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the heat is on...

impacts of climate change on plant diversity in South Africa

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IN A NUTSHELL

South Africa's botanical treasures are world-renowned, with almost 10% of the Earth's recorded plant species being found in the country, which has an area of less than 1% of the world's land surface!

The winter-rainfall Succulent Karoo and Fynbos Biomes in the south-west, and the Maputaland-Pondoland-Albany region along the eastern escarpment and its coastal plain, are all recognised as global 'hotspots' of plant biodiversity. These regions are exceptionally rich in unique plant and animal species - but many of these landscapes face severe degradation and hundreds of their unique species are listed as threatened with extinction.

Extinctions that have occurred here in the recent past have usually been the result of habitat transformation caused by agriculture and urbanisation. Today, however, a far less visible risk threatens to make vast areas of South Africa uninhabitable by the plants that have lived here for millennia. This threat is global climate change.

Scientists at the South African National Biodiversity Institute, University of Cape Town, and other collaborators nationally and internationally have been studying the possible impacts of climate change on the survival and distribution of South Africa's indigenous plant and animals. This report is a brief summary of their findings, and is the first revision of the publication ***The Heat Is On*** (2001), which derived material submitted as part of the South African Country Study on Climate Change, but can now be updated substantially with new results. The preliminary results presented in the original publication were considered disturbing enough to warrant broader exposure and discussion, and this was certainly achieved. Subsequent work has done little to dispel the sense of urgency that was engendered by those findings, and we welcome you to read ***The Heat Is On*** (2008).

PLANT PARADISE

Boasting more than 23 000 indigenous species, and great richness in insect, bird, mammal, amphibian, and reptile groups, South Africa truly is a paradise of biodiversity. Climates past and present have a lot to do with this rich diversity.

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.

What will happen to these familiar patterns of vegetation and animal distributions if projections of global climate change trends continue to hold true? A broad school of collaborating researchers led in South Africa by the South African National Biodiversity Institute has been investigating the possible effects of global climate change on indigenous species diversity in South Africa. This suite of studies is one of the first research programmes in the world to link the issues of climate change and biodiversity conservation, thereby servicing both the United Nations conventions on Biological Diversity and Climate Change.

IS THE CLIMATE CHANGING?

Our lifespans represent a mere snapshot in time. While we mark the decades, Earth history is measured in thousands to millions of years. So is it reasonable to believe that the climate change currently being observed is something completely new? Certainly, climatic changes have happened before under natural forces – shifts that have sometimes been extreme, and resulted in major extinctions. Over the last 500 000 years, we now know with exquisite precision that the Earth has warmed and cooled 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 50-100 years.

What is new, however, is that this time people are causing the Earth's climate to change. While there is a resolute band of so-called "sceptics" who insist that this is not the case, the Nobel-Prize winning Intergovernmental Panel on Climate Change (IPCC) has concluded with 90% confidence that at least half of the warming observed globally over the past few decades is due to human activity (mainly the burning of fossil fuels – coal, gas and oil – and deforestation).

Recent research shows that temperatures are rising higher and faster than can be explained by natural phenomena such as solar activity. Instead, rising temperatures mirror increases in the concentrations of so-called 'greenhouse gases'. Gases like carbon dioxide and methane naturally trap heat in the atmosphere, making the Earth a pleasant place to live. But in the last 150 years, fossil fuels have powered the industrialised world, carbon dioxide levels have increased by more than 35%, and the 'greenhouse effect' has gotten out of hand, as natural "sinks" for CO_2 like tropical forests have been transformed. We are starting to feel the effects of an atmosphere and biosphere polluted by the by-products of progress.

So is the climate really changing? Draw your own conclusions:

- Temperature reconstructions since AD 1000 indicate that the 20th Century was unusually warm - and the 1990s was the hottest decade on record, with the 2000's shaping up to revise that record.
- Global sea levels rose 10-25 cm in the last century.
- Glaciers in the European Alps have lost half their volume since the 1850s.

OUR GLOBAL RESPONSIBILITY

South Africa is a signatory to, and has ratified the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. The principle aim of this international agreement is to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner". Signatories to the Kyoto Protocol (which is in force only from 2008-2012) have agreed to reduce emissions of greenhouse gases (in the case of industrialised nations) and to report regularly on strategies to mitigate and adapt to climate change (all signatories, including developing countries). Currently, a successor to the Kyoto Protocol is being negotiated, that will enhance efforts from all parties to achieve the objective of the Convention after 2012.]

FACT!

The concentration of carbon dioxide in the atmosphere has increased more than 30% since the dawn of the industrial revolution, and is now higher than it has been in the past 650 000 years.

- In the Antarctic, the five most northerly ice shelves retreated dramatically between 1945 and 1995.
- The Arctic ice-cap has thinned by 40% since the 1950s, and a navigable north-west passage is now a distinctly imminent possibility.
- The ranges of thousands of animal species in the northern Hemisphere have shifted northwards since 1900.

SOURCES OF UNCERTAINTY

Climate change research is not an exact science. For a number of reasons, projections are uncertain:

We don't entirely understand how climate functions, and some details may be inherently impossible to model because they are "chaotic", or very sensitive to minor perturbations.

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 will depend on trends we cannot accurately predict, such as human population growth, the use of fossil fuels especially by emerging economies, and introduction of new, less polluting energy technologies.

CLIMATE CHANGE RESEARCH

Climate change research is both complex and uncertain. This is because climate itself is the result of complex interactions between the Earth's atmosphere, oceans and land surfaces that we do not fully understand.

In order to simulate and predict climate, scientists have developed computer programs known as General Circulation Models or GCMs. If, for example, information about the concentration of greenhouse gases in the atmosphere is given, these models can roughly predict the climatic conditions that will result.

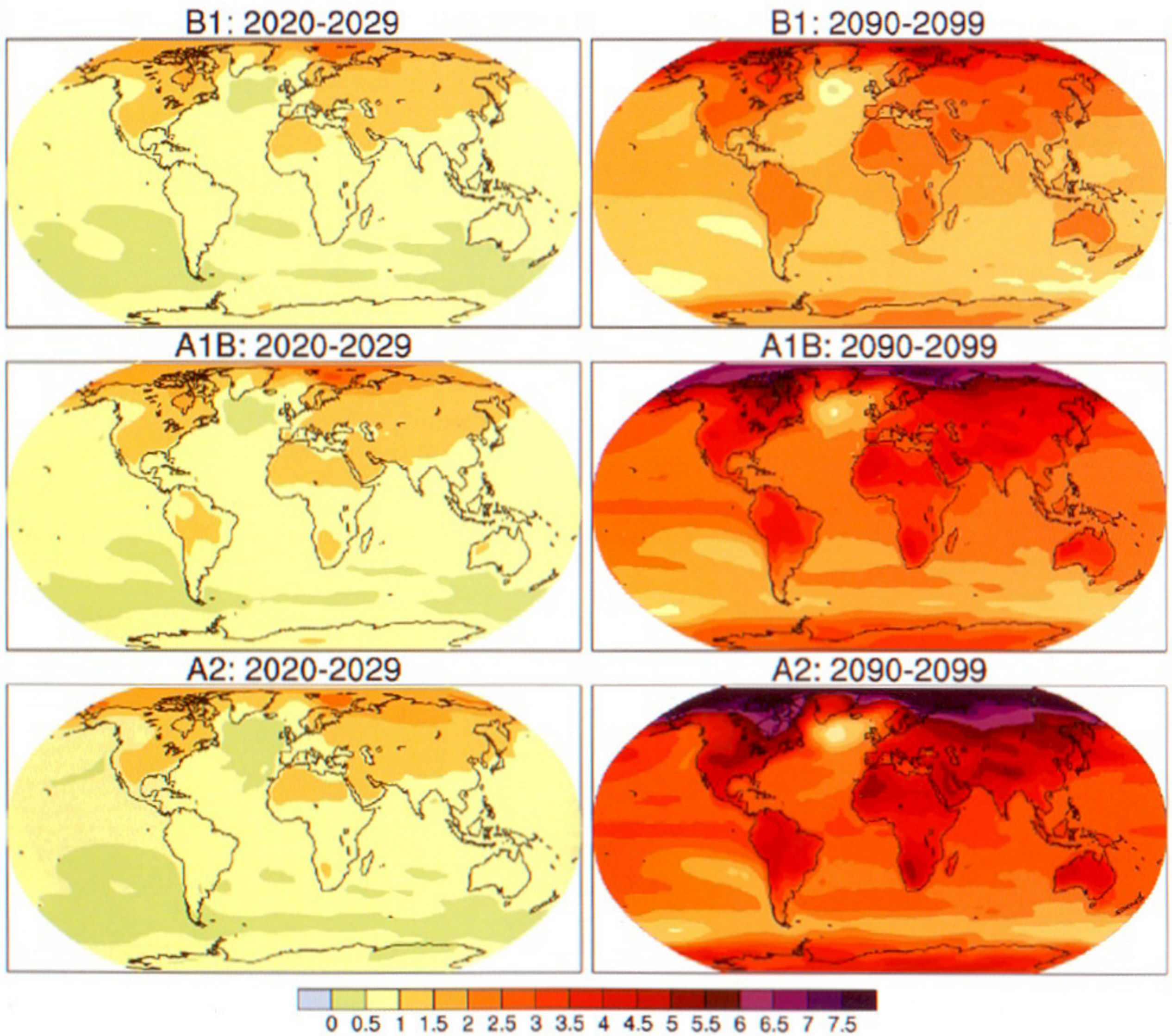
The South African Country Study and subsequent work described here was based on climate projections produced by several internationally recognised institutes. In order to understand the vulnerability of biodiversity to a range of possible development scenarios, more recent studies assume a range of possible greenhouse gas emissions pathways as described by the recent IPCC fourth assessment report.

PREDICTING THE CLIMATE

It is clear from the computer models that climate will not change uniformly across the globe. Land areas will warm up faster than the oceans and polar latitudes faster than temperate latitudes. Coastal temperatures will generally rise more slowly than inland, thanks to the moderating effect of the ocean.

In the Northern Hemisphere global warming may actually benefit agriculture, as areas that are currently too cold to farm become warmer. On the other hand, agriculture faces an uncertain future in the Southern Hemisphere, where large areas will become as much as 3°C warmer and much drier.

Higher temperatures are predicted over the whole of South Africa through the 21st century. January temperatures are expected to increase most in the central interior and Northern Cape, and least at the coast. In general, summer rainfall is currently difficult to project, and there is disagreement among the many models run by the IPCC even as to the sign of the rainfall change (higher or lower). Using a knowledge of regional climates, it seems as though the summer rainfall region might become slightly wetter, but with longer dry spells between rainfall events. Combined with higher temperatures that increase evaporation rates, this indicates a generally drier environment into the future. Almost all models agree that there will be a decrease of up to 20% or more in the rainfall of the western and southern Cape.

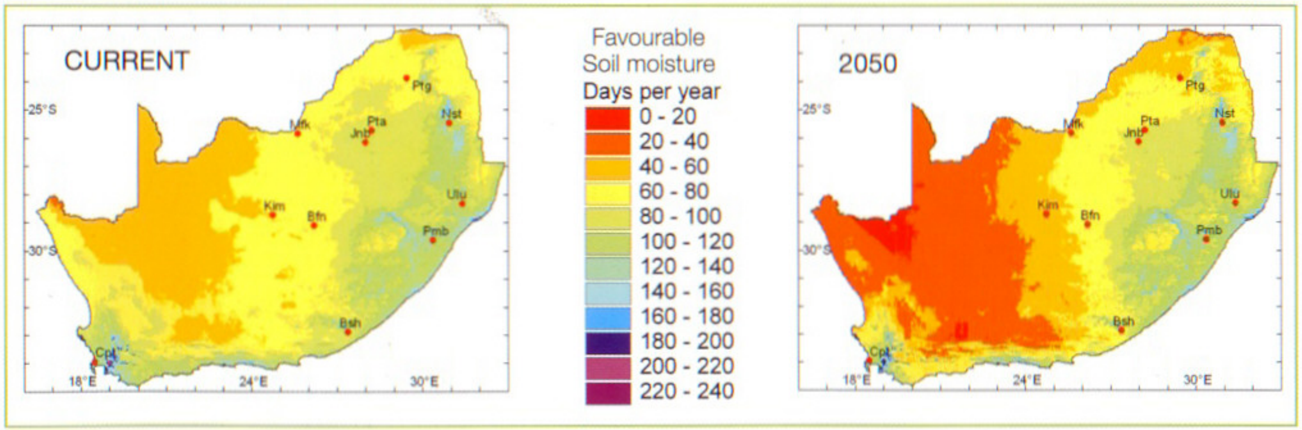


The projected effect of global climate change on mean annual temperatures during the 2020's and 2090's. Indicated are three distinct development scenarios that assume specific greenhouse gas emissions trends (see www.ipcc.ch for details of this Summary for Policy Makers report).

VEGETATION CHANGES

Each plant species or natural vegetation region (biome) occurs within a particular climatic range. Some of the climatic factors that limit plant distribution include rainfall amounts and seasonality, and minimum and maximum temperatures in summer and winter. For the purposes of the South African Country Study, an older generation GCM was used, that represents an extreme dry scenario for the future of South Africa by mid century. This is however a useful scenario to gauge the vulnerability of this region to climate change, as it depends on the sensitivity of the regional climate to global change trends, and to identify the potentially most affected areas. This also underscores the importance of ongoing monitoring of climate and ecosystem changes to test the outcome of projections against observations, and allow appropriate corrections in modelling methods to be made.

The effect of global climate change on 'soil moisture days' in South Africa (days when both soil moisture and temperature are suitable for plant growth



Soil moisture days measured in 1990
(360 ppm CO_2)

Soil moisture days predicted for 2050
(550 ppm CO_2)

The South African Country Study investigated the effects of climate change on 44 indigenous plant species and on the biomes as a whole. The researchers compared distribution maps of the plants and biomes with maps of various climatic factors. This enabled them to compile profiles of preferred climatic conditions for each biome and plant species. They then compared these profiles with maps of predicted climatic conditions in 2050 to construct future distribution maps for the biomes and plant species. Subsequent work has refined these initial studies, and now similar work has been done on many hundreds of species of plants and animals.

MORE THAN JUST CLIMATE

Although climate is important in determining where particular plants can grow, it is not the only factor. Soil types, fire, pests, grazing and competition from other plants all play a role. Furthermore, agriculture and urbanisation have fragmented many natural areas, reducing them to islands in a sea of development.

Even without the above limitations, we do not know how quickly plants will be able to disperse into new areas, and whether they will be able to keep pace with shifting climates.

Projections based on climatic factors alone represent a first approximation of possible future plant distributions in South Africa. As the actual story unfolds, the patterns that emerge may be very different, reflecting many of the interactions that influence where plants grow. What is of concern is that these other factors are likely to restrict plant distributions even further than the climate-based projections in this report.

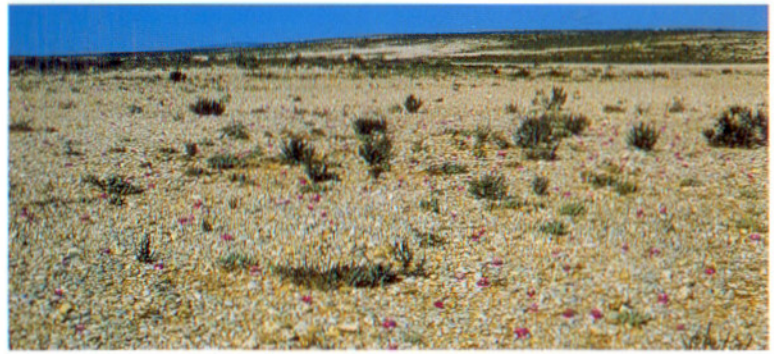
BIOMES AND HOTSPOTS

The vegetation of South Africa is so rich and varied that, when discussing plant distribution, it is convenient to refer to broad ecological regions. We call these regions biomes, and they are characterised by particular climates and vegetation types. Ecologists have described seven South African biomes, namely Desert, Forest, Fynbos, Grassland, Nama-Karoo, Savanna and Succulent Karoo.

- The Fynbos and Succulent Karoo biomes are found in the western parts of South Africa where rain falls in winter.
- Nama-Karoo vegetation, with its typical hardy bushes and grasses, covers much of the arid interior.
- In the summer rainfall areas, Grassland dominates much of the highveld where frost restricts the growth of trees.
- The coastal and lowveld regions are warm enough in winter to support Savanna vegetation.
- The smallest biomes are the Forest Biome in the southern Cape and a tiny area of true Desert in the extreme north-west of the Northern Cape.

According to climate models, within 50-100 years the biomes as we know them will have been reduced to 35-55% of their present area (see opposite). Climatic conditions in the rest of the country will be unlike anything experienced in South Africa today, but may be similar to conditions north of the border.

From the point of view of plant conservation, one of the greatest challenges is how climate change may affect plant biodiversity 'hotspots'. These areas are unusually rich in species but are highly threatened by human activities. Hotspots may also have a number of endemic species, which have such restricted natural distributions that they are found in that particular area and nowhere else on Earth!



The Succulent Karoo is a global 'hotspot' of plant biodiversity.

Climate change models predict that the western part of South Africa will become progressively drier.

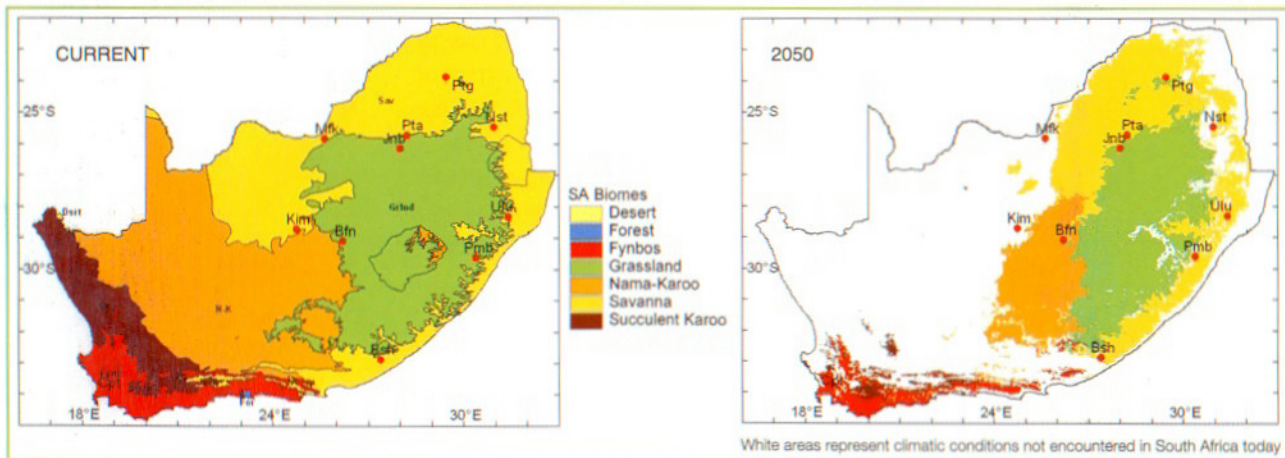
What will happen to the unique plants of this region as it becomes more desert-like?

One such global hotspot is the Succulent Karoo Biome, which has the richest succulent flora in the world. These plants live on the edge of survival, completely dependent on low but fairly reliable winter rainfall. If the climate of this region becomes any drier, the effects on the entire biome will be devastating.

The potential effect of global climate change on the biomes of South Africa:

The biomes of South Africa in the year 2050

Projections are based on climate changes brought on by an increase in the concentration of atmospheric carbon dioxide to 550 ppm, using an older generation GCM that illustrates an extreme dry scenario outcome by 2050. Please see the next figure for an updated projection for the Succulent Karoo Biome, based on updated scenarios.



The biomes of South Africa as mapped in the year 2000

A THREATENED HOTSPOT

Of all the projections made in the South African Country Study report, the most worrying relate to the Succulent Karoo. Subsequent work has not contradicted this finding. The older generation climate change models project that within 50-100 years, areas that support Succulent Karoo vegetation today will become so arid that only the hardiest plants of that biome will be able to survive.

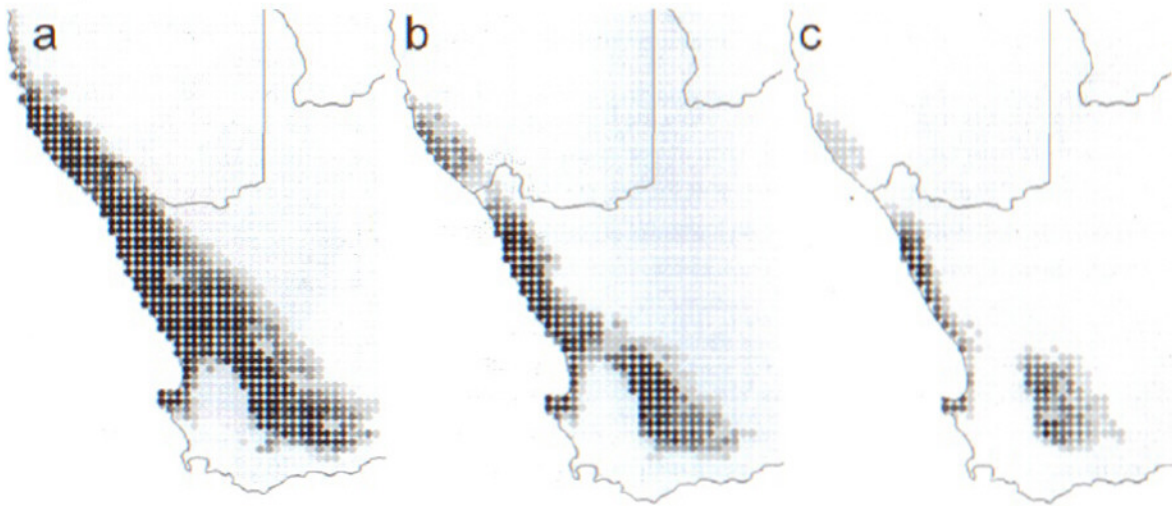
However, updating these projections with more recently produced climate projections has produced some interesting findings.Indications are that the changes projected, while similar in spatial pattern, may be less extreme and may occur over a longer time frame. Essentially, this implies that conservation strategies are feasible for this region of the world, and actions such as providing spatial continuity between protected areas may allow key species to migrate across landscapes to keep pace with climate change shifts.

Further work has also been done to investigate if early changes in vegetation can be observed in this biome, because temperatures have been observed to rise significantly over the past thirty years. Our work on *Aloe dichotoma*, the quiver tree, has indicated that this species is showing signs of decline in the northern part of its range (the hottest part of its geographic range) and it is showing expanding populations in the south (the coolest part).

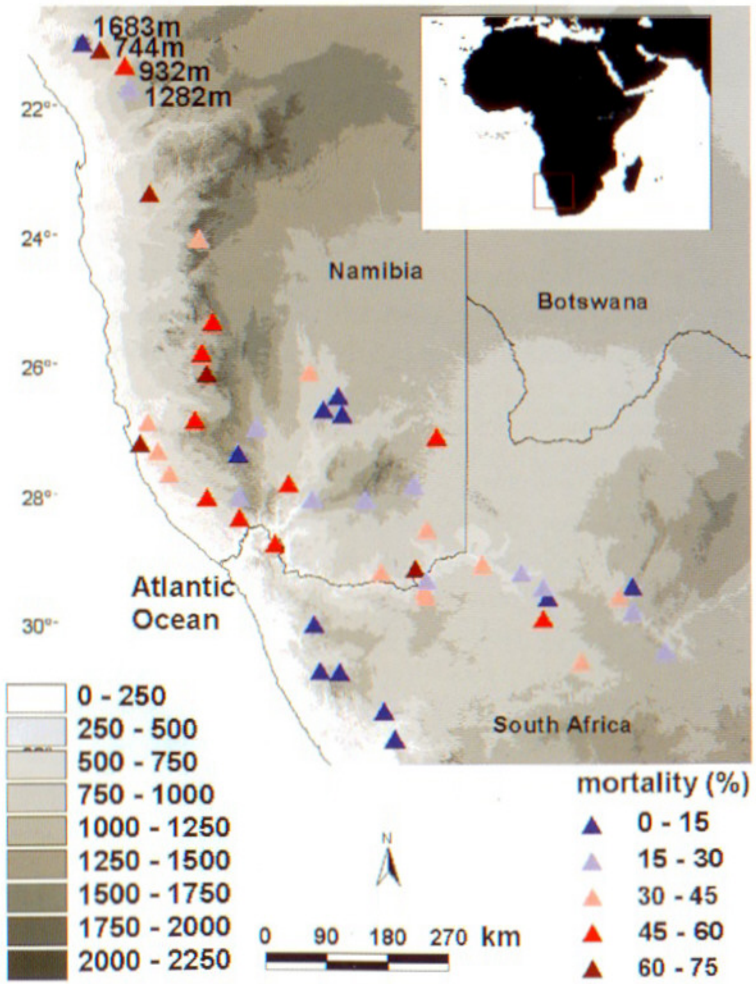
This indicates that the observed shifts in temperature are affecting the survival of this species as projected by climate and species models, implying the presence of a 'fingerprint' of climate change, and we can expect the range overall to contract in the north, and expand in the south, as long as the species is able to migrate southward. Unfortunately, it seems that the regions of highest genetic diversity of this species are in the north, and this ongoing change will both reduce the range of the species, and reduce its genetic diversity (see Figure opposite for a map of Kokerboom mortality).

Revised projections of the impacts of warming and rainfall change on the original extent of the Succulent Karoo Biome (a); by ~2050 (b) and ~2090 (c), using updated modelling methods, development scenarios and climate projections.

Results indicate substantial impacts on the extent of the biome, but these could occur at a slower rate than initially projected in "The Heat Is On (2001)".



Patterns of mortality of Aloe dichotoma *(Quiver tree) in Namibia and western South Africa, indicating a response to warming which results in greater mortality at the northern reaches of its geographic range.*



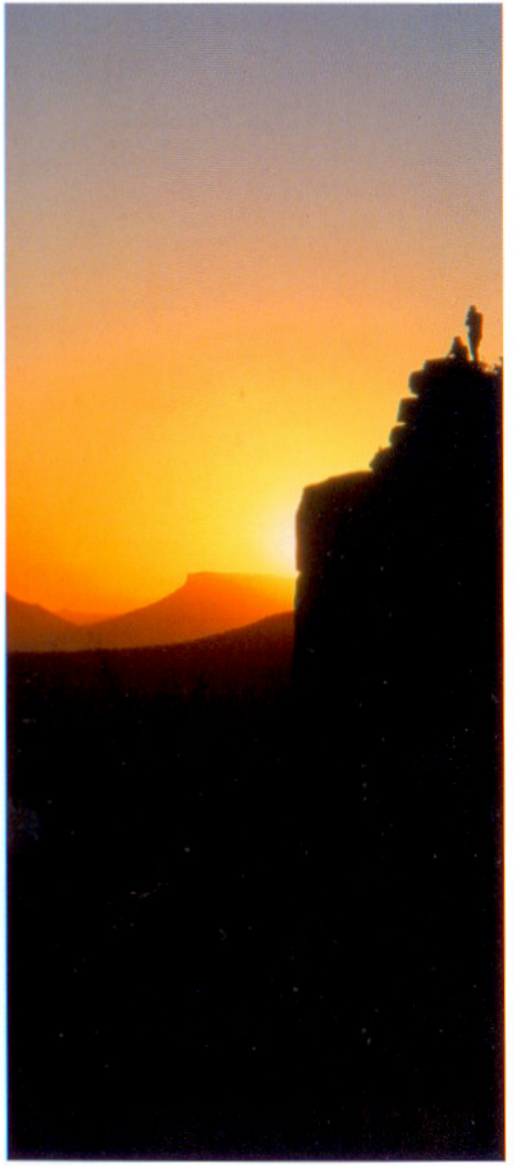
TRANSFORMING GRASSLANDS

There is considerable debate about how the Grassland Biome resists invasion by trees. Frost is thought to help maintain the Grassland Biome by killing the seedlings of many trees and shrubs that would otherwise grow there. However, it is also possible that grassland fires eliminate trees at higher altitudes because of a limited growing season length for trees at the cooler high altitudes. As the climate warms up and frost becomes less frequent, or the growing season for trees lengthens, woody plants could well be able to invade grasslands, transforming them into Savannas. Ongoing work at UCT will address this question and provide a better idea of what to expect with warming trends.

Ongoing research done by SANBI and UCT suggests that, in addition to affecting global warming, an increase in atmospheric carbon dioxide may also directly stimulate the growth of trees and shrubs in the following ways:

- Increasing carbon dioxide levels affect the metabolism of grasses such that they need less water to grow. Water that is not absorbed penetrates more deeply into the soil where it is available to the roots of shrubs and trees.
- Carbon is the raw material that plants use to build their cells and tissues. Plants absorb carbon in the form of carbon dioxide and convert it into building materials like cellulose and wood. Woody plants need much more carbon than grasses, so higher levels of carbon dioxide in the atmosphere will stimulate the growth of trees and shrubs.

Overall, trees may be expected to grow faster in these summer rainfall regions, as long as water is available, and we could see some dramatic changes in vegetation structure in these regions as temperatures and CO_2 continue to rise.



EFFECTS ON EVOLUTION

In the past, climate change probably had a lot to do with the process of speciation (the evolution of new species) that created the plant-rich Fynbos and Succulent Karoo Biomes.

As climates cooled during glacial periods, Fynbos expanded northwards and Succulent Karoo plants took refuge in the Knersvlakte and Richtersveld, both centres of endemism today. As the climate warmed during interglacial periods, the Fynbos retreated into the cooler mountainous areas, and the Succulent Karoo expanded into its current distribution.

These ebbs and flows of plant distribution led to populations of plants becoming fragmented, and then making secondary contact. This provided fertile ground for speciation through genetic changes and hybridisation.

THE FUTURE OF FYNBOS

Two of South Africa's biomes are rated as global plant biodiversity hotspots. We have looked briefly at the Succulent Karoo, but the Fynbos Biome, also found in the winter rainfall region, is probably better known. This biome has an extraordinarily rich flora, with at least 5 600 of the 8 000 plant species being endemic (restricted) to the region.

Although it covers a relatively tiny area of the Earth's surface, Fynbos is so unusual in terms of its plant groups that it is recognised as part of one of only six floral kingdoms of the world - the Cape Floral Kingdom.

Human activities like the emission of greenhouse gases threaten to raise temperatures on Earth higher than they have been in the last 1.5-2.5 million years. How might this affect the Fynbos Biome and, indeed, the entire Cape Floral Kingdom?

As in the Succulent Karoo Biome, climate change will seriously threaten the Fynbos Biome over the next 50-100 years. The northern arm of this biome may disappear altogether, and we will lose many of the more drought-sensitive fynbos plants. Because the biome has a very high proportion of endemic species, any loss of range will result in extinctions.

Despite these concerns, the mountainous terrain of much of the Fynbos Biome provides some hope. Within these rugged habitats are many niches where plants can survive. As it gets hotter, plants can also theoretically retreat to higher, cooler altitudes. Furthermore, coastal fynbos may experience less extreme changes in climate, thanks to the moderating effect of the ocean.

Climate change may also cause fynbos plants to go extinct because of a number of secondary effects:

As the climate becomes hotter and drier, fires may become more frequent and extensive. If Fynbos burns before plants are old enough to set seed, local extinctions could result. Drought may also kill adult plants before they can set seed.

Many plants rely upon animals for their survival. Pollination and seed dispersal are two processes aided by a variety of birds, insects and rodents. Climate affects animals and plants in different ways: day length may influence flowering, but temperature may control the life cycles of insects. What could happen if the life cycles of these mutually dependent plants and animals got out of synch? At this stage, our understanding of the physiology of indigenous plants and animals is limited - but we can speculate that climate change could disrupt many of these close and essential relationships.

Climate change may also affect the growth of alien plants in the Fynbos Biome. As the fires on the Cape Peninsula in January 2000 showed, woody aliens are a hazard not only to the fynbos but also to people's property. Increasing levels of carbon dioxide in the atmosphere encourage the growth of woody plants. Could this exacerbate the alien problem in the Fynbos Biome?

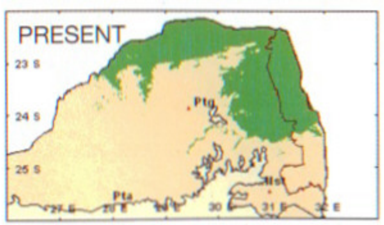
Despite these concerns, large tracts of mountain fynbos are conserved and may provide this globally important centre of endemism with a hedge against extinction.

SHIFTING SAVANNA

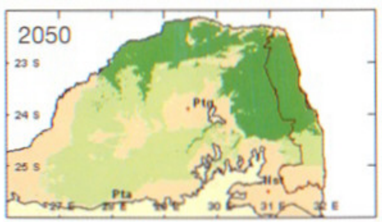
The Savanna Biome is as typical of Africa as the herds of game that it supports. The term Savanna describes a wide range of vegetation types, from the arid camel-thorn veld of the Kalahari to the bushveld and the coastal woodlands of KwaZulu-Natal. As climate changes, there may be a major rearrangement of plant species from these various savanna vegetation types. Some species may disappear altogether, while the distribution ranges of others may shrink or expand.

For example, as the temperature rises, some lowveld plants like the tree wisteria (*Bolusanthus speciosus*) may be able to spread to higher altitudes along the edge of the escarpment. As previously mentioned, trees and shrubs from the Savanna Biome may start encroaching into what is currently the Grassland Biome.

The mopane tree (*Colophospermum mopane*) is one species that is predicted to extend its range substantially in the Northern Province and Mpumalanga lowveld. The maps show that mopane trees could colonise the southern parts of the Kruger National Park. This is bad news for tourism because, although mopane woodland supports large numbers of elephants, it does not favour the diversity of large mammals that most tourists visit the Park to see.



Current distribution of mopane trees in the Kruger National Park

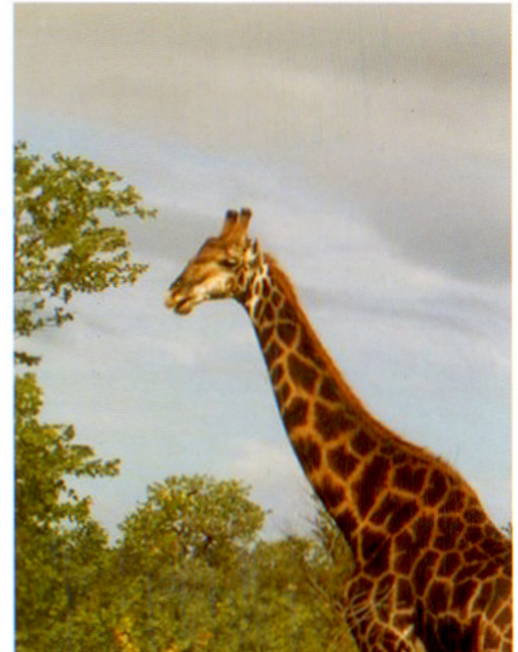


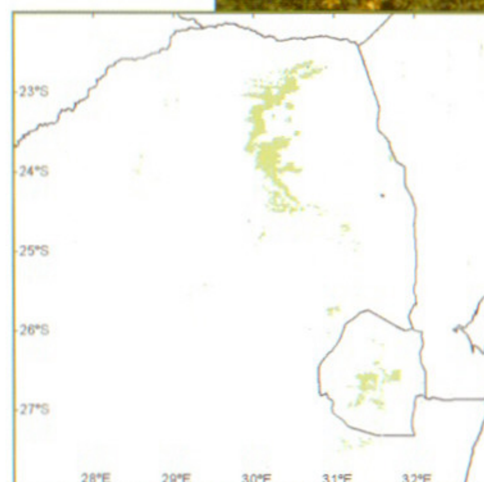
Predicted distribution of mopane trees in the Kruger National Park

In South Africa, Savanna is found mainly in the north and east but it is also widespread north of the border, where some types of savanna vegetation occur in warmer and drier climates than are typical of most of its South African distribution.

As the climate changes, Savanna as we know it in South Africa may retreat from the northern and eastern borders of the country, and be replaced by plants adapted to hotter and drier conditions further north.

The Miombo woodlands of Zimbabwe and other parts of south-central Africa were previously thought not to occur anywhere else in South Africa. However, the Msasa (*Brachystegia spiciformis*), a typical Miombo woodland tree, has very recently been discovered in a tiny area of the Northern Province. The study shows that this plant was indeed expected to occur in small numbers in South Africa and that the future climate in large parts of the Northern Province and Mpumalanga will potentially be able to support Miombo woodland, as it expands from its present remnant population (as the map below indicates).



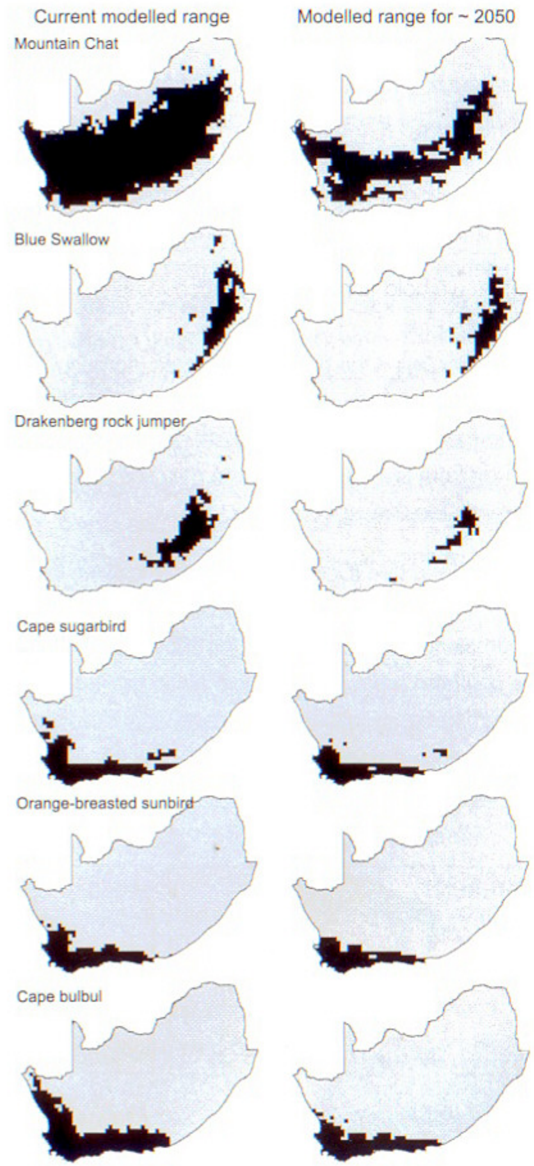


Today, Brachystegia spiciformis *occurs from Mozambique and Zimbabwe northwards into central Africa, and only in a recently discovered, tiny spot in South Africa. Within 50-100 years, the climate of much of the Northern Province will be favourable for the growth of this tree*

ANIMALS

Developing the kind of models we describe above for animals is even more complex and uncertain than the models we have developed for plants. While plants are more obviously directly controlled by climate and soils, animals are generally more mobile, adaptable with respect to shifting their ranges, and more dependent on habitat than on climate alone. Despite this, we have taken the first steps in projecting shifts of geographic ranges in a large number of mammal and bird species in the subcontinent. In general, the findings are similar to those for plant species, with many species projected to shift or lose at least a part of their current geographic ranges.

Ongoing work to explore the recent shifts in bird species in South Africa by enhancing monitoring efforts especially by engaging the assistance of dedicated members of the public are underway, and we hope to be able to report on these findings in the near future.



WHAT CAN WE DO?

As with most environmental issues, ignoring global climate change won't make it go away. Mounting evidence demands that we start taking climate change seriously, both individually and collectively.

Individual action:

Before we hold 'dirty industry' accountable for global warming, we should ask ourselves:

- How much do our needs for light, heat, transport and waste disposal contribute each day to the emission of greenhouse gases?
- How many trees have we planted to absorb carbon dioxide from the air?
- Are we lobbying for a safe and efficient transport system in South Africa, with all the social and environmental benefits that this would provide?

Individual actions do matter - and we can make a difference.

National recommendations:

The South African Country Study report recommends a number of actions to limit the effect of climate change on the region's plant diversity, and subsequent work underscores these recommendations:

- ***Establish a biodiversity monitoring network***: In order to plan appropriate conservation strategies, it is essential to monitor how climate change affects plant biodiversity. Monitoring sites could form part of a proposed network of Long-term Ecological Research sites (LTERs) in South Africa. The effects of climate change should be monitored regularly as part of a National Biodiversity Audit Programme.
- ***Plan protected area networks***: Conservation areas will need to be planned with climate change in mind. For example, reserves should include as much topographic variation as possible, to provide climatic refuges for plants and animals. Natural corridors should be created between protected areas to allow for the migration of species as conditions change.
- ***Manage vegetation appropriately***: As parts of the country become more arid, new approaches to vegetation management will be needed. Grazing and fire will have to be used more cautiously as veld management tools, especially during dry years. Managers will need to be opportunistic in taking advantage of fewer good rainy seasons.
- ***Plan for ex-situ conservation***: Plants highly threatened by climate change may have to be preserved artificially in seed banks or botanical gardens as an insurance against extinction.
- ***Undertake rescue efforts***: Already the Cederberg cypress (*Widdringtonia cederbergensis*) is being propagated and reintroduced into the wild. As the climate changes, other plant species may need to be actively 'gardened' or moved to areas where the climate is more suitable.
- ***Tolerate loss***: As hard as it may be to accept, it will not be possible to save all species threatened by climate change. Resources are limited and we will have to make some choices. We will need criteria and a mechanism for implementing decisions.
- ***An international voice***: As a signatory to the Framework Convention on Climate Change, South Africa has a voice in the international policy arena. Developed nations produce most greenhouse gas emissions, and yet the southern hemisphere may experience the most catastrophic effects of climate change. South Africa must insist that the international community reduces greenhouse gas emissions in order to conserve globally significant hotspots of plant biodiversity such as the Succulent Karoo.

LAST WORDS

The timing and extent of global climate change remain somewhat uncertain, and as a result our actions in the area of conservation need to be pragmatic and forward thinking at the same time. Plans to conserve South Africa's rich biodiversity must take account of future climate change scenarios. However, they must be equally valid right now.

The evidence for climate change is all around us, and the science for projections is improving. It is important for future generations that we do our best to prove the projections wrong, and develop ways of both avoiding the worst climatic changes (by reducing greenhouse gas emissions), and finding new ways to adapt to the changes that seem increasingly inevitable.

GLOSSARY

Biodiversity: The variety of life on Earth

Biome: A natural climatic and vegetation region

Centres of endemism: Areas with particularly high numbers of species found there and nowhere else on Earth

Endemic: An indigenous species with a very restricted natural distribution

Fossil fuels: Fuels like coal, oil and natural gas formed from ancient plant materials

General Circulation Model: A computer program used to simulate and predict climate

Global climate change: Changes in climate that affect the entire world

Greenhouse effect: The warming of the Earth's atmosphere caused by the presence of 'greenhouse gases'

Greenhouse gases: Gases like carbon dioxide, methane and nitrogen oxides that absorb and trap the energy of sunlight within the Earth's atmosphere, causing it to warm up

Hotspot: A region with exceptionally large numbers of species, but also threatened by human activities

Indigenous: Occurring naturally in an area

Interglacial period: Warmer periods between ice ages

Speciation: The evolution of new species

FURTHER INFORMATION

Organisations and Web pages

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

Hadley Center for climate prediction and research, United Kingdom: www.metoffice.gov.uk/research/hadleycentre/

South African National Biodiversity Institute: www.sanbi.org

Intergovernmental Panel on Climate Change: www.ipcc.ch

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

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WWF

IUCN The World Conservation Union

WCPA WORLD COMMISSION ON PROTECTED AREAS

Global Environment Facility

UNEP

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