

CHANGE IS IN THE AIR

Ecological trends and their drivers in South Africa



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SAEON
South African Environmental
Observation Network

New perspectives on global change for South Africa



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IN A NUTSHELL

South Africa covers less than 1% of the world's land surface area and is home to nearly 10% of the world's plant species, about 7% of the world's vertebrates and 5.5% of all known insect diversity, making it a biodiversity treasure trove. South Africa's biodiversity is a spellbinding natural draw card for a lucrative nature-based tourism industry. The diversity of our natural areas also provides essential services, including grazing land, medicinal plants, fruits, timber, fuel and water purification – essentially for free! South Africans have a responsibility to understand and protect these economically and ecologically valuable systems. South Africa also has a legal responsibility to conserve its land according to its commitments under the Convention on Biological Diversity.

Yet the natural areas in South Africa are changing, altering the biodiversity which they are housing and the economic value that comes from them. Many South African landscapes have changed as a result of conversion of natural systems to croplands, forestry plantations and urban sprawl. Direct threats by poaching and over-harvesting of both plants and animals continue to rob South Africans of their natural assets for the benefit of a few. But in the late 1990s, a new threat was recognised, that of global climate change.

Across the country, variations in temperature and rainfall patterns provide a wide range of living conditions for plants and animals. The semi-desert of the dry west contrasts dramatically with the subtropical vegetation of the east coast, while the fire-prone fynbos is as unusual in Africa as the winter rainfall regime that supports it. These familiar patterns of vegetation and animal distributions are now changing and could change even more dramatically in future if global change trends continue.

The contents of this booklet extend and expand upon previous work – see the *The Heat is On (2001 and 2008) from species to whole ecosystems* – and highlight the remarkable changes that are already occurring over large parts of South Africa, particularly in the last two to three decades. Since the 1990s, South African scientists, with international collaborators, have been studying the potential impacts of climate, atmospheric CO₂ and land-use change on South Africa's natural areas, spurred by early projections of very dire potential impacts. The results have been illuminating and, sometimes, unexpected. In some parts of the country, where creeping desertification and expansion of Karoo shrubs was widely predicted, the reverse has happened and grassland is expanding. Over vast areas, woodland is encroaching on open savanna plains. Some western shrublands have barely changed at all. New research is revealing the scale of these changes, their likely causes, and how

The diversity in our natural areas also provides a range of important natural ecosystem goods and services – essentially for free!

and why some of the earlier projections were limited or inadequate. There is great value in revisiting earlier projections, testing them, and adjusting them where appropriate. Understanding the causes of change, and knowing why earlier work had not taken them into account, positions us to make better projections of further change. It allows us to begin developing strategies for managing ecosystems in preferred directions, based on a uniquely South African perspective.

This brief report focuses on the contribution that this more recent work has made to understanding environmental changes better, and points to ways that could support a uniquely South African set of adaptation responses. We welcome you to read “Change is in the Air”.

THE VALUE OF A SOUTH AFRICAN PERSPECTIVE ON CLIMATE CHANGE

The climate of the world is changing. We often hear how global warming is causing plants and animals to shift their distributions towards cooler and higher places so as to stay within their preferred temperature range. These changes are very common in the cooler parts of the world, such as Europe, where observations are supported by a long history of data collection, funding and many people working on the problem.

Not surprisingly, the effects of warming on species’ ranges are widely reported and many people and policy makers assume that plants and animals will respond in a similar manner across the world.

But, in warmer parts of the world, such as South Africa, temperature is less of a factor in limiting species. Here, water availability, fire and the presence of herbivores are equally important in shaping the natural world. Therefore it is important to understand that the impacts of global change vary across the world and a local perspective and local information is required to understand changes in our own areas, project their likely outcome, and plan accordingly.

IS THE WORLD'S CLIMATE CHANGING?

Increasing CO₂ - the invisible hand of global change.

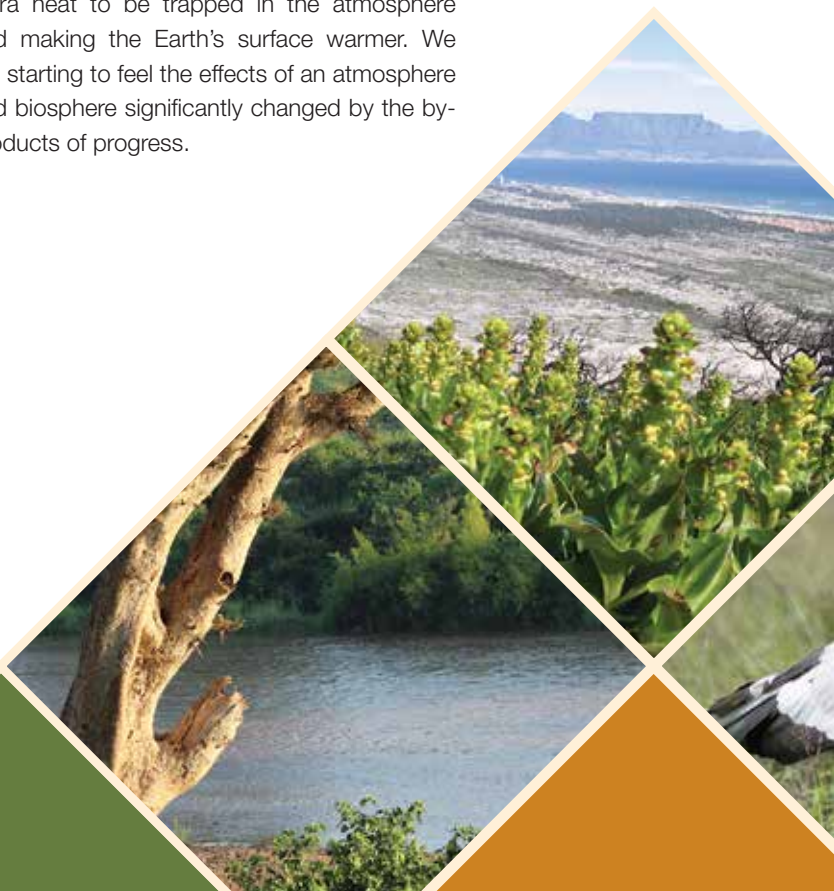
Our lifespans represent a few decades – a mere snapshot in time. Earth's biological history is measured in millions and even hundreds of millions of years. So is it reasonable to believe that the climate change currently being observed is anything new?

Climatic changes have happened before under natural forces – climatic shifts that have sometimes been extreme, and resulted in major extinctions. Over the last 800 000 years, scientists are highly certain that the Earth has warmed and cooled very significantly at least 20 times, with glaciers retreating and advancing and sea levels rising and falling in response. Sometimes changes have been rapid and extreme, with mean temperatures fluctuating by more than 2°C in just 50 to 100 years.

The difference this time around is that people are causing the Earth's climate to change. In 2014 the Nobel Peace Prize-winning Inter-

governmental Panel on Climate Change (IPCC) concluded that at least half of the warming observed globally over the past six decades is due to human activity (primarily the burning of fossil fuels – coal, gas and oil – and deforestation).

Global temperatures are rising higher and faster than can be explained by phenomena such as solar activity. Instead, rising temperatures mirror increases in the concentrations of 'greenhouse gases'. Gases like carbon dioxide (CO₂) and methane naturally trap heat in the atmosphere, helping to make a habitable planet. But in the last 150 years, since fossil fuels began powering the industrialised world, CO₂ levels have increased by more than 40%, causing extra heat to be trapped in the atmosphere and making the Earth's surface warmer. We are starting to feel the effects of an atmosphere and biosphere significantly changed by the by-products of progress.



Is the climate really changing? Draw your own conclusions:

- Global sea levels rose 10 to 25 cm in the last century.
- Each of the previous three decades has been successively warmer than any preceding decade since records began.
- In the Northern Hemisphere the 30-year period from 1983 to 2012 was likely the warmest 30-year period in the last 1 400 years.
- The late summer and early autumn Arctic sea-ice thickness has declined by ~ 40% in the last 30 years.
- The extent of Northern Hemisphere snow cover has decreased by ~10% since global observations became available in the late 1960s.
- Many species have shifted their geographic ranges, seasonal activities and migration patterns in response to ongoing climate change. In a study of 329 plant and animal species, 84% had shifted their ranges towards the cooler poles, or to higher elevations.

FACT!

The concentration of CO₂ in the atmosphere has increased by more than 40% since the dawn of the industrial revolution, and is now higher than it has been in the past 800 000 years. The rate of increase in CO₂ has been accelerating in the past two decades, to the extent that actual CO₂ increases have exceeded predictions.

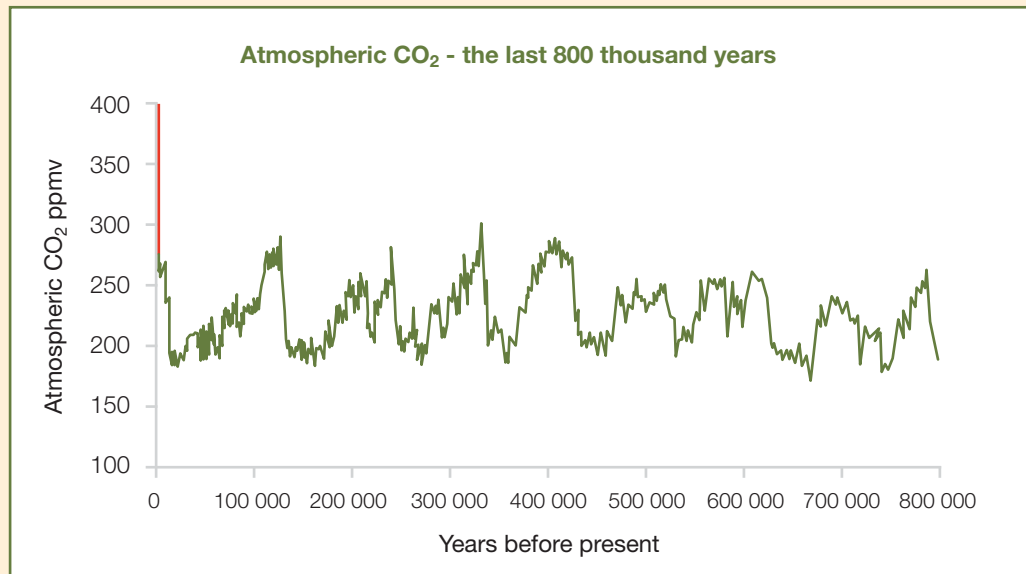


Figure 1: Bubbles of air trapped in Antarctic ice show trends in atmospheric CO₂ for the past 800 thousand years. CO₂ (green line) increased to ~280 ppm during warmer periods (interglacials) and decreased to as low as 180 ppm in colder periods ('glacials'). Since the start of the industrial revolution, CO₂ has increased by more than 40% (red line) and more than doubled from the low trough of the last glacial. (Data from Luthi et al. and Mauna Loa for modern trends)



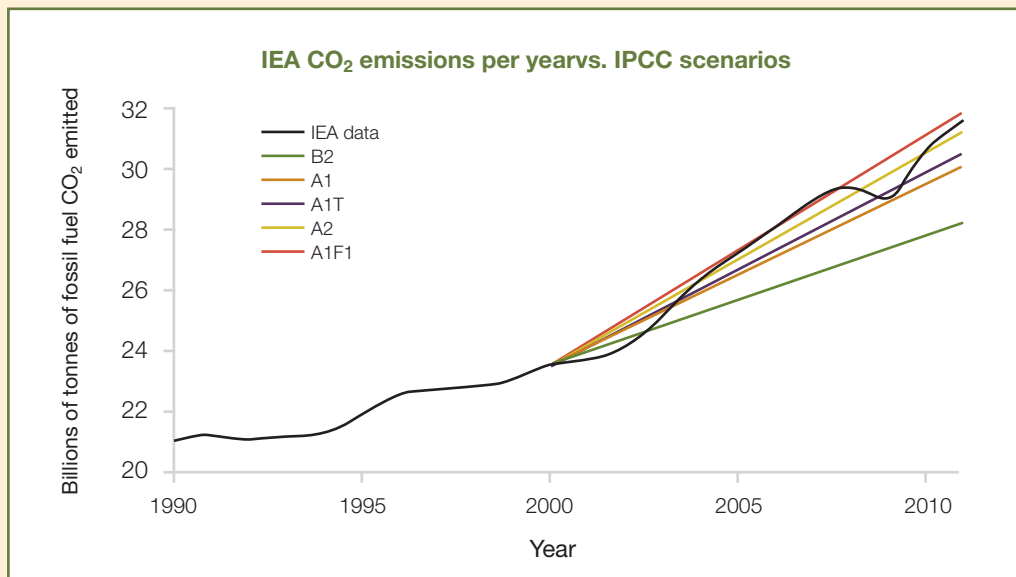


Figure 2: The concentration of CO₂ (black solid line) is increasing beyond amounts that were ever predicted. The different coloured lines represent the different scenarios of CO₂ emissions control. Actual CO₂ increases often exceed worst case scenario projections.

SOURCES OF UNCERTAINTY

Predicting the future is a tricky business. Just ask the world's economists who failed to predict the global recession of 2008 despite infinitely better data and a far simpler system to understand than the ecology of our planet. Climate change research is not an exact science. For a number of reasons, predictions are uncertain:

- We still have much to learn about how climate functions, and some details may be inherently impossible to model because they are 'chaotic', or very sensitive to minor changes.
- Computer models of climate are increasingly sophisticated, but remain simplifications of reality that do not include all the factors affecting the climate.
- Climate model projections are generally made at a global scale; the details of projections of climatic shifts at the regional or local scale are subject to compounding uncertainties.
- Future levels of greenhouse gases in the atmosphere depend on trends we cannot accurately predict, such as human population growth, the use of fossil fuels, especially by emerging economies, and the introduction of new, less polluting energy technologies.
- We cannot predict accurately the response of plants and animals to changes in climate and CO₂ concentrations.



FUTURE CLIMATE SCENARIOS FOR SOUTH AFRICA

The complex computer models used to simulate global climate change (General Circulation Models or GCMs) predict that climate will not change uniformly across the globe as greenhouse gases increase: land areas are likely to warm up faster than the oceans, polar latitudes faster than temperate latitudes, while temperatures of coastal zones should rise more slowly than continental interiors. These patterns can already be seen.

South Africa warmed between 1960 and 2010. Maximum and minimum temperatures have increased across the country, with the exception of the central interior where the minimum temperatures have decreased slightly. In future, warming is expected to increase. Temperature increases of more than 4°C are projected under a “business as usual scenario” (where emissions remain high) in the central and northern interior regions of South Africa for the period 2080 -2100. Autumn and winter seasons are projected to warm the most. The coastal regions are expected to experience the least amount of warming.

Rainfall patterns have also changed in South Africa. There is less autumn rainfall and fewer days with rain in the central and north-eastern parts of the country. Spring and summer rainfall has increased in the Southern Drakensberg region. While future predictions for temperature trends are considered to be more certain, there is much less consensus about what future precipitation trends will look like in South Africa. Current simulations project rainfall reductions over Limpopo and the south-western Cape in the near future. Moderate to strong increases in rainfall are projected for the central interior of South Africa extending to the southeast coast in the far future. These increases are projected to occur in spring and summer.

Contrary to model projections, a decrease in evaporation and lower average wind speeds have been observed, at least in the western Cape region, for which some of the most accurate data is available.

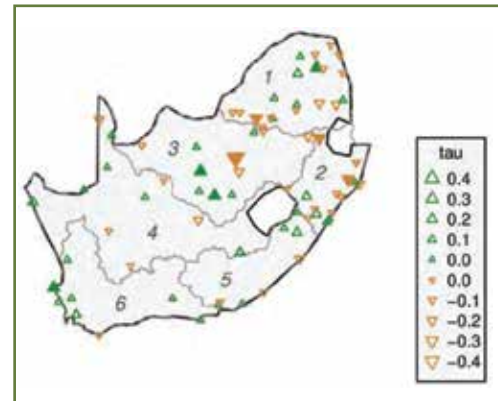


Figure 3: Trends in annual mean rainfall. The green triangles indicate an increase in mean rainfall between 1960 -2010. Non-filled triangles indicate an increase that is not statistically significant. The larger the triangle, the larger the increase. Brown triangles indicate a decrease. Reproduced with kind permission from N. MacKellar, M. New and C. Jack. (MacKellar et al. 2014)

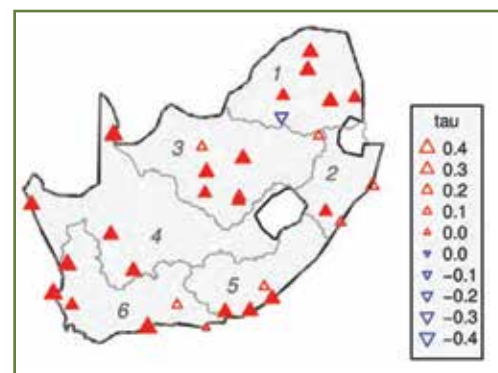


Figure 4: Trends in annual mean daily maximum temperatures. The red triangles indicate an increase in mean daily maximum temperature between 1960 -2010. Non-filled triangles indicate an increase but one that is not statistically significant. The larger the triangle the larger the increase. Blue triangles indicate a decrease. Most parts of the country, except for parts in the interior, have experienced an increase in mean daily maximum temperatures. (MacKellar et al. 2014)

For more details on climate trends in South Africa and future climate change scenarios, see Long-term adaption scenarios for South Africa: Climate trends and scenarios for South Africa (<http://www.sanbi.org/biodiversity-science/state-biodiversity/climate-change-and-bioadaptation-division/ltas>)

REDUCING UNCERTAINTY: PREDICTING VEGETATION CHANGE

Long-term methodical observation is crucial as a way to test models, and identify approaches that will be most useful for projecting future change with a view to designing management and other responses.

As South Africa has a rich biodiversity, there has been considerable interest in the impacts of climate change on plants and animals. These can be at the level of individual plant and animal species, or on entire vegetation types (referred to as 'biomes' at large enough spatial scales). There are different ways to model these changes, and their projections do not always agree, due to different assumptions and various shortcomings. Long-term methodical observation is crucial as a way to test predicted climate change impacts, and identify approaches that will be most useful for projecting future change with a view to designing management and other responses.

Plant species occur within a defined geographic area, their geographic range. The range can be related to particular climatic characteristics so that if you know where a species occurs, you can describe the range of climate factors that coincide with its distribution. Then, given projected future climates, it is a simple matter to predict the expected future distribution range of the species.

Not only species, but also whole biomes can be modelled in this way (see *The Heat is On*, 2001). However, this method makes some critical assumptions that are not necessarily true. The most important assumption, of course, is that climate alone controls species or biome distributions. In South Africa, and most of Africa, our ecosystems do not fit the assumption. Take, for example, the distribution of forests. Natural forests are very rare in South Africa, covering

about 0.5% of our land area. Where the climate is warm enough and wet enough for forests, we have grasslands, savannas and in the south-west, our unique fynbos shrublands. The same is true for vast areas of higher rainfall regions of Africa. We know that these regions can support forests because we find forest patches within grassy or fynbos-dominated landscapes. Foresters have based their important industry on this fact, establishing highly productive pine and eucalypt plantations in grasslands and fynbos. Furthermore, trees have 'escaped' the plantations and invaded natural systems, a problem that has been met by South Africa's Working for Water programme, which focuses on clearing invasive alien plants.

The missing forests have long puzzled ecologists here and in other parts of the world with similar anomalies. For most of the 20th century, the missing forests were thought to be due to deforestation by cutting, burning and loss to crop farming beginning, in South Africa, about 1 500 years ago. We now know this idea is wrong. Our grasslands (and fynbos) are much older than this. An obvious clue to their ancient origins is their rich biodiversity. Fynbos is crammed with plant species, mostly found nowhere else. Our Highveld grasslands, the vegetation type most often attributed to deforestation, also contain thousands of plant species, most of which occur nowhere else. Of our 14 globally threatened bird species, ten have major strongholds in the Grassland Biome.

It is simply not possible for all these species to

have evolved to live in these open habitats in the short period that people have been farming the land. Fossils, ancient pollen, analyses of soil carbon, and dating of species living in these environments using molecular clocks, show that our non-forested ecosystems have existed for hundreds of thousands to millions of years before farmers began to burn and fell forests. Indeed there is strong evidence that forests have not been contracting but expanding into grasslands and savannas over the last few thousand years based on analyses of soil carbon sources. These discoveries have important implications for understanding the future of our natural ecosystems under global change.

What prevents forests from taking over?

Grasses, and fynbos shrubs, may seem puny competitors next to tall forest trees, but they have two major 'tree-eating' allies: the big game of Africa and another kind of tree-eater, fire. Both classes of tree-eaters have been altered,

suppressed or extinguished in the process of industrialisation. Both are ancient ecological forces, long pre-dating human impacts on the environment.

In Europe, the source of many ecological ideas, big mammals were extinguished thousands of years ago and their ecological role forgotten. Fires still occur in parts of southern Europe where immense resources are used to try and extinguish them. In South Africa, and Africa more generally, the big animals have been missing from certain areas for only a century or two and still exist in our national parks. Fires still burn and, in the rare instances where people are excluded, lightning fires continue to burn the fynbos and our montane grasslands. In the analyses of land cover change that follow, diagnosing the causes of vegetation change is greatly complicated by changes in fire regimes as a result of fire suppression and, especially in our savannas, replacement of Africa's indigenous big mammal fauna by domestic livestock.



Figure 5: The vegetation in many parts of Africa is not only set by climate. Very different types of vegetation can grow in the same climate. [Photo: Geoff Clinning]

MORE THAN JUST CLIMATE

It should be clear, by now, that changes in vegetation in South Africa are not simply a matter of shifting plant species in response to changing climate. We also have to take into account changes in fire regimes and changing numbers and kinds of animals.

However, there is an additional global driver of particular importance to African ecosystems. Over the last 15 years, it has become clear that increasing carbon dioxide (CO₂) is also a major contributor to vegetation change. CO₂ is usually considered as contributing to global warming through the greenhouse effect. However CO₂ also has direct effects on plant growth. These effects are particularly apparent in South Africa's fire-prone grasslands and savannas. Models of how climate change will affect species and vegetation often ignore CO₂ effects (they require much more complex models). In our grassy systems, CO₂ is the invisible driver of global change – it has become a major factor contributing to South Africa's changing nature.



HOW INCREASING CO₂ ALTERS PLANT GROWTH

Trees will grow faster: Plants use carbon from the atmosphere to grow and produce wood, leaves and roots. They achieve this through photosynthesis. Higher concentrations of CO₂ in the atmosphere make CO₂ more readily available to trees, especially where plant growth is not limited by other factors such as shade or low nutrient supply. They can now take in more CO₂ for the same amount of energy expenditure. Trees store the extra carbon in their roots or woody stems. Increasing root storage means that trees can resprout and recover more quickly if the tree is damaged, e.g. if a tree is burnt by a fire or eaten by an animal, it can resprout and regrow quicker if there is more CO₂ in the atmosphere. Similarly, tree seedlings can grow quicker and have higher chances of survival. There are other unexpected effects, including channelling of more carbon to plant defences such as spines or tannins.

Plants will use less water when growing: As there is more CO₂ in the air, it is easier for plants to 'inhale' carbon from the air. Carbon dioxide is taken in by leaves through many tiny holes on the leaf surface called stomata. When the stomata are open to 'inhale' CO₂ they also lose water (like getting a dry mouth when panting). As there is more CO₂ in the air, plants do not need to open the stomata as wide and therefore lose less water. This means that for the same amount of rain, plants will grow more, a benefit that should be most effective for plants growing in drier areas of South Africa. Experiments elsewhere in the world show a general increase in grass production under elevated CO₂ because of this effect. We would therefore expect a general increase in grass production in our drier grassy biomes.



Figure 6: The amount of carbon in the atmosphere matters! These are the roots of the common *Acacia karroo* (sweet thorn) exposed to different levels of CO₂. Relative to CO₂ levels typical of pre-industrial conditions (far left), saplings of common tree species exposed to the high CO₂ of the late 1990s (second from right) grew more than three times the biomass, making massive root systems with increased starch concentrations. These effects will promote rapid resprouting after fire and recovery from browsing. The increases in CO₂ are radically transforming growing conditions of trees. (Bond and Midgley, 2012)

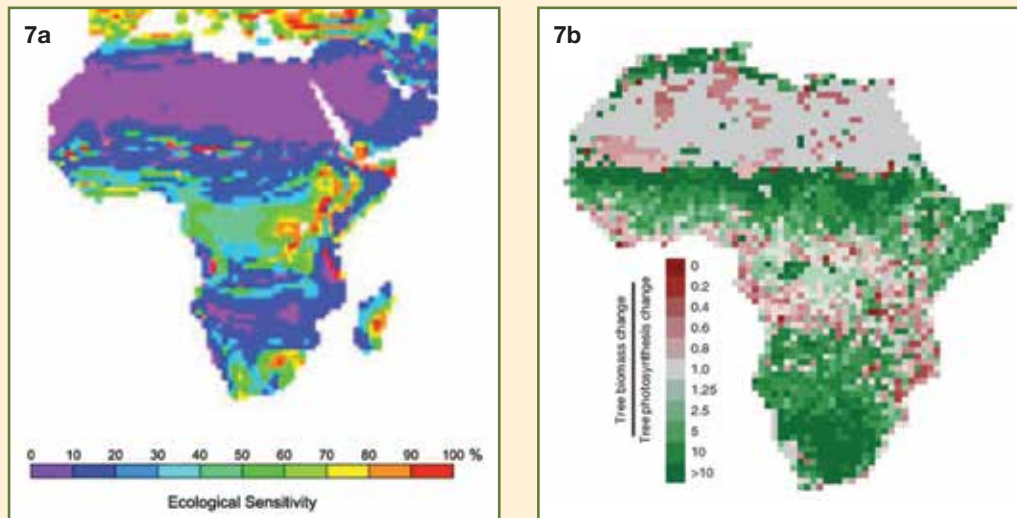


Figure 7: There is a lot of uncertainty in predictions. These two maps show vastly different predictions of vegetation change in Africa in response to global change. The figure on the left suggests that Africa will be the world's most stable continent in terms of vegetation change in response to climate change (from Bergengren et al. 2011). The figure on the right suggests that the vegetation in Africa will change dramatically (Higgins et al. 2012) to become much more wooded. The maps are very different because they are based on models with different assumptions. The first model assumes that climate determines the distribution of vegetation in Africa, while the second assumes that vegetation is determined by the interaction of fire, climate and carbon dioxide. The findings in this booklet support the predictions of the second model. These very different predictions show why monitoring and research are essential for understanding global change impacts for Africa.

7a: Reprinted with kind permission from Springer Science+Business Media: *Climatic Change, Ecological sensitivity: a biospheric view of climate change*, 107, 2011, 433-457, Bergengren, JC, Duane EW, & Yuk LY, Figure 8. **7b:** Reprinted by permission from Macmillan Publishers Ltd: *Nature*, Higgins & Scheiter (2012).



ARE SOUTH AFRICA'S BIOMES CHANGING?

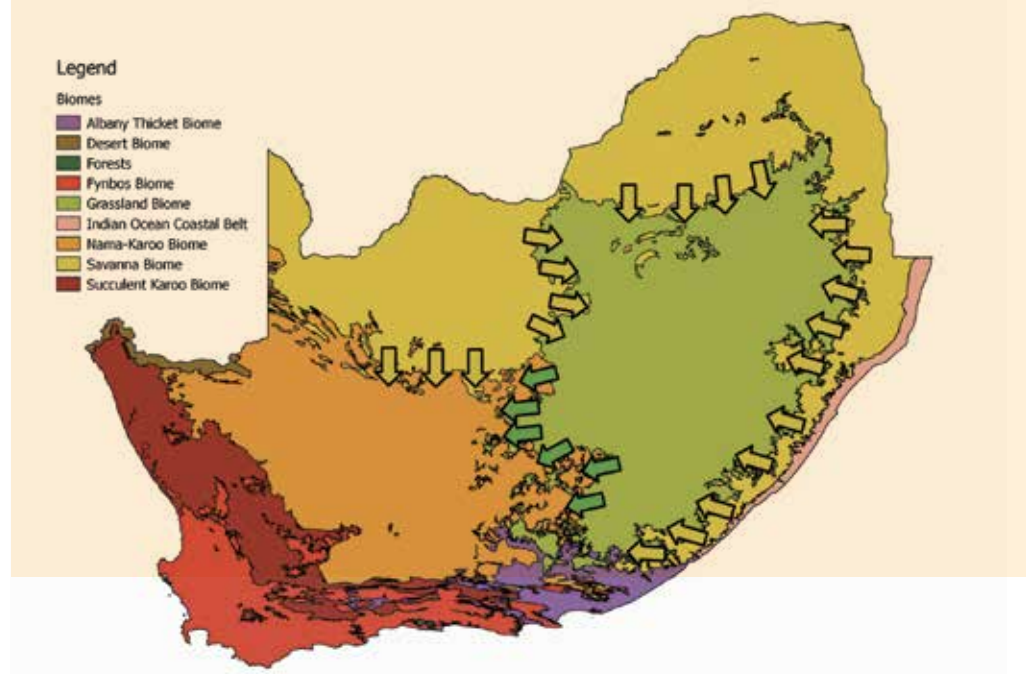
The vegetation of South Africa is so rich and varied that, when discussing plant distribution, it is convenient to refer to broadly similar types called biomes. Biomes are characterised by distinct major plant growth forms and are often associated with particular climates. Ecologists have described eight South African biomes, namely Desert, Forest, Fynbos, Grassland, Nama-Karoo, Succulent Karoo, Albany Thicket and Savanna (see below). The Indian Ocean Coastal Belt is a complex mosaic of other biomes.

- Where the climate is warmer, **savannas** occur in summer rainfall regions, forming the most extensive biome in the country.
- In the summer rainfall areas, **grassland** dominates much of the Highveld where cooler conditions restrict the growth of trees.
- **Nama-Karoo** vegetation, with its typical hardy bushes and grasses, covers much of the arid interior.
- The **Fynbos and Succulent Karoo Biomes** are found in the western parts of South Africa where rain falls in winter.

- **Albany thicket** reaches its greatest extent in the eastern Cape and consists of a complex tangle of trees, shrubs and succulents.
- The smallest biomes are the **Forest and Desert Biomes**. The Forest Biome reaches its greatest extent in the southern Cape, but with small patches in wetter regions elsewhere. A tiny area of true desert occurs in the extreme north-west of the northern Cape.

Based on the work from many scientists using two major sources of evidence, aerial photographs and historical photographs, we are building up a clear picture of how the natural areas of South Africa have changed over the past century. The next series of photographs shows some of the changes that are representative of these observations. Not all biomes have changed, and certainly some biomes have changed far more than others. These changes are occurring across South Africa in response to changing climate, CO₂ levels and land use practices.

Figure 8: A map of South Africa's biomes. The direction of the arrows indicates where biomes are expanding into other biomes. Some biomes have barely changed, while others have changed dramatically. Savannas are becoming woodier, and are expanding into grasslands. Grasslands tend to be expanding into the Karoo.



MORE TREES IN SAVANNAS (32.5% of South Africa's land area)

The general image of a savanna is of parkland with tall Acacia trees set among the grasses. This image may have been true a century ago, but tree cover has been increasing rapidly across South African savannas (~5-6% per decade). The biggest increase in the number of trees has occurred in the wetter savannas (e.g. Zululand and northern KwaZulu-Natal). In some places the density of trees has become so high that savannas have been transformed into thickets or forests, which function very differently from savannas. The invading broad-leaved trees shade out grasses. With no grasses, fires seldom penetrate invaded areas and grazing land is lost. This huge change in ecosystem structure and function means that large parts of savannas, their biodiversity and the ecosystem services they provide (such as tourism and grazing land) are threatened.

Trees have also increased in the drier savannas, resulting in open areas becoming much woodier but here the forests do not invade, so savannas still function as savannas. Interestingly the presence of elephants in the drier savannas is sufficient to prevent tree increases.

In some places the density of trees has become so high that savannas have been transformed into thickets or forests, which function very differently to savannas.

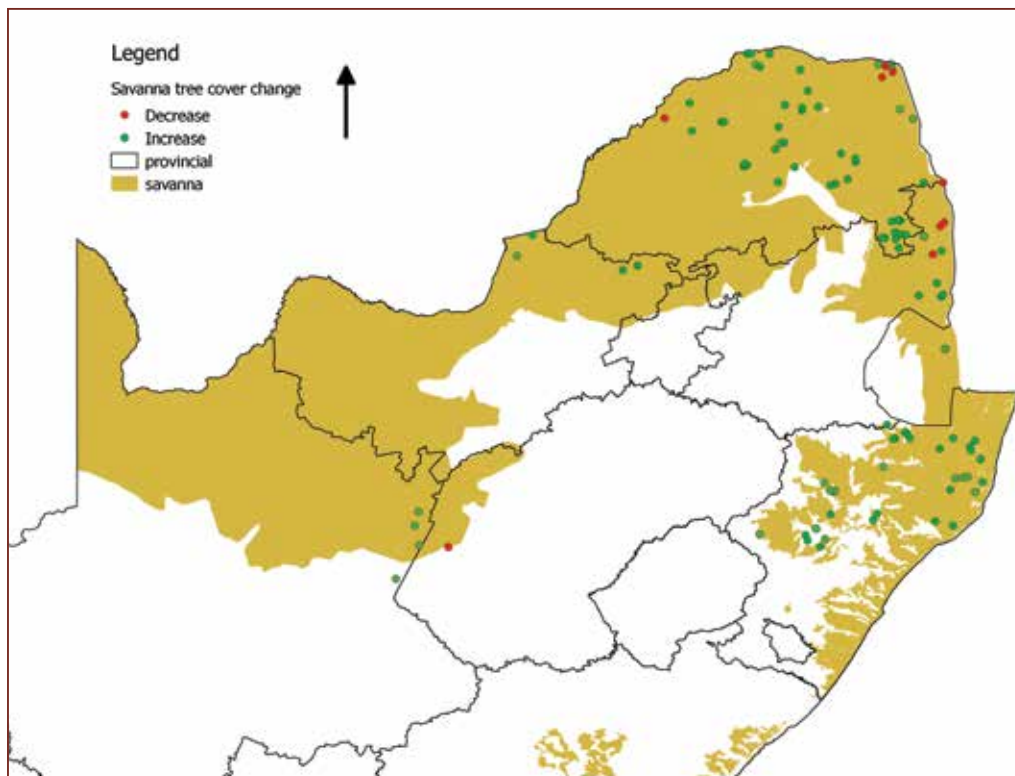


Figure 9: An overview of studies that have measured tree cover change in untransformed savanna areas. The green dots show sites (~10km²) where tree cover has increased over time. The vast majority of savanna areas have experienced an increase in tree cover and bush encroachment. (O'Connor et al. 2014; Stevens et al. 2014 unpublished data)



Figure 10: Aerial photographs showing tree cover change in Zululand from 1939-2010. Areas of once open savanna woodlands are being lost to closed canopy thickets and forests.

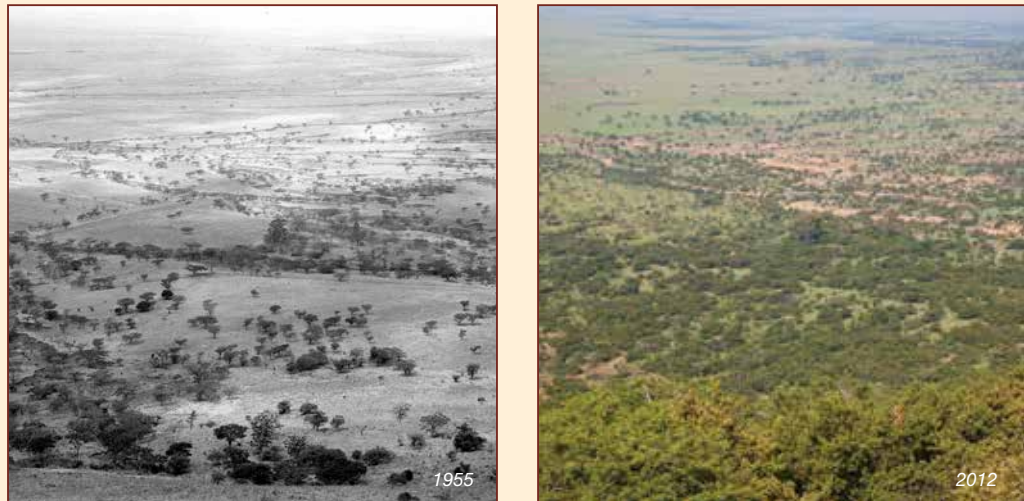


Figure 11: Tree cover has increased across most of South Africa's savannas, such as is seen at Spioenkop near Ladysmith, KwaZulu-Natal. [Photos: Left: Denzil Edwards, 1955; right: James Puttick, 2012]

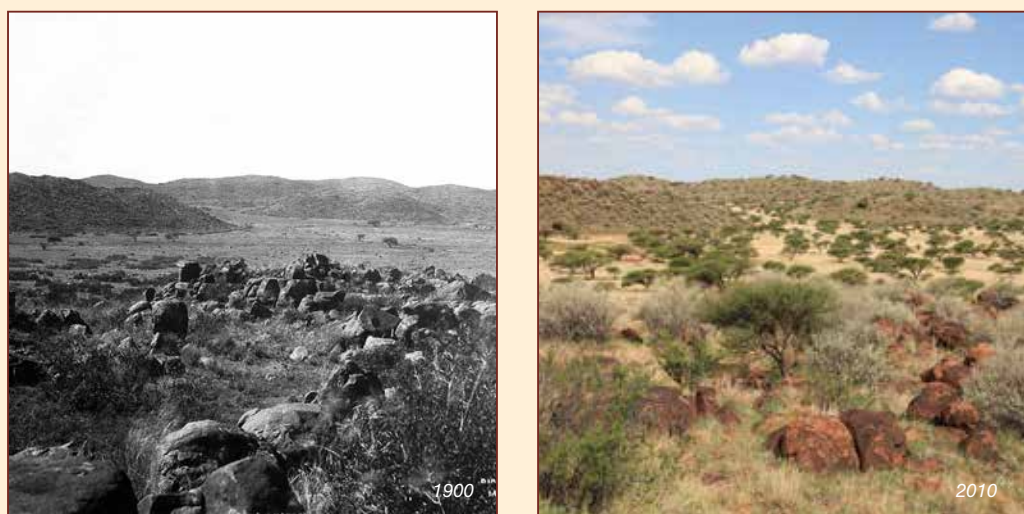


Figure 12: Tree cover is even increasing in the driest parts of the country. Compare the Magersfontein battlefield near Kimberley in 1900 with a more recent photograph taken in 2010. [Photos: Left by Unknown photographer, 1900; Right by Timm Hoffman and Dave Ward, 2010]

MORE TREES IN GRASSLANDS (27.9% of South Africa's land area)

The Grassland Biome is South Africa's second largest biome and only 2.5% of the remaining natural area is formally conserved. According to the Endangered Wildlife Trust's Threatened Grassland Species Programme, more than 60% of the grasslands have been irreversibly transformed into croplands, urban areas, plantation forestry and coal mines. In untransformed grasslands, cattle and sheep grazing is an important land use practice.

As with savannas, trees are increasing in grasslands. Forest patches within the grasslands are expanding, especially on rocky koppies and near streams. Trees are also colonising grassland areas where they have not occurred before. The boundary between the savanna and grassland biome is being eroded by savanna trees which are colonising previously treeless grasslands. As yet the extent of change at the biome boundaries is small (several hundred metres), slowly increasing the extent of savanna at the expense of grassland. An example from the Midlands of KwaZulu-Natal shows that savanna invasion into grasslands achieved an altitude gain of up to 100 m since the 1950s.



Figure 13: Woody plants have invaded the lower grassland slopes of this mountainside near Clarens in the Free State. [Photos: Top by John Acocks, 1945; bottom by James Puttick, 2011]

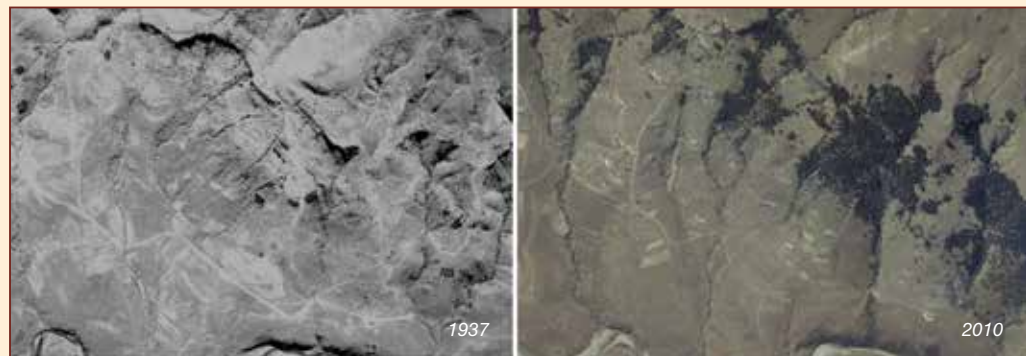


Figure 14: Aerial photograph of a grassland in Mpumalanga in 1937 and 2010. Previously grassy areas are being invaded by trees.



Figure 15: Woody plant cover has increased on all the slopes and mountain tops at this site near Ntabankulu in the Eastern Cape. This pattern is repeated across areas of South Africa particularly at sites where old cultivated fields have been abandoned. [Photos: Top by Alexander du Toit, 1922; bottom by James Puttick, 2011]

GRASSES INVADING THE KAROO

(19.5% of South Africa's land area)

While grasses are threatened in many savanna regions, paradoxically they are expanding into the eastern Karoo. The Nama-Karoo Biome was heavily used for livestock production in the 19th and early 20th centuries. There was concern at the time that overgrazing was leading to desertification and that the Karoo would expand into the grasslands to the north. In the mid-20th century, the South African state invested heavily in farm improvements, stock reduction schemes and agricultural extension services.

In recent decades we have seen the opposite pattern to that predicted half a century ago. Instead of Karoo shrubs invading grasslands, the grasses are invading the Karoo. This is especially the case in the eastern Karoo where grasses are replacing the dwarf shrubs typical of the biome. Grass-fuelled fires are beginning to burn, adding an almost unknown ecological hazard to Karoo farms. Valleys and ephemeral stream banks have thickened with taller shrubs and trees, especially *Acacia karroo*, as have the slopes of Karoo koppies.



Figure 16: Grass and shrub cover in the Nama-Karoo Biome fluctuate in response to changes in rainfall and grazing. This view of the plains below the Renosterberg, just south of Middelburg in the Eastern Cape, shows a substantial increase in grass cover since 1971 when the original photograph was taken. This pattern of grass cover increase is repeated at many locations across the broad ecotone between the Nama-Karoo and Grassland Biomes. [Photos: Top by John Acocks, 1971; bottom by Timm Hoffman and Mmoto Masubelele, 2010]

FYNBOS (6.6% of South Africa's land area)

Over the past century, large parts of the natural areas of the Fynbos Biome have been transformed through agriculture, habitat loss and alien plants. Many of the remaining natural areas of fynbos have been invaded by alien plants. These invasions continue to transform fynbos vegetation and several districts are among the most infested in the country. While the release of biocontrol agents and clearing by Working for Water programmes have reduced the rate of spread, the battle against alien plant invasions remains serious in large parts of the Fynbos Biome. An increase in forest patches and woody shrubs has also been documented in many places across the Fynbos Biome, including Table Mountain National Park where forests have expanded by more than 60% over the last century. A potential cause of forest expansion at the expense of fynbos is possibly fire suppression.

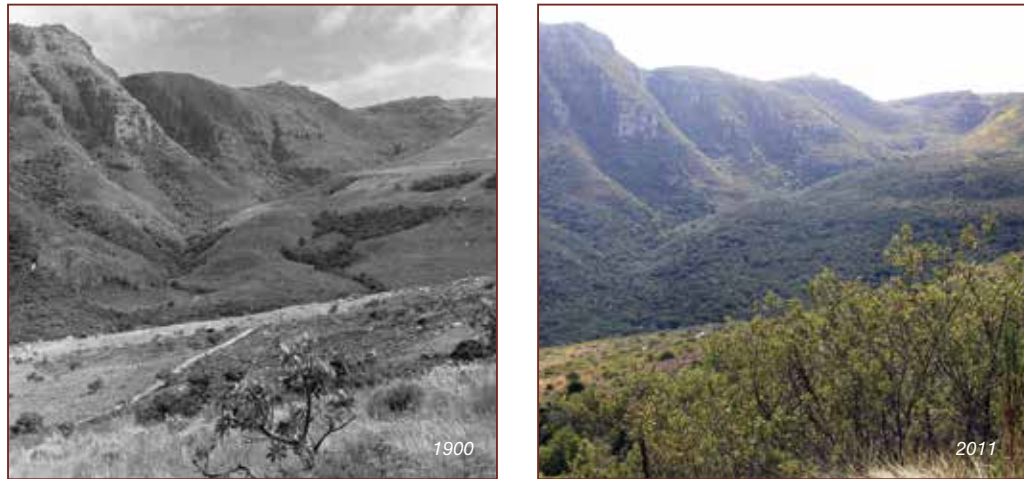


Figure 17: When protected from fire, trees tend to invade many fynbos areas such as the amphitheatre above Orange Kloof, Table Mountain where the increase in trees and tall woody plants is clearly evident. [Photos: Left by Elliot, 1900 (Courtesy of the Western Cape Archives and Record Services); right by Zoë Poulsen, 2011]

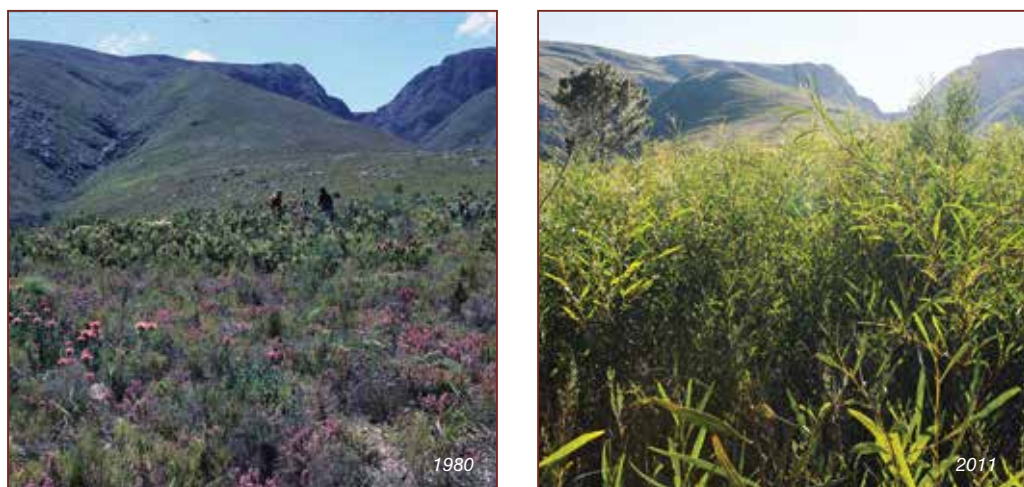


Figure 18: High densities of alien plants such as these Australian Acacias and European pines near Hermanus can have a devastating impact on the local flora. What was once a diverse community of proteas, ericas and restios is now a mono-specific stand of invasive species. [Photos: Left by Tony Hall, 1980; right by Mishak Boshoff, 2014]

SUCCULENT KAROO

(6.5% of South Africa's land area)

In the semi-arid, western part of the country, vegetation cover and composition has been relatively stable over the last century, especially on privately-owned farms. On the heavily-stocked communal areas of Namaqualand, however, centuries of overgrazing have transformed the lowland environments. The rocky upland environments are better buffered from the impacts of grazing and especially from the impacts of cultivation and remain relatively intact. In the Little Karoo section of the Succulent Karoo, centuries of cultivation and grazing have transformed much of the lowlands. Ostrich farming, in particular, has impacted negatively on the lowlands. Invasive alien plants have transformed parts of the Little Karoo, particularly along river courses, which are now infested with several alien species.

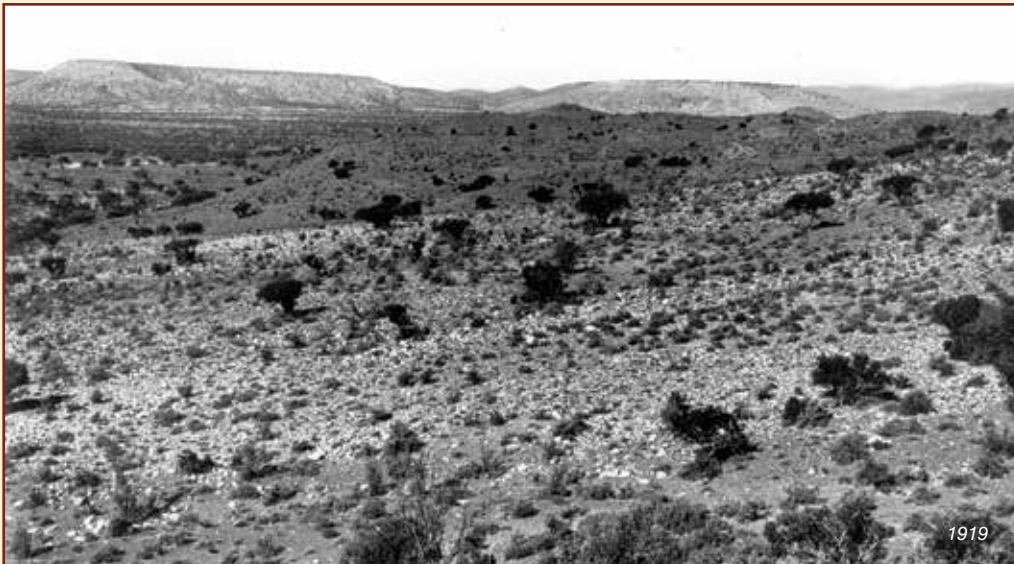


Figure 19: Large parts of the Succulent Karoo have remained relatively stable over long time periods like this site south of the Touwsberg, near Ladismith. Most of the trees are still present and have grown taller, while the cover of the lower shrubs is largely unchanged. [Photos: Top by I.B. Pole Evans, 1919; bottom by Timm Hoffman, 2014]

ALBANY THICKETS

(2.2% of South Africa's land area)

The Albany Thicket Biome has experienced a range of changes, mostly due to transformation to croplands and urban sprawl. Heavy stocking, especially with goats, has also led to the loss of thicket and its replacement by low Karoo shrubs or savanna elements. Under less extreme livestock farming, thicket has remained intact and no directional trends have been noted.

FOREST EXPANSION

(0.3% of South Africa's land area)

The Forest Biome is the smallest biome in South Africa, with pockets of forest occurring in small patches wherever the climate is wet enough. A trend of forest expansion into the surrounding biomes has been noted where scrub forest patches have shown a tendency to increase in size over time. Such increases have been recorded in the Fynbos Biome in the Cape Peninsula, northern Zululand and within the Indian Ocean coastal belt. In heavily populated areas where forest patches have been subjected to intense utilisation, they have declined in size. However in natural protected areas, or urban and other areas with low utilisation, there is a trend of increasing forest patch size.



WHY IS SOUTH AFRICA'S NATURAL LANDSCAPE CHANGING?

Fire and grazing influence our vegetation, but there is growing evidence that increasing CO₂ is also contributing to land cover change.

Global warming is causing rapid large-scale changes in the distribution of birds, butterflies and plants in northern Europe. But in South Africa, whole biomes are changing, and as they change there are cascading consequences for the many plant and animal species that make their home in a particular biome. In South Africa, these changes are linked to changes in habitat structure, unlike cooler Europe where changes are linked directly to climate. Changes in habitat

are caused by increases in woody plants in the grassy biomes or increasing grasses in the eastern Karoo. The potential for habitat change is massive where grasslands occur in climates where there is the potential to form closed forests.

While the changing face of South Africa is increasingly well documented, there is much less certainty as to the causes of the changes.

Fire and grazing practices have long been known to influence our vegetation. But there is growing evidence that global drivers, especially increasing CO₂, are also contributing to land cover change. The fact that local land use has major effects on our veld types is well known. Fence-line contrasts and a wealth of long-term burning and grazing experiments have shown how sensitive our ecosystems are to grazing and fire and their interaction (Figures 20-22). People also influence vegetation directly by collecting fuelwood for burning and felling trees for building purposes. The intensity of their use of natural ecosystems is also changing with urbanisation and electrification.

There are also less obvious and poorly studied drivers of change that are distinctively African. Little more than a century ago, elephants roamed over much of South Africa, and springbok trekked in their tens of thousands in the Karoo. In other parts of the world, the large mammal fauna has long been extinct. Our big mammals are largely restricted to game reserves and game farms. Comparisons of woody thickening

in our drier savannas inside and outside conservation areas have shown that elephants prevent significant tree increases. Thus part of the changes in vegetation may be an aftershock of killing off the large game animals.

Despite the importance of fire and herbivory, there is growing evidence that global change is increasingly contributing to vegetation change. Temperature, especially maximum temperature, shows a general increase over the last 50 years. Warmer temperatures have been linked to changes in species distribution but not, as yet, to changes in vegetation in South Africa. Rainfall amount and seasonality is thought to be far more important than temperature in determining vegetation in the country. Many plants adjust key life rhythms to rainfall seasonality, so that shifts in seasonality could have major repercussions, not least for the distribution of grassy biomes in summer rainfall regions and shrubby biomes of winter rainfall regions. For example, shifts of grasslands into the eastern Karoo have been tentatively attributed to changes in rainfall seasonality in the area.

Radical new thinking, and new management approaches, may be needed.



Figure 20: Fence-line contrast between communal rangeland (left) and commercial ranch (right) in the Witteberge east of Lady Gray. (Photo: Martin Kleynhans)



Figure 21: A fenced area where herbivores have been excluded for 10 years next to an area where herbivores have been present. This herbivore exclusion plot is located in the Hluhluwe-iMfolozi game reserve. The absence of herbivores can radically change the structure and type of vegetation growing in an area. (Photo: William Bond)



Figure 22: Fire (or the absence thereof) can completely change the type of vegetation growing in an area. (Photo: Murray Ralfe)

CO₂ AND SOUTH AFRICA'S CHANGING BIOMES

Among global drivers, increasing carbon dioxide (CO₂) is the most likely candidate driving the changing balance between grasses and woody plants, and is likely to be a very important contributor to vegetation change across Africa.

Increasing CO₂ can improve tree growth and the CO₂ fertilisation effect should allow responsive species to cope far better with fire and browsers than in the past (see box for details). Long-term burning experiments in the Kruger National Park and eastern Cape have shown striking increases in three dominant woody species, *Acacia karroo*, *Dichrostachys cinerea* and *Terminalia sericea*. Negligible change was recorded in Kruger from the 1950s to the 1970s, but from the 1970s to the early 2000s, there was a ten-fold increase in the number of *Terminalia sericea* and an eight-fold increase in *Dichrostachys cinerea*. These changes occurred in spite of the same fire treatments over the entire period. The change in tree response is most likely a result of a global driver, the inadvertent effects of CO₂ fertilisation. No comparable changes were seen in *Acacia nigrescens* in semi-arid

savanna, so the CO₂ fertilisation effect is not a general one. Screening of CO₂ responsiveness is needed for a wider diversity of species to establish which species are likely to become natural invaders.

An important message on the CO₂ effect on woody plants is that land practices that were effective in controlling trees in the past, may be ineffective today and into the future. Yet management practices do clearly influence ecological trajectories of land cover change. With innovative thinking, we have far more potential to manage our future ecosystems to the most desired state than, say, nations in the north where global warming is transforming the environment. Alternatively, we can passively accept the changes and face the uncertain consequences of our changing nature.

WEIGHING UP THE CONSEQUENCES: MEETING THE NEEDS OF PEOPLE AND ECOSYSTEMS

South Africa's natural areas have undergone remarkable changes, particularly in the summer rainfall areas. These changes are likely to continue if unchecked. We have early indications that these changes will have far-reaching economic and ecological impacts, however much is still to be learnt. Some of these impacts are indicated below:

Biodiversity

- The changing land cover has changed the habitats for many species. Bird atlasers have noted changes in the distribution of birds, with increases in birds preferring more woody areas.
- Savanna animals preferring open habitats are beginning to decline in some protected areas as woody trees and shrubs increase. Visibility of game to tourists has also declined because of woody increase in some popular parks.
- Bush encroachment causing savannas to switch to closed thicket vegetation causes a cascading change in species. In one example, 102 plant species and 25 ant species exclusive to savanna sites were lost from the invaded areas (Parr *et al.* 2012).



Land cover changes have economic consequences

- The change in land use can affect important ecosystem services. For example, large increases in trees can significantly increase water use by vegetation, thereby reducing the amount of water entering rivers and wetlands.
- Increasing tree cover in game parks reduces appeal to visitors as game viewing opportunities are affected and the sense of place is altered. This not only reduces the tourism potential of an area, but also forces managers to increase the amount of time and money spent clearing bush.
- Grazing land is impacted. For example, in Namibia it has been calculated that bush infestation affects 26 million hectares and has led to a 60% decline of commercial livestock over the last 40 years, causing losses to the national economy. Farmers not only lose grazing land, but also face additional bush clearing costs.
- On a positive note, the additional wood provides a potential economic benefit and can be used as a source of clean energy and fuelwood.
- Alien plant invasion in areas like the Fynbos Biome is converting large natural areas, reducing water yield and damaging these natural areas. For example, a study on alien plant invasions in some parts of fynbos showed that alien invasion of catchment areas could result in a 30% loss of water provision services to Cape Town.

OPTIONS FOR MANAGING OUR FUTURES

South African ecosystems are changing and are very likely to continue to change. However we do have options available to us to manage these changes. Given the range of different and new drivers of change, the management actions that farmers and land managers successfully used a few decades ago will no longer work in the same manner. Rigorous and objective scientific analysis should identify sustainable pathways to manage natural resources and ensure ecosystem integrity.

In this booklet we have highlighted the importance of fire and herbivory in shaping our ecosystems and how creative use of these 'tools' in a management context provides additional options for managing the future of South Africa's nature. In addition to looking for new tools, research indicates that we need a co-ordinated, creative and supportive system to allow us to manage the change that we are experiencing, including some of the following:

- **Legislation.** While South Africa has some of the most progressive environmental legislation in the world (e.g. NEMA, NEMBA) its implementation has not always been effective. Effective implementation requires a clear communication strategy from government, adequate enforcement of the legislation and the inclusion of end users in the regulatory process, amongst other factors.
- **Research and monitoring.** We need to understand the extent of the changes and their consequences. Satellite imagery provides the opportunity to document recent changes across South Africa. We can use this knowledge to understand why they have occurred, to manage them and to predict future changes. It is vital that we have a comprehensive monitoring network with world class instrumentation to assess these changes (e.g. SAEON, SANBI) and that we use the wealth of historical data that is present in South Africa to our best advantage.

- South Africa has a **wealth of long-term experiments** that have been carried out in conservation areas and agricultural research stations. Some of these long-term experiments have been maintained, others have fallen into disrepair or been discontinued. The continued maintenance and re-establishment of such studies are a priceless asset in understanding and adapting to global change.
- **Governance.** We need to organise ourselves at multiple levels – from local to national levels – to ensure that we address the critical problems of land cover change and/or land degradation in a co-ordinated manner. Organisations like SANBI and the Natural Resource Management Programmes of the Department of Environmental Affairs (including Working for Water) are institutions that can take a lead.
- Management interventions. We have the opportunity to draw on a well-established body of knowledge concerning **land management**. The challenge is to do so in new and creative ways so as to manage and, if possible, benefit from the changes that are occurring.
- **Education and awareness.** Climate change has become a prominent societal concern. Our ability to respond to global change in South Africa will benefit from an informed public. We should consider including this environmental information in the school curriculum. Awareness programmes should also be initiated to inform land users most likely to be affected by changes, e.g. agricultural boards and communal farmers.



Figure 23: There is a need to understand how elevated CO_2 will impact growth of South Africa's crops and native plants. This picture shows a new facility for elevated CO_2 research in South Africa being installed at Rhodes University. (Photo: Brad Ripley)



WHEN PLANTING TREES IS NOT A SOLUTION

One of the clearest changes that we have noticed in South Africa is the dramatic increase in trees and shrubs in our economically and ecologically important open areas. Some observers suggest that this is “nature’s way of healing itself” since trees ‘soak up carbon’. However woody thickening represents a huge threat to biodiversity, ecosystem functioning and the ecological services that these open systems provide. South Africa’s Working for Water programme is built around clearing alien invasive trees from grasslands and fynbos to promote streamflow. As regards farming, widespread bush encroachment comes with a heavy economic cost through loss of tourism potential, increased clearing costs and loss of grazing land, as has been well documented in Namibia.

In contrast to the negative effects of woody increase at the local (South African) scale it is often proposed that this is a solution for storing carbon (and reducing the greenhouse effect) at the global scale. Such thinking is also often the basis of tree planting campaigns. So will the increase in trees in grassy biomes contribute to a reduction of carbon, mitigating the effects of global warming?

Let’s put this proposed solution in perspective. Firstly, studies in the USA indicate more carbon is released into the atmosphere when trees invade arid savannas due to loss of soil carbon. So carbon sequestration can only successfully happen in higher rainfall savannas where a net gain of carbon occurs by accumulating in tree stems and in the soil. A recent study in South Africa measured the net increase in carbon that occurred when an ancient grassland was invaded by a forest. The forest stored more carbon in stems (121 tons/ha more than grasslands) and more carbon in the soil (45 tons/ha more than the grasslands). This increase may seem beneficial however when putting this in perspective: CO₂ in the atmosphere is increasing at a rate of about 2.5 parts per million (ppm) per year, largely from fossil fuel use. To soak up just one year’s increase of CO₂ (2.5 ppm CO₂), you would need to convert about 300 000 km² of grassland into forest using these values. That is equivalent to the area of Limpopo, Mpumalanga and KwaZulu-Natal combined, or more than 80% of South Africa’s Grassland Biome! For just one year’s increase in CO₂!

Full accounting of the consequences of replacing grasslands with forests must also explore additional earth-atmosphere feedbacks. An increase of tree cover makes the earth’s surface darker. Darker colours absorb more heat, which warms up the world. Conversely, open areas like grasslands are bright, especially in winter, and they reflect heat off the earth’s surface. Thus a switch from grassland to forest would be expected to warm the planet, countering the effect of any carbon sequestered. Full accounting of the effects of land cover change on global warming is needed to guide decisions on tree planting in African grassy ecosystems.



TAKE-HOME MESSAGES

- South Africa is a treasure trove of biodiversity which delivers a number of critical ecosystem services for people.
- The biodiversity is impacted by both global drivers, such as CO₂ and climate and local drivers such as fire and land use.
- Both global and local drivers have changed significantly over the last few decades. Some, such as temperature and CO₂ have shown directional changes over time while others, such as fire and herbivory are relatively haphazard and changes have been determined mostly by local circumstances.
- Woody plants now dominate large parts of what was previously open savanna vegetation in the summer rainfall areas of South Africa. Trees and shrubs have expanded into areas that were once purely grassland environments.
- In the semi-arid shrublands of the country, grass cover has increased in the eastern Karoo to such an extent that fires are beginning to burn where they never did before. There is little change in western shrublands except in the lowlands of the heavily grazed communal areas. The largest changes that have happened in the fynbos occurred when invasive alien plants have spread or where fire has been excluded and forest and thicket species have taken over.
- Reasons for these changes are complex and include both local (e.g. land management) and global drivers (e.g. climate change). We need to improve our understanding of the role of CO₂, and how it interacts with other drivers as its influence is likely to increase in the future with ever increasing CO₂ levels.
- Land management strategies (e.g. managing grazing land and bush encroachment) that were successful in the early 20th century may no longer be effective. We therefore need a broad response to the changes that are occurring. This includes novel management approaches, effective legislation and governance, research and monitoring as well as education and outreach.
- South African ecosystems are changing. What will they look like in ten or 50 years from now and what can be done to alter their current trajectories? We need to examine the costs, and benefits of these large-scale changes. In this uncertain new world, we welcome new observations, innovations, and ideas to help direct South Africa's nature so as to benefit all.

FURTHER INFORMATION

Climate Systems Analysis Group, University of Cape Town: www.csag.uct.ac.za

CSIR Climate Studies and Modelling Group: www.csir.co.za

Intergovernmental Panel on Climate Change: www.ipcc.ch

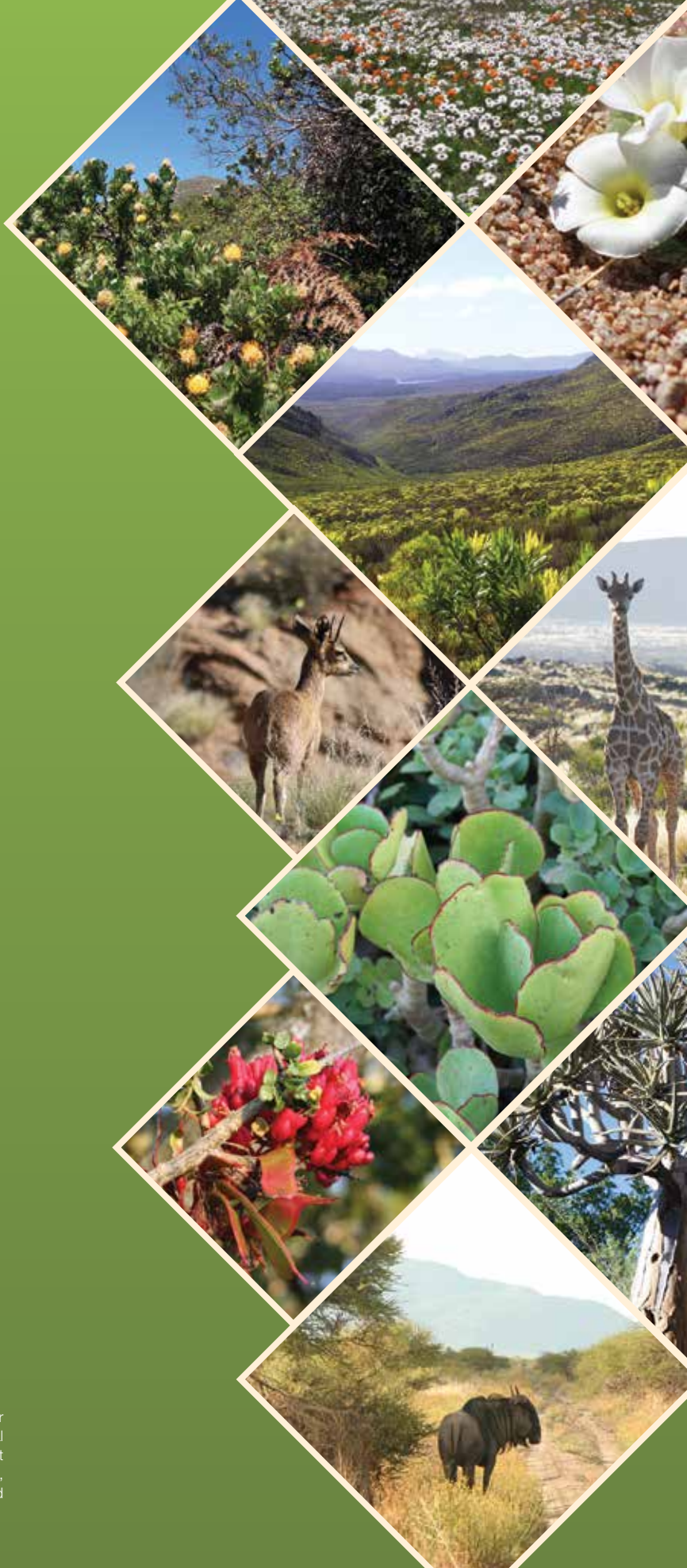
South African Environmental Observation Network: www.saeon.ac.za

South African National Biodiversity Institute: www.sanbi.org

United Nations Framework Convention on Climate Change: www.unfccc.org

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