the inaccessibility of these areas. It is here that the impacts of changing climates and fire regimes are most clearly observed particularly in terms of the decline in Cedar populations.

The maintenance or restoration of ecosystems is one of the fundamental goals of conservation management (Hunter, 1996), and in ecological reserves or protected areas, this goal should be achieved as comprehensively and completely as possible.

Wilderness Areas are crucial components of most conservation schemes, the purpose of which is to protect important species, ecosystems and landscapes from potential threats. Although the transformation of Cederberg lowlands and midlands has been widespread, the uplands are still relatively untransformed. Even though conservation management encourages the preservation and maintenance of the biodiversity of this region the impact of a changing climate and a changing fire regime might have serious consequences for iconic species such as the Clanwilliam cedar.

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APPENDIX 1: REPEAT PHOTOGRAPH PAIRS SPANNING THE NORTH-SOUTH DIVIDE OF THE CEDERBERG MIDLANDS

Figure 1: Sneeuberg shale band 2.
Location: S 32.5611, E 19.1666. Altitude (m): 1424.
Original: A. Nov-Dec 1937, K. Howes-Howell.
Repeat: B. Feb 2007 (423).
Description: Flat valley plain with small flowing stream in front of the photo station. It is made up of fine sandy soils of valley bottom. In the Immediate foreground *Protea acaulis* still evident, with *Restios* dominating at approximately 50%. *Pentashistis* and other grasses make up around 20%. The mid foreground - river stream has tall emergent grass cover and a weedy composite. This grass cover is extensive all the way to the rocks in the left distance. There appears to have been a fire in the region in the last 4 or 5 years.

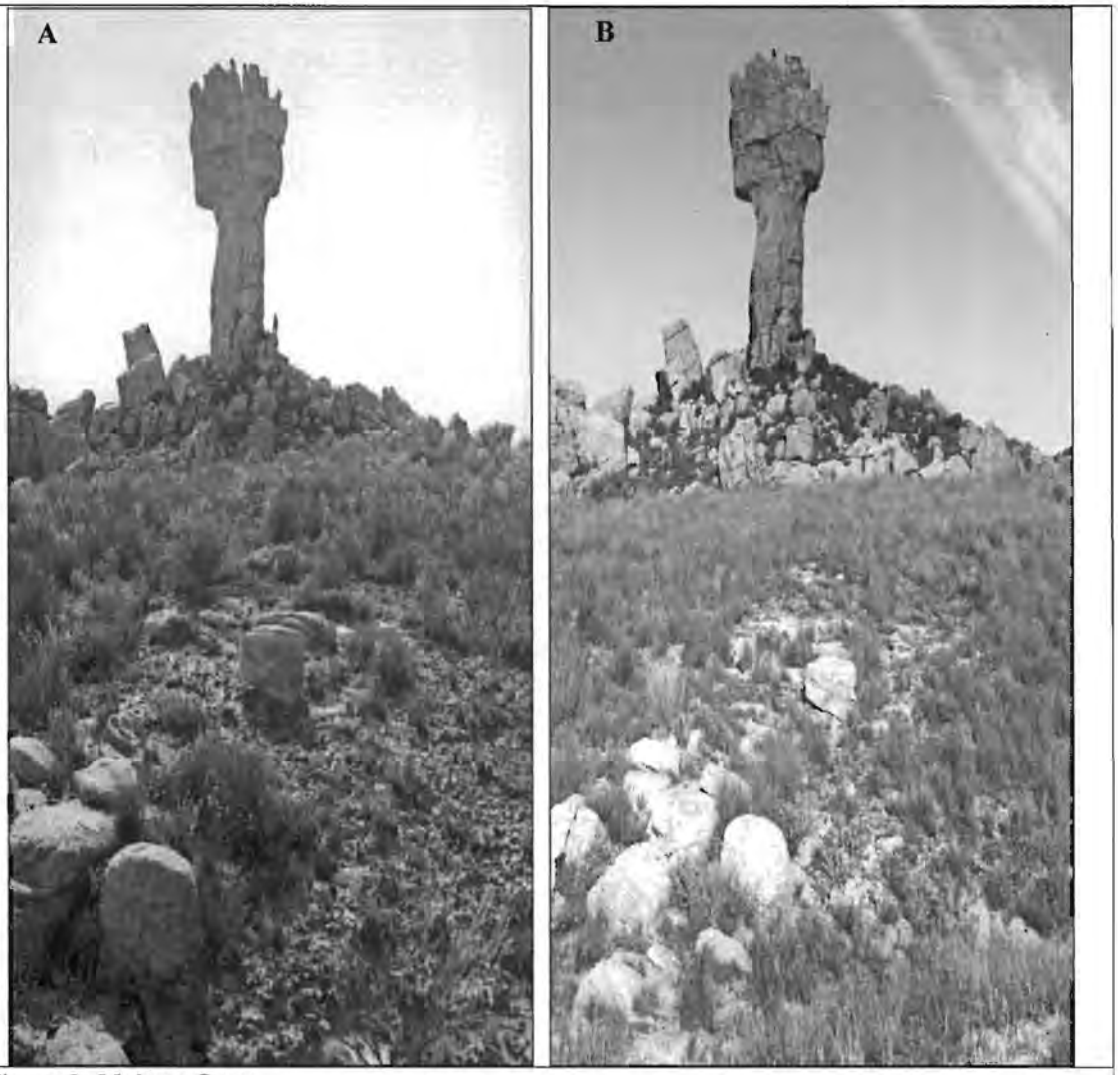


Figure 2: Maltese Cross.
Location: S 32.5121, E 19.13496. Altitude (m): 1400.
Original: A. Jan-Feb 1931, K. Howes-Howell. Total number of trees:
Repeat: B. Feb 2007 (424).
Description: Two zones have been identified in analyzing this site: Zone A: immediate ridge in foreground and Zone B: the mound directly below Maltese Cross. This area is made up of fine sandy soils with small red angular pebbles scattered on the surface of the slope. This suggests very shallow soils, particularly where the large boulders are exposed on the surface – here the soils may be close to bedrock.

In zone A there presently appears to be more Restio cover as opposed to Asteracious species in the past. Erica's are still common around the exposed boulders in the immediate foreground. In zone B, the vegetative cover seems to have increased. This increase seems to be as a result of an increase in restionaceae.

Figure 3: Leipoldt's farm – Sandrift.

Figure 3: Leipoldt's farm – Sandrift.
Location: S 32.4886, E 19.2673. Altitude (m): 825.
Original: A. 1948, K. Howes-Howell.
Repeat: B. Feb 2007 (425).
Description: Three zones were once again identified in examining this site: Zone A: Immediate foreground; Zone B: Other side of river and Zone C: Ridge. In zone A, scattered shrubs are now replaced by open sand, which may have been purposefully landscaped to create a beach-like effect for tourists. The riverine thicket is fairly well circumscribed. A large pine tree can now be seen on the right of the photo, with a 4.5 m tall oak seedling and behind that a poplar tree next to the road as it crosses the river. Pine and oak trees are growing out of the riverine thicket vegetation, and to the left of the photo station – out of view, a bramble thicket is starting to cover the indigenous vegetation. Notably, the pine tree to the right of the photo seems to have grown rather quickly and is probably around 10 years old, with a large extension at the top reflecting one season's growth of about 2m. In zone B, the main river channel seems to have changed course slightly, being cut deeper – possibly as a result of the road crossing the river in the centre. However, the main river thicket is largely unchanged, although it may have thickened on the left of the frame and grown taller – evidenced by the rocks at the foot of the hill now being obscured. The previous trees at the base of the ridge were probably pines, which have now been replaced by oak trees, although a single pine tree is still evident at the left of the frame. A road now runs along the base of the ridge. In zone C little change is evident, possibly a slight increase in cover? There has not been much opportunity for the support of more vegetation on this ridge. The bushy clumps between rocks on the left of the frame, which were present in 1948, were still present in 2007 at much the same size.

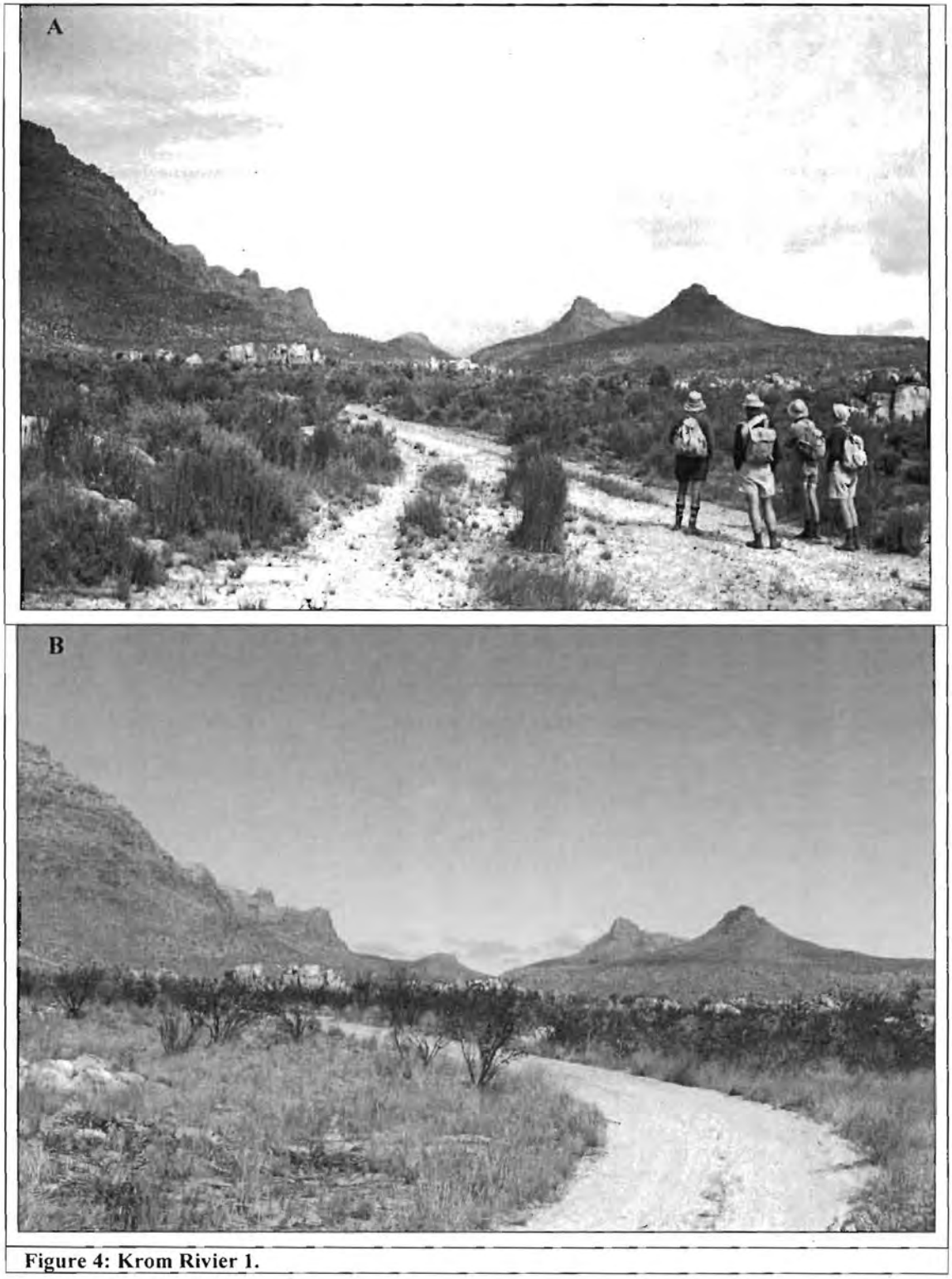
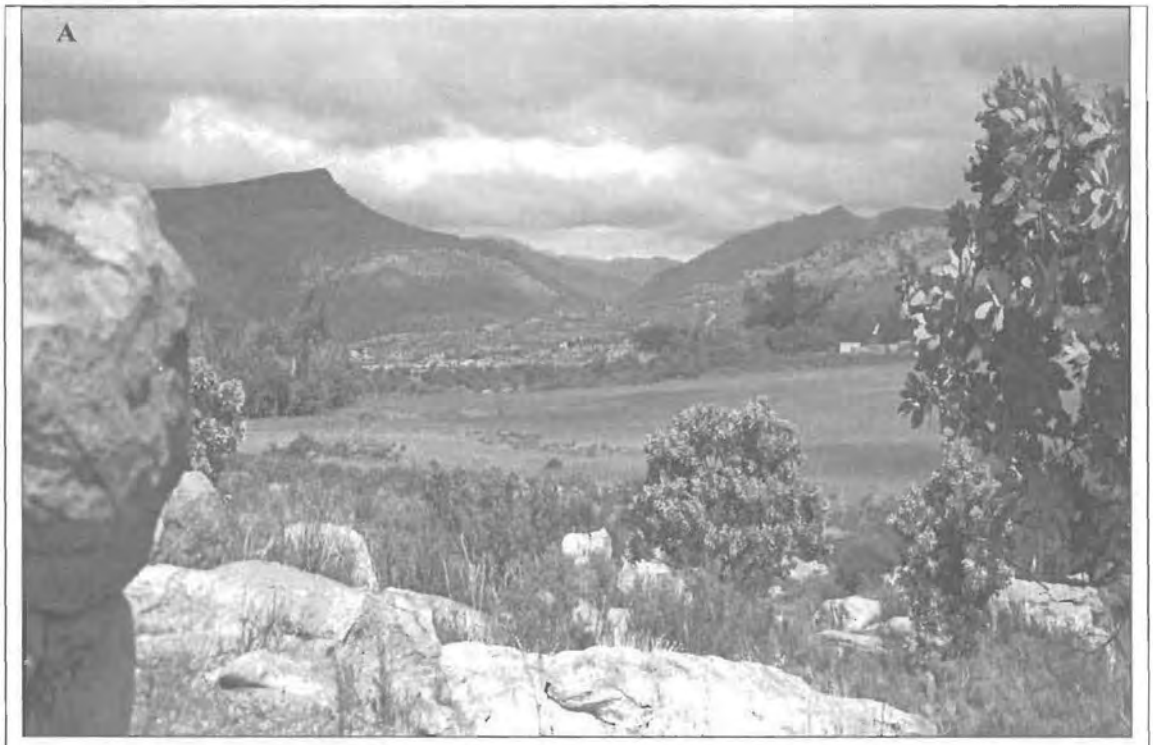


Figure 4: Krom Rivier 1.

Figure 4: Krom Rivier 1.
Location: S 32.5399, E 19.2785. Altitude (m): 857.
Original: A. 1955, K. Howes-Howell.
Repeat: B. Feb 2007 (426).
Description: Four zones were recognized at this site: Zone A: Foreground left, Zone B: Foreground right, Zone C: The mountain slope on the left and Zone D: The first mountain on the right. In zone A, a recent fire has transformed the thicker shrubby vegetation and replaced it with post-fire dominance of *Ehrharta cf. villosa*. Succulent leafed *Pelargonium* was also evident on the rocky outcrops on the left of the new photo. The large Protea trees, which appear burnt in the foreground of the repeat photo don't appear in the 1955 photo. In zone B, thick shrubby vegetation again replaced *Ehrharta* after the fire. The *Protea lorifolia* present in the original photo in the background and around rocky outcrops, were still present in the repeat image but were found to have extended forward and were also burnt by fire which occurred in the area shortly before the repeat photo was taken. This same fire burnt the east-facing slope of zone C. It was noticed that *Protea nitida* populations at the foot slope increased. A lot of shadow covers zone D in the 1955 photo, but on taking the repeat it was noticed that a series of patchy burns appeared visible and patches of *Stoebe plumosa* and *Erica* were locally dominant.



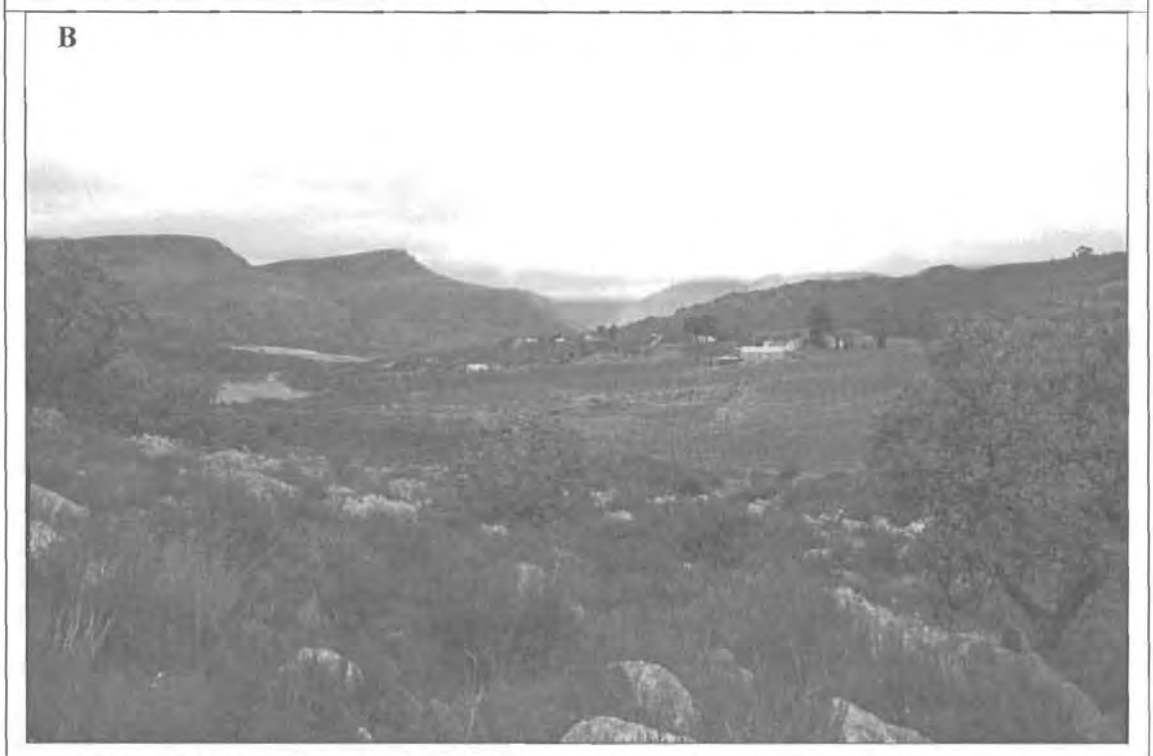


Figure 5: Sandfontein: Interviewee B's farm.

Figure 5: Sandfontein: Interviewee B's farm.
Location: S 32.3837, E 19.1539. Altitude (m): 856.
Original: A. Oct 1949, K. Howes-Howell.
Repeat: B. Aug 2007 (435).
Description: In zone A - the immediate foreground: the two Waboom in the immediate right-hand foreground have disappeared, and there are now Waboom seedlings appearing. The Waboom to the left is still present in the repeat photo. The vegetation has increased in the foreground of the repeat image and there's a patch of yellow leafed *Leucodendron silignum* that's increased quite substantially. *Montinia caryophyllacea* is fairly dominant in the foreground of the repeat image. The shrub to the left of the large Waboom in the original photo is *Mateynus oleoides*. Other species in the foreground include: Renosterbos and a range of *Restionaceae*. In zone B – the distant midground: what once looked like a meadow where wheat was possibly grown, is replaced in the repeat image by fruit orchards of peach, pear and cherry trees. These orchards have been extended to the base of the rocky ridge. In this area, the thicket of poplar trees at the left of the original photo, have been removed. The hill slope in the distance of the repeat photo has a number of labourer's cottages on it and new lands have been cleared in the distance for the planting of onions and other vegetables. On the distant mountain slopes, the vegetation looks quite sparse in the repeat image – this may be as a result of result of recent fires?

This image perhaps reflects the general land use trends in this region i.e. natural vegetation remains largely unchanged in terms of cover and composition, but the valley bottoms have seen an intensification of land use with a switch from grain crops such as wheat to fruit crops and the planting of vegetables (in this case onions).

Figure 5: Sandfontein: Interviewee B's farm.
Location: S 32.3837, E 19.1539. Altitude (m): 856.
Original: A. Oct 1949, K. Howes-Howell.
Repeat: B. Aug 2007 (435).
Description: In zone A - the immediate foreground: the two Waboom in the immediate right-hand foreground have disappeared, and there are now Waboom seedlings appearing. The Waboom to the left is still present in the repeat photo. The vegetation has increased in the foreground of the repeat image and there's a patch of yellow leafed *Leucodendron silignum* that's increased quite substantially. *Montinia caryophyllacea* is fairly dominant in the foreground of the repeat image. The shrub to the left of the large Waboom in the original photo is *Mateynus oleoides*. Other species in the foreground include: Renosterbos and a range of *Restionaceae*. In zone B – the distant midground: what once looked like a meadow where wheat was possibly grown, is replaced in the repeat image by fruit orchards of peach, pear and cherry trees. These orchards have been extended to the base of the rocky ridge. In this area, the thicket of poplar trees at the left of the original photo, have been removed. The hill slope in the distance of the repeat photo has a number of labourer's cottages on it and new lands have been cleared in the distance for the planting of onions and other vegetables. On the distant mountain slopes, the vegetation looks quite sparse in the repeat image – this may be as a result of result of recent fires?

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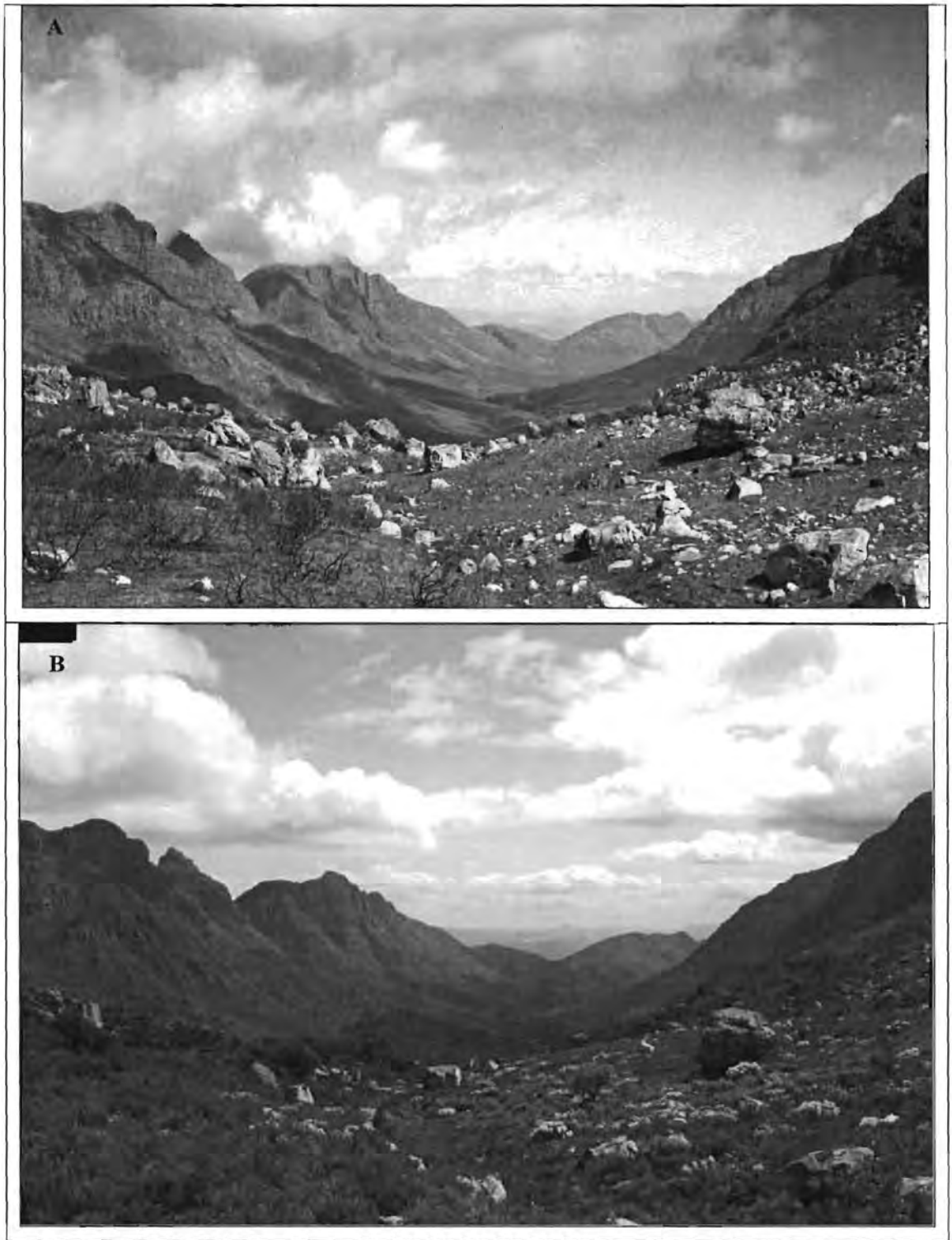

Figure 6: Uitkyk Pass 1: looking to Algeria.
Location: S 32.4067, E 19.1081. Altitude (m): 1017.
Original: A. Oct 1949, K. Howes-Howell.
Repeat: B. Aug 2007 (437).
Description: The foreground was heavily burnt at the time of the original photo – seen by the skeletons of plants. In the distance of the repeat photo, one can see the establishment of Pine plantations on the left-hand slopes, that weren't present in the original image. On the right-hand side of the original photo there was a forest plantation, which is no longer there.

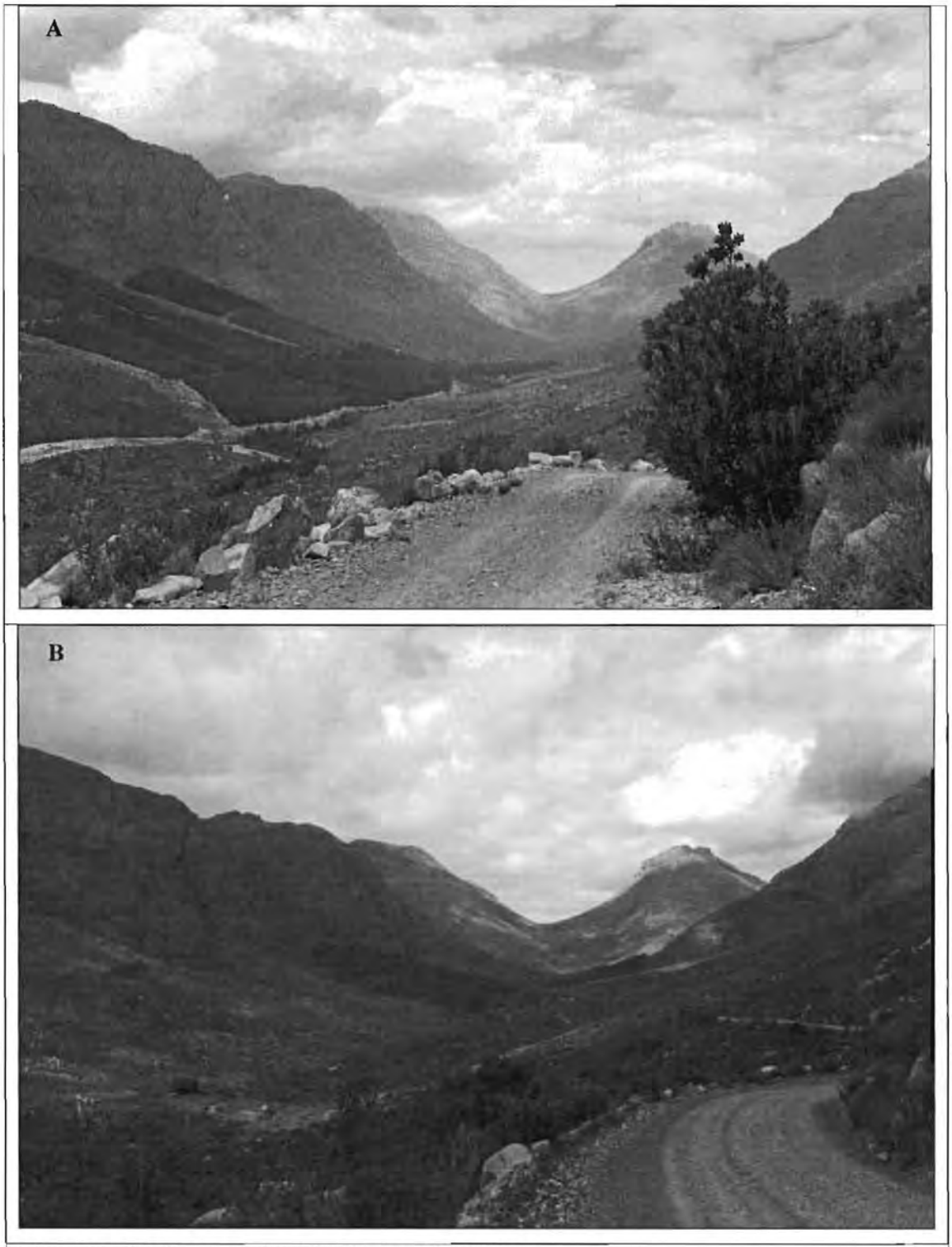

Figure 7: Algeria: on road looking back to Uitkyk Pass.
Location: S 32.3578, E 19.0322. Altitude (m): 566.
Original: A. 1940-41, K. Howes-Howell.
Repeat: B. Aug 2007 (439).
Description: The plantations of Pine trees on the immediate left-hand slope of the original photo, have disappeared, and now appear slightly more south. The *Protea laurifolia* in the immediate right foreground of the original photo has also gone. The road has been made wider. More visible erosion of the Uitkyk Pass is evident. The alien plants along the river in the foreground of the original image have been removed. The bluegums in front of the Pine plantation seen today have grown larger.

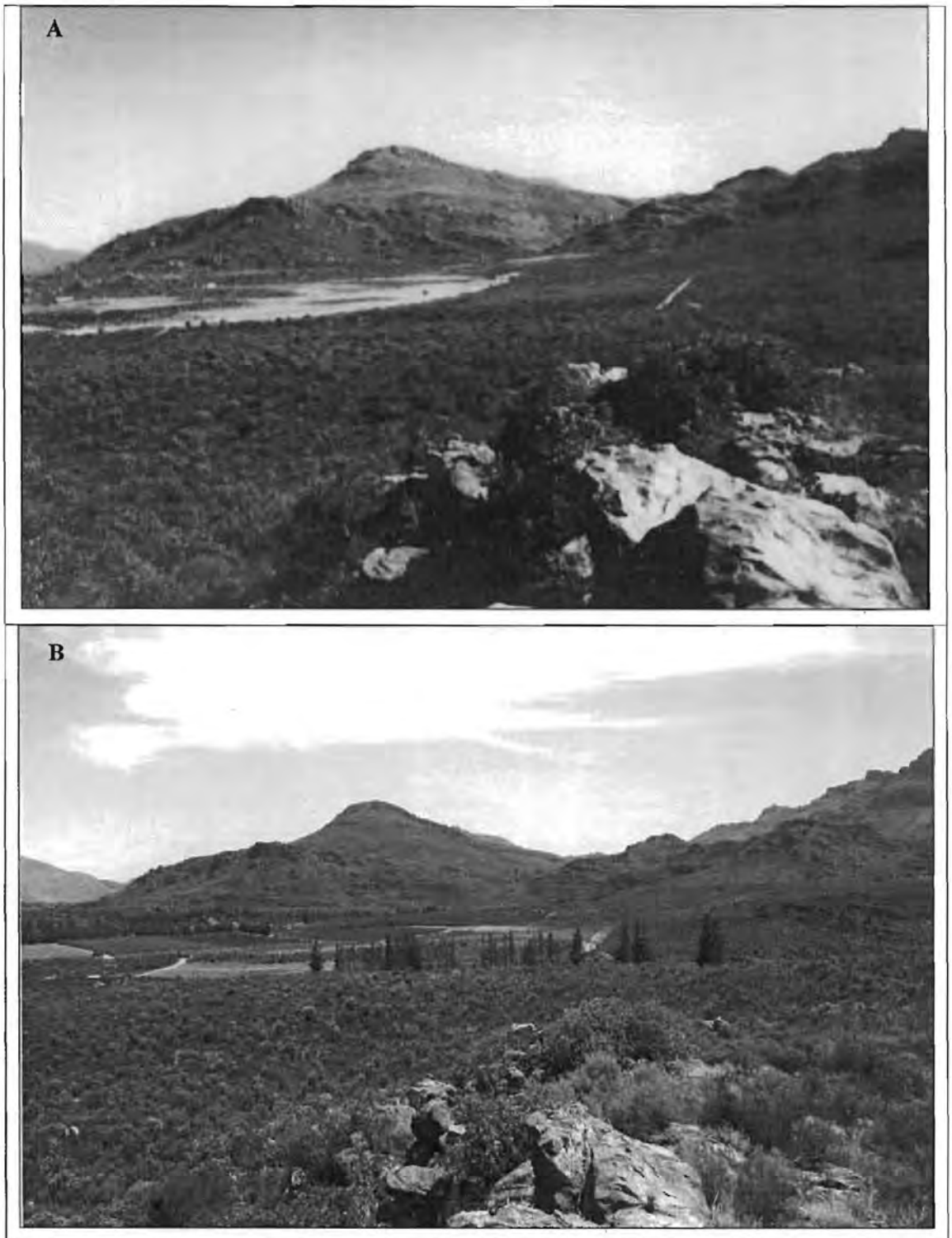

Figure 8: Suikerbossie Farm 2.
Location: S 32.6682, E 19.2675. Altitude (m): 749.
Original: A. 1979-80, Interviewee A.
Repeat: B. Oct 2007 (441).
Description: Zone A: Rocky ridge: the vegetative cover is more or less the same in the original and repeat images – dominated by *Heeria argentea*. Zone B: Pediment just below ridge: this is still comprised of natural veld, although the *Protea laurifolia* density is perhaps slightly lower in the repeat photo. Zone C: The pediment beyond the natural veld: Fruit orchards have now evident in the repeat image and more land has been cleared to the left of the road.

Figure 9: Suikerbossie Farm 3.
Location: S 32.6640, E 19.2577. Altitude (m): 726.
Original: A. Ca. 1976, Interviewee A.
Repeat: B. Oct 2007 (442).
Description: The *Cassuarina's* evident in the foreground of the repeat photo, were not present in the original image. There are now a series of orchards in the background, which were also not present in the original photo. Another addition is the flower garden in the immediate foreground of the new photo. There is evidence of a cultivated field just behind the rocks. This is a completely transformed landscape.

APPENDIX 2: LOCAL FARMER INTERVIEWS

INTERVIEW WITH INTERVIEWEE A ON 21 AUGUST 2007 AT HIS FARM HOUSE IN THE CITRUSDAL AREA.

Lived on the farm for 23 years.

HISTORY OF FARM OWNERSHIP:

When was the farm established? This farm was established about 23 years ago when father inherited this portion. The broader farm Ysterplaat however, has been in the family for 250 years. Around 1975, his father inherited this piece of land from his grandfather. This farm is 1450 ha

Who was the first owner? Title deed from 1884 for Twee Riviers Drift made out to Interviewee A's grandfather.

Has the region seen a large influx of Cape Town based professionals now owning farms over the last few decades? Has there been an increase in Capetonian professionals moving in here? What do you feel about this? Farm at Zandfontein now owned by vets. Influx has been from the whole of the Cape Province. People even from overseas are buying farms in the region especially wine farms and fruits farms. It is happening a lot. In the last 15 years there has been an increase in people from the cities buying land.

Is there much collaboration? If I look at my neighbours about 50% just buy land for speculation for tourism or guest houses or change the agricultural land for nature conservation and ecotourism. This area is part of the GCBC and part of the leopard conservancy. In the past a number of doctors and others in that profession bought land for tax purposes but government has tightened this loophole and now those buying are mostly from overseas.

What is your general perception or feeling of this? Well, I think the positive side of this is that the value of our property goes up if you look at it from a tourism point of view. If it is just for agriculture the price also goes up but if your vistas are good then you can ask a premium. It has brought a 'mind change'. The other positive side is the water. If land is taken out of agriculture then there is more water available because not as much is used for water. On the other hand, people buying land for agricultural purposes just run it like commercial farming and they use more and more water. Tourism is saving water but on the other side [when the land is used for agriculture] water is disappearing. If you love the land you try to keep a balance between plantings and water sources. Water wasn't a scarcity but it has become a scarcity because of agriculture. Cropland has at least doubled in size over the last 15 years because of deciduous fruit and vegetables.

Is there good collaboration between farmers in the region? Because people don't have much agricultural land they 'speculate' in tourism. People are in touch with each other and ask permission for guests to come in and have a picnic.

LAND USE HISTORY (What has changed, when has it changed and why?)

How was the land used in the past? Ysterplaat – family farm for a long time. Has been farmed with citrus, sheep and deciduous fruit and a few vegetables.

What were the major crops that were grown? Was livestock grazing an important part of the farming operation? What animals were kept and how many? In the past people kept animals to be self-sufficient. People couldn't go to the city and so had to

have own rog (rye), koring (wheat). There was a water mill at Yzerplaat where they milled the wheat and made rye bread. Had their own meat and made their own soap. All their workers had to get their food out of the veld.

When did it start to change? Started to change about 30-35 years ago. Today, crops are still grown but not for the same reason as in the past. They are planted for organic material now and for fodder for sheep and cattle. Still have sheep and cattle and there might even be more perhaps more sheep and fewer cattle than in the past. Animals graze in veld. All people with livestock have Karoo farms near the Bidouw Valley. They move their animals there during the winter months and in the summer they move them back to the Koue Bokkeveld. At certain times, after the harvest they graze in the orchards. This practice is an old practice. In the past people used to trek but nowadays they use a truck. At Ysterplaat they were still trekking about 35 years ago. Farmers move because it is too cold in the Koue Bokeveld and there is also not enough grazing.

What has been the impact? "Hulle [livestock] hou die veld jonk." Without grazing, the veld becomes too rank and old. The veld then gets so thick that you need wild fire to germinate the seeds. It is a good practice [to graze the veld]. In the past you used to get 'kolbrand' (a fire here and there which was started intentionally). Kolbrand enabled farmers to open up the veld a bit and let animals get access to the veld further away from the homestead. It is a bit more difficult to implement this practice today because Nature Conservation doesn't like it. They established a 'Brand Bestrydings Forum' and you now need to get permission before burning. This is also to prevent runaway fires and deal better with insurance claims issues if your have fires. This Brand Bestrydings Forum is to prevent fires being set at the wrong time of the year. In the summer fires are too hot and burn the ground as well as the seed [turns seed to ash] and prevents recruitment. You can get a switch from Proteas to reeds if the fires are too frequent. Your smaller species need about two years before setting seed but your Proteas need more time. If too frequent then they would not be able to germinate.

What were the burning practices of the natural veld in the past? Has there been an increase in fire events over the last 23 years? I don't think so. Fires are coming and going. We have to burn in the winter time. Normally, when the evenings are very cold in June and July maybe also in May but I don't like August. It is like fire breaks. Do it on this side of the mountain and then three years later burn on the other side. I would like to see it burn about once in every five years but you cannot always do it like that. The main problem is that certain species need longer fire cycles. Some species like Proteas produce seed after five years but you never get a real adult bush. Proteas especially need a longer fire cycle.

Have you seen a decrease in certain species? I have not seen a decrease in suikerbossie (?P. laurifolia) if anything there has been an increase on my own farm. Where there were wild fires, about 10 years ago there are a lot of Protea species. According to my dad in the past there was a lot more tolbos (?Leucadendron) in certain areas. On the southern side there was more tolbos in the past but in my 23 years there has been none. I think it is the veld fires that have done this.

When were dams first established on the farm? Don't know when the first dam was established but the current dam [just behind Interviewee B's house on the hill above Zandfontein] was established about 25 years ago [1978/9]. One trend you see is an enlargement of dams or the lifting or deepening of dams. I am using the river as a reservoir at this stage but when people upriver need to irrigate they just take the water

and that is a problem for me. In 2003 and 2004 was the first time I saw the river standing (i.e. not flowing).
Have you had any major drought years? Previous three years (2006, 2005 & 2004) were the worst in my 23 years on the farm.

CURRENT LAND USE PRACTICES (How is the land used?)

What are the main land use practices on the farm? Citrus, deciduous fruit, vegetables. Grew up with a few cattle in Citrusdal.
Has there been an intensification of land use over the last few decades? Yes – see earlier comments.

FUTURE PLANS

What changes would you like to bring to your farming operation in the years ahead? What plans do you have for using and managing the natural veld particularly in terms of grazing and fire? This farm is very young and everything has happened in the last 26 years. My idea is to make the farm a self-sustaining farm in terms of fruits and onions (potatoes and onions – because I know them and because of the soil (too many rocks is no good for potatoes). Because this land is very rocky it is the best for fruit. There are a few patches of sandy areas for vegetables. I would also like to be in harmony with nature and farming and develop tourism. We have three camping areas that we would like to enlarge and develop. There is a need for people coming from the city to have relaxation. I am trying to mix it with the farming so that they get a bit of an experience of farming. There are so many people who have not experienced picking a peach from a peach tree, for example. We have lots of education to do around farming. I would like to give people from the city the experience of farming.

PERCEPTIONS OF ENVIRONMENTAL CHANGE

Do you have any farm records? (rainfall, flood events, fire events, animal numbers, crop production, etc). No.
What are your perceptions of changes in rainfall, floods and fires? There is the perception of global warming and rainfall has definitely declined over the last four years.

THE ROLE OF CONSERVATION IN FARM OPERATIONS

Has the development of the GCBC/Cederberg Wilderness Area had an influence on the region in terms of land use practices, profitability, impact on the veld? From my point of view everything is more organized and there is more discipline in doing more things. In the future, all these things will come together - conservation, plants, fire and water – there will come a time when things will be-more organized. Sometimes it is a negative. I am a bit worried about tourism because your privacy will be compromised. For example Next to the river a resident will build 13 houses across the river. Maybe that's the one thing – your privacy but your property value will go up. You get a wide range of people who buy here and it is interesting to talk to everyone – 'it's like cross-pollination'. In the beginning it is difficult because people don't know where their

boundaries are and there is a bit of tension between people but after about 2 years it is not so bad anymore.

DISCUSSION ABOUT PHOTOGRAPHS

[434] Main photograph from Sandfontein peak. Area which is now Suikerbossie farm. Cattle used to graze in this area. The bare patches in the valley could perhaps have been as a result of 'kolbrand' [but also as a result of heavy grazing]. In the rivers you get flat open areas which were burnt for grazing in the past. This part of the family farm was called the 'veepos' where the cattle used to graze during the day.

One thing I can assure you of is the fact that the river has grown closed tremendously in the last 23 years (Palmiet, Wilde Amandel, was not as common in the past. Area is now so much more overgrown that "hy spoel nie so veel as tevore. Die rivier was mooi oop" [in the old photograph].

INTERVIEW WITH INTERVIEWEE B ON 22 AUGUST 2007.

Interviewee B's father was born in 1904 on the farm. The farm was first owned by Interview B's family in 1879. Interviewee B is now 75 years old, he was born in 1932.

They first planted fruit trees, but in those days transport was quite bad and a railway bus came from Ceres to transport their goods. They used to sow wheat and rye for animals and also used rye straw to cover the roofs of houses. In the old days they used to grow more dried fruit because the transport of wet fruit was difficult.

They only had horses for transport, and didn't have tractors. The first tractor on the farm came in 1956. Electricity only came in 1986.

They used "lappiesbrand" (patch burning) and burnt "kol-kol" (in patches). "The difference from today is that people in the past used to burn small pieces of veld in the beginning of the winter season when there had been a bit of rain. They burnt a small patch so that when fires started in between it wasn't so bad so that fires got out of control. Today we are told what to do. We have to pay money to belong to the Brand Bestrydings Forum (fire fighting form). Hulle praat en praat en hulle kom nerens nie (They just talk and talk and they get nowhere). If the fire starts on your property and it damages your neighbours property then he can claim from you."

"...hulle plant klomp dennebome..." (They plant lots of Pine trees). "They shouldn't have allowed this plantation as they escape .Who is going to control the escapees? They are very heavy on water. And this is going to be a problem, especially since the tree spreads in the mountains and are thus impossible to get to." Interviewee B's wife says she has seen them expand a great deal in the last few years.

"We have had very poor winters in the last ten years. This winter we have had the 'outydse winter' (old type of winter). We usually had our rains in the Easter months but in the last ten years this has been getting worse. This year has been the best we have had for a long time. The future of this area is bleak."

"The farms in this area have expanded a great deal especially Tuinskloof, Kunje and Sandfontein. We used to plant at low densities and had to replace individuals. The density of trees has now increased."

Are there many people moving into the area? No, there are not that many new people coming into the area.

"The decision to sell Zandfontein was largely because we don't have sons. When my husband's mother died the farm was inherited but we had to put in quite a bit of money. We got the farm in 1986 and had ten years to farm. All the new technologies, fertilizers, machinery and technology that led to the decision to sell. The farm was sold in 1997. The farm has three 'kaarte' (sections/houses): Zandfonteins Berg (1,416 ha), Zandfontein (104 ha) and Braambosfontein (646 ha). We are now living on Braambosfontein. Zandsfonteins Berg was sold to a man from the city and Zandfontein was also sold to a couple from the city."

Interviewee B's father used to have a small farm in the Karoo called Kapelsfontein in the Ceres Karoo but was sold after Interviewee B and his wife were married (in 1967). The animals (sheep) were moved to the farm in winter months. They reduced the number of sheep when the farm was sold.–During the stock reduction scheme Interviewee B and his brother had to bear the costs of the farm. They hired the farm from their father. They reduced the animals and sold many.

Interviewee B's father used to grow tobacco even after 1967 for a little bit. But tobacco is no longer grown here. In earlier days they had cherries (kersie bome) in Zandfontein and also at Tuinskloof. "It was a difficult farm operation and they had a wide variety of crops because if one crop failed then there was at least another one. Kersies (cherries) ripened first, then appelkose (apricots), lospit perskes (stone-free peaches), taaipit perskes (clingstone peaches), pere (pears), kwepers (quince) and lemoene (oranges). Because transport was a problem we had to do our own transport."

When were the dams built? Interviewee B and his brother made the first dam with an old scraper and four donkeys in the 1950s.

We showed Interviewee B and his wife the Howes Howell picture - number 435 (see appendix 1). They mentioned that the bare foreground of the original photo may have been land sown to crops because animals needed to graze.

DISCUSSION WITH INTERVIEWEE C (FARM MANAGER FOR ZANDFONTEIN)

We later spoke to Interviewee C about the kolbrand (patch burn system) and how Nature Conservation has prevented them from doing it. He mentioned that he wanted to bring cattle back to the region to also keep the veld short as this prevents the veld from getting too "ruig" (overgrown). However, he mentioned that care must be taken not to overstock as this leads to erosion. His view is that kolbrand was very similar to the natural fire regime which was usually started by lightning as he felt that an hour or so after lightning, it rains and puts the fire out.

Kolbrand is not allowed by Nature Conservation but farmers feel it is necessary to use it as fires become too out of control. Since kolbrand was stopped in the 1980s there have been three big fires in the region 1986, 1992 and 2000. " The farmer who took over Zandsfonteins Berg in 1997, his first ambition was to cut down the pine plantations and prevent alien escape. He worked on the plantations himself. In the last two years it has been drying and wabooms have been on the decline. The fire of 2000 might have killed quite a few waboom in the veld."

Onion plantings: 750,000 seedlings per ha. They are going to plant 7 ha. They get 1,000 or more crates from this with an expected tonnage of 65-80 tonnes (as one crate is about 420 kg). You can get R1,000 per crate (or R500 farm gate price). This is their fourth year of onion planting.

INTERVIEW WITH INTERVIEWEE D ON 23 AUGUST 2007

DISCUSSION OF THE PHOTOGRAPH (436 – Visser's farm):

"After the Second World War many poor whites needed a little bit of land to work and so they hired land. The Visser's were one such family who worked as bywoners on many of the larger farms in the area which were owned at the time by families such as the du Toit, Nieuwoudt and Wagener. The Visser father's name was Berend Petrus Visser but he came with his son Frikkie Visser and both lived at this site (de Riff) where the photograph was taken in 1934 by Howes Howell. They had a lot of children and all were bywoners in the area."

"Frikkie was the father of Isaac, Igna, Pietman and Mias, Ellie and Letta. Isaac stayed at Krom Rivier sometimes in the mountains looking after livestock because the veld was full of leopards. Mias (stayed at Perdekloof as a bywoner of Niewoudts from Dwarsrivier who owned this farm). After this Pietman Visser (another son of Frikkie) stayed there. After Pietman the Perdekloof house was used for tourists (about 40 years ago) and more recently (about five or six years ago) it has been sold to people from the Cape (Shaun and Tanya Moolman). Igna was one of the daughters of Frikkie Visser and was born in 1939. She says that her father was staying there for a long time before she was born. In September 1947 they moved down from the farm to Welbedacht to go to school."

"At de Riff the Visser's sowed wheat, op die ou tyd se manier (in the old fashioned way) and used sickles. They planted mostly fruit trees along the edges of the lands and these trees included: perskes (peach), kwepers (quince) and pere (pear). There was one druiwe stok (grapevine). They also had varke (pigs) in a hok (pen) and bokke (goats), skape (sheep), beeste (cattle) and donkies (donkeys) to do the ploughing and pull the wagon."

GENERAL DISCUSSION OF THE AREA:

"At Eikerboom it was the Burgers who were also bywoners who worked the land." Lands at Eikerboom (in the valley below where the Howes Howell photograph was taken in 1934 (No. 421)) were worked by Interviewee D's father.

The Cederberg Wilderness area was declared in 1973, has it made a large difference to you? "Many people used to live in the mountains and people had to break down their buildings. Nature conservation broke everything down and removed the oak trees. For example, at Hoogvertoon the Burgers were living there and settled at a place where there was water. This was generally the place where everyone had settled in the mountains. The Burgers and most others who settled in the mountains planted oak trees where they settled."

"From when I was a child I know this farm to be a wet and cold farm in winter, and we used to move our animals to karoo farms in the winter but it was too dry there in the summer. The karoo farm is called Droedam. We used to have four main farms: Driehoek (about 390 ha), Rondeheuwel (about 80 ha), Hartebeeskloof (350 ha) and Droedam (1800 ha). My brother bought this farm and other farms were sold off to

other people. My other sister who lives in Cape Town bought Rondeheuwel but uses it as a weekend place. My brother, however, decided not to farm and my husband took over the farm." So, because they no longer had the Karoo farm they could no longer trek there in winter and stopped this practice.

When they arrived on the farm at Driehoek (after Interviewee D's brother had bought the farm back on auction) the fruit trees were in a terrible state as the baboons had destroyed them. "We went on for five years and went on with fruit trees but trees were too old and broken. We decided to leave this and made the orchards into fodder and started with tourism and started slowly with a cottage and camp site. Last year we started the vineyard and hope to grow wine."

"At the moment about 60% of our income comes out of tourism and 40% from beeste (cattle) and skape" (sheep) [apparently about 200 sheep]. "Cattle graze in the vleis but because we have limited ground we only keep the animals because my husband loves animals. We will go on with vineyards. Not too many but have good wine. This is the highest farm [in altitude] which will have wine in South Africa."

Krom Rivier says they started first with tourism (in the 1940s) but had much of their tourism infrastructure burnt down in a large fire which happened in the area.

"We don't have dams on the farm but have fountains that come out the rocks and this is the water that we use for our animals. If we want to irrigate our fields we lift it out of the river. We don't pump at all but now with the vineyard we will need to pump for the first time. There is enough water."

"The people who come in from outside don't last here. The elements are pretty extreme here and it takes it out of you. The summers are hot and the winter's cold and the roads are bad. This is one of the main reasons why we have stopped farming deciduous fruits because the roads are so bad and the costs so high to take fruit to the market."

They are planning for a tarred road. "The winter has too much frost. In November we have had snow and the weather is very changeable."

Have many farms been bought by outsiders? "Yes, but not the main farms only the smaller portions of the main farms have been bought."

"We make good friends with the people who come in but they never become 'Cederbergers' they stay stadsmense (city people). Outsiders don't really contribute to the church community. Outsiders don't make a contribution to this community. They don't strengthen it."

What about your privacy? "If you farm with tourism then you have to be prepared to offer up some of your privacy. You need to make outsiders feel welcome 'tuisvoel' (feel at home). I love to walk in the mountains and so I like to give people first hand experience."

INTERVIEW WITH INTERVIEWEE E IN THE CERES DISTRICT ON 30 OCTOBER 2007

Interviewee E was born on the farm.

When was the farm first established? "It is the Northern-most property in the Worcester district, and was created in 1831 but by then the farm was about 100 years old already estimated by the thickness of the trees." Interviewee E's father was born in 1895 and the pine trees were the same size as when he was born. The original survey document is dated to 1819. The land was originally hired from the state – leningplaats (loan farm) and after a certain sum of money had been paid over, the land became part of the farmers land – a system called erfpag (tenure by long lease).

Has there been an influx of urbanites in the region? Some but not really to farm. Most just come to enjoy the environment. It isn't a concern for us. A lot of people come and get ownership of the small holdings for holiday houses and not to farm really.

What are the main crops grown? At the moment perskes (peaches), pere (pears) and citrus are the most important crops. When I was a youngster it was the same although not at the same scale. At first it was a wine farm with some wine and brandy.

How far back do your farm records go? Maybe ten or 15 years of data. Rainfall goes back 46 years (to 1961).

Has rainfall declined? Not really. Not worried about climate change. Data show two or three wet years followed by a few dry years. You can also get hail and snow in November (when Interviewee E lost about 60 sheep from the cold). There has been no clear change of rainfall in the area over the last 50 years.

The farm received 1,095 mm of rain up until the end of October 2007.

The farm is about middle size in comparison to the others in the area. It produces about 6,000 tonnes of fruit per year.

"Up until the 1960s land was sub-divided but the law was very strongly against this and farmers had to have economic units. Now farms are being consolidated but they are not always being used for the same purposes. Many people aren't consolidating their land because it is more difficult to do so."

"There are three ways to degrade the land: Innocence (onkundige – pioneer farmers and black cultures), greed (geurigheid) and survival (oorlewing). Overgrazing is especially bad."

Was the area more heavily grazed in the past? "Yes, it was overgrazed in some cases. In those days (1850s to the 1960s) people's wealth was measured by the number of animals they had. All the farmers around here also had a Karoo farm where they moved to in the winter. At the moment this farm is 2,000 ha and uses 150 ha for orchards with an additional 60 ha of orchards. The remainder is used as a reserve and we just walk there for relaxation. Plants are recovering. In the past this farm kept 500

sheep and 25 cattle and 10 horses and mules (equivalent to 40 sheep)." But Interviewee E used to have a total of 10,000 ha and in total he used to run 1500 sheep and 100 cattle on this area.

"We used to burn lappieskombers (patch-burn) patterns. When this is done then fires cannot run away."

"The early farmers needed grazing and so they burnt a lot. There was then always new growth because they burnt very frequently. But this might also have had an impact. Most of the plants, however, are resprouters. Those that are not resprouters germinate from seed after fire. You can get severe erosion after fire if there is not enough vegetative cover."

"We divided the area into three zones in a leopard reserve and water afloop gebied (runoff area). We did this with nature conservation in the late 1980s. Some farmers still farm a little with sheep but not many. Sheep farming is now not worth it. A farmer can get R150,000 per ha for fruit, but can only get R12-R15,000 per ha for sheep. In the past roads and markets were poor. Now with good roads (after the world war) it has become much easier to market. Now we market all over the world."

In 1989 a fire burnt from Citrusdal and burnt for 60 km length and 25 in width and nothing escaped.

Are there dams on this farm? Not big ones but we are using water from streams at 850 litres per hour during the summer periods, which can go up to 1 million litres per hour in high summer – using microjets.

"There used to be 100,000 sheep in this district (to the Bokkveld) since the 1960's though, there haven't been more than 10,000 sheep in the area. People used to be traditional skaapboere (sheep farmers) and they used to hang onto the culture of their fathers."

What about vegetable farming? In the Bokkveld streek (stretch) itself people are growing potatoes and onions. This farm used to have 100 ha of potatoes and onions but not a single ha today because fruit are more stable than vegetables. Many fruit cultivars can only grow here.

"In this region the wine industry is not very big at all. Just at Dwarsrivier. The climate is a bit too cold here."

"Income from tourism is very low, about R200,000 as opposed to R12 million (omset) (turnover) from fruit. We are some of the biggest citrus farmers and can market from November to March."

It costs R30-40,000 per ha for established orchards. R500/ha for grazing veld.
R70,000 to establish an orchard of fruit crops. Interviewee E believes the veld has improved in the area because people are more aware of things. "We have also established a 'Fire Association'."

We have been taking repeat photographs and at a lot of the sites we have noticed that Proteas have increased. When you don't graze the veld, a lot more plants come up because animals graze them when they are small. Also, people used to use firewood (mostly proteas) but now they don't do it anymore. People use electricity. People are now putting a lot of pressure on other resources especially water.

"I am very concerned about frogs because of chemical pollution of the water. The biggest polluters are the municipalities because of the offloading of industrial waste. The compost/fertilizer that you use also has a big impact on the water, and rivers don't get a chance to flood and clean themselves out. When I was a child I used to hear a chorus of frogs but now I don't hear that anymore except in the main rivers."

What are your feelings about the GCBC? It is a good thing but it needs to be well managed. A third of our farms (especially the mountainous areas) we manage under the policy of the wilderness area. Farmers in the area are very happy to do this.

"GMOs are being used in the area. I have been cloning trees for 25 years."

"My future plans include (1) an increase in tourism because it is a pretty part of the world and (2) I have a bit of land that I want to give to black empowerment (for people who have worked on the farm for all these years. I want to wait though until the government policy settles down a little. (3) We also want to extend our season (currently at 8 months) and cash in on a wider market."

Interviewee E said they should make the Maltese Cross inaccessible. This was done for a while and now it has recovered. Photo 424. He feels that local community has very little conservation consciousness.

APPENDIX 3: REPEAT PHOTOGRAPH PAIRS OF *WIDDRINGTONIA CEDARBERGENSIS* IN THE CEDERBERG UPLANDS, SHOWING TREE COUNTS WHERE GREEN INDICATES LIVE TREES AND RED INDICATES DEAD TREES

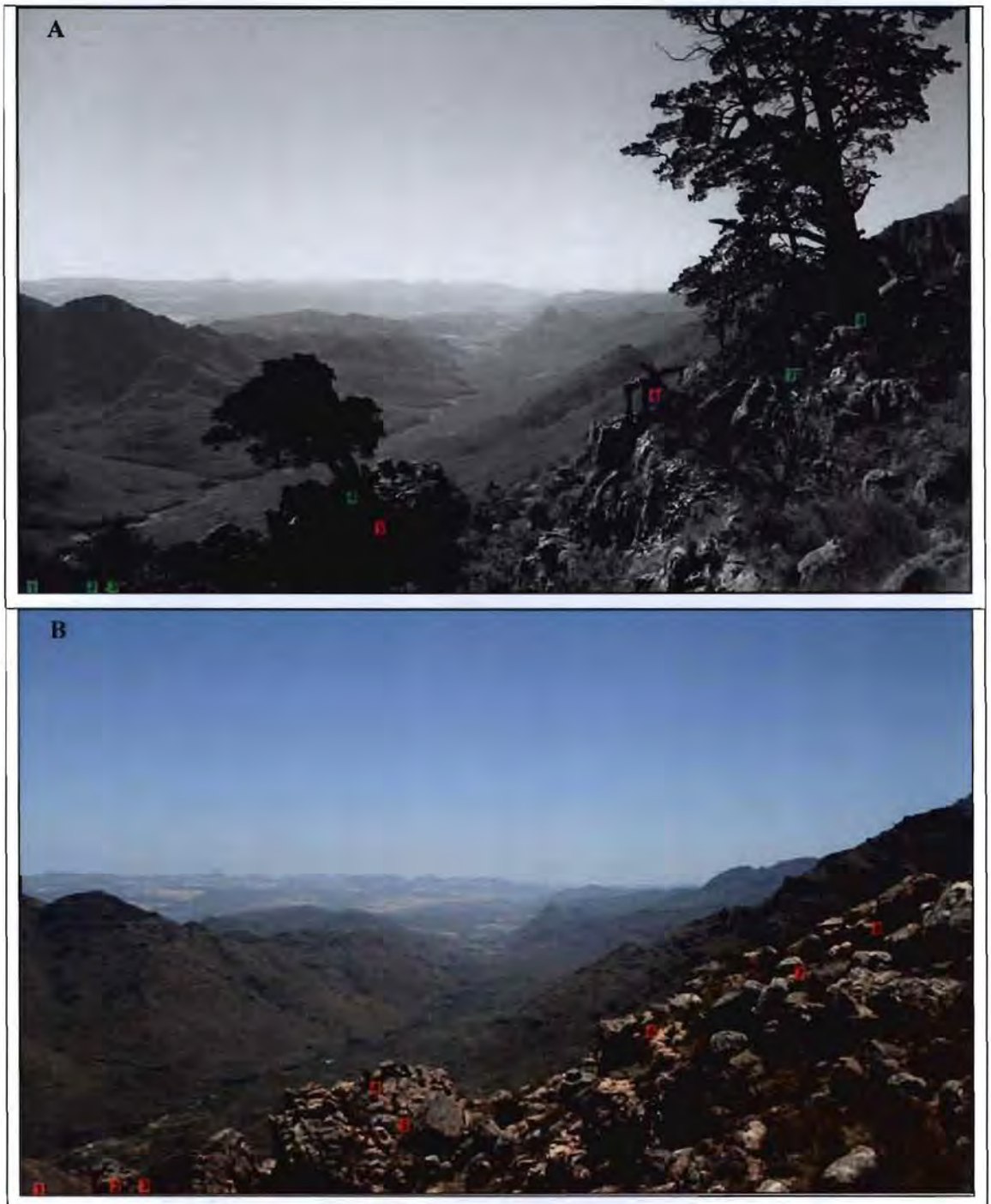

Figure 1: Skerpioenspoort (1): looking down Bosch Kloof.
Location: S 32.31575, E 19.10268. Altitude (m): 1151.
Original: A. Oct 1941, K. Howes-Howell. Total number of trees: 8. Alive: 6. Dead: 2.
Repeat: B. Dec 2007 (450). Total number of trees: 8. Alive: 0. Dead: 8.
Description: This is a West-North-West facing slope with a mean aspect of 299°. All the Cedar trees in the foreground of the original photograph have disappeared. In all other respects the foreground vegetation is little changed. Note that in 1941 there were some dead cedars. The river course at the bottom is mostly unchanged. The distant plain has seen a noticeable increase in the area of cultivation.

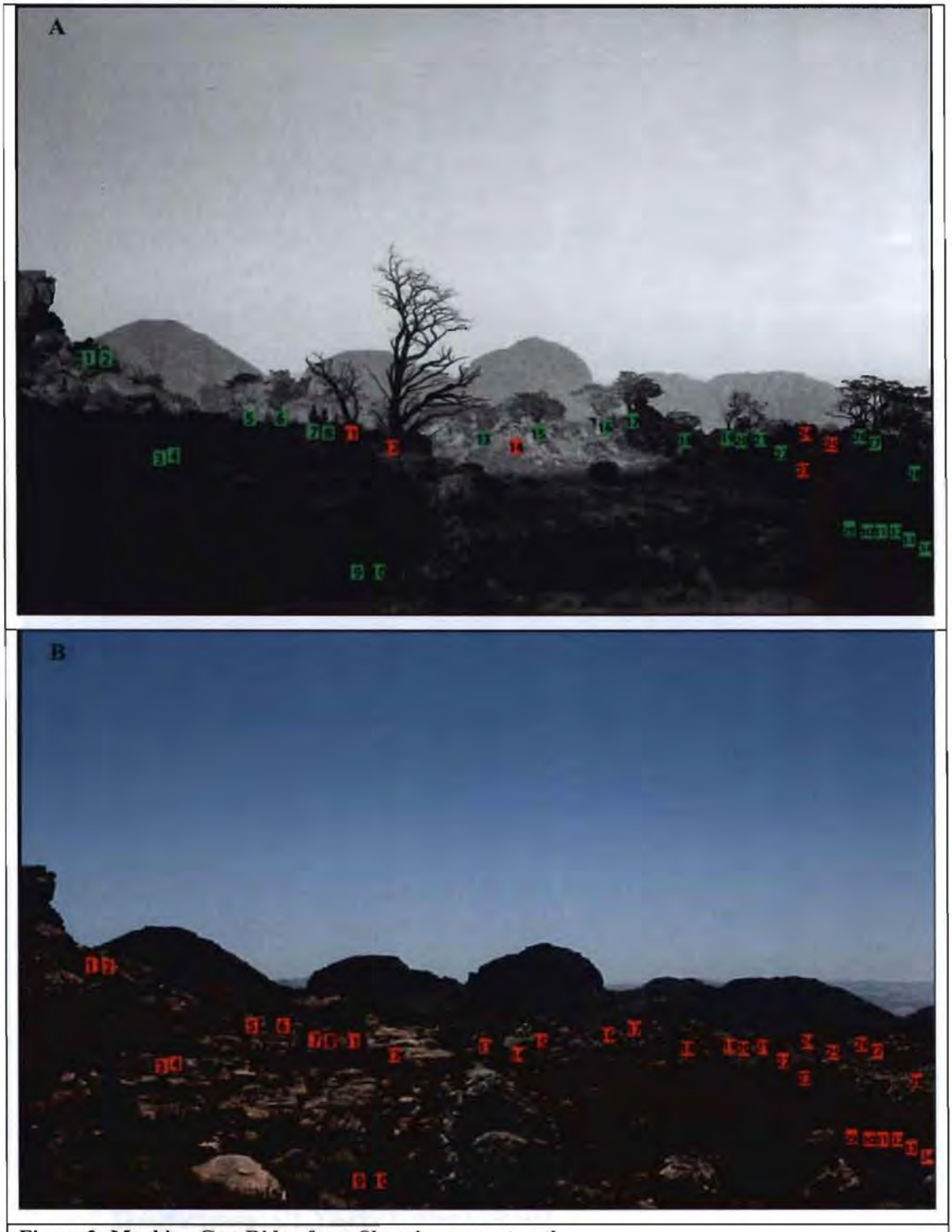

Figure 2: Machine Gun Ridge from Skerpioenspoort path.
Location: S 32. 32013, E 19.10192. Altitude (m): 1197.
Original: A. Jan-Feb 1931, K. Howes-Howell. Total number of trees: 34. Alive: 28. Dead: 6.
Repeat: B. Dec 2007 (451). Total number of trees: 34. Alive: 0. Dead: 34.
Description: This is a North-West facing slope. 28 out of the 34 cedar trees counted in the original photograph were alive. All 28 trees are now dead, there are only a few skeletons (eg. Plant 6) remaining in the landscape today.

Figure 3: Skerpioenspoort (2): Vlaktes looking to Sneeukop.
Location: S 32.32324, E 19.10607. Altitude (m): 1239.
Original: A. Oct 1941, K. Howes-Howell. Total number of trees: 133. Alive: 129. Dead: 4.
Repeat: B. Dec 2007 (452). Total number of trees: 133. Alive: 10. Dead: 123.
Description: This site has been divided into three zones according to aspect (see Table 3, Chapter 5). Zone A refers to plant numbers 1-99 and 129-132, and is a SW-facing slope with a mean aspect of 219 degrees. Zone B includes plants 100-109 and has a mean aspect of 284°, making it a WNW-facing slope. Lastly, zone C incorporates plants numbered 110-128 & 133 and is a N-facing slope with a mean aspect of 1°. The immediate foreground vegetation (a mixture of restios, serruria and leucodendron) seems little changed. There were a lot of young cedar trees in the foreground of the original photo, which have all disappeared. There is now a tall cedar leaning over the path which may have been a young tree in 1941. The left-hand S-W facing slope has experienced an orgy of destruction with approximately 90% mortality. The right-hand slope still sees quite a few adult trees in existence.

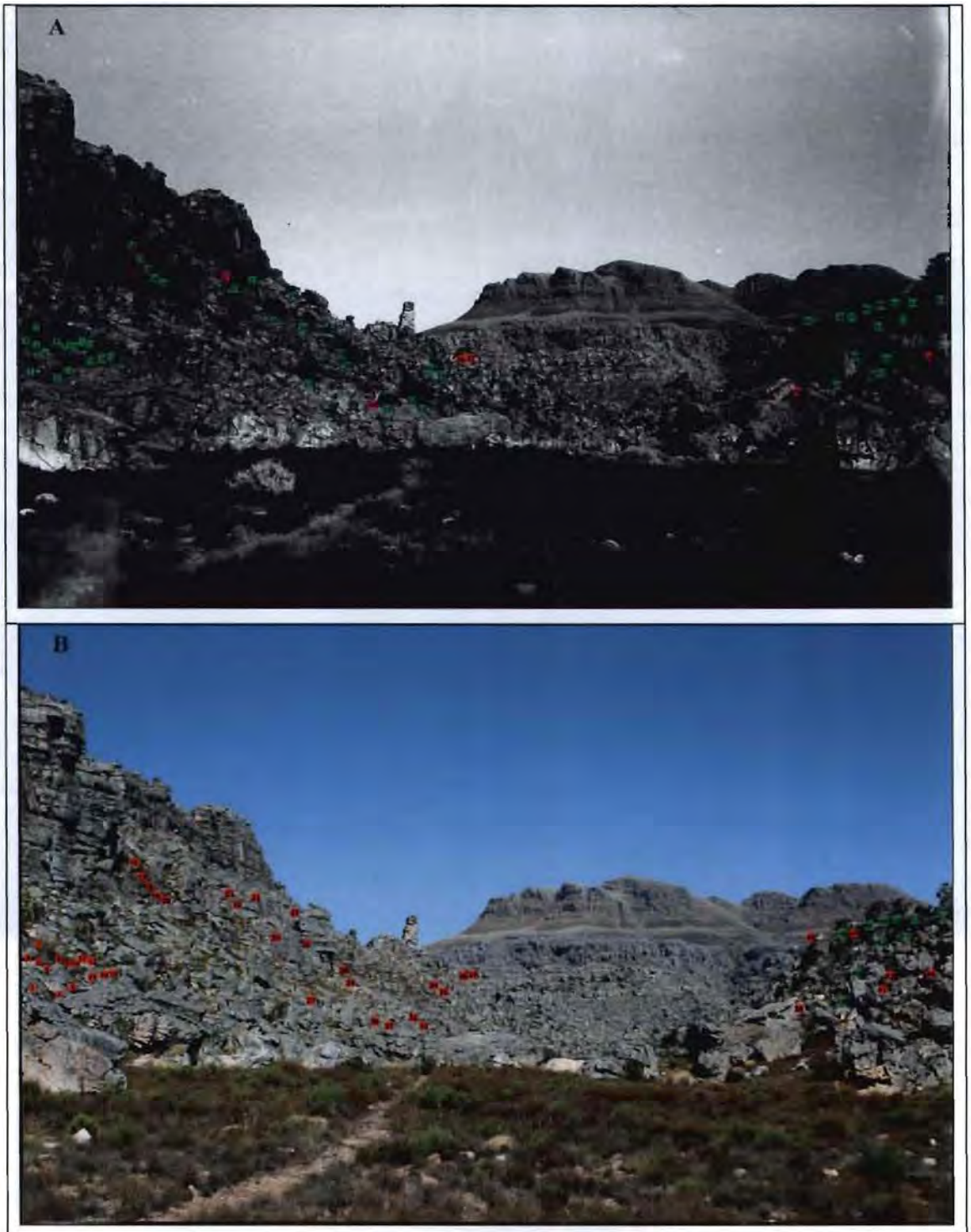

Figure 4: Sneeukop from Skerpioenspoort path near Crystal Pool.
Location: S 32.32631, E 19.11045. Altitude (m): 1273.
Original: A. Jan-Feb 1931, K. Howes-Howell. Total number of trees: 53. Alive: 47. Dead: 6.
Repeat: B. Dec 2007 (453). Total number of trees: 53. Alive: 10. Dead: 43.
Description: This site has been divided into two aspect classes (see Table 3, Chapter 5): 453a includes plants 1-37 and is a SSW-facing slope and 453b comprises plants 38-53, which are found on a NE-facing slope. The Foreground vegetation (a mixture of restios and Aspalathus type shrub) is little changed. The right-hand NE facing slope sees quite a few adult trees still in existence. On the left-hand South- facing slope however, all of the cedars have disappeared.

Figure 5: Vanzylspoort (1): looking under cedar towards Western Peak.
Location: S 32.32814, E 19.11421. Altitude (m): 1234.
Original: A. Nov-Dec 1934, K. Howes-Howell. Total number of trees: 6. Alive: 6. Dead: 0.
Repeat: B. Dec 2007 (454). Total number of trees: 7. Alive: 4. Dead: 3.

Figure 6: Vanzylspoort (2). Looking down from high part of path.
Location: S 32.33891, E 19.13020. Altitude (m): 1269.
Original: A. Oct 1944, K. Howes-Howell. Total number of trees: 27. Alive: 26. Dead: 1.
Repeat: B. Dec 2007 (455). Total number of trees: 27. Alive: 6. Dead: 21.
Description: The plants at this site were once again divided into groups according to the slopeson which they were found (see Table 3, Chapter 5). Plants 21-27 are part of 455a, a ENE-facing slope on which there has been a 7% annual mortality rate over 63 years. Zone 455b refers to the remaining plants 1-20 which are on the more moderate WSW-facing slope and have experienced a lower rate of annual mortality of 2.3%.

The large, very old cedar on the left of the original photo has now died and has a noticeable fire scar on its trunk, which has split into two parts. The other large cedar, located just to the right of the very large rock (centre left) is still alive, although growth is confined to the tips of the branches only. None of the seedlings in the centre foreground have survived and the skeleton of only one individual is still visible. A group of very young adult trees in the central right-hand part of the original photograph, where the two hikers were standing have today grown up into mature adult trees. Their sizes range from about 3-7 m in height with a diameter of breast height of about 19cm for some of the larger individuals. The branches sticking into the image on the right are from a mature tree which has survived since 1944.

Figure 7: Crystal Pool (1): Outside hut.
Location: S 32.34566, E 19.13780. Altitude (m): 1284.
Original: A. Jan-Feb 1931, K. Howes-Howell. Total number of trees: 16. Alive: 9. Dead: 7.
Repeat: B. Dec 2007 (456). Total number of trees: 16. Alive: 5. Dead: 11.
Description: 456a, a north-facing slope includes plants numbered 6-16. Plants 1-5 are labelled 456b, a NNW-facing slope (see Table 3, Chapter 5).

Foreground: This region is still dominated by restios and a large Elegia type of restio. Stoebe plumosa is evident today in the foreground although it wasn't present in the 1931 photograph. All the cedars that were present in the foreground at this site are now dead. Dead skeletons are visible for some of the individuals but not all. The centrepiece of the original photo – the cedar at centre right, has completely disappeared from view today. The right-hand slope appears to have experienced a lower degree of mortality of the cedars than the left-hand slope.

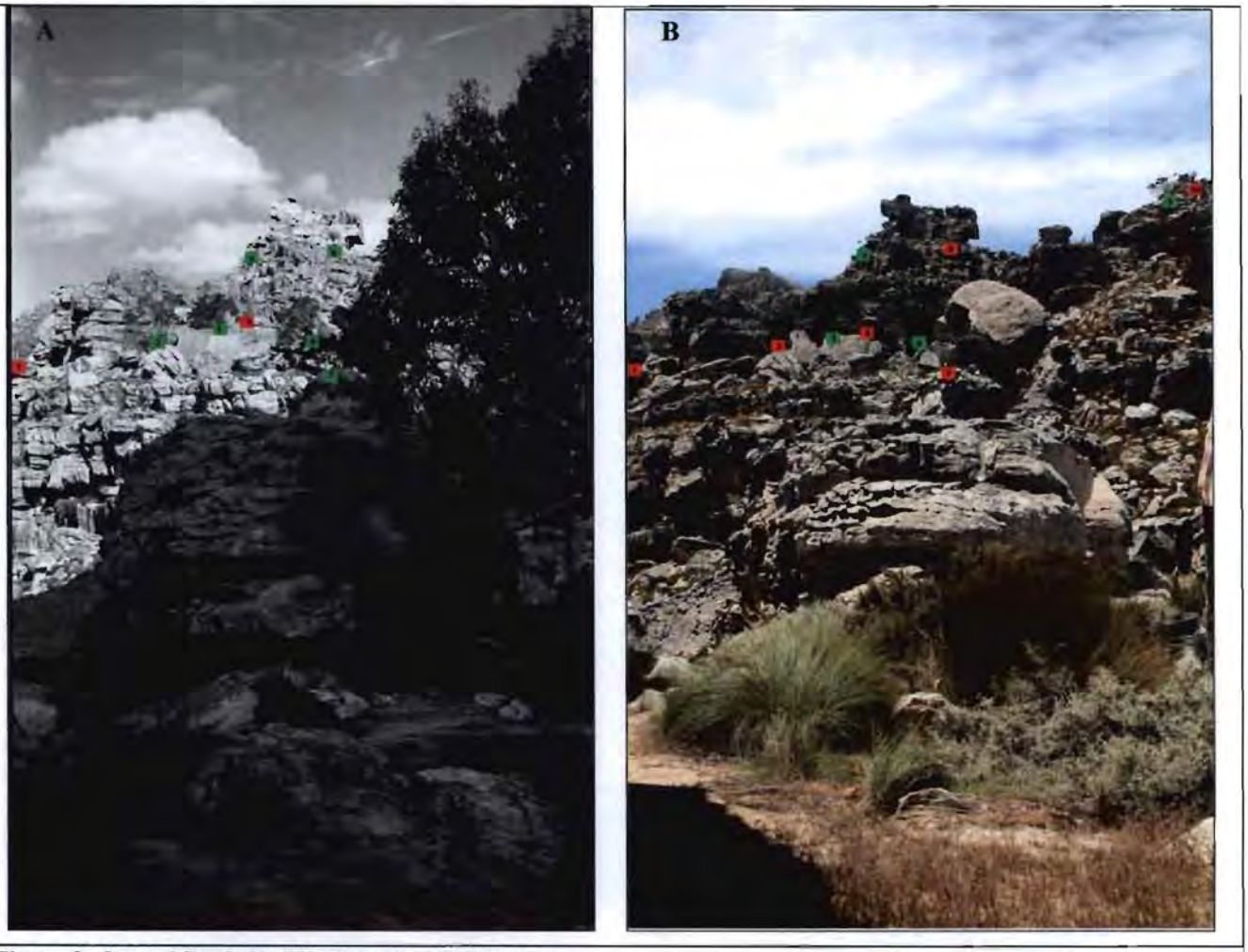

Figure 8: Crystal Pool (2): "Ye dogs head" from hut.
Location: S 32.34792, E 19.13461. Altitude (m): 1307.
Original: A. Nov-Dec 1934, K. Howes-Howell. Total number of trees: 8. Alive: 6. Dead: 2.
Repeat: B. Dec 2007 (457). Total number of trees: 10. Alive: 4. Dead: 6.
Description: This is a NW-facing slope, tree's 3 and 6 have grown into healthy adults, tree's 9 and 10 were blocked by the gum tree in the original photo so excluding them, the annual perecent of mortality on this slope has been 1.5% over 73 years. The gum trees in the foreground have disappeared. The rocks in the in foreground are now covered by grass – Merxmuellera , Cliffortia ruscifolia, Stoebe plumosa and a restio.

Figure 9: Crystal Pool (3).
Location: S 32.34824, E 19.13496. Altitude (m): 1307.
Original: A. Jan-Feb 1931, K. Howes-Howell. Total number of trees: 1. Alive: 1. Dead: 0.
Repeat: B. Dec 2007 (458). Total number of trees: 1. Alive: 0. Dead: 1.
Description: There was one old cedar in the original photo of 1931, which had very limited foliage. Today it is still present but is dead. The foreground is now heavily dominated by restios, Cliffortia ruscifolia and Stoebe plumose. Erica's seen in the foreground of the original photo are no longer present. The diameter of the old tree is approximately 85 cm with a circumference of 2.16 m.

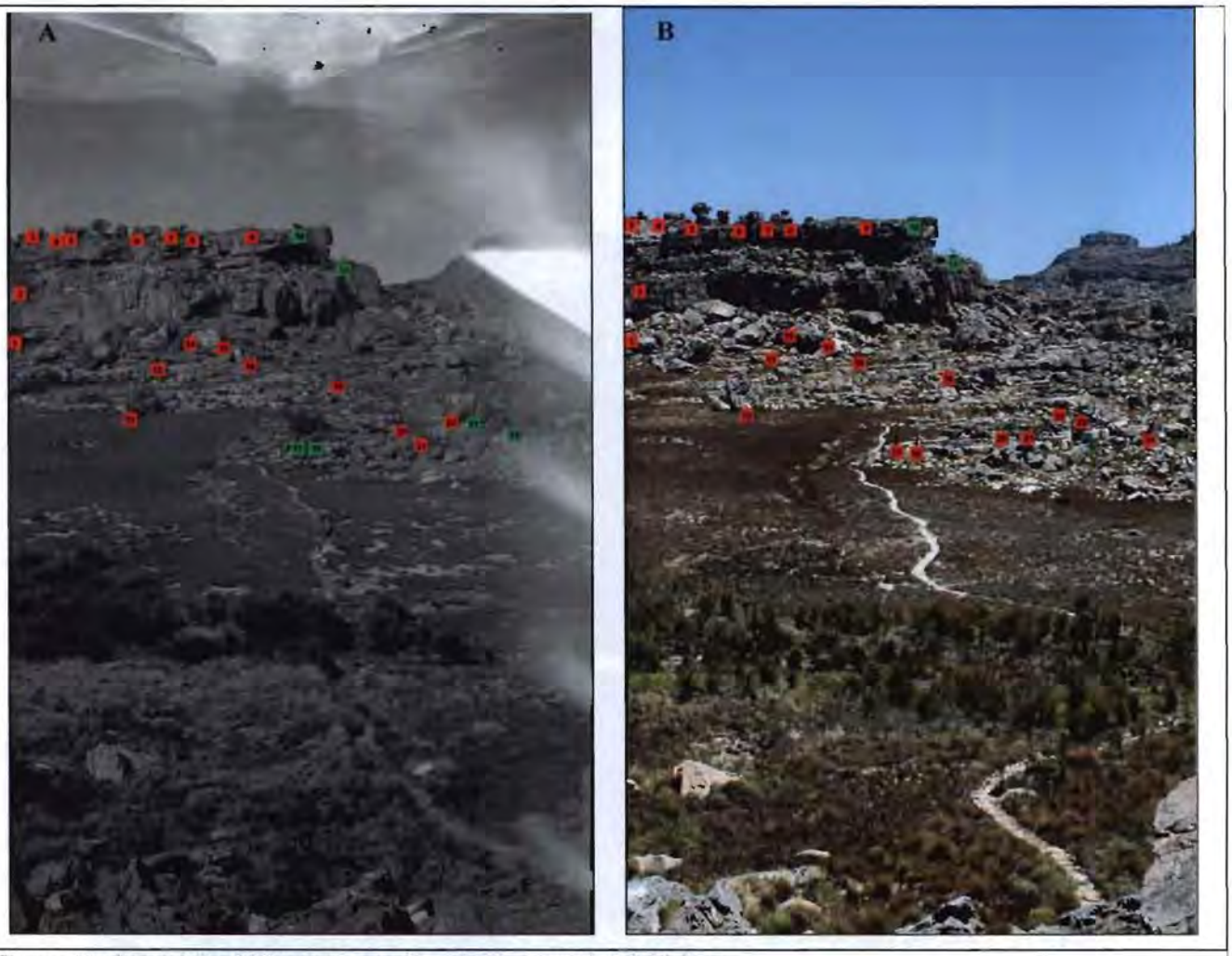

Figure 10: Crystal Pool (4): party crossing vlakte towards Middelberg.
Location: S 32.35028, E 19.13349. Altitude (m): 1273.
Original: A. Nov-Dec 1934, K. Howes-Howell. Total number of trees: 24. Alive: 6. Dead: 18.
Repeat: B. Dec 2007 (459). Total number of trees: 24. Alive: 2. Dead: 22.
Description: In terms of aspect, this site was divided into two aspect classes: 459a: plants 12-24 ENE-facing, and 459b: plants 1-11 NNW-facing.

For the purpose of the general ecological description of changes at this site, 5 zones have been described:
Zone A (immediate foreground): was covered with Stoebe plumose in 1934, however today only restios and grasses are common.
Zone B (river channel): there has been a thinning of reeds along the left-hand side of the river channel and a thickening of reeds on the right.
Zone C (vlaktes): The open erosion patches to the left and right of the path seem to have recovered and filled in.
Zone D (rocky area on right of photo): All cedars are now dead, some of the skeletons still remain.
Zone E (left-hand slope): Only two cedar trees were alive on this slope in 1934, the same is still true today, with most skeletons still remaining.

Figure 11: Crystal Pool (5): looking down Skerpioenspoort.
Location: S 32.34535, E 19.13531. Altitude (m): 1296.
Original: A. Nov-Dec 1934, K. Howes-Howell. Total number of trees: 17. Alive: 4. Dead: 13.
Repeat: B. Dec 2007 (460). Total number of trees: 17. Alive: 2. Dead: 15.
Description: Zone A (foreground + rocky area on right): It appears little changed, except for the leggy shrub which could have been a Leucospermum, has disappeared and is nowhere to be seen in this area. Three or four different restio species now dominate the foreground. The cedars on the rocks to the right are now dead. Zone B (rocky ridge on right back): Most of the cedars on this hillslope are now dead. Trees 16 and 17 which were very young trees in 1934 are still alive today as larger adults.
Zone C (rocky ridge on left): All cedars on this slope were already dead in 1934, a few skeletons still remain.

Figure 12: Vanzylspoort (3): Peaklet near Vogelsangvallei.
Location: S 32.33641, E 19.12729. Altitude (m): 1237.
Original: A. Oct 1944, K. Howes-Howell. Total number of trees: 56. Alive: 38. Dead: 18.
Repeat: B. Dec 2007 (461). Total number of trees: 56. Alive: 13. Dead: 43.
Description: Two aspect classes once again described – 461a: plants 14-56 on a ENE-facing slope, and 461b: plants 1-13 on a NNE-facing slope (see Table 3, Chapter 5).
In terms of general ecological changes, 3 zones are described: Zone A (foreground): very little difference in foreground vegetation although there might be fewer Elegia today than in past – (tall reeds lining the river course). Zone B (central – right-hand ridge): Many of the cedars are now dead, a few skeletons of dead trees still remain. Zone C (left-hand ridge): Quite a few cedars on this ridge were already dead in 1944, a few young trees have grown up since then.

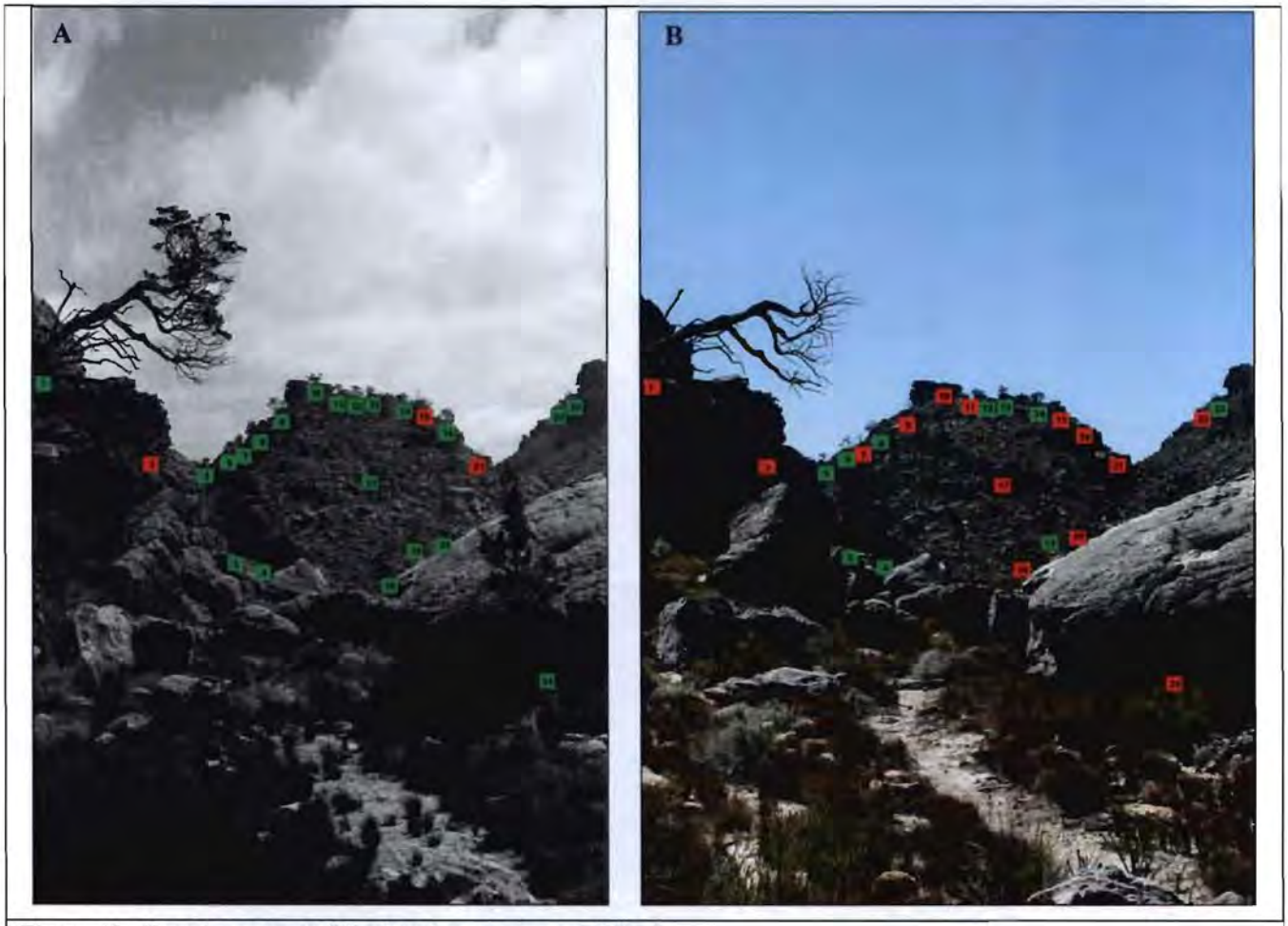

Figure 13: Skerpioenspoort (3): view down near Anvil Peak.
Location: S 32. 33390, E 19.12091. Altitude (m): 1208
Original: A. Oct 1944, K. Howes-Howell. Total number of trees: 24. Alive: 21. Dead: 3.
Repeat: B. Dec 2007 (462). Total number of trees: 24. Alive: 10. Dead: 14.
Description: At this site, we only allocated an aspect classing for the central slope with plants 5-21, which is SE-facing. Zone A (foreground): the small cedar in front of the large rock in the original photo is now dead. Its skeleton is lying on the ground and has been burned. The large cedar on the rock (upper left) is now dead but the skeleton is still there. Just behind this (middle distance) are two large cedars (numbers 3 + 4) that are still alive. Zone B (distant hillslope): there are still a fair number of cedars on this slope that are still alive, although their numbers have thinned considerably since 1944.

Figure 14: Vogelsangvallei (1).
Location: S 32.33232, E 19.11996. Altitude (m): 1223.
Original: A. 1951, K. Howes-Howell. Total number of trees: 25. Alive: 19. Dead: 6.
Repeat: B. Dec 2007 (463). Total number of trees: 25. Alive: 9. Dead: 16.
Description: At this sire the only landform worth mentioning is the rocky "peaklet". This is a west-facing slope, and while there has been some mortality at this site a surprisingly large number of trees are still alive and have grown into healthy adult trees since 1951. There has been no recruitment of new cedars at this site, and the annual percent of mortality has been 1.33.

Figure 15: Vogelsangvallei (2).
Location: S 32.33234, E 19.12299. Altitude (m): 1228.
Original: A. Oct 1941, K. Howes-Howell. Total number of trees: 28. Alive: 19. Dead: 9.
Repeat: B. Dec 2007 (464). Total number of trees: 28. Alive: 6. Dead: 22.
Description: This is an east-facing slope on the other side of the "peaklet" from site 463. There has been a far higher degree of mortality of cedar trees on this slope compared to that of the adjacent west-facing slope of 463.

APPENDIX 4: R SOURCE CODE

Function 1:
Calculates population size, using an individual based simulation, for a population starting with n0 individuals, with a mortality rate of pMort, after *years* years

```
popSize <- function(n0, years, pMort)
 {
  n <- n0
  for (y in 1:years)
   {
    n <- sum(runif(n) > pMort)

    if (n==0)
     {
      break()
     }
   }
  return(n)
 }
```

Function 2:
Calculates how often the population size was nTarget, doing times simulations using popSize()

```
pPopSize <- function(n0, years, pMort, nTarget, times=1000)
 {
  sims <- sapply( 1:times,
            function(i)
            {
             popSize(n0, years, pMort)
            }
            )
  return( sum(sims == nTarget) / times )
 }
```

Function 3:
Calculates the mortality rate which results with a probability of pTarget, into the population going extinct after *years* years. Uses pPopSize. n *times* simulations are conducted to determine the probability.

```
findPMortZero <- function(n0, years, pTarget=0.95, pMortMin=0, pMortMax=1,
times=1000)
 {
  f <- function(p)
   {
    return( pPopSize(n0=n0, years=years, pMort=p, nTarget=0, times=times) -
pTarget )
   }

  result <- uniroot(
```

```
            f = f,
            lower = pMortMin,
            upper = pMortMax,
            )
  result$f.root <- result$f.root + pTarget
  return(result)
}
```