Journal of Southern African Studies
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/cjss20

Changing Patterns of Rural Land Use and Land Cover in South Africa and their Implications for Land Reform

M. Timm Hoffman[a]
[a] University of Cape Town
Published online: 31 Jul 2014.

To cite this article: M. Timm Hoffman (2014) Changing Patterns of Rural Land Use and Land Cover in South Africa and their Implications for Land Reform, Journal of Southern African Studies, 40:4, 707-725, DOI: 10.1080/03057070.2014.943525

To link to this article: http://dx.doi.org/10.1080/03057070.2014.943525

Journal of Southern African Studies, 2014
Vol. 40, No. 4, 707–725, http://dx.doi.org/10.1080/03057070.2014.943525

*Changing Patterns of Rural Land Use and Land Cover in South Africa and their Implications for Land Reform**

M. Timm Hoffman
(University of Cape Town)

Land use and land cover have changed significantly in South Africa since the 1913 Natives Land Act, in response to a wide range of political, social, cultural and environmental influences. This review examines the response of the vegetation of three biomes to these changing patterns. Vegetation change over the last 100 years is described along an aridity gradient from the arid Succulent Karoo biome in the west, across the wide expanses of the semi-arid, central Nama-Karoo biome, to the mesic Savanna biome on the east coast of South Africa. While Namaqualand has been relatively stable or has even improved in vegetation cover and composition, the Little Karoo is considered severely degraded, with a significant loss of ecological integrity. The Nama-Karoo biome has experienced a significant increase in grassiness since the 1960s in response to decreasing livestock numbers and changed rainfall seasonality. Bush encroachment has occurred over much of the Savanna biome, although this process has a long history in the region. Invasive alien plants pose an increasingly serious threat to the Savanna biome. The main implications of these findings for the land reform programme are that land use has important effects on the vegetation of South Africa, that the state has an important role to play in maintaining the proper functioning of ecosystems,,and that some degree of planning for future climate and land cover change is critical within the land reform process.

A Divided Past

South Africa's interrelated political, social, cultural and natural environments have all changed fundamentally since the Natives Land Act of 1913. Any review of land use and land cover change, therefore, cannot be considered in isolation. Such an assessment needs to be contextualised within the political history of the country, with its successive colonial and apartheid governments who divided the land into separate areas of very different sizes reserved for different race groups. The former black 'bantustan' or homeland areas under communal tenure possess a fundamentally different environmental history from the state-owned conservation areas and white-owned farmland under freehold tenure which surround the former homelands. The communally managed areas, which have had different population pressures, cultivation practices, stocking densities, resource uses, tenure arrangements and levels of state support in relation to the neighbouring state- or privately owned areas, have consequently exhibited a different trajectory of environmental change over the last

*Many colleagues have contributed to the understandings conveyed in this paper, particularly Rick Rohde, Ben Cousins, Cherryl Walker, Mmoto Masubelele, James Puttick and Sam Jack. Field work was undertaken with the support of the Mazda Wildlife Fund.

100 years.[1] While there are exceptions to the general view,[2] the perceptions of many natural resource managers, agricultural extension advisers and researchers are that the communal areas differ significantly from private farms in terms of the cover and composition of the vegetation and the ecosystem services that they provide both on- and off-site.[3] Several studies have also shown that environmental conditions within communal areas continue to deteriorate as a result of demographic and economic pressures, over-use, land abandonment and poor state support for land users, amongst a host of other causes.[4] It is within this broader political and social context that interpretations of environmental change should take place.

While much has been written about South Africa's political past, far less is known of the country's environmental history, particularly how South African landscapes have changed over the course of the twentieth century in response to important climatic and land use influences. This review is an attempt to fill some of this gap. It describes the pattern of change in the vegetation of different regions of the country over the last 100 years in relation to the key drivers of change. These include the main land-use impacts that have occurred over time, primarily through activities such as the cultivation of crops, the grazing of livestock, fire, and alien plant invasions. Additional influences include several climatic variables, such as rainfall, temperature and atmospheric carbon dioxide concentrations, which have also changed considerably since the early twentieth century, with important consequences for the vegetation of South Africa. Understanding the interrelatedness of such factors is important, especially for management. It is difficult to determine in practice, however, particularly at a landscape or regional scale and over long periods.

The implications of past environmental change for the land reform programme are discussed in the final section. How the land has been used in the past and at what intensity has a critical effect on vegetation cover and composition and on other ecological aspects of the environment (e.g. soil and water movement). This in turn affects the current production potential of the land and the services it provides for both on- and off-site communities. In addition, the critical lessons learnt since the 1913 Natives Land Act, in terms of how the state can be an agent of both positive and negative outcomes for the environment, should also inform current land reform initiatives and direct government's efforts. Finally, past trajectories of environmental change suggest the likely direction of future changes. Such insights should also form part of the land-reform planning process, for instance, by cautioning against certain types of land use, settlement patterns or stocking densities, or by calling for particular forms of government support mechanisms which have proved effective in the past. The climate in some regions of the country is also predicted to change significantly in the next 50 years, with important consequences for the environment and its ability to supply key services.[5] Critical

1 M.T. Hoffman and A. Ashwell, *Nature Divided: Land Degradation in South Africa* (Cape Town, UCT Press, 2001).

2 C.M. Shackleton, 'Are the Communal Areas in Need of Saving?', *Development Southern Africa*, 10, 1 (1993), pp. 65–78.; A.R. Palmer and J.E. Bennett, 'Degradation of Communal Lands in South Africa: Towards an Improved Understanding to Inform Policy', *African Journal of Range and Forage Science*, 30, 1 & 2 (July 2013), pp. 57–64.

3 M.T. Hoffman and S.W. Todd, 'A National Review of Land Degradation in South Africa: The Influence of Biophysical and Socio-Economic Factors', *Journal of Southern African Studies*, 26, 4 (December 2000), pp. 743–58.; K.J. Wessels, S.D. Prince, P.E. Frost and D. van Zyl, 'Assessing the Effects of Human-Induced Land Degradation in the Former Homelands of Northern South Africa with a 1 Km AVHRR NDVI Time-Series', *Remote Sensing of Environment*, 91, 1 (July 2004), pp. 47–67.

4 V. Kakembo and K.M. Rowntree, 'The Relationship Between Land Use and Soil Erosion in the Communal Lands near Peddie Town, Eastern Cape, South Africa', *Land Degradation and Development*, 14, 1 (January–February 2003), pp. 39–49; M. Giannecchini, W. Twine and C. Vogel, 'Land-Cover Change and Human–Environment Interactions in a Rural Cultural Landscape in South Africa', *The Geographical Journal*, 123, 1 (March 2007), pp. 26–42; K.L. Coetzer, B.F.N Erasmus, E.T.F. Witkowski and B. Reyers, 'The Race for Space: Tracking Land-Cover Transformation in a Socio-Ecological Landscape, South Africa', *Environmental Management*, 52, 3 (September 2013), pp. 595–611.

5 C.L. Davis, *Climate Risk and Vulnerability: A Handbook for Southern Africa* (Pretoria, Council for Scientific and Industrial Research, 2011).

awareness of both past trajectories and future scenarios will enhance the ability of land users and the state to respond to the challenge of land reform under a changing climate.

Environmental Change in South Africa over the Last 100 Years

What did South African landscapes look like in terms of the dominant vegetation at the time of the 1913 Natives Land Act? Which parts of the country have changed the most and why? How have changing land-use practices affected what we see in the landscape today? While these are all critical questions for the development of a comprehensive environmental history of the country, there is a general paucity of information on the subject, particularly at the spatial (national) and temporal (century) scales of interest. However, the few local and regional studies that have been undertaken suggest that the nature, extent and rate of change have not been the same for all parts of the country. What follows is a description of the major changes within the agriculturally important biomes of South Africa (the Succulent Karoo, Nama-Karoo, Grassland and Savanna biomes), arranged along an aridity gradient from the arid western part of the country to the more mesic eastern seaboard (see Figure 1). A biome is a large, relatively homogeneous area defined primarily by the major growth forms (e.g. trees, grasses, shrubs) within it and secondarily by the climate of the area.[6] The biome concept provides an important organising principle through which South Africa's rich and dynamic environments have been interpreted for decades.

The biomes discussed here differ not only in their climatic and biological environments but also have very different socio-political histories. For example, it is primarily in the Grassland and Savanna biomes of the more mesic and productive eastern parts of South Africa that the 1913 Natives Land Act and subsequent apartheid legislation had direct and immediate consequences for smallholder and sharecropper African farmers living in communal areas or on white-owned commercial farms at the time.[7] In contrast, the environments of the Nama-Karoo biome, in the arid interior of South Africa, and those of the Little Karoo, which forms part of the Succulent Karoo biome in the south, were almost exclusively under freehold tenure (held by white landowners) and were used primarily for commercial agriculture. Namaqualand, however, which forms part of the Succulent Karoo biome of the semi-arid western part of the country, comprised predominantly white-owned farms held under freehold tenure. About 25 per cent of the land here was set aside for people of mixed-race descent and managed under communal land tenure. These communal areas were, however, governed by a different set of laws from the 1913 Natives Land Act.[8]

Early Colonial Impacts on the Vegetation of the Succulent Karoo Biome

As its name suggests, this biome is dominated by low, succulent-leaved shrubs. From a biological perspective it is considered to be the richest desert in the world, because of the large number of species, particularly of plants and insects.[9] It is characterised by a relatively low (50–250 mm) but reliable annual rainfall, which falls predominantly in the winter

6 L. Mucina and M.C. Rutherford, *The Biomes of South Africa, Lesotho and Swaziland* (Pretoria, South African National Biodiversity Institute, 2006).
7 C. van Onselen, *The Seed is Mine. The Life of Kas Maine, a South African Sharecropper 1894–1985* (Cape Town, David Philip, 1996).
8 The most important laws to affect the communal areas of Namaqualand were the Communal Reserves and Mission Stations Act of 1909 and the Coloured Rural Areas Act of 1963.
9 D.A. Snijman, *Plants of the Greater Cape Floristic Region Volume 2: The Extra Cape Flora* (Pretoria, South African National Biodiversity Institute, 2013).

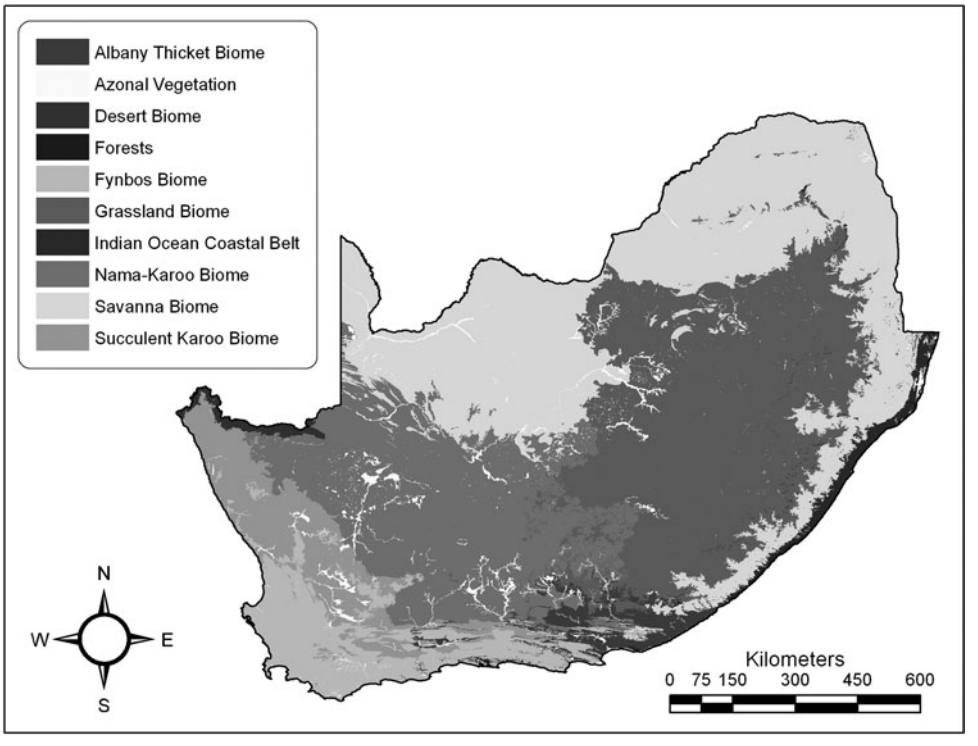

Figure 1. The biomes of South Africa.

months.[10] The environmental history of two large areas within the biome will be discussed separately. These are Namaqualand, located in the north-western part of South Africa, and the Little Karoo, situated between the two large Cape Fold mountain ranges in the southern part of the country.

Environmental changes in Namaqualand have been contextualised within three broad overlapping phases: pastoral, colonial and post-agrarian.[11] The first, pastoral phase, from about 2,000 years ago to the late eighteenth century, was characterised by low densities of Nama-speaking pastoralists who moved over large distances with their domesticated livestock, across areas that had previously been occupied by people with hunter-gatherer lifestyles. The second, colonial phase, from the late eighteenth century to around the mid-twentieth century, witnessed the steady rise, first of subsistence and later of commercial agriculture, accompanied by crop-cultivation and large herds of sheep and goats. This phase was also accompanied by the large-scale dispossession of the original inhabitants of their land and their confinement to six main communal areas in the region.[12] These compose about 25 per cent of the area of Namaqualand but support 45 per cent of the population. The more recent post-agrarian phase, which is associated with the demise of commercial agriculture, started from about the middle of the twentieth century and continued after the 1994 transition to a democratically elected government in South Africa. This phase has been accompanied by

10 P.G. Desmet, 'Namaqualand: A Brief Overview of the Physical and Floristic Environment', *Journal of Arid Environments*, 70, 4 (September 2007), pp. 570–87.

11 M.T. Hoffman and R.F. Rohde, 'From Pastoralism to Tourism: The Historical Impact of Changing Land Use Practices in Namaqualand', *Journal of Arid Environments*, 70, 4 (September 2007), pp. 641–58.

12 The main communal areas are Leliefontein, Komaggas, Concordia, Steinkopf, Pella and Richtersveld.

a decline in cultivated area and animal densities, particularly on privately owned farms, and by a general depopulation of the rural areas as the size of freehold farms has increased and the owners of smaller farms have moved to cities in pursuit of better opportunities, including education for their children. After 1994, there has also been an emphasis on land reform and the creation of commercially based agricultural opportunities for former inhabitants of the communal areas of Namaqualand.[13] The collapse of the mining industry and the expansion of protected areas and tourism also form part of this more recent phase.

While the socio-political context for each of these phases influenced settlement patterns and land use practices in both the privately owned and communally managed areas, their impacts need to be assessed separately for the three dominant land forms which characterise Namaqualand. These are the rocky uplands, the relatively flat or undulating lowland environments, and the riverine habitats of the many ephemeral rivers and streams which run from the inland mountains to the coast in the west. Evidence from nearly 300 historical photographs, the majority of which date from the first part of the twentieth century, shows that Namaqualand's rocky uplands have been relatively well buffered from the impacts of both communal and commercial agricultural practices.[14] Because of the rockiness of this land form, little cultivation has been possible. While goats do utilise the uplands, particularly in times of drought, rocky upland environments are not as heavily grazed as the lowlands, even in the communally managed areas.[15] Detailed field assessments across fence lines between privately owned farms and communally managed areas support this finding. While some impact of heavy stocking in the communally managed areas is evident, particularly in terms of the overall cover of vegetation as well as the relative cover of perennial grass species, there is no significant difference in cover of all other growth forms (e.g. annuals, bulbs, shrubs and trees).[16]

It is within the lowland environments of Namaqualand where the greatest changes have occurred, particularly as a result of the impact of cultivation, the location of stock posts and the associated effects of grazing and stock trampling. However, these impacts have not been consistently applied over the last 100 years. Data from the agricultural census records undertaken at irregular intervals between 1911 and 1993 indicate that the number of hectares under cultivation in Namaqualand peaked in the 1970s and declined thereafter, while the number of livestock was greatest in 1957 and has also subsequently decreased.[17] On the privately owned farms, the abandonment of cultivation, particularly in marginal environments, is everywhere accompanied by the demise of spring flowering displays as a result of the widespread recolonisation of old fields by early successional perennial species such as *Lebeckia sericea* (Bloufluitjiesbos) and *Galenia africana* (Kraalbos). The reduction in livestock, particularly of goats on the privately owned farms, has also resulted in a visible increase in the height of dominant species in repeat ground photographs and an increase in vegetation cover in the latter part of the twentieth century. This appears to have continued into the first decade of the twenty-first century. Evidence for this comes from a remotely

13 H. May and E. Lahiff, 'Land Reform in Namaqualand, 1994–2005: A Review', *Journal of Arid Environments*, 70, 4 (September 2007), pp. 782–98.

14 Hoffman and Rohde, 'From Pastoralism to Tourism'. While care has been taken to match the repeat photograph in terms of season, this has not always been possible. However, the vegetation of the Succulent Karoo biomes is largely perennial and evergreen and interpretations of the changes are not significantly compromised by differences in the timing of when the photographs were taken.

15 M.I. Samuels, N. Allsopp and R.S. Knight, 'Patterns of Resource Use by Livestock During and After Drought on the Commons of Namaqualand, South Africa', *Journal of Arid Environments*, 70, 4 (September 2007), pp. 728–739.

16 P.M.L. Anderson and M.T. Hoffman, 'The Impacts of Sustained Heavy Grazing on Plant Diversity and Composition in Lowland and Upland Habitats Across the Kamiesberg Mountain Range in the Succulent Karoo, South Africa', *Journal of Arid Environments*, 70, 4 (September 2007), pp. 686–700.

17 Hoffman and Rohde, 'From Pastoralism to Tourism'.

sensed, time series analysis of vegetation productivity in the Kamiesberg region between 2000 and 2011,which shows an improvement in conditions for this area. Changes are interpreted as being the result of the abandonment of agricultural fields in both privately owned and communally managed areas.[18]

Despite the reduction in cultivation in the communal lands of Namaqualand, these areas have remained relatively heavily impacted over the course of the twentieth century. These impacts, primarily the result of heavy stocking, were, however, already apparent in the early twentieth century (see Figure 2).[19] While they have increased in some areas, such as around Kubus in the Richtersveld, where vegetation cover has declined alarmingly in some places since the mid twentieth century, this is not universally the case. Detailed long-term surveys from some locations, such as around Paulshoek on the eastern slopes of the Kamiesberg, suggest that the decades-long impact of high stocking rates on the cover and composition of key forage species appears to have stabilised.[20] Palatable perennial shrubs have even germinated and grown up at some sites, despite the continued grazing pressure from large numbers of goats, sheep and donkeys. The provision of electricity after 1994 to nearly all households in the communal areas of Namaqualand has reduced significantly the reliance on fuelwood collected from the veld. This reduction in fuelwood demand has also undoubtedly facilitated the recruitment of shrubs under the canopies of nurse plants which would otherwise have been removed for fuelwood purposes.[21]

The riparian vegetation and adjacent floodplains of Namaqualand have experienced a general increase in cover over the last 100 years, as evidenced by an analysis of 32 sites which used repeat photographs covering a time span of 36–113 years.[22] The widespread woody species, *Acacia karroo* (Sweet thorn), has increased considerably along ephemeral rivers and streams, primarily in response to a decline in its use for firewood and construction purposes, a reduction in livestock densities, particularly on privately owned farms, and a decrease in the number of large-scale erosional events which occurred in the region during the centuries prior to when the first photographs of the riverine habitats were taken.[23] While the invasion of *Prosopis* spp. appears not to have occurred yet over large areas of Namaqualand,[24] it remains a persistent threat to the ephemeral rivers of the region.

The same topography-related pattern of environmental change described for Namaqualand has occurred in the Little Karoo region of the Succulent Karoo biome. However, unlike the Namaqualand regions of the Succulent Karoo biome, almost all of the Little Karoo is under freehold tenure and used for commercial farming. Communal land tenure has been absent from the Little Karoo for nearly all of the twentieth century. In recent decades, large areas have been set aside for conservation, both by the state and by private

18 C.L. Davis, 'Trends in Vegetation Productivity and Seasonality for Namaqualand, South Africa between 1986 and 2011: An Approach Combining Remote Sensing and Repeat Photography' (MSc dissertation, University of Cape Town, 2013).

19 R.F. Rohde and M.T. Hoffman, 'One Hundred Years of Separation: The Historical Ecology of a South African "Coloured Reserve"', *Africa*, 78, 2 (May 2008), pp. 189–222.

20 S.W. Todd and M.T. Hoffman, 'A Fence Line in Time Demonstrates Grazing-Induced Vegetation Shifts and Dynamics in the Semiarid Succulent Karoo', *Ecological Applications*, 19, 7 (October 2009), pp. 1897–1908.

21 A.M. Solomon, 'The Use and Valuation of Natural Fuelwood Resources in Paulshoek, Namaqualand and the Ecological Impacts on Rangeland Dynamics', (MSc dissertation, University of Cape Town, 2000).

22 M.T. Hoffman and R.F Rohde, 'Rivers Through Time: Historical Changes in the Riparian Vegetation in the Semi-Arid, Winter Rainfall Region of South Africa in Response to Climate and Land Use', *Journal of the History of Biology*, 44, 1 (February 2011), pp. 59–80.

23 G. Benito, V.R. Thorndycraft, M.T. Rico, Y. Sánchez-Moya, A. Sopeña, B.A. Botero, M.J. Machado, M. Davis and A. Pérez-González, 'Hydrological Response of a Dryland Ephemeral River to South African Climatic Variability During the Last Millennium', *Quaternary Research*, 75, 3 (May 2011), pp. 471–82.

24 E.C. van den Berg, 'Detection, Quantification and Monitoring Prosopis spp. in the Northern Cape Province of South Africa Using Remote Sensing and GIS', (MSc dissertation, North-West University, 2010).

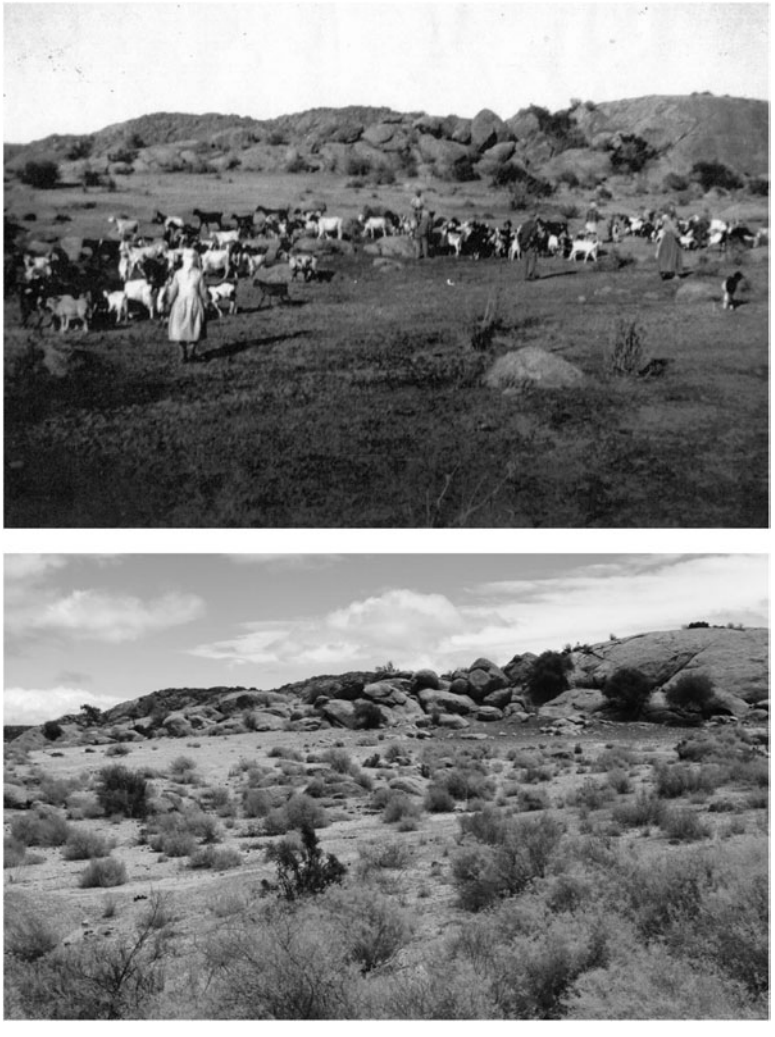

Figure 2. The original photograph, taken in 1937, of a stockpost in the communal area of Paulshoek, Namaqualand, shows a landscape that had already been heavily impacted by large numbers of animals. Even though this site has been occupied continuously for nearly 70 years, the repeat photograph, taken in 2014, shows an increase in height of the dominant shrub, *Galenia africana*, in the foreground, and of the main fuelwood species, *Searsia burchelli*, among the background rocks. [No. 126. Bloubeard se Hoek, Paulshoek. S 30.37436, E 18.23439, 1028 m. Original photograph taken by A. Andrews in 1937; repeat by M.T. Hoffman on 7 January 2014.]

landowners. Because of the low-nutrient soils of the surrounding mountains, the rockiness of the substrate and the poor quality *fynbos* vegetation which dominates large portions of the uplands, this land form has been well buffered from the impacts of livestock grazing. Other vegetation types, such as the Succulent Karoo and Thicket Mosaic, which also occur on rocky upland and footslope habitats, have only been lightly impacted by domestic livestock (see Figure 3). The pediment and bottomland habitats of the lowlands, however, have been significantly transformed by a combination of cultivation and livestock, especially ostrich farming. Estimates for the Little Karoo are that only 9 per cent of its natural vegetation may be considered as intact, with the remaining natural habitat degraded to some extent. Nearly a quarter (24 per cent) of the area is so severely degraded that active restoration is

Figure 3. Many of the rocky valley pediments and valleys of the privately owned farms of the Little Karoo have remained relatively stable in terms of vegetation cover and composition for most of the twentieth century, as seen in this pair of photographs taken just south of the Touwsberg near Ladismith. [No. 55. South of Touwsberg. S 33.58306, E 20.87433, 422 m. Original photograph taken by I.B. Pole Evans on 23 May 1919; the repeat by M.T. Hoffman on 24 May 1993.]

considered necessary to return these environments to some acceptable level of ecological functionality.[25]

As in the case of Namaqualand, much of the impact of land use on Little Karoo environments occurred during the late nineteenth and first half of the twentieth centuries. Agricultural census records for the five main magisterial districts of the Little Karoo (Montagu, Ladismith, Calitzdorp, Oudtshoorn and Uniondale) show, for example, that much of the roughly 70,000 hectares (ha) that are used for cultivation today had already been cleared and

25 M. Thompson, J. Vlok, M. Rouget, M.T. Hoffman, A. Balmford and R.M. Cowling, 'Mapping Grazing-Induced Degradation in a Semi-Arid Environment: A Rapid and Cost-Effective Approach for Assessment and Monitoring', *Environmental Management* 43, 4 (April 2009), pp. 585–96.

planted by 1910. Stocking rates, too, were far higher in the past than they are today. Census data confirms that goat numbers have decreased by more than 50 per cent over the course of the twentieth century, while sheep numbers peaked in the 1960s and have declined by about a third since then. While ostrich numbers have fluctuated over the last 100 years, they were highest in the first two decades of the twentieth century, when they approached nearly 800,000 birds at the height of the ostrich boom in 1914. After the collapse of this industry during the First World War, ostriches became a relatively minor component of the agricultural landscape of the Little Karoo until the late 1970s, when their numbers started to increase again, reaching over 300,000 birds in the mid 1990s. Regular outbreaks of bird flu have plagued this industry over the last two decades, and the culling of animals has kept bird numbers at these levels. Overall, however, stocking rates have declined by more than 40 per cent in the Little Karoo over the last 100 years, from nearly 7.5 Large Stock Unit (LSU) equivalents per km^2 at the end of the nineteenth century to just over 4 LSU per km^2 in 1995.[26]

The riverine environments of the Little Karoo have been far more heavily impacted than those of Namaqualand. The original riparian vegetation has been removed and replaced by irrigated croplands. This has affected the flow rates, nutrient and organic contents and sediment levels of the rivers in the region. There has also been widespread invasion of alien plants such as *Populus* spp. (Poplar), *Nerium oleander* (Oleander) and *Arundo donax* (Spanish reed). A recent assessment of the integrity of landscape-level hydrological processes in the Little Karoo suggests that more than half of the lower reaches of the river floodplains are severely degraded as a result of historical land-use impacts. The costs of rehabilitation are also considered prohibitive, particularly in the short term.[27]

An Increasingly Grassy Nama-Karoo Biome

For the first half of the twentieth century, agricultural officials considered the north-eastwards expansion of the dwarf shrublands of the Nama-Karoo biome into the perennial grasslands of the white-owned farms of the Free State province to be the most important environmental issue facing the country. This concern developed over several decades through a number of local studies, but was most clearly articulated in John Acocks's comprehensive analysis of the problem published in 1953.[28] The main argument was that more than a century of heavy grazing by domestic livestock, particularly sheep, had resulted in the elimination of important grass species, which facilitated the spread of less useful shrubs. Because of the scale of the problem, the concern was that most of the semi-arid grasslands of the south-western Free State had been converted from productive environments, dominated by sweet grasses such as *Themeda triandra* (Rooigras), to less productive shrublands dominated by relatively unpalatable dwarf shrub species such as *Chrysocoma ciliata* (Bitterbos) and *Walafrida saxatilis* (Witaarbos). There was no suggestion that the pattern of change observed in the region had occurred as a result of a decline in rainfall. Rather, the argument built on the findings of the 1923 Drought Investigation Commission, which warned of the consequences of high stocking rates, the lack of proper fencing, and the absence of scientific grazing management systems.[29]

26 N. Nongwe, 'A Systematic Conservation Assessment of Habitat Transformation and Degradation in the Little Karoo, South Africa', (MSc dissertation, University of Cape Town, 2008).

27 D.C. Le Maitre, S.J. Milton, C. Jatmain, C. Colvin, I. Saayman and J.H.J. Vlok, 'Landscape-Scale Hydrology of the Little Karoo: Linking Ecosystems, Ecosystem Services and Water Resources', *Frontiers in Ecology and the Environment*, 5, 5 (June 2007), pp. 261–70.

28 J.P.H. Acocks, 'Veld Types of South Africa', *Memoirs of the Botanical Survey of South Africa*, 28 (1953), pp. 1–192. For a history of the desertification debate in South Africa, see M.T. Hoffman, 'Environmental History and the Desertification of the Karoo, South Africa', *Giornale Botanico Italiano*, 129, 1 (1995), pp. 261–73.

29 Anonymous, '*Final Report of the Drought Investigation Commission*' (Pretoria, Government Printer, 1923), U.G. 49/1923.

Even though the Drought Investigation Commission recommended a reduction in stock numbers, this occurred with any measure of success only from the 1960s onwards, as a result of increased commercialisation of the small stock industry and greater emphasis on the production of quality meat and wool products (which required good quality forage). The agricultural extension service, which was well supported by the apartheid government at the time and focused its efforts predominantly on the white farming community, played a significant role in the improvement of veld quality and animal productivity. However, the greatest influence on the reduction of stocking rates in the eastern Karoo was probably the provision of state subsidies from the 1960s to the late 1980s to the white farming community in the Nama-Karoo and adjacent Grassland biomes, for both fencing and the reduction of livestock numbers. The involvement of resource conservation technicians and a skilled, professional agricultural extension service, funded by the state and supported by the research efforts of individuals such as Charles Tidmarsh, John Acocks and Piet Roux, influenced this shift in policy as well as grazing management practices on the ground.[30]

In addition to his 1953 publication, the *Veld Types of South Africa*, John Acocks produced four colour maps which had a powerful influence on the desertification debate for the rest of the century. Three of these maps portrayed the distribution, and by inference the ecological condition or integrity, of the different vegetation types in South Africa at three different times (1400, 1950 and 2050 CE), while a fourth map showed what the vegetation could look like under proper 'scientific management'. In many ways the maps foreshadowed the kind of graphic images that have been produced by climate change researchers in more recent years.[31]

Acocks's portrayal of the devastating impact of commercial agriculture on the vegetation of South Africa was so compelling that little original research was undertaken on this theme for decades after his publication. No attempt was made, for example, to document the effects of the stock reduction scheme and changing land-use practices in the region on the proportion of grasses and shrubs in the landscape. By 1990, however, it was clear from several lines of evidence that rather than shrubs increasing in landscapes of the eastern Karoo, they were actually decreasing and being replaced by grasses. Repeat photographs of several sites across a 500-km aridity gradient, first sampled in the early 1960s and again in 1989, showed that grass cover was greater in the latter period than in the former.[32] A more recent repeat survey of these same sites has shown that this trend has continued at most locations.[33] Apart from the continued positive effect of lower stocking rates on the grass sward, other explanations are that the recent widespread increase in grass cover in the eastern Karoo might also be attributed to a measured change in rainfall seasonality. An analysis of the long-term climate record for Middelburg in the Karoo Midlands shows that the amount of early summer rain has increased over the last few decades, while autumn rain has declined over this period.[34] Such shifts in rainfall seasonality are known through the results of long-term grazing trials to have a significant influence on the proportions of grasses and shrubs in the landscape.[35]

30 P.W. Roux, 'Principles of Veld Management in the Karoo and the Adjacent Dry Sweet-Grass Veld', in W.J. Hugo (ed.), *The Small Stock Industry in South Africa*, (Pretoria, Government Printer, 1968), pp. 318–40.

31 G.F. Midgley, M.C. Rutherford, W.J. Bond and P. Barnard, *The Heat is on … Impacts of Climate Change on Plant Diversity in South Africa* (Cape Town, South African National Biodiversity Institute, 2008).

32 M.T. Hoffman and R.M. Cowling, 'Vegetation Change in the Semiarid Eastern Karoo Over the Last 200 Years – An Expanding Karoo – Fact or Fiction', *South African Journal of Science*, 86, 7–10 (July–October, 1990), pp. 286–94.

33 M.L. Masubelele, M.T. Hoffman, W.J. Bond and J. Gambiza, 'A 50-Year Study Shows Grass Cover Has Increased in Shrublands of Semi-Arid South Africa', *Journal of Arid Environments*, 104 (May 2014), pp. 43–51.

34 J.C.O. Du Toit, 'An Analysis of Long-Term Daily Rainfall Data from Grootfontein, 1916–2008', *Grootfontein Agric.*, 10 (2010), pp. 24–36.

35 T.G. O'Connor and P.W. Roux, 'Vegetation Changes (1949–71) in a Semiarid Grassy Dwarf Shrubland in the Karoo, South Africa – Influence of Rainfall Variability and Grazing by Sheep', *Journal of Applied Ecology*, 32, 3 (August 1995), pp. 612–26.

How widespread is this phenomenon of grass-cover increase in the Nama-Karoo and Grassland biomes, and what other changes are associated with this pattern? A recent analysis of 63 repeat photographs spanning more than a 100 years suggests that this is indeed a general occurrence in the region.[36] Within a wide range of habitats and land forms, and across extensive rainfall and altitudinal gradients, the cover of grasses has increased almost universally in the eastern part of the Nama-Karoo. On the plains, this has amounted to an average increase in grass cover of 4.5 per cent per decade, while dwarf shrub cover is adjudged to have declined at the sites re-photographed by an average of 1.5 per cent per decade. At some sites there has been a complete switch in the biome reflected in the landscape. For example (see Figure 4), dwarf shrub species such as *Chrysocoma ciliata* (Bitterbos), *Felicia filifolia* (Draaibos) and *Eriocephalus ericoides* (Kapokbos) have largely been replaced by the grass species *Merxmuellera disticha* (Mountain wire grass), which now covers almost 60 per cent of the plains.

The ephemeral streams in the eastern Karoo have also changed substantially over the last 100 years as a result of an increase in tall shrubs and trees, especially *Acacia karroo* (Sweet thorn) (Figure 4). Photographic comparisons suggest that tree cover has increased by an average of more than 2 per cent per decade in the region and by nearly 6 per cent per decade in some localities. The hydrology of the few perennial streams in the eastern Karoo, such as the Fish River, has been dramatically altered by several large-scale water transfer schemes, and this impact is reflected in the vegetation. For example, the cover of tall trees has generally decreased over time, while the cover of both indigenous (*Phragmites australis* – Common reed) and alien (*Arundo donax* – Spanish reed) reeds has increased, presumably as a result of increased sedimentation rates and supply of nutrients.

Although there are no published accounts which document the changes that have occurred on the rocky uplands of the Nama-Karoo and Grasslands biomes, there is some suggestion from the photographic analysis discussed above that these land forms have also undergone substantial changes over the last several decades. While grass cover has increased and dwarf shrub cover has decreased in this land form, in keeping with the general pattern for the plains environments in the eastern Karoo, there has also been an increase in tall shrubs such as *Searsia lucida* (Blinktaaibos), *S. erosa* (Besembos) and *Diospyros austro-africana* (Kraaibos) at most rocky, upland sites in the region.

Finally, while the full extent of the westward expansion of grass cover has not been delineated accurately, several studies for regions in the western part of South Africa, at the ecotone between the Nama-Karoo and Succulent Karoo biomes, suggest that grass cover has increased here as well. For example, grasses have replaced succulent shrubs at the few localities for which records are available in Bushmanland[37] and on the eastern foothills of the Kamiesberg.[38] Such changes in the Nama-Karoo biome have important implications for a wide range of ecosystem processes such as hydrology, infiltration, run-off, sedimentation and erosion.[39] They affect the kind of animal that can be supported on the veld. A dense grass sward may also promote the incidence of fires, which have never been recorded in the semi-arid lowland environments of the Karoo in the past. In most instances the increase in grass

36 M.L. Masubelele, 'Understanding the Past to Conserve the Future: Long-Term Environmental and Vegetation Change in the Karoo Midlands, South Africa over the 20th Century', (PhD thesis, University of Cape Town, 2012).

37 E. Honglso, R. Rohde and T. Hoffman, 'Landscape Change and Ecological Processes in Relation to Land Use in Namaqualand, South Africa, 1939–2005', *South African Geographical Journal*, 91, 2 (February 2009), pp. 63–74.

38 N.N. Shiponeni, 'Spatio-Temporal Distribution of Grass and Shrubs at the Ecotone Between an Arid Grassland and Succulent Shrubland: Ecological Interactions and the Influence of Soils', (PhD thesis, University of Cape Town, 2007).

39 J. Keay-Bright and J. Boardman, 'Evidence from Field-Based Studies of Rates of Soil Erosion on Degraded Land in the Central Karoo, South Africa', *Geomorphology*, 103, 3 (February 2009), pp. 455–65.

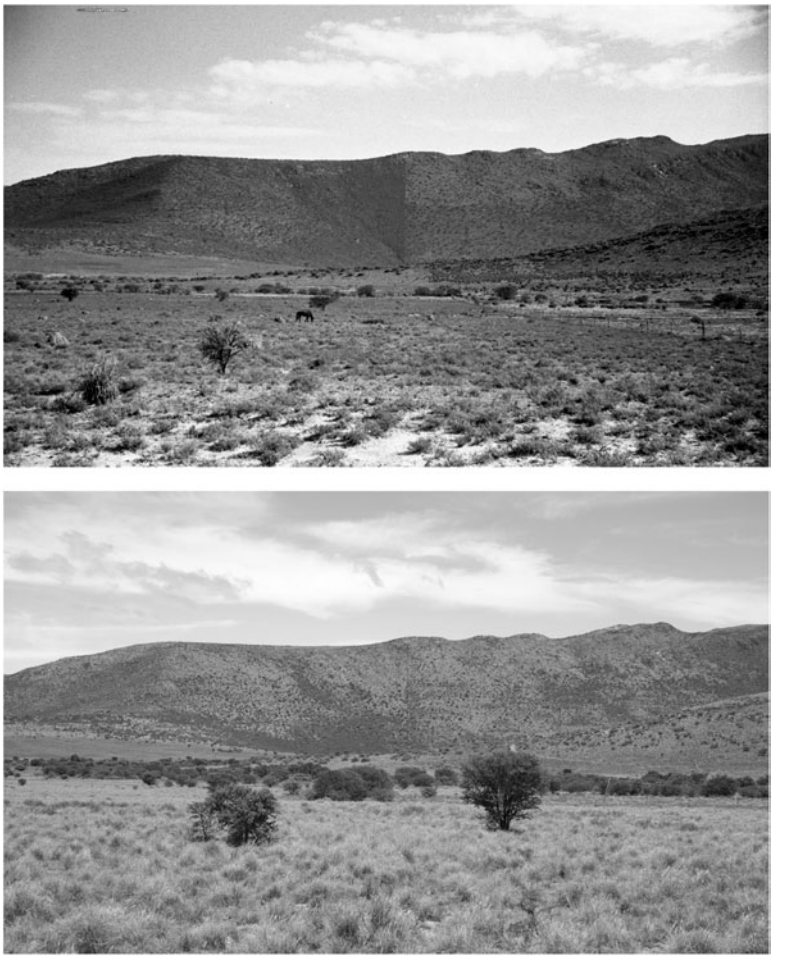

Figure 4. There has been an almost complete switch of biome in the foreground plains at this site. In the original photograph, dwarf Karoo shrubs were dominant, but vegetation cover in 2009 was dominated by grasses with very few shrubs present in the understorey. The spread of *Acacia karroo* trees from out of the ephemeral stream at the bottom of the low plain in the middle of the image is also notable. *Euryops* spp. continue to dominate the background slopes. [No. 541. Oudekraal near Tarkastad. S 32.10460, E 26.31957, 1373 m. Original photograph taken by J.P.H. Acocks on 23 August 1946; the repeat by M.T. Hoffman and M.L. Masubelele on 13 December 2009.]

cover is perceived by ecologists and agricultural resource conservationists as being beneficial for ecosystem health, as grasses are thought to reflect the kind of environment which dominated the Nama-Karoo biome before the arrival of colonial farmers in the area in the mid eighteenth century. The widespread recovery of the grass sward also has implications for the state's land reform programme. High stocking rates, which usually accompany the settlement of land-reform farms by beneficiaries, are likely to lead to a reversion from grassland environments back to annual and short-lived perennial plants of low forage value only.

Bush Encroachment and Alien Invasions in the Grassland and Savanna Biomes

Of all the biomes in South Africa, it is probably the relatively mesic Grassland and Savanna biomes in the east that have experienced the greatest change in land use and land cover over

the last 100 years. They incorporate large parts of the former homelands of Ciskei, Transkei and KwaZulu, and are amongst the most densely populated biomes in the country. This is also a region with high agricultural potential. It is this region, in which major initiatives around reserves and, later, bantustan consolidation took place, where the impact of state policies on people's lives and the environment was greatest in the twentieth century. Land use changes here should, therefore, be interpreted as forming part of a strongly coupled human–environment system.

The most obvious change in the vegetation of the Savanna biome has been the increase in trees and tall shrubs at the expense of grasses, a phenomenon called 'bush encroachment' in much of the world's literature. It occurs both as a process of densification of tall shrubs and trees in areas where they might already exist and as a process of expansion in which woody elements colonise new environments where they have not previously occurred. The major impacts of such encroachment are related to a reduction in grass cover, with knock-on effects for a wide range of ecosystem properties and services such as biodiversity, livestock (particularly cattle) production and water provision. Most rangeland ecologists and resource conservation technicians perceive bush encroachment as being detrimental to ecosystem health. However, there are also advantages of having an abundance of low tree cover, particularly for subsistence goat production, which is common in many communal areas.

Although there has been a significant recent upsurge in literature concerned with the global occurrence of woody plant increase, bush encroachment is not a new phenomenon in South Africa. Several published accounts suggest that it was already a matter of agricultural concern in the late nineteenth and early twentieth centuries. In this early period an increase in woody plants was reported from many different localities across the country, including those in central and northern KwaZulu-Natal,[40] the Springbok Flats in Limpopo,[41] and in several places in the Eastern Cape.[42] By the 1980s, bush encroachment was estimated to have affected as much as 53 million ha of previously open savanna vegetation in some form or another.[43] It was considered to be of such agricultural significance that the Department of Agriculture convened a workshop in Pretoria in 1980 to assess the extent of the problem.[44] Estimates from the delegates at this meeting were that 4 per cent of the 38 million ha considered in their analysis was heavily encroached upon by trees, with little or no grass production, 24 per cent was lightly to moderately infested and deteriorating, while 19 per cent was vulnerable to bush encroachment. Only 54 per cent of their study area, which was confined to land held under private ownership, was not affected by bush encroachment. The communal areas such as the former Ciskei and Transkei were not considered part of the Republic of South Africa at the time and were not assessed. Had they been included, the overall values for bush encroachment would probably have been far lower, as for most of the twentieth century the communal areas were characterised by relatively high fire frequencies, heavy goat browsing pressure and the harvesting of trees for fuelwood and construction purposes. This combination of land use activities, particularly when population

40 J.W. Bews, 'The Plant Succession in the Thorn Veld', *South African Journal of Science*, 14 (1917), pp. 153–72; R.D. Aitken and G.W. Gale, 'Botanical Survey of Natal and Zululand. A Reconnaissance Trip Through North-Eastern Zululand', *Memoirs of the Botanical Survey of South Africa*, 2 (1921), pp. 1–19.

41 E.E. Galpin, 'Botanical Survey of the Springbok Flats (Transvaal)', *Memoirs of the Botanical Survey of South Africa*, 12 (1926), pp. 1–100.

42 R. Story, 'A Botanical Survey of the Keiskammahoek District', *Memoirs of the Botanical Survey of South Africa*, 27 (1952), pp. 1–184.

43 For an account of the early literature on bush encroachment, see M.T. Hoffman, S. Todd, Z. Ntshona and S. Turner, 'Land Degradation in South Africa', (unpublished Final Report, Cape Town, 1999), pp. 19–31, available at http://www.pcu.uct.ac.za/resources/landdeg/frontpage.htm, retrieved 27 October 2013.

44 A.J. Pienaar (ed.), 'Proceedings of a Workshop on Bush Encroachment and Bush Thickening' held in Pretoria, 28–29 October 1980, (Pretoria, Department of Agriculture and Fisheries, 1980), pp. H1–H18.

densities are high, acts to keep bush encroachment in check or at least to slow the rate of increase.[45]

More recent estimates of the extent of bush encroachment in South Africa are not available, partly because of the difficulty in first defining the term and then measuring its extent, but also because of the scale of the problem. Several local case studies, however, confirm that it remains an important issue in the savanna biome (Figure 5).[46] While there is some indication that the rate of encroachment has increased in recent years,[47] there is not enough evidence to establish the extent of the problem across the county, particularly since a decrease in woody plant cover has also been reported at some localities under both communal and freehold tenure.[48]

Early explanations for bush encroachment were that land use, particularly overgrazing by domestic livestock, was the primary cause. It was suggested that heavy grazing reduced grass cover which in turn led to lower fuel loads and consequently fewer large fires. Abandoned cultivated lands acted in much the same way, in that the low occurrence of grasses on old lands allowed for the invasion of these sites by woody elements. Without fire, trees were able to establish, particularly during good rainfall years, and grow to a size where fires were no longer able to kill the adult plants. Early descriptions of bush encroachment portrayed it as a successional process in which thorn trees acted as pioneers and invaded grassland habitats, thus 'preparing the way' for other, usually broadleaved, species to follow.[49] The suppression of fire was critical to the process of bush encroachment, and the view was expressed as early as 1921 that fire regimes had changed, and were different in areas where farming occurred under freehold tenure compared with some of the more densely populated areas of northern KwaZulu-Natal, where land was managed communally. In the account of their journey to the Ingwavuma District in 1921,the botanists Aitken and Gale reported that:

> Scarcely a night during winter but that a grass fire is seen somewhere on the veld, and, as the country is not divided into farms, a single fire may rage for three days before it dies out. In the less populated districts this factor does not operate to the same extent, and it is precisely in these districts that one finds the climax stage in the thornveld succession. In places, however, and especially in the valley of the Hluhluwe, the trees are gaining ground; for example, a native, who had lived in that district all his life, pointed to a hillside studded with thorn trees, and volunteered the information that in his childhood there had not been one tree there.[50]

Even though it was widely known at the time that fire reduced woody biomass and promoted grass cover,[51] the lighting of fires was actively discouraged as a management tool in the early

45 B.J. Wigley, W.J. Bond and M.T. Hoffman, 'Thicket Expansion in a South African Savanna Under Divergent Land Use: Local vs Global Drivers?', *Global Change Biology*, 16, 3 (March 2010), pp. 964–76.

46 M.T. Hoffman and T.G. O'Connor, 'Vegetation Change Over 40 Years in the Weenen/Muden Area, KwaZulu-Natal: Evidence from Photo-Panoramas', *African Journal of Range and Forage Science*, 16, 2 & 3 (December 1999), pp. 71–88.

47 P.J. Gordijn, E. Rice and D. Ward, 'The Effects of Fire on Woody Plant Encroachment Are Exacerbated by Succession of Trees of Decreased Palatability', *Perspectives in Plant Ecology, Evolution and Systematics*, 14, 6 (December 2012), pp. 411–22; D. Ward, M.T. Hoffman, S.J. Collocott, 'The Influence of Local and Global Drivers on a Century of Woody Plant Encroachment in the Dry Kimberley Savanna of South Africa', *African Range and Forage Science* (under review).

48 J.E. Bennett, A.R. Palmer and M.A. Blackett, 'Range Degradation and Land Tenure Change: Insights from a 'Released' Communal Area of Eastern Cape Province, South Africa', *Land Degradation & Development*, 23, 6 (November/December 2012), pp. 557–68; J.R. Puttick, M.T. Hoffman and J. Gambiza, 'The Influence of South Africa's Post-Apartheid Land Reform Policies on Bush Encroachment and Range Condition: A Case Study of Fort Beaufort's Municipal Commonage', *African Journal of Range and Forage Science* (forthcoming).

49 J.W. Bews, 'The Plant Succession in the Thorn Veld', *South African Journal of Science*, 14 (1917), p. 154.

50 R.D. Aitken and G.W. Gale, 'Botanical Survey of Natal and Zululand. A Reconnaissance Trip through North-Eastern Zululand', *Memoirs of the Botanical Survey of South Africa*, 2 (1921), pp. 1–19.

51 W.J. Bond, G.F. Midgley and F.I. Woodward, 'What Controls South African Vegetation – Climate or Fire?', *South African Journal of Botany*, 69, 1 (March 2003), pp. 79–91.

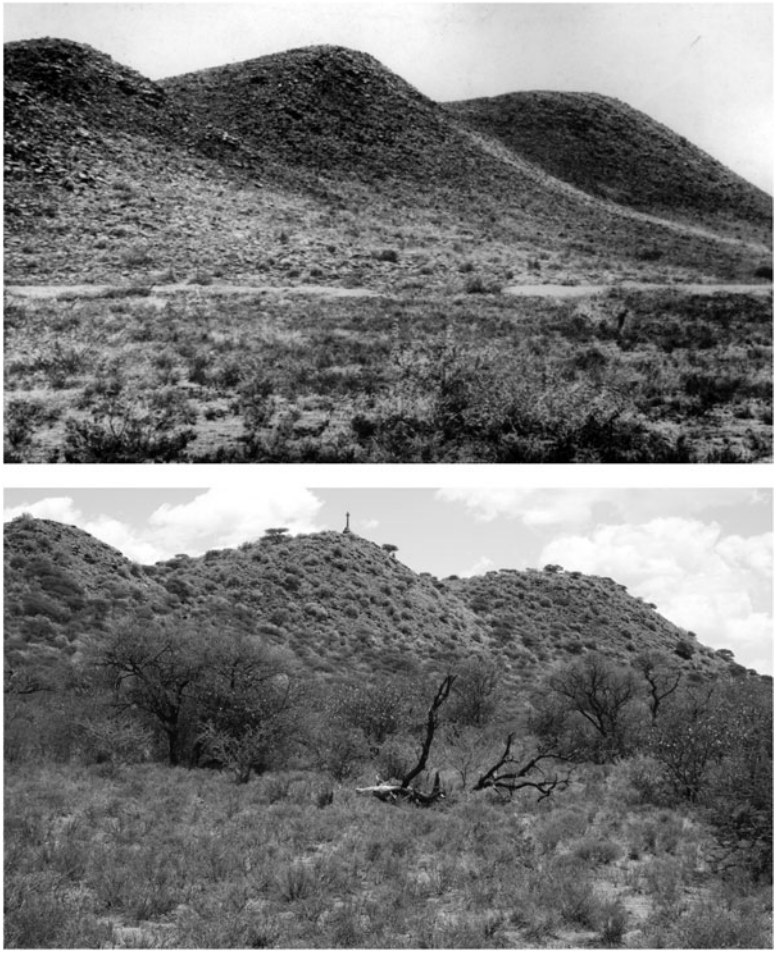

Figure 5. The Magersfontein battlefield was open and devoid of trees at the time of the Anglo-Boer war in 1900, when the original photograph was taken. Since this time there has been a significant increase in woody plants both on the rocky hill slopes, which are now dominated by *Tarchonanthus camphoratus*, and on the bottomlands, where *Acacia mellifera* and *A. tortilis* have increased in cover. [No. 597. Magersfontein 3 Hills south of Kimberley. S 28.97317, E 24.69994, 1146 m. Original photographer unknown; repeat photograph taken by M.T. Hoffman and D. Ward on 8 December 2010.]

part of the twentieth century. For example, in their list of recommendations to Parliament in 1923, the Drought Investigation Commission went so far as to suggest that 'the ultimate goal would be to stop all veld fires'.[52]

A far more complex interpretation of bush encroachment has emerged in recent years, one in which local drivers (e.g., fire, herbivory) as well as global drivers (e.g., temperature and the concentration of atmospheric CO^2) interact to promote woody plant thickening.[53] A central theme is how the growth rates of woody plant saplings are influenced by higher temperatures and more CO^2, as faster growth rates mean that young trees are more easily able to survive intense ground fires. Several recent experimental studies find strong support for the role of

52 Anonymous, *Final Report of the Drought Investigation Commission* (Pretoria, Government Printer, 1923), U.G. 49/1923. Point 486.

53 W.J. Bond and G.F. Midgley, 'Carbon Dioxide and the Uneasy Interactions of Trees and Savannah Grasses', *Philosophical Transactions of the Royal Society, B – Biological Sciences*, 367, 1588 (February 2012), pp. 601–12.

such global drivers in promoting bush encroachment.[54] However, land use remains an important local driver of change, particularly within the heavily utilised rangelands of the communal areas, where both increases[55] and decreases[56] in woody plant cover have been documented.

In addition to woody plant thickening, the Savanna biome has also experienced a significant degree of invasion from alien plants over the last 100 years. Not all of the invasive species are tall shrubs or trees. Some of the most significant problem weeds include herbaceous shrubs such as *Chromolaena odorata* (Triffid weed), *Parthenium hysterophorus* (Parthenium weed) and *Lantana camara* (Lantana). The last two species are particularly pernicious and have the ability to transform large tracts of potentially productive agricultural land into unusable wasteland. A recent survey, which compared all of South Africa's biomes in terms of their priority for alien plant removal, ranked the moist Savanna biome of the east coast third below the Indian Ocean Coastal Belt and Fynbos biomes.[57] These surveys also assessed the former Transkei, Ciskei and parts of KwaZulu-Natal as being among the most invaded areas of South Africa in terms of the percentage cover of invasive alien species recorded.[58] These invasive alien species currently have significant impacts on surface water run-off, biodiversity and livestock production and, unless they are adequately controlled, their impacts will increase in the future.[59]

Implications of Land-Use and Land-Cover Change for Land Reform

What lessons are there for South Africa's land reform programme in knowing how the vegetation has changed over the last 100 years? The first observation is that land use matters. The way in which the land is used affects the cover and composition of landscapes as well as the on- and off-site functionality of ecosystems. Vegetation can be transformed over relatively short time frames in densely populated landscapes, or in landscapes which support large numbers of domestic livestock. For example, evidence from Riemvasmaak, one of the first land restitution settlements in South Africa, shows that between 1995 and 2005, after the community had returned to their land (in 1995), the cover of perennial grasses and some shrub species was reduced significantly by grazing animals (Figure 6).[60] The trend in vegetation when heavily grazed is always from a dominance of palatable perennial plants (often grasses) to a community dominated by relatively unpalatable perennial and annual

54 R. Buitenwerf, W.J. Bond, N. Stevens and W.S.W. Trollope, 'Increased Tree Densities in Two South African Savannas: >50 Years of Data Suggests CO^2 as a Driver', *Global Change Biology*, 18, 2 (February 2011), pp. 675–84; J.L. Wakeling, A.C. Staver and W.J. Bond, 'Simply the Best: The Transition of Savanna Saplings to Trees', *Oikos*, 120, 10 (October 2011), pp. 1448–51.

55 B.J. Wigley, W.J. Bond and M.T. Hoffman, 'Thicket Expansion in a South African Savanna Under Divergent Land Use: Local vs Global Drivers?', *Global Change Biology*, 16, 3 (March 2010), pp. 964–76.

56 J.R. Puttick, M.T. Hoffman and J. Gambiza, 'The Influence of South Africa's Post-Apartheid Land Reform Policies on Bush Encroachment and Range Condition: A Case Study of Fort Beaufort's Municipal Commonage', *African Journal of Range and Forage Science*, (In Press).

57 B.W. van Wilgen, D.C. le Maitre, G.G. Forsyth and P.J. O'Farrell, 'The Prioritization of Terrestrial Biomes for Invasive Alien Plant Control in South Africa' (Stellenbosch, CSIR, 2010), Report No. CSIR/NRE/ECO/ER/2010/0004/B.

58 I. Kotzé, H. Beukes, E. van den Berg and T. Newby, 'National Invasive Alien Plant Survey' (Pretoria, ARC, 2010), Report No. BW/A/2010/21.

59 B.W. van Wilgen, B. Reyers, D.C. le Maitre, D.M. Richardson and L. Schonegevel, 'A Biome-Scale Assessment of the Impact of Invasive Alien Plants on Ecosystem Services in South Africa', *Journal of Environmental Management*, 89, 4 (December 2008), pp. 336–49.

60 M.T. Hoffman, S.W. Todd and J. Duncan, 'Environmental Change in Riemvasmaak 10 years after re-settlement' (unpublished report, University of Cape Town, 2005), available at http://www.pcu.uct.ac.za/resources/reports/riemvasmaak_report_2005.pdf, retrieved 28 October 2013.

Figure 6. The cover of perennial grasses such as *Stipagrostis uniplumis* and *S. namaquensis* has declined significantly in the foreground over the 10 years since domestic livestock was re-introduced to this wide river valley. Tree and shrub cover, however, has remained relatively stable. [No. 330. Above Xubuxnap, Riemvasmaak. S 28.46465, E 20.14012, 531 m. Both photographs were taken by M.T. Hoffman: the top photograph on 21 January 1995; the bottom photograph on 15 January 2005.]

plants; the latter can occur in abundance but only for short periods of the year, and then only in good rainfall years.

The way in which land is used, and altered as a result of this use, further affects its production potential and thus the livelihood options available to its users. For example, perennial shrubs play an important role in the inter-annual transfer of forage stored in previous years. Their removal has important knock-on effects for the animal production system itself, with poor conception rates and high levels of mortality recorded during drought

periods. But land use also affects the services provided by the environment at relatively distant locations and for many different social needs. For example, the widespread degradation of the Little Karoo since colonial settlement has resulted in a 20–50 per cent decline in a range of ecosystem services such as forage production, erosion control, water flow regulation and even the experiences of tourists who visit the region.[61] Such negative changes in the environment have occurred primarily as a result of inappropriate commercial farming practices. The end result is that they narrow future options, increase unemployment and increase the vulnerability of user communities to future economic, political and climate shocks.

Abandoning land or not using it for productive purposes can equally affect vegetation composition and cover. For example, the de-agrarianisation of large parts of the communal areas in South Africa has resulted in a significant increase in bush encroachment on abandoned lands. Evidence from the Wild Coast of the former Transkei indicates that a reduction in cultivated fields to about one-fifth of the extent found in 1961 had resulted in a doubling of forest and woodland cover by 2009.[62] Also, a 74 per cent decline in the extent of cultivated fields at a land restitution project in Makotopong in Limpopo, following the transfer of land to inexperienced and poorly supported land claimants, has resulted in a 30 per cent increase in shrubland cover at this site.[63] To return these fields to full production will first require the bush to be cleared. This is a labour-intensive and costly exercise and in most cases is beyond the capacity of individual land users or even groups of households. Such instances of bush encroachment impact negatively on the agricultural potential of a region and limit the options available for new land reform initiatives.

The second lesson to take from this review of vegetation change is that the state has a critical role to play in maintaining the ecological integrity of the environment. There is evidence from the last 100 years of both the positive impact that the state has had on the environment and the negative role it has played in promoting land degradation, either through neglect or through active interventions, such as the enforcement of colonial and apartheid policies in the communal areas of South Africa. The role of the state in reversing the trend of desertification in the eastern Karoo in the second half of the twentieth century has already been discussed. A more recent example of how the post-apartheid state has intervened to make a positive change is that of the 'Working for Water' programme. This relatively well-funded and well-managed public works initiative was established in 2004 with the aim of clearing alien invasive plants and restoring ecological function to the environment, while providing employment for unemployed people. Despite criticisms of both its biological effectiveness and its impact on poverty,[64] it is widely regarded as having had a positive influence on both.[65]

However, the state can also have a negative impact on the environment. The 'betterment schemes' that were initiated in the former homeland areas in the mid twentieth century are a

61 B. Reyers, P.J. O'Farrell, R.M. Cowling, B.N. Egoh, D.C. le Maitre and J.H.J. Vlok, 'Ecosystem Services, Land-Cover Change, and Stakeholders: Finding a Sustainable Foothold for a Semiarid Biodiversity Hotspot', *Ecology and Society*, 14, 1 (June 2009), Article 38.

62 R. Shackleton, C. Shackleton, S. Shackleton and J. Gambiza, 'Deagrarianisation and Forest Revegetation in a Biodiversity Hotspot on the Wild Coast, South Africa', *PLOS ONE*, 8, 10 (October 2013), e76939.

63 Z. Lidzhegu and L.G. Palamuleni, 'Land Use and Land Cover Change as a Consequence of the South African Land Reform Program: A Remote Sensing Approach', *Journal of Food, Agriculture & Environment*, 10, 3 & 4 (2012), pp. 1441–7.

64 M.M. McConnachie, R.M. Cowling, C.M. Shackleton and A.T. Knight, 'The Challenges of Alleviating Poverty through Ecological Restoration: Insights from South Africa's "Working for Water" Program', *Restoration Ecology*, 21, 5 (September 2013), pp. 544–50.

65 J.K. Turpie, C. Marais and J.N. Blignaught, 'The Working for Water Programme: Evolution of a Payments for Ecosystem Services Mechanism that Addresses both Poverty and Ecosystem Service Delivery in South Africa', *Ecological Economics*, 65, 4 (May 2008), pp. 788–98.

good example of how active intervention by the state can have a disastrous effect on both the vegetation and the soil on which agricultural productivity depends. The re-zoning of land, for example from cultivation to grazing, and the relocation of people into small nucleated settlements some distance from their fields meant that small erosion channels were no longer repaired on these lands. Subsequent heavy rains led to their enlargement, and over the following decades they turned into large dongas which continue to transport tonnes of soil downstream each year.[66] (See also Wotshela, this issue.)

The final lesson to be learnt from this brief review of vegetation change in South Africa is that variables such as rainfall, temperature and the concentration of CO^2 in the atmosphere, which are influenced more by regional and global processes than local land-use impacts, are also important drivers of change. These variables are constantly changing. Most projections suggest that South African climates could be fundamentally different by the end of the twenty-first century from those experienced in the first decade of the new millennium. Some degree of planning for climate change is, therefore, essential in the land reform process, if beneficiary communities are to be able to adapt to its future impacts.

M. Timm Hoffman *Plant Conservation Unit, Department of Biological Sciences, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa*. E-mail: timm.hoffman@uct.ac.za

66 M.T. Hoffman and A. Ashwell, *Nature Divided: Land Degradation in South Africa* (Cape Town, UCT Press, 2001).