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Landscape Change and Ecological Processes in Relation to Land-use in Namaqualand, South Africa, 1939 to 2005

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ABSTRACT

This paper examines the consequences of land use on vegetation over a sixty-six year period, within various agrarian landscapes across the winter/summer rainfall ecotone in northern Namaqualand. We employ repeat ground and aerial photography and interviews with land users to elucidate the causal factors that explain environmental change and stability. Ecological literature on landscape change in Namaqualand has suggested that communal land-use is detrimental to vegetation cover and species richness. Our study shows that there have been very few changes in vegetation cover and species richness in cultivated and grazed communal areas during the last 65 years, but that there has been a regeneration process in the private and protected areas. We demonstrate that these different vegetation responses reflect different land management histories. This evidence suggests that the potential for increased vegetation cover and species richness in response to land-use change is higher than was previously assumed and provides a new perspective on the latent capacity of communal landscapes to regenerate from changes caused by cultivation and grazing pressure. The environmental history presented in this paper spans a temporal and spatial scale that elucidates the complex relationship between land-use, climate, soils and vegetation change.

Introduction

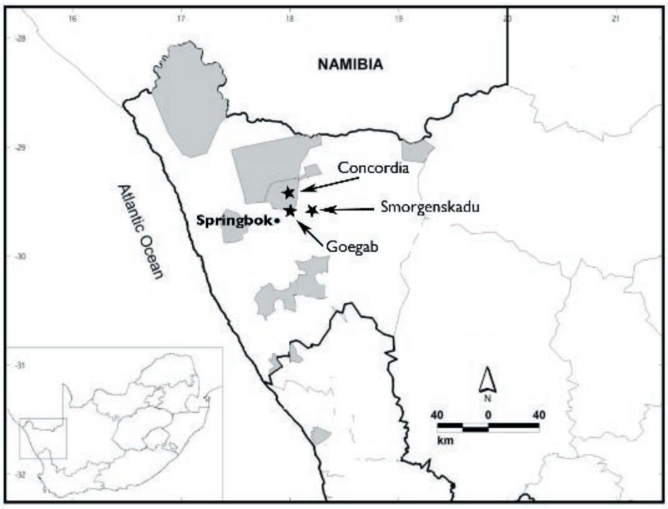
In this study we investigate the environmental consequences of livestock grazing and cultivation on vegetation in three distinct land-use categories - a communal farming area, a private farm and a protected area - in Namaqualand, South Africa over a period of 66 years. Using repeat landscape and aerial photography complemented by interviews with land users we provide insights into the region's environmental history. We explore the question of whether grazing and cultivation have long-term impacts on the environment and seek to establish a temporal measure of regeneration of vegetation cover and species richness in areas impacted by agriculture.

Previous studies from Namaqualand indicate that parts of the communal areas are severely affected by cultivation and grazing (Allsopp, 1999; Todd and Hoffman, 1999; Hoffman and Ashwell, 2001; Hoffman *et al*., 2003; Anderson and Hoffman, 2007; Hoffman and Rohde, 2007). Perennial shrub species have been replaced by annuals particularly in low-lying flat areas, with few signs of recolonization, and ploughed areas that have been fallow for up to 60 years still contain few perennial shrubs, apart from the unpalatable *Galenia africana* (Hoffman et al., 2003). Our study however, shows that although we find some changes on a local level in species composition and vegetation cover, the changes are not unidirectional. We find that since 1939, few major changes in vegetation cover and composition have occurred in previously-transformed communal farming areas. In both the nearby private commercial farm and in the adjacent nature reserve (which has been protected from grazing and cultivation since 1969), vegetation cover has increased and in some cases there has been a replacement of one growth form (succulents) by another (grasses). This paper explores the implications of this finding.

Background

Namaqualand District in Northern Cape Province covers 52,600 km2 of which 28 % is communal agricultural land and 52% private commercial farms. In addition, about 5% of the land is conservation areas, 8% state land and the remaining 7% is owned by mining companies (Rohde *et al*., 2002). We use May and Lahiff's (2007) definition of Namaqualand, which corresponds with the historical Magisterial District of Namaqualand as it was before the demarcations of new municipalities in 2000. The former Namaqualand District is now a part of the much larger Namakwa District municipality. Namaqualand has a population of about 66,000 of whom about 45% live in the communal areas which were created during colonial and apartheid eras as 'Reserves' and the remainder of the population reside in towns or on private commercial farms. The population in Namaqualand is almost entirely Afrikaans-speaking, and most people are of mixed Nama descent (Rohde and Hoffman, 2008).

Figure 1: Map of Namaqualand, showing communal areas, Goegap Nature Reserve and Smorgenskadu farm.



Farming in Namaqualand

Similar to the rest of South Africa, the Namaqualand landscape has been influenced by its colonial and apartheid past. Colonialism resulted in the alienation of indigenous communities in Namaqualand from large areas of land, which were taken over by white farmers. Until the 1950s, communal farmers coexisted with white farmers often sharing large areas of unfenced grazing land. However, with the apartheid legislation introduced in the 1950s, along with subsidies for white farmers, large tracts of land were fenced, effectively confining communal farmers to small communal enclaves (Rohde and Hoffman, 2008). Today's skewed distribution of land is a consequence of the colonial dispossession and apartheid policies that has resulted in two distinct land-use practices in Namaqualand.

Although they co-exist in the same ecological environment, livestock farming on communal and private land differ in production practices and in objectives. Large-scale commercial farmers live on privately owned farms that usually range between 4,000 and 12,000 ha in size. Stocking rates on private farms are low, and generally below the stocking rate recommended by the Department of Agricultural (10 ha/small stock unit). Production is geared towards sale of high quality slaughter animals (sheep, goats and cattle) for the national market (Rohde et al., 2002; Sullivan and Rohde, 2002). A typical private farmer in Namaqualand has a net income of between R6,000 and R12,000 a month (Rohde et al., 2002).

Communal farmers live and work in state-owned enclaves, previously known as 'Coloured Reserves' and later as 'Coloured Rural Areas'. Such areas generally provide each individual farmer with less than a tenth of the amount of land per individual compared to their commercial counterparts on privately owned farms. Herd sizes per farmer vary from a hand-full of goats to hundreds of small stock and dozens of cattle. Stocking rates in the communal areas are often twice the recommended level set for private farms. The communal production system is oriented towards subsistence and local commercial trade: meat and milk provide important food supplements, sheep and goats serve as reserve capital for school fees, medical expenses and unforeseen emergencies and donkeys provide draught power and transport (Rohde *et al*., 2002; Sullivan and Rohde, 2002).

Land use in Concordia and adjacent areas

This study was conducted in three adjacent areas with distinctly different land-use histories: 1) Concordia – communal farms within a previously so-called "Coloured Reserve" in north central Namaqualand; 2) Smorgenskadu – a private commercial farm in close proximity to Concordia and; 3) the Goegap Nature Reserve – a protected area which is also adjacent to Concordia.

Figure 2: Repeat aerial photographs of Concordia case study farms showing very little change in vegetation cover between 1958 and 2003. Figure 2b shows position of repeat photographs illustrated in the text and the slices of the landscape depicted.

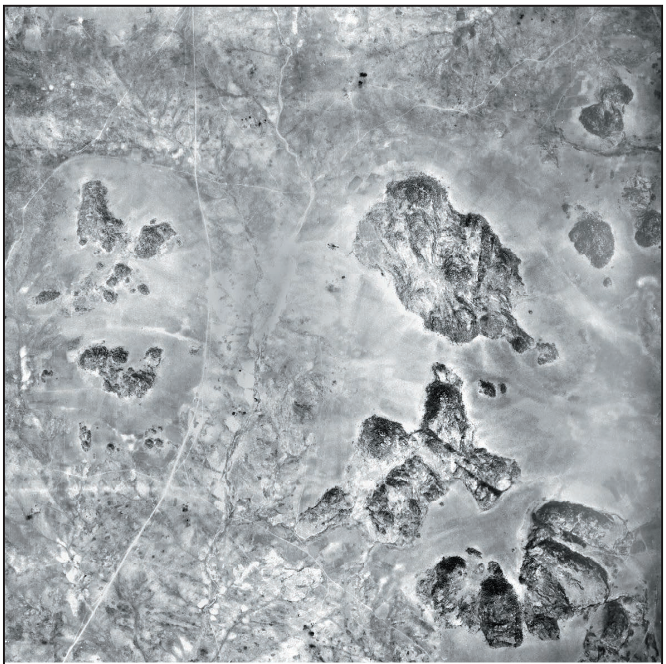


Fig 2a: 1958, November 14, 13.10. Job 408./ Strip 205/ Frame 8513

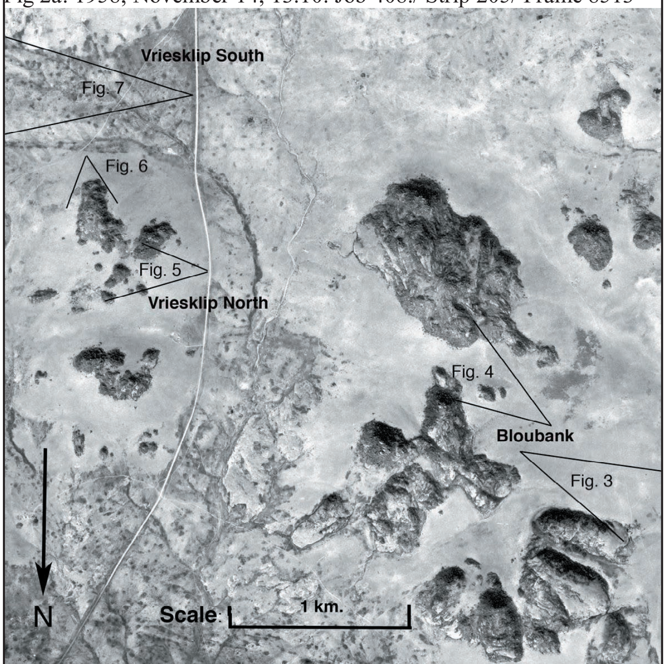


Fig 2b: 2003, August 15. Job 1079/ Strip 019/ Frame 1354

Concordia

Land in Concordia is used for residential house plots in the village and dryland crop farms *(saaipersele)* in the outlying areas while the general commonage is used for grazing. This study focuses on a cluster of three dryland crop farms (Bloubank, Vriesklip North and Vriesklip South) which are leased from year to year from the Concordia Management Board. There are approximately 300 farms in Concordia, although not all farmers lease their own farms but instead rent land informally from registered leaseholders (Benjaminsen and Sjaastad, 2008). Most farmers live in Concordia village and commute to their farms when necessary. Historically the farms were used for cultivation and grazing. A survey conducted in 2000 by government surveyors at the instigation of the Surplus People Project provided formal registration of the leaseholders and borders of all dryland farms, which vary in size between 40 and 500 hectares. Although farms do change hands from time to time, most stay in the same family and are passed on from parents to children.

Cultivation in Concordia was introduced by missionaries (Boonzaier, 1996) and dates back to about 1840 (Benjaminsen and Sjaastad, 2008). Croplands within the farms were ploughed and sown with rye, oats and wheat. Because of erratic rainfall in the area, harvests have varied significantly and in many years the harvests have been negligible. However, in good rainfall years harvests have made a significant contribution to animal fodder and household food security. Concordia has one crop growing season that occurs between the start of the rainy season (July - August) and mid-summer (December - January). In recent years most farmers have ceased cultivating as the effort and input costs tend to exceed the output and they now use the former croplands solely for grazing.

Goegab Nature Reserve

Goegab Nature Reserve lies on the southern boundary of Concordia communal area. Previous to being declared a protected area in 1969, it was a privately owned commercial farm used primarily for livestock grazing. Up until the mid-20th century the borders of this farm and that of the Concordia communal area were porous – both communal and commercial livestock farmers grazed this area depending on seasonality and climatic conditions. Since water points close to Concordia village were within 5 km of the study site at Goegab, it is not inconceivable that this area was highly impacted by grazing over a protracted time frame before it became a protected area. Furthermore, cropping on the Concordia side of this boundary occurred until recently and it is likely that small areas were cropped within the frame of the repeat photograph of this site.

Smorgenskadu

Smorgenskadu is a typical commercial farm in the area (average size 6,000 hectares) and has been stocked primarily with sheep and occasionally with goats and cattle. This part of Namaqualand was one of the last areas to be formally titled and privatised, mostly during the first three decades of the 20th century. Prior to this, land-use within the Smorgenskadu landscape was influenced by transhumant pastoralism practiced by indigenous and later trekboere farmers. During the first three or four decades of the 20th century the area in the vicinity of the Smorgenskadu study site was heavily impacted by livestock that depended on a local water source. During the 1940s, land-use practices changed radically with the introduction of bore-holes and fencing and transhumance ceased.

Plant ecology in the study area

Concordia lies on the ecotone between two distinct ecological zones (Mucina and Rutherford, 2006). The Succulent Karoo biome, which corresponds with the winter rainfall area, dominates the western part of the study area. The Succulent Karoo biome is an area of high biodiversity (ca 3,500 species), of which about 25% of the species are endemic (Todd and Hoffman, 1999; Anderson and Hoffman, 2007). In the winter rainfall area of Namaqualand the sandy plains are dominated by leaf succulents, while non-succulent shrubs dominate the rocky hills. During good rainfall years, Namaqualand exhibits spectacular scenes of annual flowers in early spring. Trees are rare, and mostly grow along watercourses. The eastern part of Concordia falls within the Nama-karoo biome, which has summer rainfall and is dominated by annual and perennial grasses. However, when subject to heavy grazing pressure and cultivation, both the Succulent and Nama-karoo biomes tend towards a higher proportion of annual species (Anderson and Hoffman, 2007).

The case study site from the north eastern part of the Goegab Nature Reserve is on the western edge of the Succulent Karoo/Nama-karoo ecotone, but falls predominantly within the Succulent Karoo biome. Although it does receive some summer rainfall (average 50 mm or approximately 25% of total annual precipitation) this is not enough to sustain permanent grasslands. The privately owned, commercial farm of Smorgenskadu is located within the ecotone between the winter and summer rainfall areas. Here soils and substrates have an important influence on vegetation type and Succulent Karoo biome species alternate with more typical summer rainfall Nama-karoo biome grassland species depending on seasonal climate, land-use and geology.

Methodology

The choice of case study sites was arbitrary to the extent that we were limited a small set of repeat photographs from the area. The six repeat photo sites used in this study were chosen out of a wider collection of thirty-two repeat photos taken across the ecotone north and east of Springbok. The originals used in this study were taken by Hans Herre during the spectacular flower season in 1939 and are representative of changes observed in the repeat photographic collection across a wider landscape. We concentrate on Concordia and the immediate surrounding area because one author (EH) was conducting socio-economic fieldwork research here in 2007. It provided us with an opportunity to create a study with the potential to add up to more than the sum of its parts by combining historical, ecological and socio-economic research expertise. Our selection includes four repeat photographs from a cluster of three communal farms in Concordia, one from Smorgenskadu, a private commercial farm and one from the Goegap Nature Reserve. All photos span 66 years and cover the period between 1939 and 2005.1

Repeat aerial photographs that date from 1958, 1964, 1976, 1997 and 2003 were compared and analysed in relation to the ground photos. Interviews as well as walks through the photo sites were conducted with their respective farmers during which the history of management, land use and perceptions of landscape change were discussed. In addition, we interviewed several other farmers in the area about land degradation and land-use changes.

The use of repeat ground photographs and historical aerial photographs is prominent both in geographical and biological research, and is mostly used to demonstrate vegetation and landscape change (Bass 2004; Hudak and Wessman 1998). Repeat ground photography combined with repeat aerial photographs, have clear advantages when detecting landscape changes as they show the changing state of vegetation cover and species composition over time. As memory may be selective or uncertain, even among the people who have lived on and managed these farms, the photographs can be used to elicit memories by providing a factual record of the physical changes that have taken place.

In this study we encountered challenges in the interpretation of the ground photographs partly due to the difference in season of the matched images. All of the original photographs were taken in September 1939 during a spectacular flower season, whereas the repeat photos were, for practical reasons, taken in March 2005 towards the end of a hot dry summer. This visual impression of change was potentially misleading and for those untrained in interpreting vegetation change from photographs the discrepancy in time of year and difference between seasons is quite problematic. The interviews were to a certain extent also marked by this effect in that some of the interviewees referred to the lack of flowers in the later photos as evidence of degradation.

There are also other fundamental challenges in the use of repeat photography. Used uncritically, repeat photography with only two photographs imply a linear change from one point in time to the next. This is problematic in an area where the climatic variability and subsequently the inter-seasonal vegetation changes are considerable, and may contribute to a skewed interpretation of change particularly with regard to the annual component of the vegetation. In a time span of more than 60 years, and with large variations in rainfall, it is possible that several stages of vegetation change have occurred. Change may have been abrupt or gradual, and trends may have been in different directions. We deal with this challenge by complementing the ground photos with a series of aerial photos taken at different points of time, as well as with in-depth interviews with farmers and archival data.

Results

The Concordia communal area farms

The three Concordia communal farmers who tenant Bloubank, Vriesklip North and Vriesklip South were each interviewed four, two and three times respectively between November 2005 and March 2006. They have herds ranging from 190 to more than 300 animals which they keep on their farms for part of the year and in the communal grazing areas during the remainder. All three, and their fathers and grandfathers before them, have ploughed parts of their farms, predominantly the sandy pediments. The soils are nutrient rich, and have higher moisture content due to runoff from adjacent hills. Parts of the farms have been ploughed more or less continuously for decades, however this has virtually ceased during the last decade because farmers now feel that the costs outweigh the benefits due in part to the high cost of seed and the low value of wheat and oats.

All three farmers have fenced the perimeters of their farms during the last three decades, and they all have 'camps' (paddocks) within their farms in order to protect their grazing resource from other farmers' livestock.. This is somewhat unusual in Concordia, as relatively few farmers have erected perimeter fences or internal camps (Benjaminsen and Sjaastad, 2008). Paul Saal from Vriesklip North fenced the area depicted in Figure 5 about four years prior to the repeat, resulting in renewed grass cover. He avoids grazing during the ripening periods, in order to let the grass set seed before it is eaten and he can see a great difference from his farm to the adjacent farms that are not fenced. The two other farmers have not noticed much change in the quality of their grazing areas yet. However, since the fences were erected only a few years before the interviews, the land may still need more time to regain vegetation cover and species richness.

The repeat photographs elicited comments by all three Concordia farmers, many of which focused on the changes in the spring flower cover. Piet Cloete (Bloubank) remarked that he had not seen such splendid flower scenes (Figures 3 and 4) since 1957. He remembered all the best flower seasons since then, accurately recounting the years of high rainfall. He maintained that today, the rains tend to start earlier, in June and July, and the flower seasons are not as dense and spectacular: the veld is much barer now.

Memories of the landscape as having more water for the animals and more spectacular flower seasons are explained by the farmers with reference to rainfall:

It only depends on the rain [Dit hang net af die reen]. It can still become like the photograph from 1939 again sometimes, but then we must get more rain. Sometimes we can lose courage in March when it looks like this, but then comes the rain, and in June/July everything is changed. There was more rain in the old days. Now the rainfall is pathetic, it is weak. The plants will grow when they get rain, but the rainfall is the problem. There is a big difference here between the photographs, but it is because of the rainfall (Interview with Paultjie Saal with reference to Figure 6, January, 2006).

While claiming that the land has changed very little in their life-time, farmers often referred to the rain as a driving force in vegetation cover. Although rainfall figures do not indicate a decrease in long-term rainfall (Hoffman *et al*., 2009), this quote may support the notion that the vegetation in the area responds closely to rainfall. We have discounted the effects of long-term rainfall patterns from our analysis. Rainfall data from Springbok reveals a significant point of change around 1925 when precipitation declined from the previous 50 years (Hoffman, unpublished data), however, the long-term rainfall trend has in fact increased slightly since then (see Figure 10). The trendline for Steinkopf, the nearest long-term weather station to the north of the Concordia study sites, is flat since 1900.

Bloubank

The communal farm of Bloubank (Figures 3 and 4) was leased by Piet Cloete's father in the 1940s. It is likely that the farm had been abandoned by the previous lease-holder as a consequence of the droughts in the 1930s, when many farmers emigrated to find work in the mines or in other towns. The area depicted by the photographs was previously more heavily populated, but as neighbours died or for some reason stopped farming, Cloete assimilated these areas and today the farm is about 300 hectares making it one of the biggest in Concordia. The repeat ground photographs from Bloubank farm (Figures 3 and 4) reveal very few changes between 1939 and 2005. The repeat photographs tell a story of a stable environment, where the vegetation has changed only slightly. This is confirmed by the aerial photographs from the same area, which also show few changes throughout their sequence spanning 45 years.

Figure 3: Bloubank Farm looking west. The area is fenced at the perimeters, and internally into small camps. Apart from the few months during high rainfall years when annuals are abundant, this landscape provides very little in the way of grazing potential. The region at the foot of the right koppie (A) is a mobile dune of wind blown sand and has no agricultural value. Area B was cropped until 1996 and as a result the foreground is composed entirely of annuals, such as unpalatable *Tribulus pterophorus* (10%) with no perennials (total cover = 11%). The midground (B2) has not been ploughed since 1996 and is dominated by *Cladoraphus spinosa* (15%) and *Stipagrostis ciliata* (2%) that has expanded somewhat since 1939 and T. pterophorus (4%). *S. ciliata* tufts have been heavily grazed but have responded to recent rains – a few flower heads are in evidence. Total cover = 22 % (Original photo by Hans Herre, September 1939; repeat photo by Rohde and Hoffman 23 March 2005.)

Cloete remarked: “In the old days, part of this area (Figure 3) was full of bushes. The farmers removed the bushes to make kraals and use for firewood in the 30’s and 40’s.” In the years following the removal of the bushes, Cloete and his father ploughed the left two thirds of the foreground (B), sowing oats, wheat and rye. It has been ploughed more or less continuously for as long as Cloete can remember, until he stopped in 1996. Only some parts were ploughed in any one season, and then new parts would be ploughed next season. This area is dominated by annuals such as *Tribulis pterophorus*, an agriculturally useless (even toxic) ‘pioneer species’, which thrives on disturbed ground, indicating that the area has either been cultivated or grazed for a protracted period of time. The dune at the foot of the koppie (A) has never been ploughed as it is considered too windy by the farmers.

Figure 4: Looking east from a site 0.8 km south of previous site. The site has never been ploughed but has been fenced into camps. Today it is dominated by annuals, and few perennials are present.

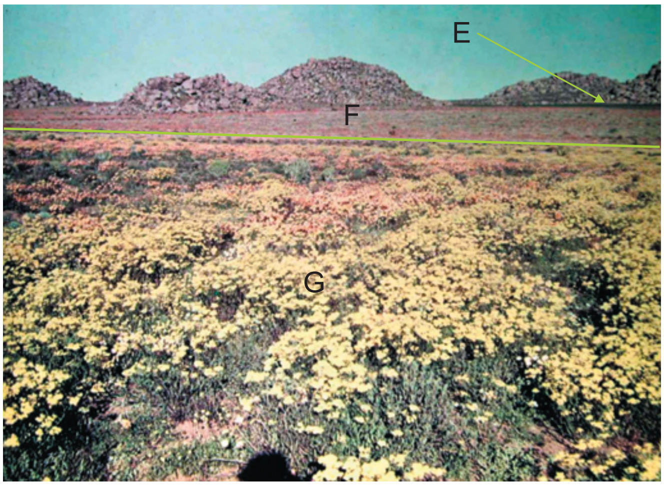
Foreground (C) is dominated by annuals such as *Tribulis pterophorus* (5%). Total cover = 15%. Mid-ground (D) now has a number of *S. ciliata* tufts (basal cover 5-10%). Distant pediment (D1) is dominated by *Cladoraphus spinosa* on sand dunes. (Original photo by Hans Herre, September 1939; repeat photo by Hoffman and Rohde 23 March 2005.)

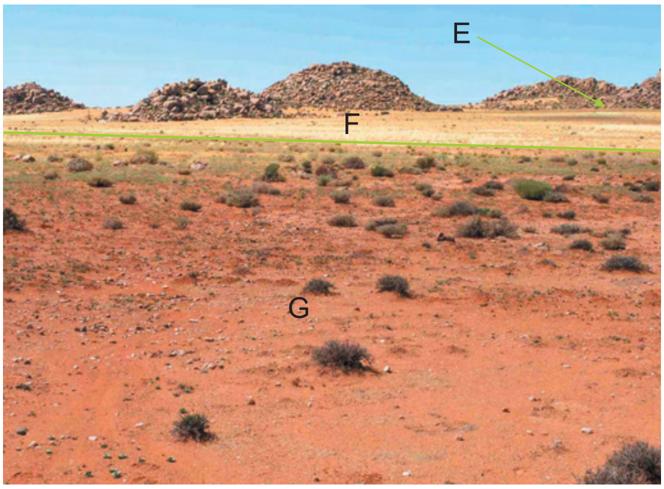
The second set of repeat images from Bloubank were taken less than a kilometre from the location of Figure 3, looking in the opposite direction (east). Piet Cloete remarked that only the upper part in the photo had been ploughed (D1), whereas the foreground (C and D) has not. This corresponds with the evidence from the repeat aerial photographs. The vegetation in the background (D1) has changed from what may have been palatable *Ruschia* spp. in 1939 to barer ground with areas of *Stipograstis ciliata* and *Cladoraphus spinosa* in 2005. Evidence from this site indicates that a combination of cultivation and high grazing pressure favours annuals and that intermittent cultivation makes the regeneration of perennials impossible.

The communal farms of Vriesklip North and South

Figures 5, 6 and 7 depict the two adjacent farms of Vriesklip North and Vriesklip South viewed from the main track north from Concordia village. These farms belong to two cousins whose common grandfather was a relatively wealthy farmer at the beginning of the 20th century and who managed an area that comprises at least six farms today. At that time ‘the whole area from Springbok to the Bushmanland’ (i.e. the whole of Concordia and O'Okiep) was divided between five large extended families. Their grandfather had thousands of sheep, and the family stayed on the farm all year round. At that time cows were kept in the communal grazing area to the north of the leased farmlands and there were hardly any cattle at Vriesklip apart from a few milking cows. In the 1940s he subdivided his farm between his sons. One of his sons kept about three hundred sheep and twenty cattle. Up until the 1960s the sheep and the draught animals stayed on the farm all year, the cows stayed in another grazing area. Later, one of the sons (Bennie Saal's father) subdivided his farm in two between his two sons.

Figure 5: Looking east at Vriesklip North. The area adjacent to the granite koppie (E) shows standing crops in the 1939 photo, and according to the farmer was cultivated until about 1985. The other areas have never been cropped. The grey patches in the original photo (F) suggest that the original grass cover in 1939 might have been *Stipagrostis. brevifolia* interspersed with annuals. Also the presence of ungrazed *Hirpicium alienatum* (<1%) and *Tripteris sinuatum* (1%) indicates that the site has been rested in the last several years and the present grass cover shows no sign of having been grazed in 2005 *(S. ciliata = 10%; Galenia sarcophylla* = 10%; total cover = 30%). The *Euphorbia mauretanica* in left foreground (G) shows no sign of either increase or decrease. The site is heavily disturbed by mole activity, which often accompanies grazed and cultivated sites. (Original photo by Hans Herre, September 1939; repeat photo by Rohde and Hoffman 23 March 2005.)





Vriesklip North (Figure 5) is dominated by annuals today and shows little change in vegetation cover between 1939 and 2005. The flower cover in the earlier photo seems to be of annual species only, which indicates that the area has been ploughed at an earlier stage. At the base of the koppie to the right (E) there is a cultivated area with standing crops, probably wheat. Correspondingly, the farmer, Paul Saal, confirms that they ploughed the area to the foot of the rocky outcrops until the mid 1980s. From the earlier photo it appears as though areas in the middle distance (F) are dominated by the perennial grass *Stipagrostis brevifolia* whereas today *Stipagrostis ciliata* is dominant, and although it provides somewhat less cover, it is more palatable and indicates a decline in grazing pressure. Saal has fenced this land recently, and tries to protect this part to some extent, which accounts for the ungrazed grasses and perennials. The rocky area in the left foreground (G) was previously dominated by shrubby perennials whereas today only the unpalatable *Euphorbia mauritanica* is still in evidence.

The aerial photographs confirm that there have been few major changes in vegetation cover in the period between 1958 and 2003. The lack of shrubs and other vegetation in all these aerial photos as well as the testimony of Paul Saal suggest that this area had been ploughed for a long period before the first ground photo was taken in 1939. It has also been used for grazing throughout this period. The major change can be inferred to have been from a perennial shrubland on the more shallow soils and perennial grasses on the deeper sandy pediments, to an annual-dominated flora which is comprised mostly of short-lived leaf succulent members of the family Aizoaceae, grasses with a few remaining perennial grass tufts.

Figure 6: Vriesklip South, fence-line contrast showing grazed (right) and ungrazed (left) camps. Ungrazed camp: *Stipograstis ciliata* – 10% , *S. namaquensis* 15% cover; grazed camp: *S. ciliata* – <3%, *S. namaquensis* 15% cover. (Photo R. Rohde 23 March 2006)

The ploughed sandy pediment in Vriesklip South, approximately 0.8 km to the south of the site at Vriesklip North, makes an interesting case for the recruitment of annual and perennial grasses on a cultivated and grazed area (Figure 6). Today the area is dominated by *Stipagrostis ciliata, S. brevifolia and S. namaquensis.* The aerial photos show that this area was cultivated in the early 1970s and according to Bennie Saal, it was last ploughed in 1984. In the aerial photo of 1997 and 2003 we can clearly see a transformation in the ploughed area, as patches of vegetation (*Stipagrostis* spp.)

colonized the lower pediment that was ploughed more than 21 years previously. The area has changed considerably from the time of the latest aerial photograph (2003) when some cover is detectable and until March 2006 when a considerable cover of *Stipograstis* spp. is visible from satellite imagery. This latter change can be attributed to increased rainfall, as there was a drought during 2002 and 2003 and above average rainfall in the following two years.

Figure 7: Vriesklip South, looking east over drainage area of shallow, stony soil and hard substrate, bordered to north and south by granite koppies surrounded by deep sandy pediments (see Fig. 6). Vegetation in the mid-ground (H) is dominated by *Ruschia robusta* (10%) *Galenia sarcophylla* (10%) *Tripteris sinuate* (2%) *Aptosimum spinescens* (1%). Total cover = 30%.

A large part of the Vriesklip South area is situated within broad rocky drainage habitats dominated by perennial shrubs (Figure 7). The foreground of the repeat photograph is a road verge now used for the transhumance of livestock to and from the communal grazing area to the north – hence the signs of trampling loss of vegetation on the near side of the fence.

Several factors may explain the changes in Vriesklip South farm as seen in the repeat photographs. Firstly, the area has never been ploughed, although aerial photographs do show that stockposts and kraals were sited in this area during the last 50 years. The farmer, Bennie Saal, contends that the palatable perennial shrub commonly known as Perslein *(Tetragonia fruticosa)* and the palatable annual herb Gousblom (probably *Dimorthotheca sinuata*) have always been common in the area. He suggests that the condition or composition of the veld has not altered from when his father was farming. Thus there has been little or no change from a generation or two ago to what we find today. Secondly, Saal has introduced a camp system with frequent animal movements during the early spring and summer months. The vegetation in the camp seen in the middle distance area (H) was not heavily grazed in 2005 as evidenced by the good growth of palatable shrubs such as *Tripteris sinuata, Hirpicium alienatum, Hermannia cuneifolia* and *Tetragonia fruticosa.* The mid-ground *Stipagrostis namaquensis* in the ephemeral stream channel (hidden from view in mid-ground) further suggests low stocking rates, consistent with this farmer's erection of camp fences within the last five to eight years.

Despite the fact that this communal farm has been heavily grazed in the past, the diversity of palatable shrubs is relatively high. The vegetation is remarkably similar to that of the landscapes to the south, including the study site at Goegap Nature Reserve (Figure 9).

Smorgenskadu

Smorgenskadu is a private commercial sheep farm in the summer/winter rainfall transition zone approximately 28 km due east of Concordia village. The owner of Smorgenskadu, Jan Kennedy, took over the farm in 1980, and is still an active farmer. His grandfather bought the title to the farm in 1919 and at that time his well was one of the few watering points for 30 km. The original photograph (Figure 8) was taken within a kilometre of the old well where the surrounding area had been trampled by neighbouring and trekking animals daily for decades before the perimeter fences were erected in the 1940s. Subsequently, this area continued to be subjected to considerable trampling and animal movements as this was the only source of water on the farm, until new water points were drilled in the 1950s and 1960s. At about the same time, Jan Kennedy's father received support from the government to put up camp fences. This made the management of the veld a lot easier as they no longer needed herders for each flock of animals. In addition, the new watering points combined with camp fencing distributed the grazing pressure more evenly around the property allowing for a lower stocking rate within this intensively used area. The area has never been ploughed.

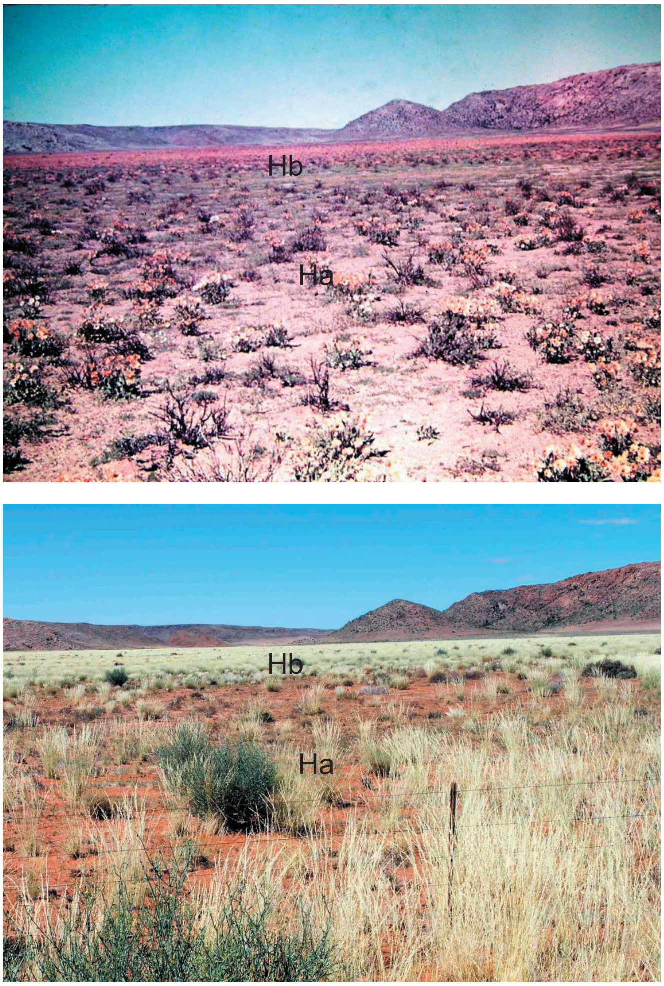


Figure 8: The private commercial farm Smorgenskadu. The shrubs in the foreground (Ha) in 1939 (probably *Ruschia robusta* or *Monechma incanum*) have been replaced with *Stipagrostic brevifolia* and *S. ciliata* interspersed with *Sisyndite spartea* (1%) and *M. incanum* (<1%). The area mid-ground in the original photo (Area Hb) showed bare ground dominated by annuals with few perennial plants. In 2005 this area has been transformed with the recruitment of *S. brevifolia* (20%), *S. obtusa* (10%) and *S. ciliata* (1%) Total cover = 35%. (Original photo by Hans Herre, September 1939; repeat photo by Rohde and Hoffman 20 March 2005.)

The photo site looks due south from a very slightly raised pediment derived from the outwash of a nearby quartzite mountain. It overlooks a shallow floodplain of somewhat finer red sandy flats and a distant granite ridge. These three substrate divisions correspond with distinct vegetation transitions. This area has changed considerably since 1963, and Jan Kennedy attributes the overall increase in grass cover in the 2005 photo to the reduced stocking rate since 1980. However, the succulent shrubs (probably *Ruschia* spp.) in the 1939 foreground (Ha) have not reappeared. Furthermore, the distinct difference in the 1939 photograph between the vegetation of the bare peneplain in the middle distance (Hb) and that of the raised pediment at the base of the ridge in the far distance is a clear reflection of differences in soil properties. The middle distance site is comprised of looser, coarser and deeper sandy soil while in the distance where the dwarf leaf succulent shrub *Ruschia muricata* dominates, the substrate is finer, harder and more compact. The most remarkable change however is the transformation from the dominance of annuals and leaf succulent perennial shrubs (probably *Ruschia robusta*) to perennial grass species on the peneplain (Hb) comprised in 2005 of *Stipagrostis brevifolia (20%), S. obtusa (10%) and S. ciliata (1%).*

Goegap

The evidence from Goegap Nature Reserve (Figure 9) is indicative of the time scales necessary for vegetation in environments dominated by succulent and deciduous perennials regain cover and species richness. The study site, which is 20 km due south of Vriesklip and Bloubank, was used for grazing until the first phase of the reserve (then Hester Malan Nature Reserve) was fenced in 1969 and turned into a conservation area. The reserve comprises an area of 14, 856 hectares and was established with the goal of protecting biodiversity (Republic of South Africa, 2005). This site was grazed by neighbouring farmers until the owners (a local copper mine) donated it to the conservation initiative. The repeat photographs show a remarkable change both in vegetation cover and species composition.

Figure 9: Goegap Nature Reserve. Since game fences were erected in 1969 there has been no livestock grazing. In the foreground (J) cover has changed increased considerably: *Ruschia robusta* (10%); *Cheiridopsis denticulata* (10%) *Tripteris sinuata* (4%), *Leipoldtia schulzei* (2%), *Hirpicium alienatum* (2%). Midground (K) is now dominated by *Galenia sarcophylla* (25%) and *Drosanthemum hispidum* (4%). Total cover of areas J and K = 35%. The apron at the base of the koppie (L) is dominated by *Leipoldtia schulzei* (10%) *G. sarcophylla* (4%) and *Ruschia robusta* (2%). (Original photo by Hans Herre, September 1939; repeat photo by Rohde and Hoffman 22 March 2005.)

In the foreground (J) the perennial, leaf succulent shrub, *Ruschia robusta* is significantly more abundant and more widely dispersed in 2005 than in 1939. Increased cover of perennial succulents and palatable non-succulent shrubs such as the palatable *Tripteris sinuata*, which are large and outgrown, indicate very low herbivory. In the mid-ground (K), the vegetation has thickened and in the middle distance (L), what seems to be old cropland has thickened and is now dominated by the annual *Galenia sarcophylla* and relatively unpalatable short-lived shrubs like *Drosthanthemum hispidum*. This trend towards more cover is supported by the aerial photographs. Such changes, after 36 years of protection, indicate the time frame necessary for a diverse, palatable mix of perennial shrubs to regenerate under conditions of livestock exclusion and very low wildlife herbivory.

Discussion

This paper is unique in that it studies the consequences of land use on vegetation over a 66 year period, within various agrarian landscapes close to the winter/summer rainfall ecotone in northern Namaqualand. Previous studies of landscape change in Namaqualand (Hoffman and Rohde 2007; Rohde and Hoffman 2008) have focused on vegetation surveys of rocky slopes and sandy bottomlands in the Kamiesberg (Todd and Hoffman 1999; Anderson and Hoffman 2007), which have strikingly different ecological character to the patchy ecotone vegetation communities in the vicinity of Concordia. The Kamiesberg experiences higher and more stable rainfall and the vegetation is dominated by succulent and non-succulent shrub species (Anderson and Hoffman, 2007). Vegetation in the Concordia region is dominated by a patchwork of grasses characteristic of sandy substrates of the Nama-karoo biome summer rainfall areas to the east, and shrublands, which tend to dominate shallow soils on rocky substrates characteristic of the Succulent Karoo biome to the west and south. In many of our study sites, species from these two biomes co-exist in a patchwork of vegetation communities largely determined by substrate conditions (Shiponeni, 2008).

This study illustrates the variety of factors that contribute to vegetation change over time. Land-use practices have not been static over the course of the 20th century - cultivation, livestock grazing and conservation have had important consequences with regard to landscape change in Namaqualand (Hoffman and Rohde, 2007). Cultivation has declined in both commercial and communal areas since 1970, especially in more marginal areas where it is no longer economically viable. The result has been the widespread re-establishment of perennial vegetation on once barren or fallow croplands. Livestock numbers have also fallen by up to 30% since 1960 reflecting a trend in stock reduction on commercial private farms (Hoffman and Rohde, 2007), whereas communal farmers have tended to maintain relatively high numbers of animals over long time periods (Benjaminsen *et al*., 2006). These changes in land-use, coupled with a highly variable climate across an ecotonal gradient, result in a variety of vegetation responses. However, underlying this complexity are common trends that relate to three ecological processes:

1) *regeneration* of vegetation cover and diversity due to cessation of cultivation, reduced stocking rates or complete protection;
2) *ecotonal shifts* due to the combined impacts of climate change and land-use that result in the transformation of shrubland to grassland;
3) *stability* of cover and composition over decadal temporal and regional spatial scales under conditions of communal land-use impacts.

There are three interrelated sets of variables, apart from land-use, that further influence these general trends:

1) climate: winter/summer rainfall;
2) substrate: shallow rocky soil or deep sandy bottomlands and pediments;
3) vegetation type: Nama-karoo (grassy shrublands) or Succulent Karoo (leaf succulent shrublands) biomes.

There is no doubt that cultivation transforms natural habitats. Change from this transformed state depends on many factors including time since the area was last ploughed, soil fertility, climate and surrounding vegetation type. Transformation after cultivation is far more rapid in grasslands than in Namaqualand's perennial shrublands, largely due to the seed dispersal mechanisms and seed bank longevity of the dominant grass species in the region. An increase in vegetation cover after prolonged heavy grazing is probably more rapid in grasslands although our findings indicate that shrublands also increase in cover more quickly than previous estimates (Dean and Milton, 1999) under near total protection. We also speculate that the transformation of the ecotonal bottomlands to the east of Concordia from shrubland to grassland has taken place as a result of the reduction in stocking rates after prolonged heavy grazing combined with a possible slight westward shift in the summer rainfall climatic zone. However, in spite of these changes and transformations, we find a significant level of stability in terms of vegetation composition and cover over larger spatial and temporal scales, especially in the communal farmlands. The following discussion provides more detail to these findings.

Cultivation and transformation - grasslands

There is little doubt that cultivation has had a marked impact on the communal landscapes of Concordia, particularly in the late 19th and early 20th centuries. Although cultivation was introduced by the missionaries of the mid-19th century, the division of the Concordia commons into leased croplands (saaipersele) was most pronounced during the early 20th century (Benjaminsen and Sjaastad 2008). Our photographs of communal croplands (Figs.3 & 5) reveal only minor changes in perennial vegetation cover in the time span from 1939 until today. This suggests that the most dramatic transformation of this area took place before 1939 and possibly more than 100 years ago when these sandy pediments, ideal for cultivation, were probably dominated by perennial grasses and Nama-karoo shrubs. Today, however, these areas have a sparse and variable cover of annual grasses, herbs and leaf succulent shrubs.

The existence of Hans Herre's photographs is almost certainly due to the fact that in October 1939 this landscape was covered in a profusion of colourful annual leaf succulents as a result of one good winter rainy season. However, during periods of increased summer rainfall, with the cessation of cultivation, these areas now show a significant increase in annual and perennial grasses in part due to the long-lived seed banks of grasses particularly within the genus *Stipagrostis* (Skinner,

1964) and their ability to disperse over large distances. This trend indicates that the area has not lost its ability to transform or regenerate to grassland under the right circumstances even after a century of cultivation and grazing.

Cultivation and transformation – shrublands

Apart from one area in the Goegab site (Figure 9), this study did not incorporate any cultivated shrublands. From aerial photographic evidence coupled to the repeat ground photographs of the Goegab site, it is likely that a cropland was in use here before and after 1939 (Figure 9, mid-ground). By 2005 this area had been colonised by the annual *Galenia sarcophylla* and relatively unpalatable perennial shrubs like *Drosthanthemum hispidum*. These species are considered indicators of previous cultivation or heavy disturbance and their presence in this protected area after 40 years is a demonstration of the long time scales necessary to overcome the impact of ploughing on soil structure and fertility (Allsopp, 1999).

Grazing and transformation – grasslands

In areas with no history of cultivation, where we can compare the response of grasslands to different management regimes, we find a direct correlation between the histories of stocking rates, rainfall and grass cover. This can be observed when we compare change over time at the same site (Figure 5), when we compare camps within the communal area (Figure 6) and when we compare the communal and commercial grazing sites (Figure 5 and Figure 8). Although we are unable to distinguish the relative influence of climate and rainfall on observed changes in grasslands, we can show that both factors are instrumental. The high coefficient of variation of rainfall, coupled with different stocking regimes results in varying degrees of response by grasses in the sandy pediments and plains of the communal and commercial farms.

Grazing and transformation- shrublands

Recent analysis of Succulent Karoo biome vegetation communities in Namaqualand suggests that heavy grazing over periods of several decades influences plant species composition resulting in a reduction of palatable perennials, an increase in annual species and a reduction in cover (Anderson and Hoffman, 2007). When we compare the photos of shrublands in communal areas (Figure 7) with those in a protected area (Figure 9), we find that a previously heavily-grazed area, where livestock have been excluded for 36 years, displays a remarkable increase in vegetation cover and species composition. There can be no doubt that the area in question was heavily used in 1939 and the vegetation survey carried out in 2005 shows that species typical of the ecotonal transition between the Namaqualand Rocky Hills and Bushmanland have reappeared. Meanwhile, the communal shrubland of Vriesklip South, under heavy stocking rates over a long time-frame retains the basic species composition typical of this vegetation community, although it has relatively less overall cover and perennial species diversity compared to the Goegab site.

Grazing land and ecotonal change

The temporal scale associated with the regeneration of the Goegab shrublands is similar to what we observe in the grasslands to the east. Here, ecotonal change is related to land-use impacts and changing patterns of summer rainfall over similar time scales. The reduction of perennial shrubs in the foreground of Figure 8 on the commercial farm of Smorgenskadu took place up until about 1960 when *Ruschia robusta* and possibly *Monechma spp*. were trampled and grazed almost to extinction by livestock. Subsequent to fencing and reduced stocking rates over the last 50 years this slightly raised outwash which previously supported succulent and deciduous shrubs is now dominated by palatable grasses, although there are also many new recruits of *Sisyndite spartea*, a highly palatable shrub. This change in species composition can only be explained in conjunction with an increase in the summer rainfall as reflected in the records of the nearest summer rainfall weather stations. These show a significant increase in precipitation during the second half of the 20th century (MacKellar *et al.*, 2007). The shift in vegetation type from shrubs to grasses in Smorgenskadu is a dramatic illustration of the transformations which can take place in ecotonal landscapes due to slight shifts in climatic patterns combined with rest from grazing (Pogue and Schnell, 2001).

Stability, change and scale

The story of landscape change in Namaqualand indicates that a major decline in vegetation cover and species composition in the communal areas took place before 1939, and since then has remained remarkably stable. Such stability may be interpreted in different ways. On the basis of our findings we suggest that the communal farming areas we have analyzed are in a stable state, and neither vegetation cover nor composition has changed significantly since 1939. We hypothesise that this landscape represents a classic case of 'state and transition' (Milton and Hoffman, 1994), with the transition having taken place over 100 years ago and stability in vegetation cover and composition maintained since then.

Within short time-frames (less than 10 years), vegetation cover follows climatic variations as do livestock numbers (Benjaminsen *et al.,* 2006), due to the opportunistic management of the farmers in Concordia, in common with communal farmers elsewhere in Namaqualand (Berzborn, 2007; Hoffman and Rohde, 2007; Rohde and Hoffman, 2008). Despite these fluctuations, livestock numbers in Concordia show that secondary productivity has been sustained from the 1920s until today, suggesting that communal livestock keepers are not experiencing deterioration of their resource base, although they are more at risk of stock losses during periods of drought than their commercial counterparts who practice conservative stocking rates (Gillson and Hoffman, 2007; Richardson *et al.,* 2005).

The inherent limitations to repeat ground photographs are that they provide only a small sample of the regional landscape. Our analysis offset this limitation to some extent through the use of repeat aerial photos of the region. These confirm what we see on the ground: the rocky unploughed areas have maintained a permanent population density of perennial shrubs while the sandy pediments have remained subject to short-term climatic fluctuations resulting in either lush displays of annual flowers in the early spring, or sparse annual and perennial grasses *(Stipagrostis spp)* in the summer.

At the Goegab Nature Reserve we find a classic example of Clementian succession (Tainton and Hardy, 1999) following intensive agricultural activity and rest. We show that the change in a predominantly Succulent Karoo biome vegetation community, from a highly impacted state to one that reflects the area's biophysical potential for species diversity and cover, was achieved within thirty years. At the opposite extreme, within less than 30 km to the east of Concordia and Goegab, we find an example of a threshold mechanism in a non-equilibrium environment (Gillson and Hoffman, 2007), driven by ecotonal forces of summer and winter rainfall variations coupled with land-use pressures that gives a competitive edge to either shrubs or grasses.

Conclusion

We believe that this paper presents compelling evidence of the complex impacts of land-use and climate across the Namaqualand/ Bushmanland ecotone. One of the most important insights into the environmental history of the area concerns the long-term stability of the communal farming landscapes of Concordia. Also, the fact that these so-called degraded communal areas still show a potential to transform to a vegetation state that includes greater cover and more diversity is highly significant. Finally, the highly variable patterns of change and stability described above – the interlocking elements of soils, climate and vegetation type coupled with land-use – are perhaps best described as 'complex dynamics' where the idea from chaos theory of a 'moving attractor' provides the best theoretical model for the evidence we find in our repeat photographs (Gillson and Hoffman, 2009). Computer simulations of these variables within this environment predict similar outcomes (Hahn *et al.*, 2005). The evidence presented here comprises empirical support for these theoretical simulations. Such evidence-based environmental history research is able to provide the temporal and spatial scale necessary to understanding the complex relationship between humans and their environments.

ENDNOTES

[1] These photographs are part of a collection of over 200 repeat images of Namaqualand now in the collection of the Plant Conservation Unit at the University of Cape Town. See Hoffman and Rohde 2007; Rohde & Hoffman 2008 for more details and an overall analysis of land-use and land-cover change in Namaqualand during the 20th century.

[2] Interview with Bennie Saal, March 15 2006.

[3] Interview with Kennedy in the neighbouring farm, February 2006.

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