"Africa is one of the most vulnerable continents to climate variability and change, a situation aggravated by the interaction of 'multiple stresses', occurring at various levels, and low adaptive capacity. The South African Risk and Vulnerability Atlas project is a flagship science-into-policy initiative of the Department of Science and Technology's Global Change Grand Challenge."

~ Naledi Pandor, Minister of Science and Technology ~

The South African Risk and Vulnerability Atlas is conceived and designed with the intent of providing up-to-date information for key sectors to support strategy development and decision-making in the areas of risk and vulnerability, helping to support South Africa's transition to a resilient future. This volume presents a selection of such information, translated to communicate key existing and emerging trends.

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SOUTH AFRICAN RISK AND VULNERABILITY

Atlas

SOUTH AFRICAN RISK AND VULNERABILITY ATLAS ~ THE DEPARTMENT OF SCIENCE AND TECHNOLOGY: Republic of South Africa

SOUTH AFRICAN RISK AND VULNERABILITY

Atlas

science
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Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

Mapping the way to a resilient future

Foreword by Hon Ms Naledi Pandor, MP

Minister of Science and Technology
Republic of South Africa

Africa is one of the most vulnerable continents to climate variability and change, a situation aggravated by the interaction of 'multiple stresses', occurring at various levels, and low adaptive capacity. The South African Risk and Vulnerability Atlas project is a flagship science-into-policy initiative of the Department of Science and Technology's Global Change Grand Challenge. It will support improved planning and decision-making, particularly at local levels.

Leaders in national, provincial, and local government, industry, and other social formations are required to, under very difficult circumstances, make decisions which will affect the citizens of South Africa today and in the near to distant future. In addition to enhancing the knowledge base, special measures are required in creating effective channels for disseminating information that allow decision-makers to make decisions based on the best available knowledge which is packaged appropriately.

As the world becomes more connected and competitive, information and knowledge have become the common currency through which innovation and technological advances are driven.

To support a move into a knowledge-based economy, the Department of Science and Technology has developed a 10-year Innovation Plan. Core to the Innovation Plan are five grand challenges that aim to concentrate efforts within the National System of Innovation (NSI) to a set of key innovation priorities.

One of the five grand challenges is the Global Change Grand Challenge. The Global Change Grand Challenge will support knowledge generation and technological innovation that will enable South Africa, Africa, and the world to respond to global environmental change, including climate change. The knowledge generation priorities are detailed in a comprehensive 10-year Global Change Research Plan. The Research Plan will be achieved through a set of complementary initiatives, research programmes, science-into-policy processes and institutions that will work together to effectively enhance our understanding of global change science and to act on the new knowledge that is generated.

The South African Risk and Vulnerability Atlas project is a testament to the desire of the science community's' willingness to rise to the occasion to provide relevant science which is supportive of our goal to build a sustainable future. The project will consist of a number of products, the core of which is an electronic spatial database and information system.

The purpose of this publication is to provide a condensed overview of the type of map overlays of areas sensitive and vulnerable to various kinds of risks, disasters and climate-related impacts and content which will be provided in the electronic spatial database and information system. This publication draws upon information from various sources to comprehensively showcase different sectors of interest. The impact of global change will be felt across many sectors but the challenge is to provide information in such a way as to encourage an integrated approach to seeking solutions. An effective way of achieving this is to focus on risks and vulnerabilities.

While many of the future scenarios projected to occur over the next couple of decades paint a daunting future, we must not forget that South Africa has a history of creating miracles out of dire circumstances. As we work towards making decisions today as leaders we must be cognisant of that well-known proverb, "We don't inherit the earth from our ancestors but we borrow it from our children".

Scientists have articulated the uncertainties around the science of global change, but one thing they are sure of is the enormous burden that will be levied on the most vulnerable among us. As a developing country the effectiveness of our response to global change impacts will not depend upon the quality of life among the most prosperous of South Africans, but should be measured by the loss of quality of life among the most vulnerable.

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Mapping the way to a resilient future

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Department: Science and Technology
REPUBLIC OF SOUTH AFRICA

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1. Introduction

"The South African Risk and Vulnerability Atlas was conceived and designed with the intent of providing up to date information for key sectors to support strategy development in the areas of risk and vulnerability."

The time of writing of this introduction marks twenty years since former president FW de Klerk announced Nelson Mandela's release and the effective acceleration of apartheid's demise. South Africa was to see twenty years of unprecedented change, much of it little or ill-forecasted by pundits, both within and outside of the country.

In 2010, we find ourselves within a global economy in crisis, the impacts of which South Africa is projected to only fully feel this year. We find ourselves post the December 2009 Copenhagen climate change negotiations, certainly facing a situation where the responsibility for responding to climate change rests largely on our shoulders. We find ourselves in a new phase of national and provincial government with new challenges in policy development and implementation, yet a renewed emphasis on coordinated and inter-sectoral planning. And we find ourselves facing unprecedented challenges (and opportunities) in the physical environment as characterised, for example, in the National Spatial Biodiversity Assessment 2010 which is in progress.

Long before environmental change is taken into account, South Africa experiences critical emerging and existing vulnerabilities, complicating response to any single external stressor. Such vulnerabilities include the well documented service delivery crisis, and the spatial differentiation in service delivery and development (see Chapter 4 of this volume). The crises of supply and infrastructure in the water (Chapter 5) and energy sectors, the escalations in urbanisation (Chapter 4) and land use transformation (Chapter 11), and in South Africa's complex disease burden (Chapter 7) all comprise further critical vulnerabilities complicating South Africa's plans for resilient (and environmentally sustainable) growth.

The *South African Risk and Vulnerability Atlas* was conceived and designed with the intent of providing up to date information for key sectors to support strategy development in the areas of risk and vulnerability. This volume presents a selection of such information, translated to communicate key existing and emerging trends.

Information alone cannot ensure informed planning and decision-making. Plans for capacity building linked to the Atlas and the Department of Science and Technology's Global Change Grand Challenge will support the use of such information in planning and, with information provision, ideally help support South Africa's intended transition to resilient and sustainable growth over the next decade.

2. Current Climate

A BRIEF DESCRIPTION OF SOUTH AFRICA'S PRESENT-DAY CLIMATE

Francois Engelbrecht and Willem Landman

"South Africa is a country that experiences an astounding variety of different weather conditions. Climate refers to the long-term average of weather conditions."

Our day-to-day lives are influenced by daily variations in weather - the atmospheric conditions at a specific location and moment in time. South Africa is a country that experiences an astounding variety of different weather conditions. These include the thunderstorms of the Highveld, frontal rain occuring over the southwestern Cape, berg winds along the Eastern Cape coast and even wide-spread flooding over northeastern South Africa, caused by tropical cyclones making landfall over Mozambique.

Climate refers to the long-term average of weather conditions. The different types of weather experienced over South Africa in combination cause the country to consist of vastly different climatological regions, with most regions also displaying large inter-annual variability in their climate. The variability of weather and climate over South Africa poses challenges for weather prediction, seasonal forecasting and the projection of climate change over the country.

With its latitudinal location between 35° S and 22° S, South Africa has a predominantly subtropical climate. The country is often under the influence of high-pressure systems of the subtropical high-pressure belt[1]. These systems cause air to sink over southern Africa, thereby suppressing cloud formation and rainfall. As a consequence, the western half of South Africa has a semi-arid climate. As is typical of the subtropics, rainfall patterns over the country display well-pronounced intra-annual and inter-annual variability. Summer rainfall is usually below normal during El Niño years and above normal during La Niña years[2].

Complex regional topography

Other factors that control the climate of South Africa are the complex regional topography and the surrounding oceans. The western, southern and eastern escarpments lead to a high plateau of about 1 250m above sea-level. The plateau experiences hot summers and cold winters, but the oceans moderate the climate of the coastal plains, providing milder winters. The warm Agulhas current causes the eastern coastal areas to have a warm and humid climate, whilst the cold Benguela current along the west coast contributes to the arid climate of this region.

During winter (June to August), the subtropical high-pressure belt is well-established over South Africa. As a result, winter rainfall over the interior of the country is sparse. The weather during this season is characterised by sunny days, clear skies and cold nights. Frost is common over especially the higher altitude parts of the interior. At the southern periphery of the subtropical high-pressure belt, cold fronts regularly sweep over the southern parts of South Africa during winter, bringing rain to the southwestern Cape and the Cape south coast.

The southwestern Cape is a winter rainfall region that receives the bulk of its annual rainfall in the form of frontal rain during winter. The Cape south coast is an all-season rainfall region. Cold fronts and the atmospheric circulation systems that occur in association with them in the mid- and upper levels of the atmosphere, also bring snowfall to the mountains of the Western and Eastern Cape, as well as over the Drakensberg Mountains in the east. It happens on occasion that a cold front intrudes quite far northwards, deep into the interior of South Africa. Such events are referred to as "cold snaps", and in extreme cases they can even cause snowfall to occur over the Free State and the Highveld regions of Gauteng and Mpumalanga.

During spring (September to November), a heat-low[3] develops over the western parts of southern Africa, in response to enhanced solar radiation. From spring to autumn, this low functions to trigger the formation of thunderstorms to its east. Spring is characterised by the onset of rainfall over the interior regions of South Africa, with the first significant falls of rain typically occurring over KwaZulu-Natal before spreading deeper into the interior.

The rainfall that occurs over the interior during spring is usually caused by weather systems of the westerly wind regime referred to as "westerly waves", when occurring in combination with ridging high-pressure systems in the lower levels of the atmosphere. The latter systems are responsible for the transport of moisture into the South African interior from the Indian Ocean. A weather system that may bring snow and heavy falls of rain to the South African interior during spring, is the cut-off low. These weather systems may occur at any time of the year, but are most common during spring and autumn.

[1] The subtropical high-pressure belt is a region of high pressure that encircles the globe around the latitudes of 30° S in the Southern Hemisphere and 30° N in the Northern Hemisphere.
[2] El Niño refers to the large-scale phenomenon associated with a strong warming in sea-surface temperatures across the central and east-central equatorial Pacific Ocean. An El Niño event occurs every three to seven years. La Niña, on the other hand, refers to the periodic cooling of sea-surface temperatures in the central and east-central equatorial Pacific Ocean.
[3] A heat-low is a shallow low-pressure system that develops in response to strong heating of the earth's surface.

2. Current Climate

Summer (December to February) is the most important rainfall season for the central and northern interior of South Africa. During this season the Inter Tropical Convergence Zone (ITCZ)[4] reaches its most southern location, and pulses of moisture from the tropics frequently reach South Africa. Most of the rainfall occurs through tropical-temperate trough events, where a westerly wave combines with a tropical trough or low, to cause extended cloud band formation and rainfall over southern Africa. Heat induced thunderstorms also frequent the South African interior during summer, being most abundant over the eastern escarpment and Highveld areas.

During autumn, the ITCZ advances northwards and subsidence again sets in over southern Africa. Rainfall decreases rapidly over the eastern interior of South Africa during this time. This is however an important rainfall season for the western interior of South Africa (especially the Northern Cape and Eastern Cape interiors). These regions receive significant amounts of rainfall during autumn from cloud bands that occur to the west of the most well-pronounced regions of subsidence.

South Africa has a warm climate, and much of the country experiences average annual temperatures of above 17°C (Map 2.1). The southern and eastern escarpments are the regions with the lowest temperatures, due to the decrease in temperature with altitude. The warmest areas are the coastal areas of KwaZulu-Natal, the Lowveld of KwaZulu-Natal and Mpumalanga, the Limpopo valley and the interior of the northern Cape. The oceans surrounding South Africa have a moderating influence on the temperatures experienced along the coastal areas.The warm Agulhas current causes the east coast to be significantly warmer than the west coast, where the cold Benguela current and upwelling[5] induce lower temperatures.

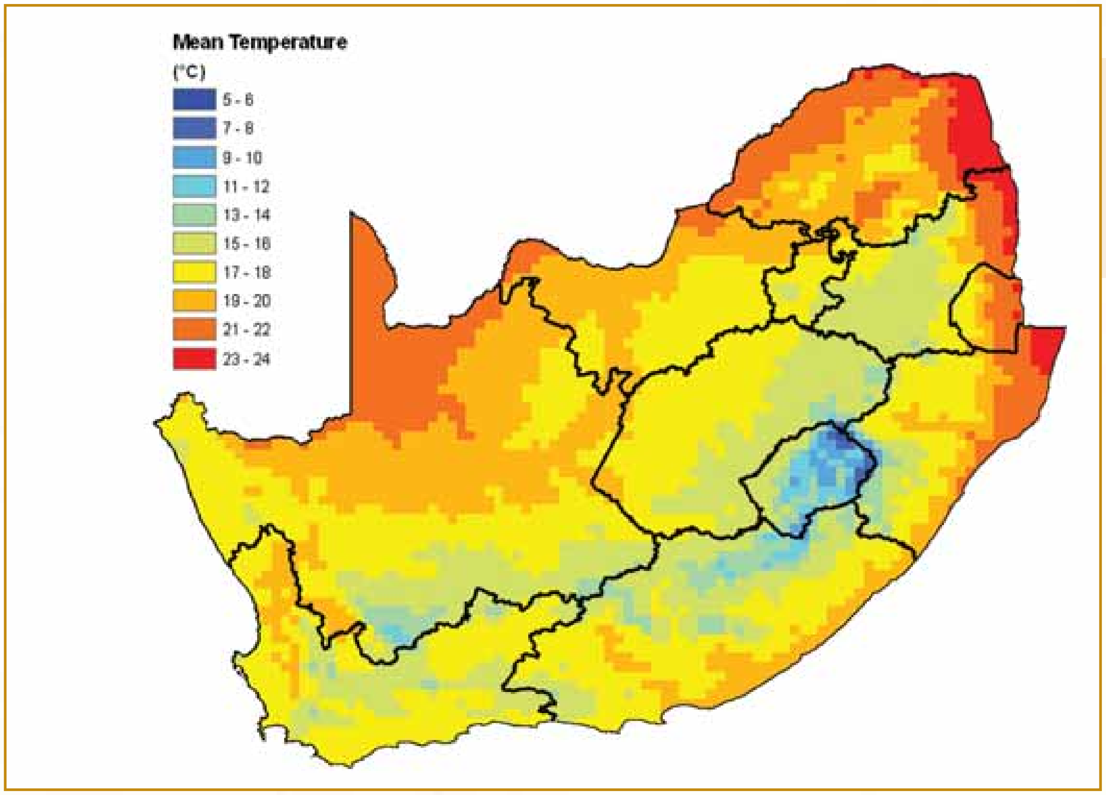
Map 2.2 shows the average annual rainfall totals over South Africa. Rainfall over South Africa is highly variable in space, and a west-east gradient in rainfall totals is evident. The west coast and western interior are arid to semi-arid areas. The air above the cold Benguela current and upwelling region along the west coast is relatively dry and cold, contributing to the dry climate of the west coast and adjacent interior. Rainfall totals are high over and to the east of the eastern escarpment of South Africa.

Moist air from the warm Indian Ocean and Agulhas Current is frequently transported into eastern South Africa by easterly winds. The air is forced to rise along the eastern escarpment, and orographic precipitation results. There are also pockets of high rainfall along the south-western Cape and Cape south coast areas, which similarly result from orographic forcing when moist frontal air is transported inland.

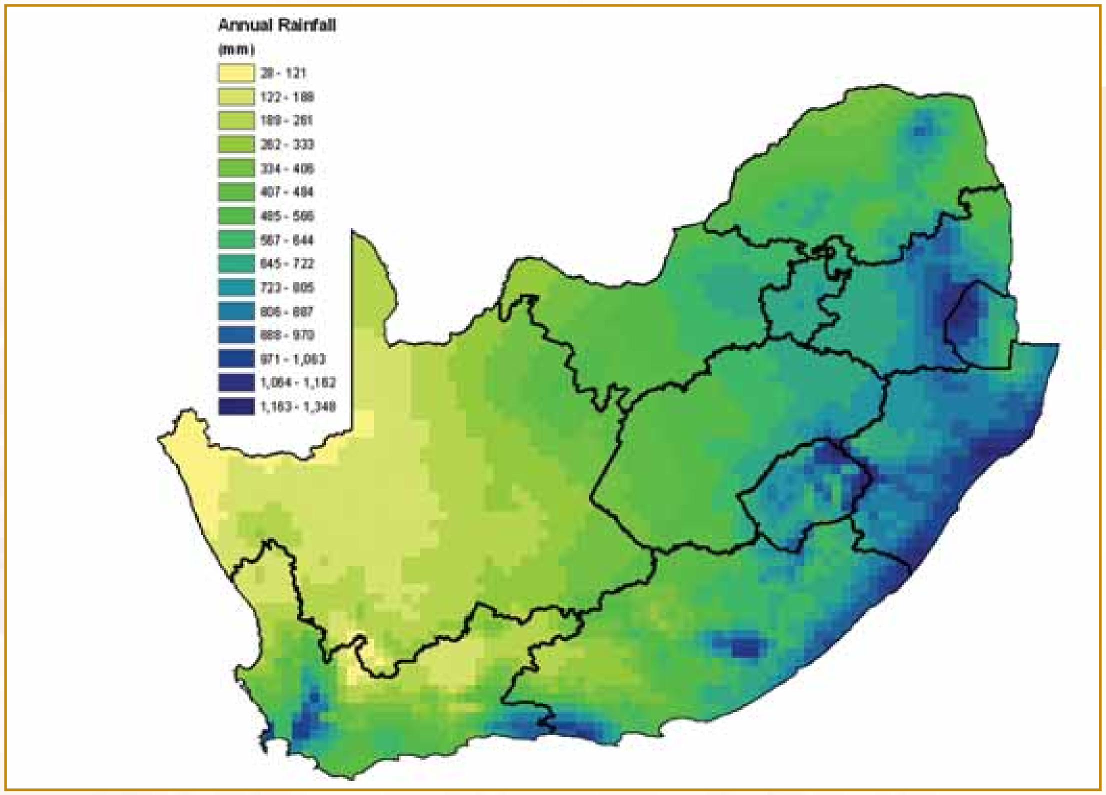
[4] A low-pressure region that encircles the globe near the equator, where the trade winds originating in the northern and southern hemisphere come together.

[5] Upwelling refers to the oceanographic phenomenon of the wind-driven rise of deep, dense and cold water to the ocean surface.

2. Current Climate

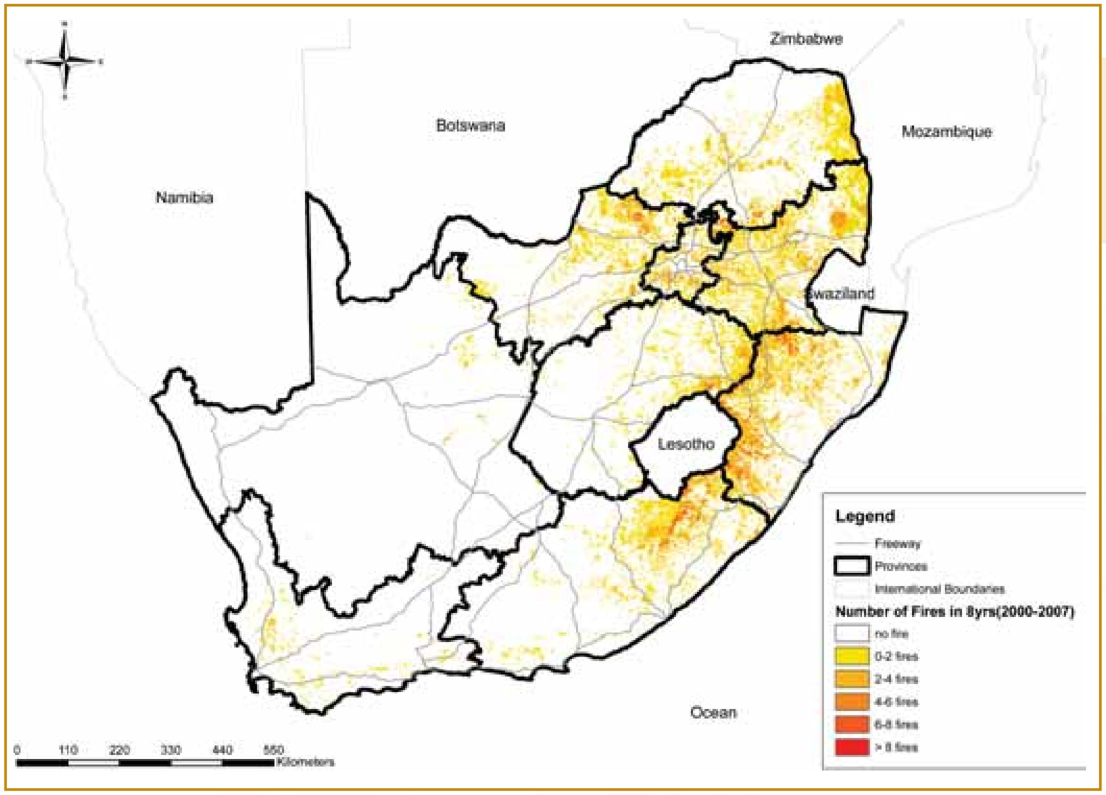


Map 2.1: Average annual temperatures (°C) over South Africa, obtained from the Climatic Research Unit, for the period 1961-1990. Map constructed by the Agricultural Research Council - Institute for Soil, Climate and Water.

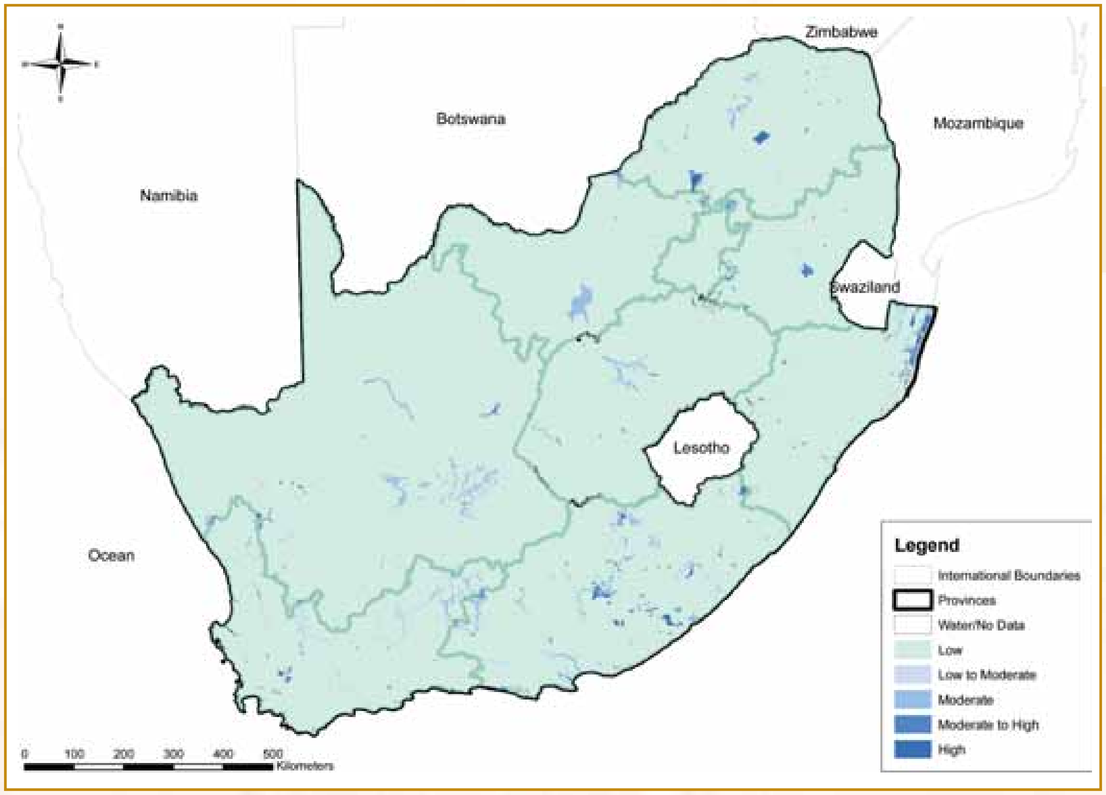


Map 2.2: Average annual rainfall totals (mm) over South Africa, obtained from the Climatic Research Unit, for the period 1961-1990. Map constructed by the Agricultural Research Council - Institute for Soil, Climate and Water.

2. Current Climate

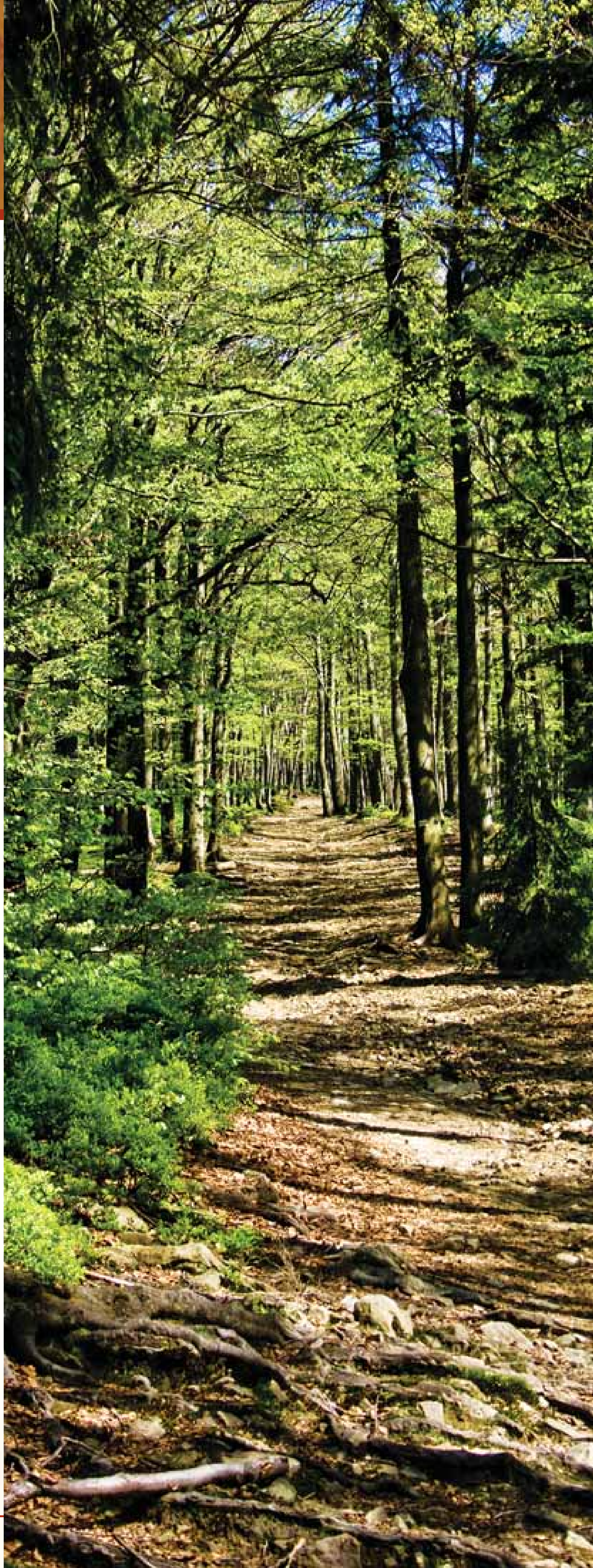


Map 2.3: Fire frequency in South Africa. Source: Archibald, CSIR (2009), based on information from Roy (2005).



Map 2.4: Flood risk in South Africa. Source: AGIS (2001).

3. Future Climate



REGIONAL SCENARIOS OF FUTURE CLIMATE CHANGE OVER SOUTHERN AFRICA

Francois Engelbrecht and Willem Landman

The Earth's climate system is driven by the energy that is continuously received from the sun. The bulk of this energy is in the short-wavelength part of the electromagnetic spectrum. About 30% of the incoming solar energy is reflected back to space by clouds and the Earth's surface before it can warm the planet.

About 70% of the incoming energy is absorbed by the oceans, continents and the atmosphere. The absorbed heat is later re-emitted in the form of infrared radiation, or transferred by sensible and latent heat fluxes. However, certain gases in the troposphere and stratosphere absorb most of the outgoing infrared radiation before it can escape to space, thereby warming the atmosphere before the heat is once again re-emitted. These are referred to as greenhouse gases.

Without the presence of these gases in the atmosphere, the average temperature at the surface of present-day Earth would be about -18°C. However, the warming effect of the greenhouse gases, called the 'greenhouse effect' or 'natural greenhouse effect', results in the average surface temperature being about +14°C. Without the greenhouse effect, life on Earth would be markedly different to that with which we are familiar. Two gases, CO_2 and water vapour, are responsible for most of the greenhouse effect.

Anthropogenic (or human driven) emissions of greenhouse gases, resulting from the burning of fossil fuels and deforestation, have increased the atmosphere's ability to absorb the Earth's outgoing infrared radiation. This is referred to as the 'enhanced greenhouse effect'. The consequences of this effect can be clearly seen in the worldwide trend of rising temperatures, that is, in the form of global warming.

Observed trends in the global climate reveal that shifts in climate regimes have occurred – with both the tropical and extra-tropical climate regimes expanding poleward (Seidel et al., 2008). Superimposed on these changes in global circulation patterns, an increase in the frequency of severe weather events can be observed. A shift in the Earth's climate regimes and changes in the nature of weather events are commonly referred to as anthropogenically induced 'climate change'. Despite international concern about global warming and associated climate change, greenhouse-gas concentrations in the Earth's atmosphere are set to increase at an accelerated rate if current trends in emission rates persist.

Global circulation models (GCMs) have become the primary tools for the projection of climate change. These mathematical models, based on the laws of physics, are used to estimate the three-dimensional changes in the structure of the atmosphere that may take place in response to enhanced anthropogenic forcing. Projections of future climate change by GCMs may provide insight into potential broad-scale changes in the atmosphere and ocean, such as shifts in the major circulation zones and the magnitude of sea-level rise. However, because these models are computationally expensive, they can only be integrated at relatively coarse horizontal resolutions – namely at typical grid spacings of about 2° - 3° in both longitude and latitude[1]. At these resolutions, the regional details of climate (such as the characteristics of orographic precipitation and thunderstorms) and climate change cannot be sufficiently described.

[1] Note that GCMs do not provide spatially continuous simulations of the atmosphere - they can only estimate the atmospheric state at a number of discrete points in three-dimensional space.

3. Future Climate

Additional uncertainties surrounding climate projections include the role of natural variability, the future rate of increase of greenhouse gas concentrations and the systematic simulation errors associated with each individual GCM. A multi-model ensemble approach[2] is required to describe the uncertainty range associated with climate projections. To improve the detail of the GCM projections, the methods of statistical and dynamical downscaling[3] are used to obtain high-resolution projections of climate change over areas of interest. Such downscaled scenarios of climate change over South Africa are described in this section.

Regional temperature projections

The projections of southern Africa's future climate by a number of coupled ocean-atmosphere global circulation models (CGCMs) are described in Assessment Report Four (AR4) of the Intergovernmental Panel on Climate Change (IPCC) (Christensen et al., 2007).

All of Africa is projected to warm during the 21st century, with the warming very likely to be greater than the global annual mean warming – throughout the continent and in all seasons. The drier, subtropical regions are projected to warm more than the moister tropics. This result is consistent with the strong observed temperature trends over subtropical South Africa (Kruger and Shongwe, 2004), which indicate that change is already occurring.

Map 3.1 shows the projected rise in temperature over southern Africa for summer (December to February, DJF), autumn (March to May, MAM), winter (June to August, JJA) and spring (September to November, SON). These projections were obtained from a dynamic regional climate model (Engelbrecht et al., 2009) under the A2 emission scenario[4] (that assumes a moderate to high growth in greenhouse gas concentrations) of the Special Report on Emissions Scenarios (SRES). The changes are for the period 2070-2100 compared to 1975-2005. For each of the seasons, the 25th percentile[5], median and 75th percentile were calculated for each of the present-day and future time series of the seasonal averages – the different maps are displayed in Map 3.1.

The model projects an increase in the median temperature of more than 3°C over the central and northern interior regions of South Africa. Over the coastal regions of the country, a somewhat smaller increase (about 2°C) is projected. The largest increase in median temperature is projected to occur over the central interior of South Africa, exceeding a value of 4°C during autumn and winter. Generally, the largest temperature increases are projected for autumn and winter, with the summer and spring changes being somewhat smaller. The projected increase in the 25th percentile and 75th percentile temperatures displays a pattern similar to the projected change in median temperatures.

The 75th percentile temperature changes are somewhat larger than the median changes, whilst that of the 25% changes are slightly smaller than the median changes.

Note that the projection depicted in Map 3.1 represents a single outcome of future changes in near surface temperature over southern Africa. While results above describe one model result, a large ensemble of temperature projections over South Africa, obtained from both statistical and dynamic downscaling procedures, is available and accessible in the Weather and Climate portal of the *South African Risk and Vulnerability Atlas*, as well as in other electronic portals.

[2] An envelope of models is used to project different (but equally plausible) climate futures
[3] A methodology that produces a detailed regional climate projection consistent with a forcing GCM projection
[4] A projection of the future rate of increase of greenhouse gas concentrations
[5] A percentile is a threshold of a variable below which a certain percent of measurements of the variable fall

3. Future Climate

Lower resolution projections by the CGCMs that contributed to AR4 indicate that future warming may be expected to be the greatest over the interior of the country and less along the coast. The amplitude of the temperature increase depends on the particular emission scenario assumed when obtaining the projections. In the case of the A2 scenario, the coastal areas are projected to warm by around 1°C and the interior by around 3°C by mid century. By the end of the century, under the same scenario, the warming is likely to be around 3°C along the coast and 5°C over the northern interior.

Regional rainfall projections

The CGCM projections described in AR4 indicate that rainfall is likely to decrease over the winter rainfall region of South Africa and the western margins of southern Africa (Christensen et al., 2007). Observed trends in rainfall over South Africa are not as well defined and spatially coherent as the observed trends in temperature (e.g. Kruger, 2006).

Map 3.2 displays the projected rainfall signal obtained from a dynamic regional climate model for the period 2070-2100 relative to 1975-2005, under the A2 SRES scenario (Engelbrecht et al., 2009). The projected rainfall change is shown in millimetres for the 25th percentile, median and 75th percentile, for the summer, autumn, winter and spring seasons respectively. The model projects a generally drier southern Africa under the A2 scenario. In the simulation, this results from a strengthening of the subtropical high-pressure belt over the region. In winter of the simulated future climate, frontal rain bands are displaced southwards on the average, resulting in a significant decrease in rainfall over the south-western Cape.

Most of the summer rainfall region of South Africa is projected to become drier in spring and autumn as a result of the more frequent formation of mid-level high-pressure systems over this region. However, during summer, a strong regional forcing – namely the deepening of the continental trough in the greenhouse gas warmed climate – becomes strong enough to overcome the enhanced subsidence of the stronger Hadley Cell. More frequent cloud-band formation takes place over eastern South Africa, resulting in increased summer rainfall totals. The projected change in rainfall has a similar pattern for the 25th percentile, median and 75th percentile.

Map 3.3 shows the rainfall projections over southern Africa obtained from an ensemble of nine CGCMs, downscaled to high resolution over South Africa using a statistical downscaling approach (e.g. Hewitson and Crane, 2006). The CGCM data were obtained from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model data set. The map shows the projected change in the 25th percentile, median and 75th percentile of rainfall (mm), for the mid 21st century (2045-2064) relative to the period 1961-1990. Here the statistics were calculated from the ensemble of CGCM projections and not from the time series data as in the case of the single dynamically downscaled scenario.

An increase in the median rainfall is projected over eastern South Africa for winter and spring, with a projected decrease over northeastern South Africa during summer. Larger changes are projected for the 75th percentile, which indicate a general increase in relatively large rainfall events (more intense rainfall events) – over eastern South Africa in particular. It should be noted that the statistical downscaling results presented here are preliminary, and will be iteratively updated in the future by a range of partners.

Map 3.4 is similar to Map 3.3, but shows the statistically projected rainfall signal for the late 21st century (2080-2099). Drier conditions are projected over the southwestern Cape during winter – otherwise the rainfall signal is very similar to that for the period 2045-2064, but with a general strengthening of the amplitude of the signal.

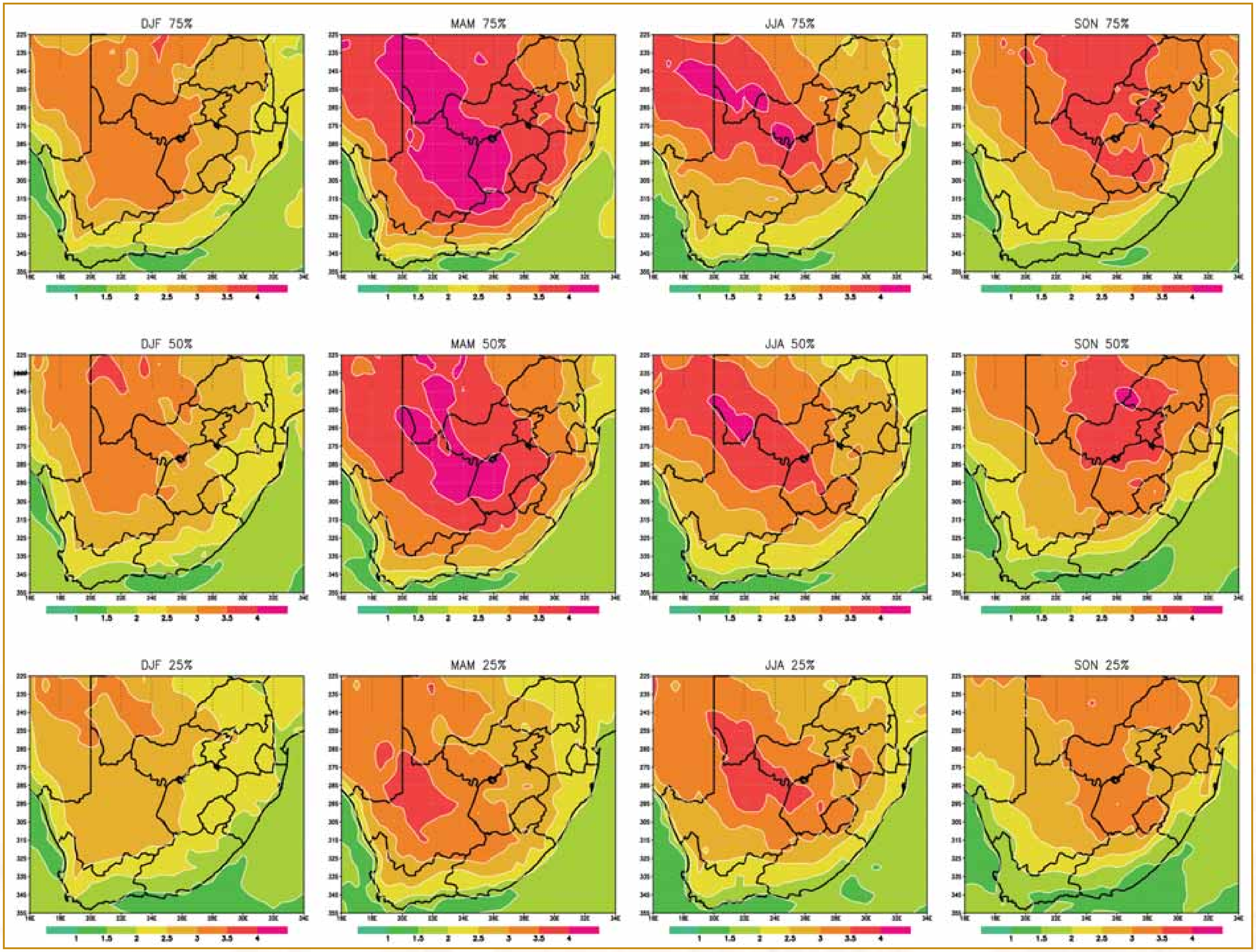
Statistical downscaling results indicate that the median duration of dry spells for the mid 21st century may be expected to increase along the western and northern margins of South Africa between spring and autumn, compared to 1961-1990 (Map 3.5). Greater increases in dry spell duration is projected for the 75th percentile of this metric for all seasons, indicating that dry spells of relatively long duration may be expected to occur more frequently. Similar patterns of change are projected for the late 21st century (Map 3.6).

Discussion and conclusions

It may be noted that in their Fourth Assessment Report (AR4) the IPCC concludes that the extent to which current dynamic regional models can successfully downscale precipitation over Africa is unclear, and that the limitations of empirical downscaling over Africa are not fully understood. The downscaled results presented here are preliminary and, as mentioned earlier, more complete and extensive downscaled results will be available for inclusion in the electronic version of the *South African Risk and Vulnerability Atlas*, as well as in portals at the University of Cape Town's Climate Systems Analysis Group, amongst others.

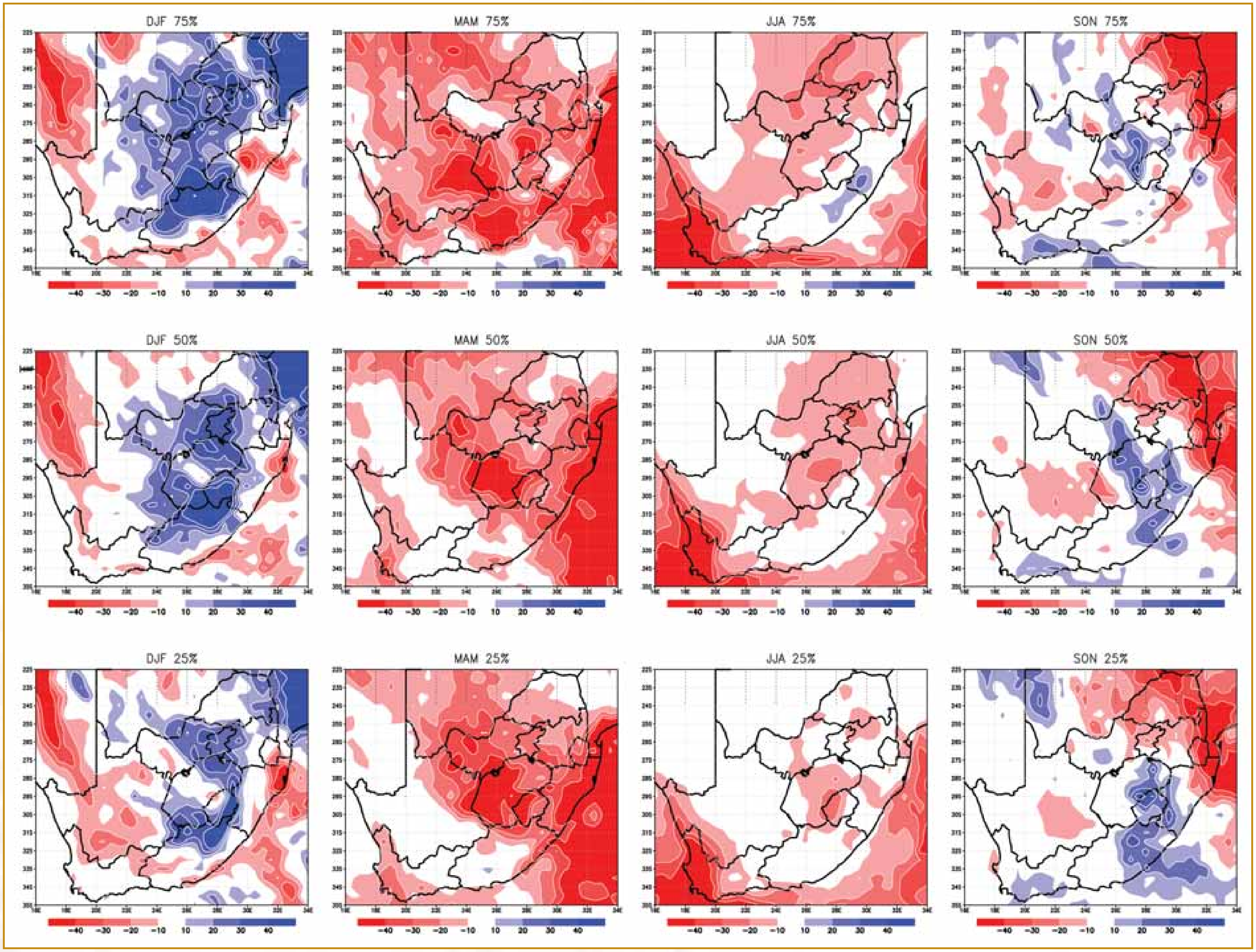
The projections presented here for South Africa are largely consistent with the results described for the southern African region in AR4 of the IPCC. Temperatures over South Africa may be expected to rise faster than the global mean temperature, with parts of the interior projected to warm with as much as 3-5 °C by the end of the century under the A2 scenario. Eastern South Africa is projected to experience summers with more intense rainfall events, whilst drier winters are projected for the southwestern Cape.

3. Future Climate



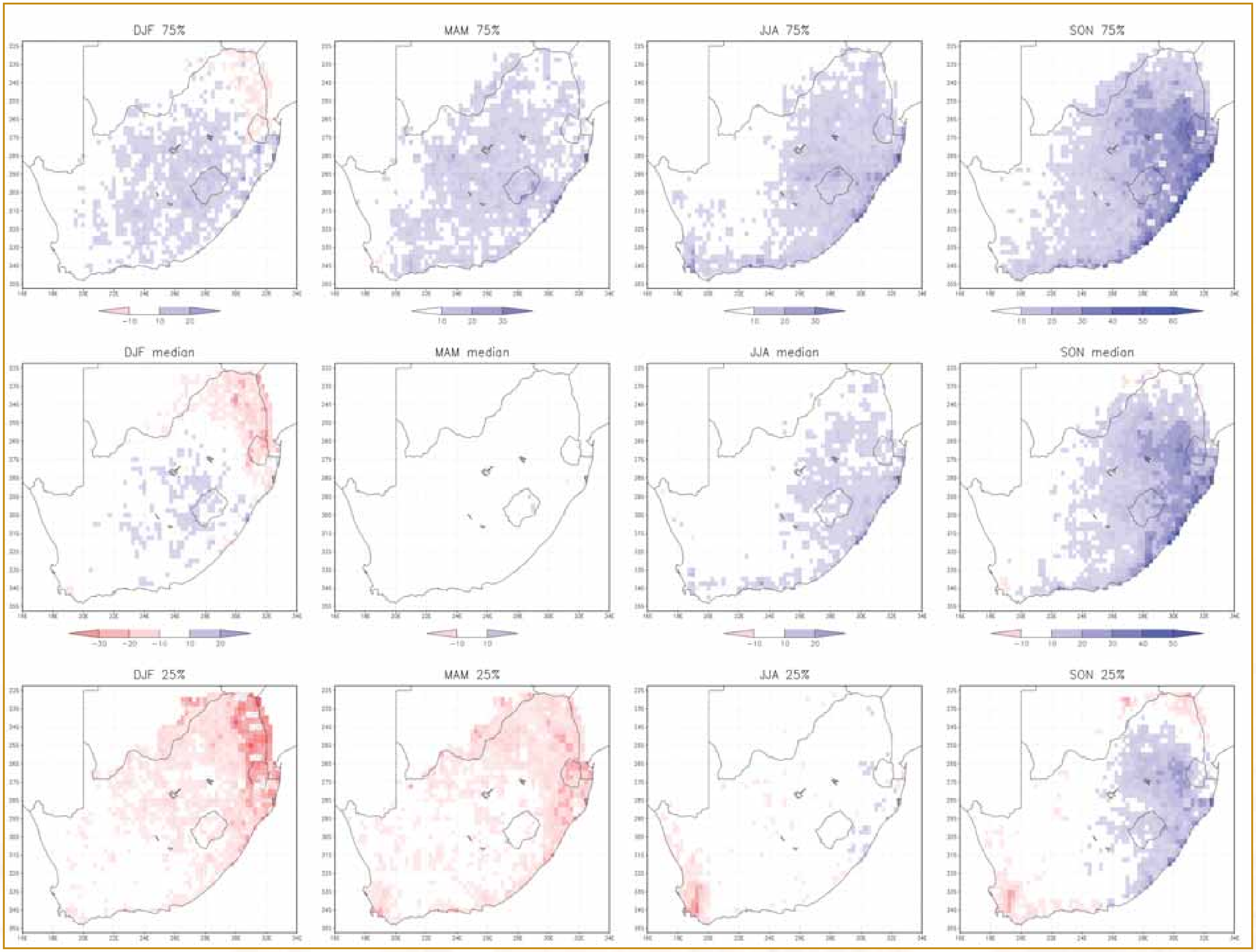
Map 3.1: Projected seasonal temperature change (°C) by a dynamic regional climate model for the period 2070-2100 vs 1975-2005 under the A2 SRES scenario. The upper row shows the change in the 75th percentile (calculated separately for each model grid point) of the simulated seasonal temperatures over the period 2070-2100 relative to 1975-2005 time series. The middle and bottom rows are similar, but represent the change in the median and 25th percentile of the seasonal temperatures respectively. Data source: WRC, UP.

3. Future Climate

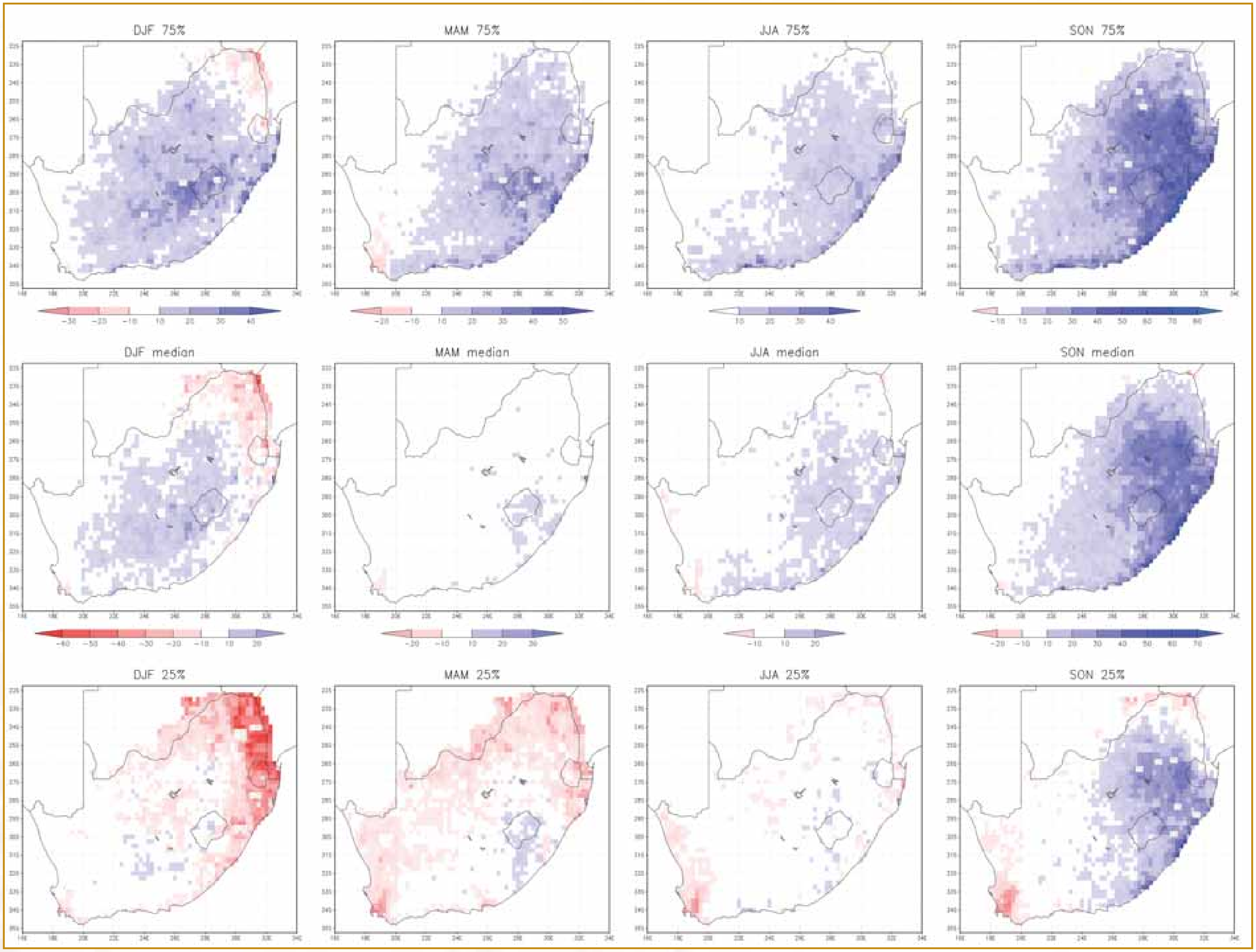


Map 3.2: Projected seasonal rainfall change (mm) by a dynamic regional climate model for the period 2070-2100 vs 1975-2005 under the A2 SRES scenario. The upper row shows the change in the 75th percentile (calculated separately for each model grid point) of the simulated seasonal rainfall totals over the period 2070-2100 relative to 1975-2005 time series. The middle and bottom rows are similar, but represent the change in the median and 25th percentile of the seasonal rainfall totals respectively. Data source: WRC, UP.

3. Future Climate

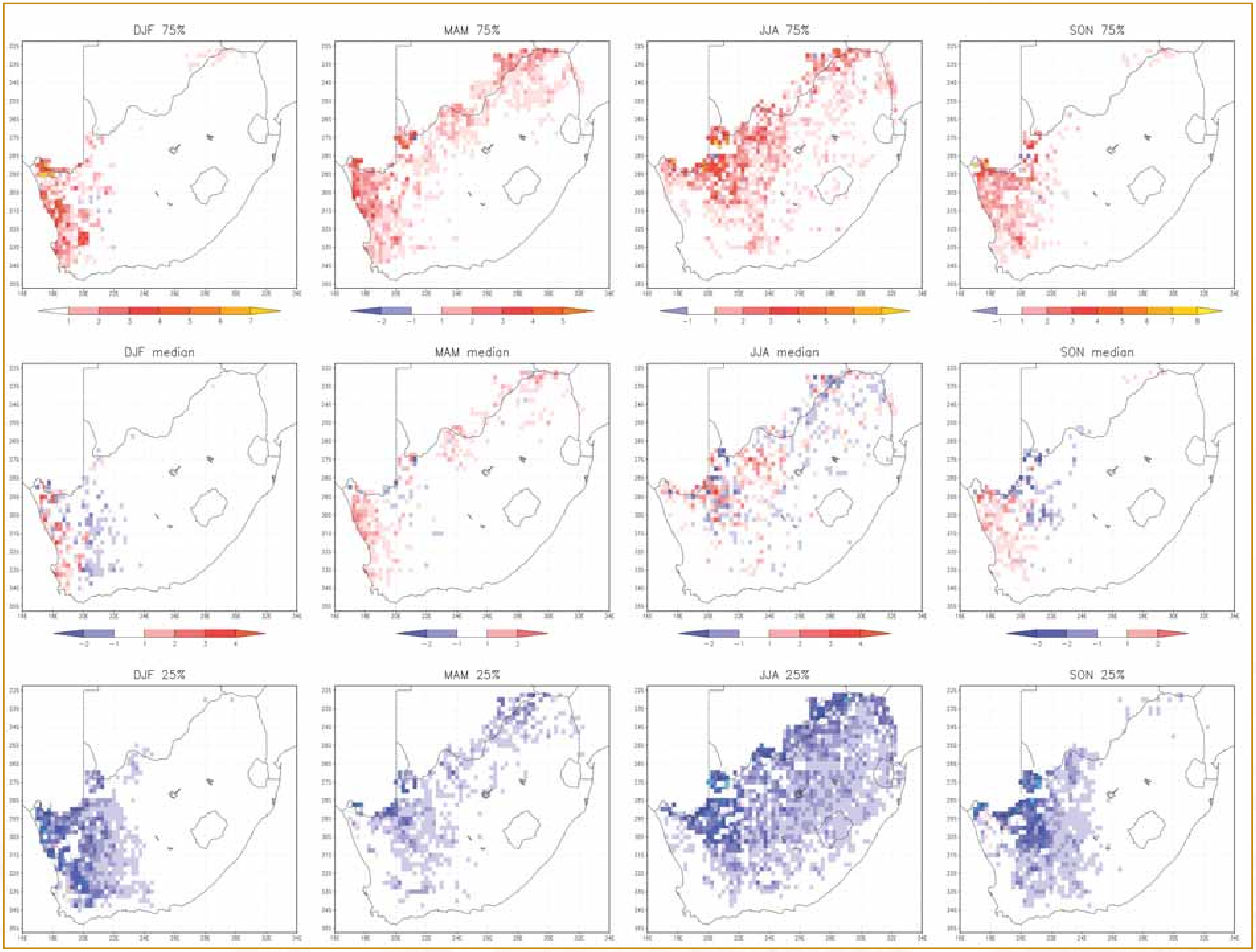


Map 3.3: Projected seasonal rainfall change (mm) downscaled from a number of GCMs of the CMIP3 archive, for the period 2046-2065 relative to 1961-1990 under the A2 SRES scenario. The upper row shows the 75th percentile of the model's projected seasonal rainfall changes, the middle row is the median, and the bottom row the 25th percentile. Source: CSAG.

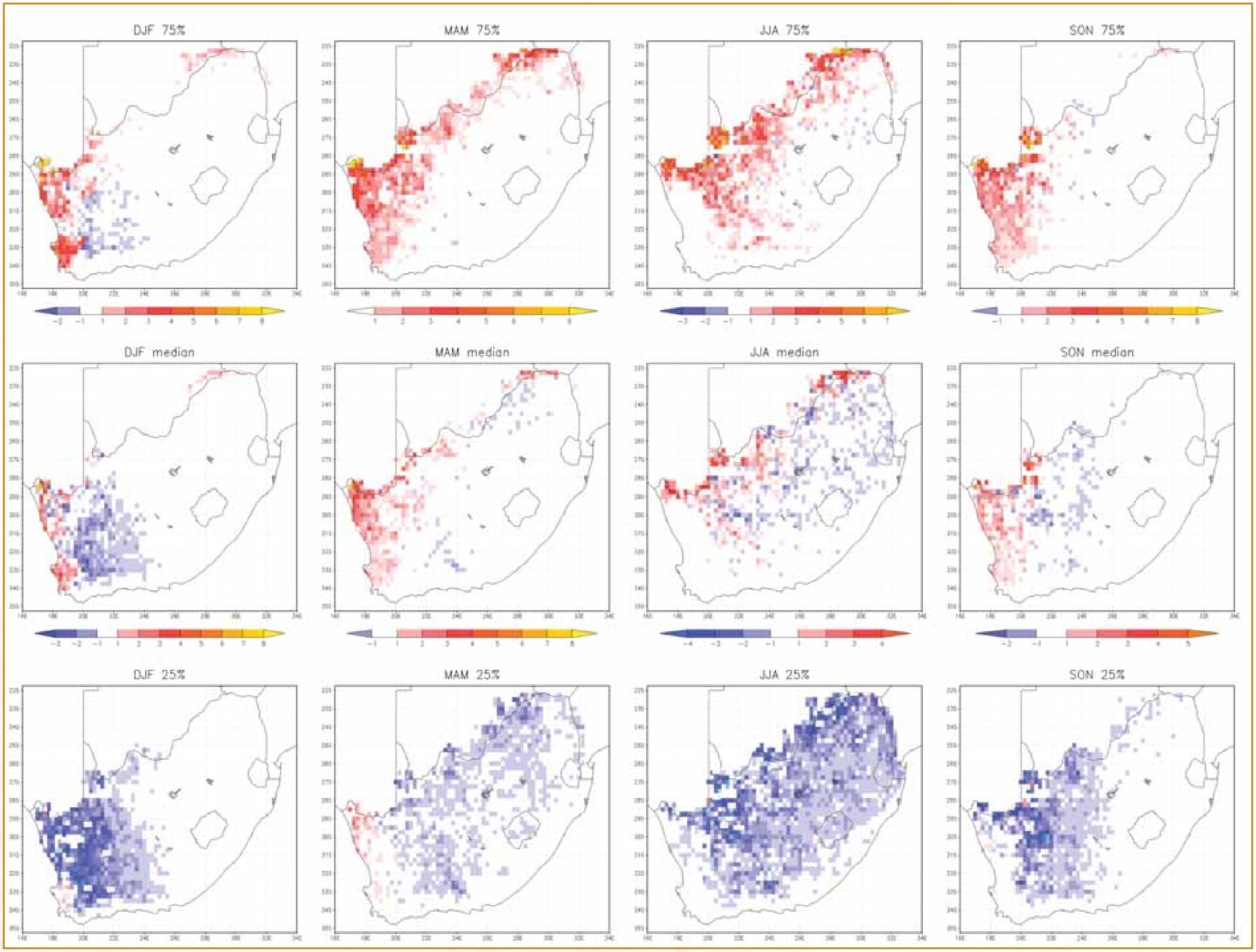


Map 3.4: Projected seasonal rainfall change (mm) downscaled from a number of GCMs of the CMIP3 archive, for the period 2080-2099 relative to 1961-1990 under the A2 SRES scenario. The upper row shows the 75th percentile of the model's projected seasonal rainfall changes, the middle row is the median, and the bottom row the 25th percentile. Source: CSAG.

3. Future Climate



Map 3.5: Projected seasonal change in dry-spell duration (days) downscaled from a number of GCMs of the CMIP3 archive, for the period 2046-2065 relative to 1961-1990 under the A2 SRES scenario. The upper row shows the 75th percentile of the model's projected seasonal changes in dry-spell duration, the middle row is the median, and the bottom row the 25th percentile. Source: CSAG.



Map 3.6: Projected seasonal change in dry-spell duration (days) downscaled from a number of GCMs of the CMIP3 archive, for the period 2080-2099 relative to 1961-1990 under the A2 SRES scenario. The upper row shows the 75th percentile of the model's projected seasonal changes in dry-spell duration, the middle row is the median, and the bottom row the 25th percentile. Source: CSAG.

4. Socio-Economic Landscape

THE SOUTH AFRICAN SOCIO-ECONOMIC AND SETTLEMENT LANDSCAPE

Alize le Roux and Elsona van Huyssteen

> **"South Africa's population is largely concentrated in the eastern and northeastern parts of the country, in and around settlements on the primary road network and along the coastal belt, while the western half of the country is sparsely populated."**

Risk implications and vulnerabilities within social ecological systems are obviously higher in areas characterised by increasingly high development pressure on the natural environment, and in areas characterised by high socio-economic vulnerability. Resilience, especially in the context of developing countries, is not only influenced by the geographic concentration of people, consumption and production, but is also closely tied to poverty, high levels of income and other inequalities.

This section provides an overview of the socio-economic and settlement dynamics of the South African landscape. The purpose is to highlight critical aspects related to the spatial manifestation of socio-economic development dynamics in order to enable an exploration of the range of relationships and interactions between socio-economic development and the natural environment as an integrated system.

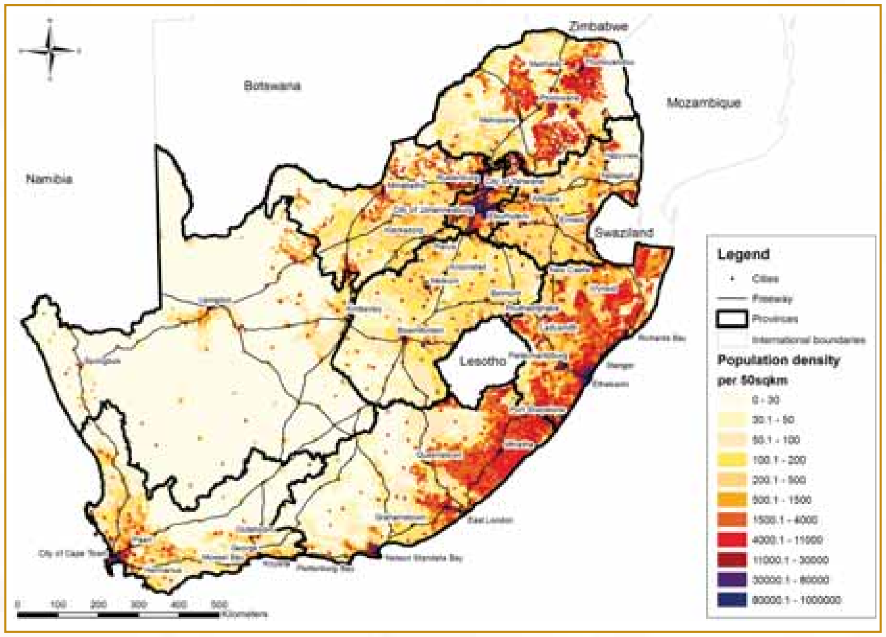
The first part of the section includes a brief overview of areas characterised by high population densities, population growth and poverty. The analysis includes an indication of employment and dependency levels, as well as of the geographic distribution of economic activity and economic growth. The latter part of the analysis focuses on the implications of these socio-economic development dynamics as evident within specific spaces and key functional settlements across the country.

The analysis is based on, and draws from research and numerous studies conducted over the last couple of years by the Planning Support Systems unit within the CSIR (Built Environment) in collaboration with government and other partners. These studies include the *National Spatial Trends Overview* (2009) conducted for the South African Cities Network, former Department of Provincial and Local Government and the Presidency; the socio-economic analysis in the regional profiler developed as part of the *Toolkit for Integrated Development* (TIP) with the Department of Science and Technology (DST) and Human Sciences Research Council (HSRC); the *Geospatial Analysis Platform* (2006) developed with the Presidency and the Department of Trade and Industry (dti), and the National Spatial Development Perspective (2006) updated for the Presidency.

The analysis can be read in conjunction with the *Human Settlement Atlas* (2010) developed for the Department of Human Settlement and the *Territorial Review* (2010) conducted for the Presidency.

4. Socio-Economic Landscape

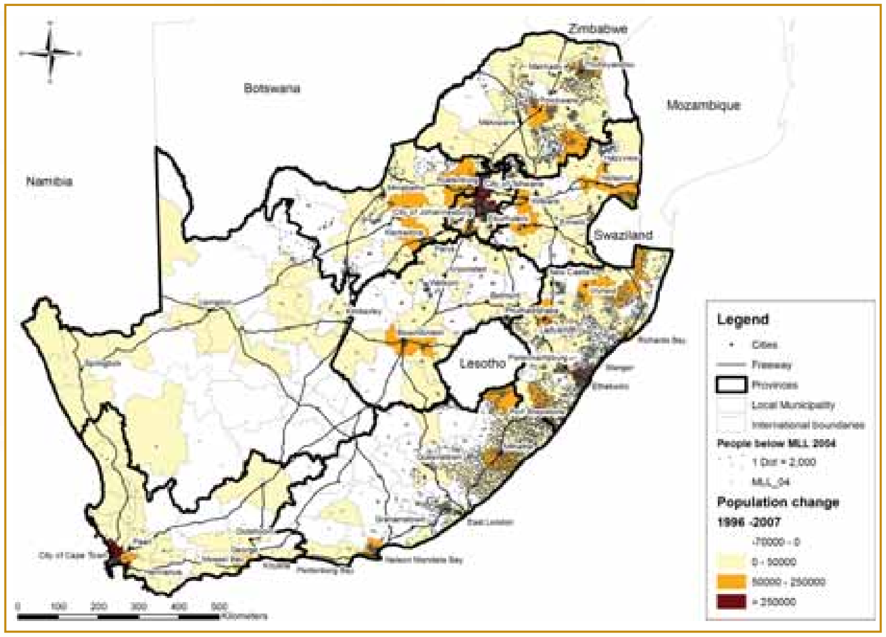
The country's population is largely concentrated in the eastern and northeastern parts of the country in and around settlements on the primary road network and along the coastal belt, while the western half of the country is sparsely populated (see Map 4.1).



Map 4.1: Population density and geographic distribution. Source: Based on geospatial analysis platform (CSIR, 2006) and STATS SA 2007 data.

The highest concentration of population is located in the Gauteng area – in the City of Johannesburg, City of Tshwane and Ekhurhuleni Metropolitan Municipality – as well as in the coastal cities of Cape Town and eThekwini. There are also significant concentrations of population along the east coast in the Eastern Cape district municipalities, which cover the former Bantustan areas of Transkei and Ciskei respectively, as well as along the KwaZulu-Natal coastline and around areas such as Pietermaritzburg, Ulundi, Richards Bay and Empangeni.

Other significant population concentrations are found in the central areas around Nelspruit (Mbombela) and Bushbuckridge (Ehlanzeni DM), Witbank (Emalahleni), Middelburg (Nkangala) and Rustenburg (Bojanala DM). Some of the northern parts of Limpopo Province are also characterised by significant population concentrations in the former Bantustan areas such as Thohoyandou and towns such as Polokwane (Capricorn DM), Musina, Phalaborwa and Tzaneen (Mopani DM) and the Greater Sekhukune areas.



Map 4.2: Population growth and geographic distribution of people living in poverty. Source: Based on geospatial analysis platform (CSIR, 2006), NSDP 2006 (The Presidency, 2006) and STATS SA 2007 data.

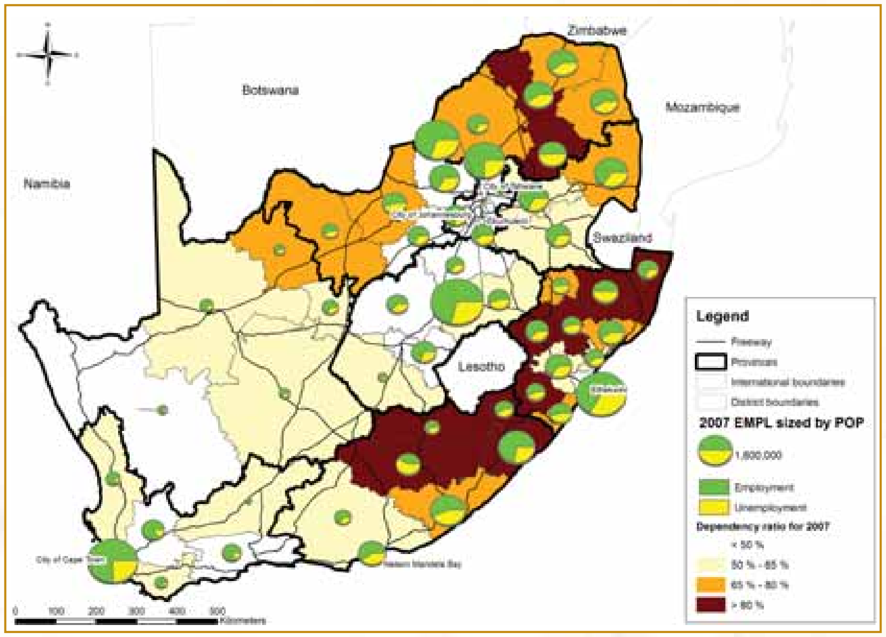
Growth trends over the last decade (population change indicated on Map 4.2 as calculated by municipality between 1996 and 2007) highlight the increased patterns of concentration and the pressures brought by urbanisation and townward migration, as well as continued expansion of the metropolitan regions and towns on major access routes and movement corridors.

Out-migration seems to take place from the Northern Cape and central parts of the country, and even from traditionally densely populated coastal districts (Eastern Cape), with population decline forming a central band from north to south in the driest and least hospitable part of the country (white areas on map). Associated with that, metropolitan areas seem to have experienced the largest growth (dark brown areas on the map indicate these as the city region areas of Gauteng and the port cities of Cape Town and eThekwini), followed by cities and large towns illustrating high growth (dark orange areas on Map 4.2 – highlighting coastal areas such as Nelson Mandela Bay, East London (Buffalo City), Mossel Bay to Plettenberg Bay and Richards Bay, as well as major inland cities and towns such as Pietermaritzburg, Nelspruit, Bloemfontein, Rustenburg, Kimberley, Middelburg and Mthata).

4. Socio-Economic Landscape

Other types of areas experiencing significant population growth are those in former Bantustan areas which also have significant population concentrations, in spite of limited economic activity and access to services (often lacking infrastructure and governance capacity and with relatively low GVA), for example in the areas of Umtata, Thohoyandou, Ulundi, Siyabuswa and Groblersdal. Although these areas are still experiencing significant population growth (due to large existing concentrations of populations), many of them are also experiencing a dramatic trend of out-migration.

Increased population pressures are exacerbated by the high number of people living in poverty, as evident in an analysis of minimum living level[1] specifically within the metropolitan areas and the former Bantustan areas (along the eastern coast and northern parts of the country). This reveals two contrasting classes of places with high poverty levels and increasing vulnerability – major towns and cities (including all six metropolitan municipalities) on the one hand and remote areas far removed from major cities and towns (for example districts such as O.R. Tambo, Amathole and Ehlanzeni) on the other hand.



Map 4.3: Dependency ratios and employment distribution. Source: Quantec 2007 and STATS SA 2007.

Map 4.3 highlights those areas in the country characterised by high socio-economic vulnerability in terms of their dependency on the economically active population, as well as high ratios and absolute numbers of unemployment. Dependency ratios reflecting the dependency of the non-economically active population (0-14 years and higher than 65 years of age) on the economically active population (15-64 years) calculated per district municipality area, clearly illustrate the areas with the highest dependency ratios as located within a band in the Eastern Cape, KwaZulu-Natal as well as North West and Limpopo provinces.

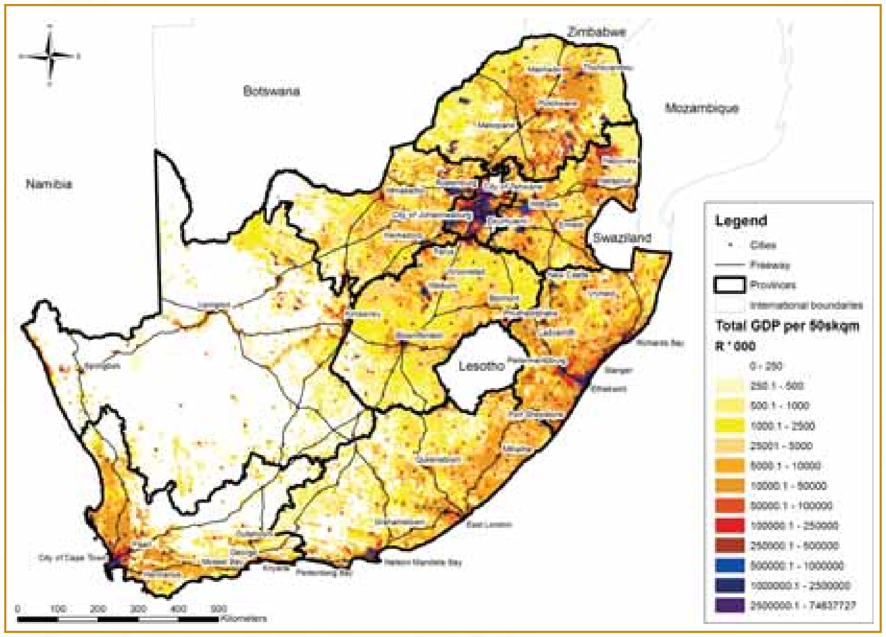
Of interest, however, is the fact that the growth of youthful populations in these areas of high dependency is not high in comparison with the growth of youthful populations in metropolitan areas. The metropolitan areas all have relatively low dependency ratios and significant growth in the economically active age group, as well as noticeable growth in the youthful population.

The breakdown in employment and unemployment figures for 2007 has been calculated for district and metropolitan areas and is illustrated in relation to population size for the respective districts. The large rates of employed and unemployed are evident within the metro areas that are also marked by the biggest and most diverse economies. Other areas bearing evidence of a significant contribution in terms of employment are, for example, areas where the economy is oriented towards primary sectors such as the mining areas in Bojanala and Waterberg districts and agriculture areas in the Cape Winelands district. The metropolitan areas and coastal cities (together with the former Bantustan areas) are also characterised by alarmingly high numbers of people in the unemployment category.

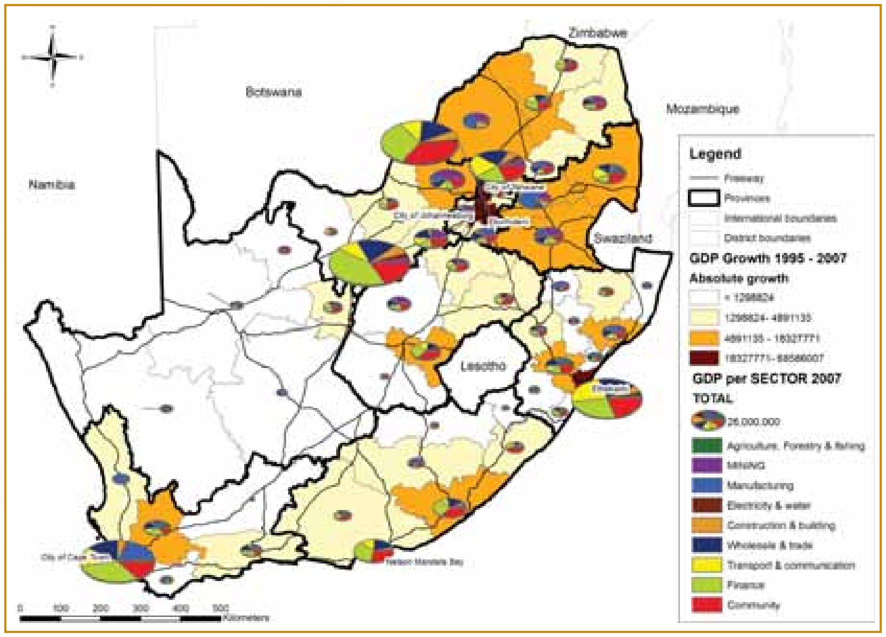
"Increased population pressures are exacerbated by the high number of people living in poverty."

[1] Measure of the minimum monthly income needed to sustain a household, based on the Bureau of Market Research's Minimum Living Level as utilised in the NSDP, 2006 (The Presidency, 2006)

4. Socio-Economic Landscape



Map 4.4: Geographic distribution of economic activity. Source: Based on geospatial analysis platform (CSIR, 2006) and STATS SA 2007 data.



Map 4.5: Comparative analysis of economic activity per district/metropolitan municipality in terms of size, sector and growth. Source: Quantec 2007 and STATS SA 2007.

Map 4.4 depicts the geographic distribution of economic activity as illustrated through the disaggregation of Gross Domestic Product, GDP (2007) throughout the country. The concentration of economic activity in the metropolitan areas and their hinterlands, as well as along major nodes and corridors and specific settlements is evident. The lack of, or extremely limited, economic activity in the eastern parts of the country (former Transkei, Ciskei and KwaZulu-Natal), the Northern Cape and southern Free State is starkly evident.

Map 4.5 illustrates a comparative and more nuanced analysis of economic activity in the different district and metropolitan municipal areas. The analysis of compound growth over the last decade is depicted in different shadings on the map, with the darkest colours indicating the most significant growth and the white indicating negative growth. The size and make up of the economy, based on an analysis of the 2007 GDP figures, are illustrated by the size of the pie charts. The significant role that the metropolitan areas, northern and southern parts, as well as key coastal towns and cities play in the economy of the country is clearly evident – not only in terms of sustained growth of the South African economy, but also in terms of increased access to job opportunities as well as diversification and innovation of economic activities.

Economic decline is mostly evident in some traditionally resource-based economies, often associated with a decline and downscaling of the mining industry and associated jobs. However, places demonstrating high economic growth over the last decade also include resource-based regions and small niche towns. The significance of the primary sectors such as mining and agriculture in district areas such as Bojanala (Rustenburg), Ekangala (Witbank/ Middelburg) and Govan Mbeki (Secunda) is evident.

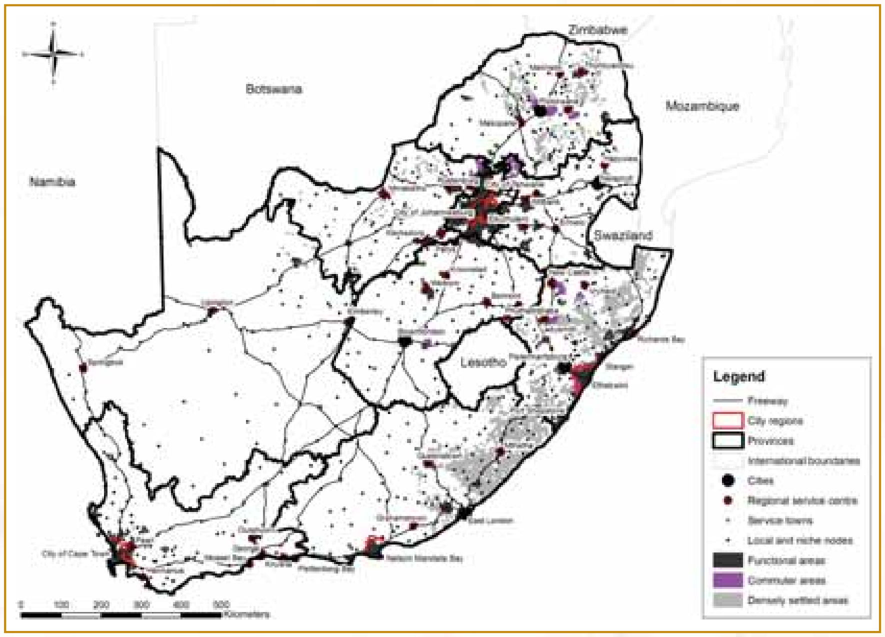
The significant role that the community and services sectors play in the respective economies is evident in the City of Tshwane (with its concentration of government services) and districts such as Amathole, Ehlanzeni, Vhembe, Mopani, Capricorn and Motheo. The latter districts are all characterised by large towns and/or secondary cities within high-density areas where significant portions of the areas formed part of former Bantustan areas. These districts host large numbers of people with less prominent and less diverse economic activity.

4. Socio-Economic Landscape

Settlement dynamics

Settlements, or functional urban areas, play a significant role within the socio-economic landscape of South Africa. The range of settlements typically consists of city or metropolitan region areas, large cities, large and medium-sized towns that fulfil the role of regional service centres, as well as small and local/niche towns. These settlements or functional urban areas house more than 70% of the South African population and more than 90% of all economic activity is generated in these concentrations. Large sections of the population (21%) are also settled in dispersed but dense settlements located in former Bantustan areas.

Map 4.6 illustrates the South African settlement structure in terms of functional urban areas. The settlement classification is set out in Table 4.1 (See Van Huyssteen et al., 2009(a) for a detailed description of the classification). These different types of settlements fulfil diverse roles and face unique challenges within their functional regions. They are typically also areas under severe pressure from increased population and impact on the natural environment and ecosystem services.



Map 4.6: Functional urban areas. Source: Based on geospatial analysis platform data (CSIR, 2006) and adapted from classification of urban areas based on the Urban Rural Typology (Naude et al., 2008 and Van Huyssteen et al., 2009(a)) and the Settlement Classification (SACN et al., 2009).

	Number of settlements identified	Population (% of national)	Economic activity (% of national GVA)	People under a minimum level of living (% of national)
Gauteng city region	1	22	39	14
Coastal city regions	3	16	25	10
Subtotal City Regions		38	64	24
Cities	5	6	5	6
Regional service centres	41	14	15	14
Service towns	44	4	3	5
Local and niche settlements	600	9	5	12
Subtotal as a % of national		71	92	61
Clusters and dispersed rural settlements	N/A	21	2	31
Farms/rest of SA		8	6	8
Subtotal as a % of national		29	8	39

Table 4.1: Summary of the network of settlements in terms of selected indicators: population, number of people living below minimum living level and economic activity (2004). Source: Adapted from SACN et al., 2009

An analysis of functional urban areas suggests that in 2004 the Gauteng city region and coastal city regions of Cape Town, eThekwini and Nelson Mandela Bay were home to more than 38% of South Africans, whilst situated on less than 2% of the land area (SACN et al., 2009). While these areas can be regarded as the engines of the South African economy and fiscus, generating 65% of all economic activity, they are also under severe pressure brought about by ongoing urbanisation and population growth, increased poverty, higher dependency ratios and increased demands on services and resources (SACN et al., 2009; Van Huyssteen et al., 2009(b)).

The concentration of population, consumption and production within metropolitan areas and cities often brings with it a multitude of associated challenges. These include the sustainability of ecosystem services such as water and energy, urban sprawl, social exclusion, increased crime, overload on basic infrastructure and services, congestion of roads and high cost of city logistics, which all threaten the resilience of the urban as well as the socio-ecological system.

4. Socio-Economic Landscape

In the South African case, the challenges faced by metropolitan regions are even further exacerbated by the inequalities and divergence in living standards – evident in large sections of the urban population with limited access to economic opportunities, housing, secure tenure, basic services (such as energy, potable water and sanitation), and social services (for example education, security and health-care) (SACN et al., 2009; Van Huyssteen et al., 2009(b)). Due to South Africa's apartheid history, these inequalities are often spatially imbedded. A recent analysis of water availability highlighted the precarious situation and vulnerability of these growing areas in terms of dependency on water transfer. In spite of significant progress in service delivery by municipalities over the last decade, city region areas face increasing backlogs in access to water, sanitation and electricity, with resulting increased demands on water and energy (Van Huyssteen et al., 2009(b)).

The analysis also highlights the increasing growth of, and demand on cities such as Nelspruit (Mbombela), East London (Buffalo City), Polokwane, Bloemfontein (Mangaung) and Pietermaritzburg (Msunduzi). Typically these are cities with growing populations and economies, fulfilling significant economic and public services functions and bearing evidence of increased urbanisation and townward migration (SACN et al., 2009).

Large and medium-sized towns such as Rustenburg, Richards Bay and Witbank (Emalahleni) within relatively resource-rich areas (areas that are seemingly characterised by growth in the economy and population), towns such as Kimberley and Upington with strong regional services functions in sparsely populated areas of the country, and towns such as Mthata and Thohoyandou with limited ranges of urban functions in highly populated former Bantustan areas, also play a critical role as regional service centres. In spite of seemingly strong out-migration trends in their surrounding areas, towns in this category are bearing the brunt of townward migration, continued natural population growth and huge dependency ratios, with economies characterised by the dependency legacy on government and community services sectors. The analysis suggests that, in total, these cities and regional service centres are home to almost 20% of the population and reflect 20% of economic activity in the country (2004).

Due to the South African apartheid history, the settlement landscape bears witness that the challenges of concentration and inequalities are not limited to metropolitan areas and cities. They are also rife in areas characterised by densely populated and highly dispersed settlements in the former Bantustan areas – often areas that are playing key roles in supplying access to natural resources such as water. High concentrations of poverty, limited access to employment, livelihoods and socio-economic services, as well as huge dependency burdens are posing significant threats to the resilience of these regions and the socio-ecological systems[2] of which they form part.

These settlements are outstretched and house significant numbers of people (primarily poor people) on the east coast (former Transkei and Ciskei areas), in areas in northern KwaZulu-Natal as well as in northern Limpopo and Mpumalanga.

Even though trends for 1996-2007 indicate that these areas are experiencing out-migration, they are still characterised by net population growth due to natural growth and large population numbers (SACN, et al., 2009). Within the context of low accessibility to opportunities and services, low base of economic activity and huge dependency ratios (SACN et al., 2009), these dense settlements and largely rural districts are facing increased demands on services (exacerbated by huge distances) as well as on resources such as land, water and energy.

[2] The term refers to the interrelated complexity of the range of systems and spheres of existence, including for example social, cultural, institutional, economic and natural systems, as well as interior spaces of collectives and individuals (see Burns and Weaver, 2008: 15; and du Plessis, 2008: 59-89)

4. Socio-Economic Landscape

CASE STUDY

CLIMATE VARIABILITY AND CHANGE: CITY OF JOHANNESBURG

Christina Fatti, Coleen Vogel and Is'Haaq Akoon

Global change – including climate change and climate variability – may strongly influence the progress of development in Southern Africa (Boko et al., 2007).

Attaining a better understanding of the relationship between climate variability and climate change remains a key challenge. Johannesburg City, for example, usually experiences a number of thunderstorms in the summer season. These storms can provide either a challenge or an opportunity, given aforementioned infrastructural and service delivery complications in South Africa's urban settlements (e.g. infrastructure damage, access to potable water, etc). The issue now arising in view of climate change in such urban settlements and elsewhere is whether these storms are changing in type, in number and in the amount of rainfall they bring.

According to available research, extreme rainfall events such as thunderstorms may increase in frequency and intensity given climate change. More investigation is needed to confirm such outlooks. As this case study attempts to show, the uncertainty around storm frequency, occurrence and magnitude may compound urban settlement and urban environmental issues, including placing additional stresses onto the system.

The City of Johannesburg is one of the largest urban conglomerations in Africa and has recently struggled with severe storm events that resulted in the loss of life. The City has seen remarkable growth over recent years, as indicated in Chapter 4. People flock to the City for employment and often find accommodation in informal dwellings located close to streams and rivers that are vulnerable to a range of stressors including storm events.

The aim of the study described here was to examine the nature of severe storm occurrence in Johannesburg. Actual rainfall data from 1960 to 2008 were used and changes in storm frequency, magnitude, amount of rainfall per storm, amongst other parameters, were tracked. The results were then compared with the recent work completed for the City of Johannesburg's Adaptation Plan (Johannesburg Draft Adaptation Plan, 2009). The City was informed of the study and several meetings were held with Metro representatives.

In an attempt to improve this knowledge, the first part of the study aimed and will continue to descriptively analyse thunderstorms in Johannesburg. The criteria used to identify a thunderstorm were the occurrence of rainfall, cumulonimbus cloud as well as the actual observation of a thunderstorm. Once the occurrence of the storms had been determined, the frequency of storms, as well as the associated rainfall, was tracked. The key emerging finding is that even though there has been a decrease in total rainfall, the data indicate that rainfall per event has increased. More detailed investigations are now underway.

These initial findings support suggestions from climate change scientists that while rainfall totals may change over time, the amounts per event may increase, possibly putting additional pressure on blocked drains, poorly drained areas and poorly maintained urban areas. Poorly constructed dwellings and poor communities living close to water courses may be at risk.

There are several lessons that can be drawn from this initial study, one of the most important being that decision-makers are faced with various planning decisions about managing urban spaces given scientific uncertainty of the climate system.

5. Water Resources

WATER – LIFEBLOOD OF LIFE ON EARTH

Rebecca Maserumule

While there is a general consensus that global warming is occurring, the impacts on the water cycle are not as fully understood and projections of changes to rainfall become less reliable as the scale reduces from the global to the regional and local level. This uncertainty hinders the ability of water managers to effectively integrate the impact of climate change into the planning processes which support decisions that are often made at the local or regional level.

Changes to the water cycle will be felt at a secondary level across many sectors in South Africa, with the agricultural sector being highly vulnerable to changes with its annual usage of 62% of the total resource. The use of water by sectors is shown in the Figure 5.1.

Given the important role that water plays in growth and development in South Africa (DWAF 2004), resilient and sustainable growth will be more likely if issues of water are integrated in the planning process across all sectors.

Overview of freshwater resources in South Africa

Water is a scarce resource in South Africa, long before the challenges of climate change are taken into account. While the National Water Resource Strategy emphasizes the importance of equitable access to reliable water supplies, the National Water Act was established to ensure that freshwater reserves have been set aside for human consumption as well as a sufficient allocation to ensure the proper functioning of healthy ecosystems (DWAF 1998). Terrestrial and aquatic ecosystems and the services they provide will be under duress in situations where a community experiences problems with water scarcity, as it will be difficult to support decisions which balance the needs of the people and the natural resource.

Freshwater resources in South Africa are classified into three sources – surface water, return flows and groundwater at 77%, 14% and 9% respectively. Groundwater is responsible for a small proportion of the total resources at a national scale, but is the primary resource for domestic use in many rural areas. As adaptation strategies focused on infrastructure to maximise the use of surface water become more difficult to implement, groundwater will serve as an important safeguard as South Africa looks to diversify its resource base. Limits to groundwater use exist, of course (see case study to follow).

Impact of climate change and variability on freshwater resources in South Africa

Streamflow, or channel flow, refers to the flow of water in streams, rivers and other channels. Changes in the concentration and timing of high and low flows are expected

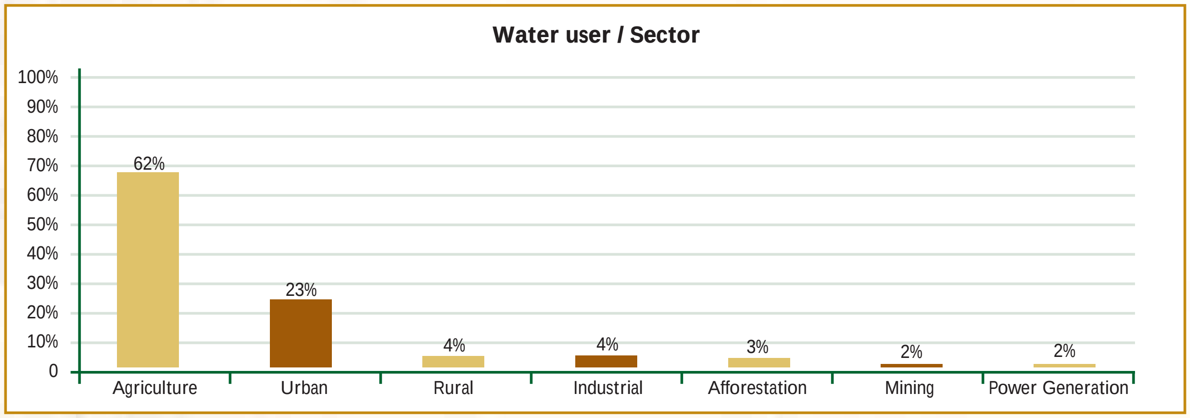


Figure 5.1. Use of water by sectors.

5. Water Resources

due to changes in rainfall patterns. Possible changes of up to 10% in rainfall can affect streamflow up to levels of 30% (Schulze 2005). Changes to the timing of high and low flows could disrupt water management decisions related to irrigation water demands, domestic and industrial use.

A projected increase in extreme events (see Chapter 3) is expected to have a negative impact on the quantity and quality of groundwater reserves and surface water. The risk that water resources face due to the increase in extreme events, droughts and heavy precipitation can be categorised in the following way:

- Decrease in water quality due to saltwater intrusion
- Increase in the occurrence of international water conflicts
- Decrease in water quality due to run-off and erosion
- Decrease in agricultural development and profits due to droughts

Immediate action is vital

Despite future uncertainty, we still have an obligation to take immediate action. An important factor in gauging a local community's ability to cope with the future consequences of climate change is the current status of their water, food and energy security. Water security depends on a community's ability or capacity to access potable water on a continual basis. Food security involves the ability to safely access nutritious food necessary to lead an active and healthy life.

The success of a developing economy relies on energy security, which involves having access to cheap energy. South Africa's extensive stores of coal allow it to play a leading role on the African continent as the provider of electricity for two-thirds of the African continent. Efforts to reduce carbon emissions by promoting the use of alternative energy resources like hydroelectric power and nuclear energy may be hindered, however, by dwindling water resources which are currently under stress.

Central to any adaptation strategy for South Africa are efforts to ensure water security for South Africans without basic access to water. The Department of Water Affairs has shown marked progress towards meeting the Millennium Development Goals by halving the water backlog in 2005 well before the expected target date of 2010 (DWA 2004). Efforts to ensure basic services to all in 2014 may, however, be hindered by changes in the water cycle due to climate variability and change. The challenges of food and energy security are also underpinned, as mentioned earlier, by the lack of a steady supply of water at the appropriate level of quality and quantity.

Integrated water resource management

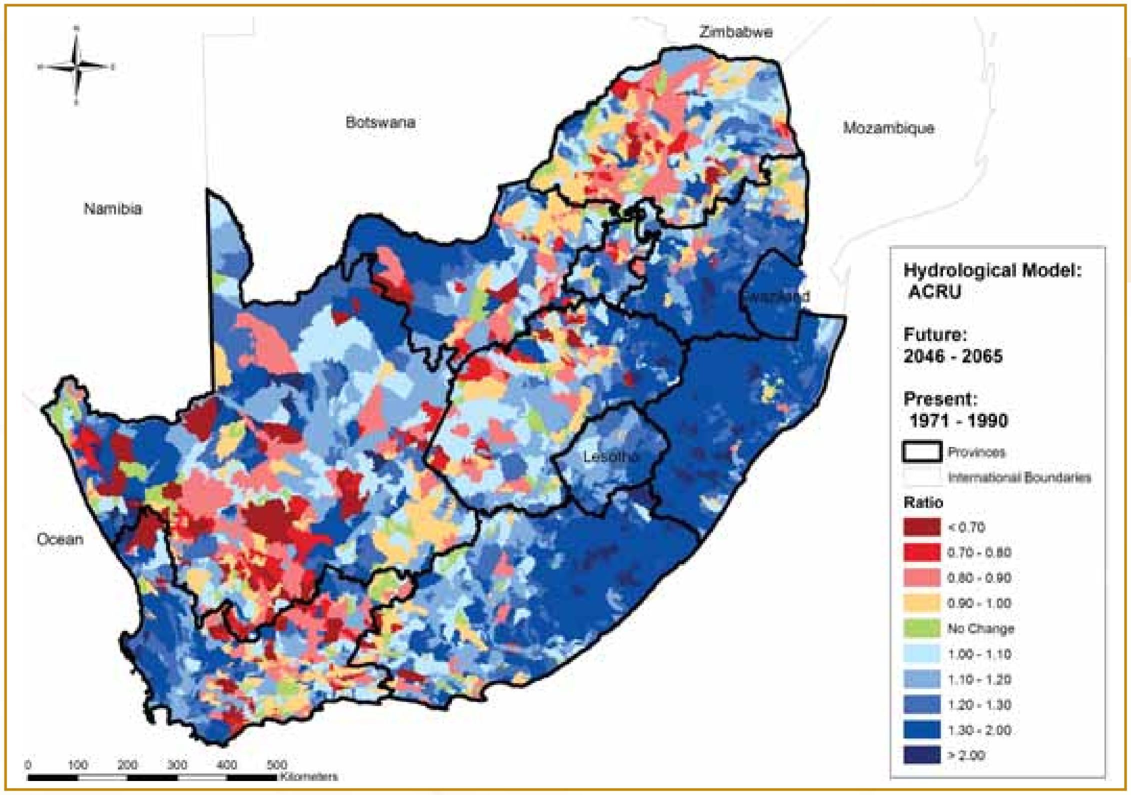
A range of factors including population growth, socio-economic conditions, political factors as well as societal views on the value of water and climate change affect the availability of freshwater in South Africa.

Integrated water resource management (IWRM) creates a framework whereby decisions for water, land and related resources are coordinated to improve the socio-economic welfare of the individuals dependent on the resource base without compromising the sustainability of vital ecosystems. IWRM will be a key component of any adaptation strategy across all sectors in South Africa.

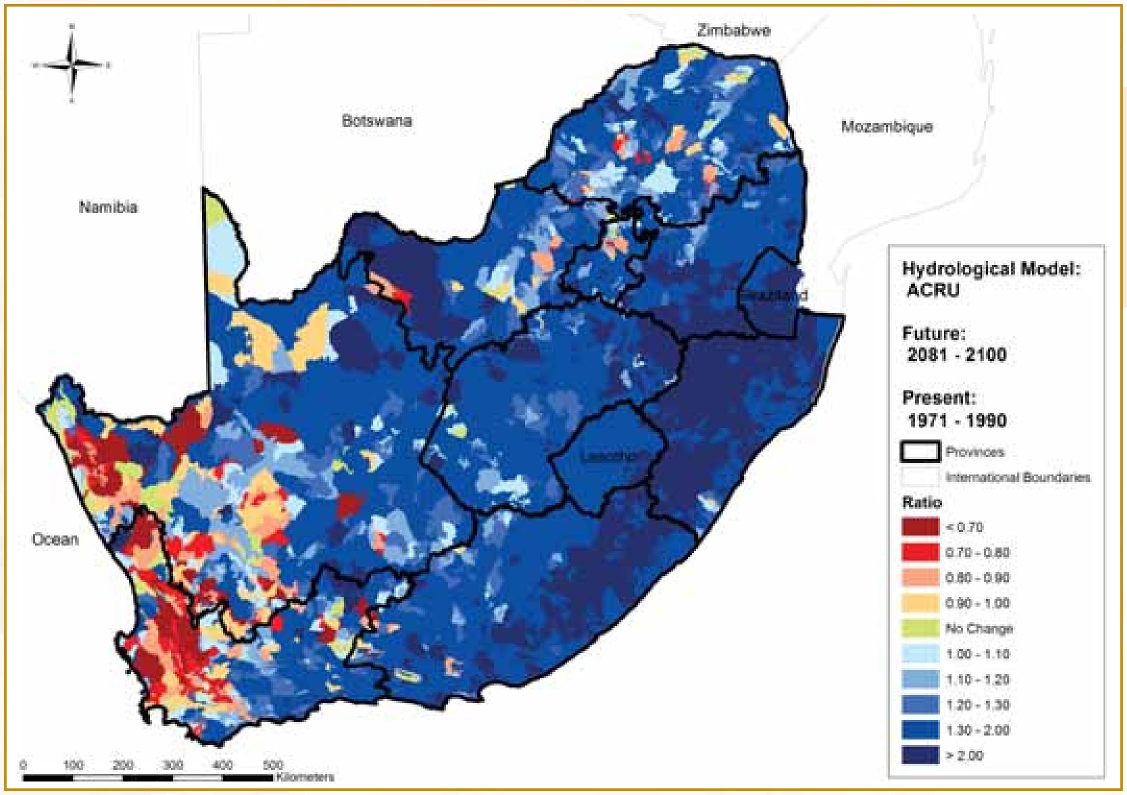
Adaptation for water resources should follow a three-fold investment in better and more accessible information, stronger institutions and natural and man-made infrastructure to store, transport and treat water (Sadoff and Muller, 2009). South Africa shares transboundary basins and aquifers, so the effective management of relations with neighbouring countries will be key in assisting capacity building at the SADC level given the issues with water scarcity within the region.

"Water is a scarce resource in South Africa"

5. Water Resources

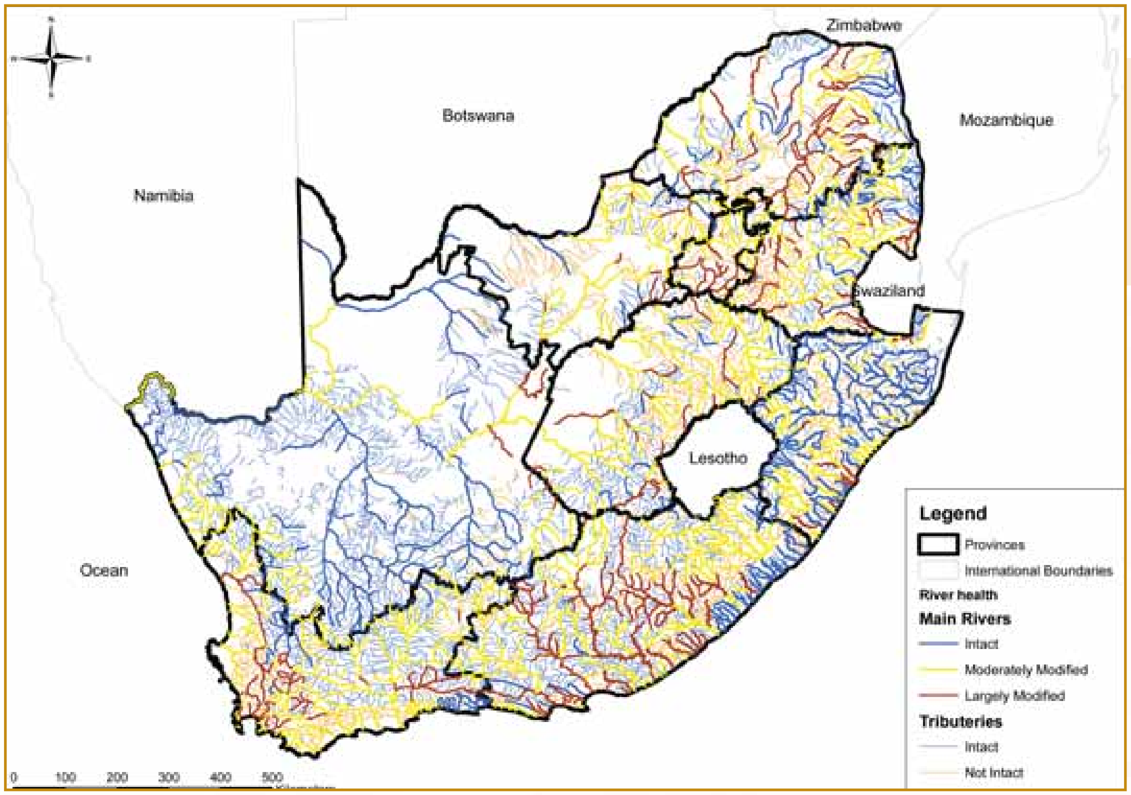


Map 5.1: Ratio of intermediate to present mean annual streamflow. Source: R.E. Schulze, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal.

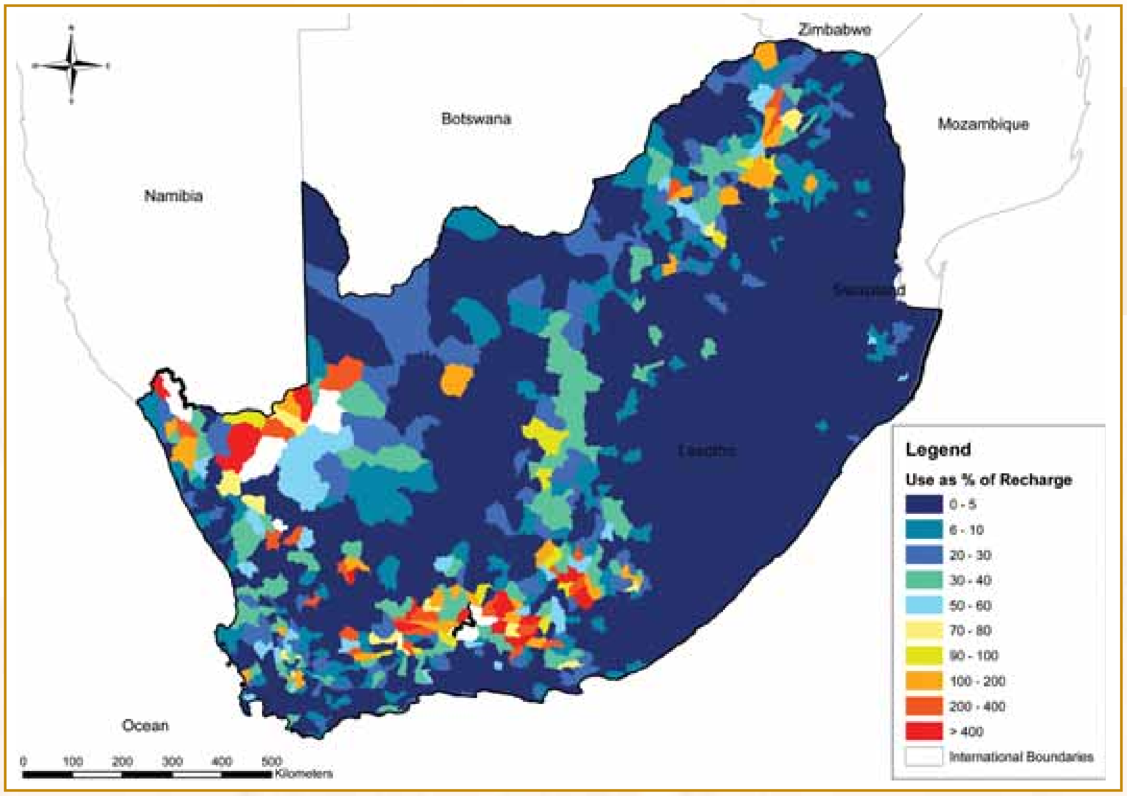


Map 5.2: Ratio of future to present mean annual streamflow. Source: R.E. Schulze, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal.

5. Water Resources



Map 5.3: Annual water balance in South African catchments 2005. Source: R.E. Schulze, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal.



Map 5.4: Balance of mean annual groundwater use vs recharge (%). Source: DWAF GRA2, 2005.

CASE STUDY

CLIMATE CHANGE AND WATER RESOURCES: ALTERED WATER AVAILABILITY AND INCREASED SOCIETAL RISKS

Christine Colvin, David Le Maitre and Emma Archer

As mentioned in Chapter 3, climate change projections for South Africa are expected to include a change in the amount and variability of rainfall. Air temperatures are likely to increase, which will increase evaporation. The net effect is likely to be a decrease in the water in our rivers and water stored in the ground. These changes are critical as South Africa is already using almost all of its available water.

Climate change poses three major risks to our nation's water resources:

- increased incidence of drought as rainfall decreases in many areas;
- increased incidence of floods as the incidence of very heavy downpours increases; and
- increased risk of water pollution linked to erosion, disasters and algal blooms.

For example, in the semi-arid Sandveld in the Western Cape, sectors of the commercial agriculture sector are highly dependent on groundwater for irrigation. In a study sponsored by Cape Nature's Greater Cedarberg Biodiversity Corridor, Potato South Africa and the South African Rooibos Council, a team of scientists partnered with industry to investigate the implications of climate change for groundwater (and other) dependent commercial farming in the area (Archer et al., 2009). The Sandveld comprises one of South Africa's areas of higher groundwater vulnerability (Map 5.4). As a result, climate change has to be considered as one of a range of stressors affecting water quality and supply in the area.

As shown in Chapter 3, higher temperatures are expected throughout South Africa, as well as higher rates of evapotranspiration. In addition, for western South Africa where this area falls, less winter rainfall is expected. Groundwater stress indices are affected by a range of factors, with temperature and rainfall comprising critical climatic variables. Theoretically, higher temperatures would indicate higher irrigation needs, while lower rainfall indicates lower rates of groundwater recharge.

The study team focussed on using groundwater recharge models to show the expected change in groundwater recharge under future rainfall scenarios (see Chapter 3). Most results indicated lower rates of groundwater recharge in the farming area, particularly towards the south, where intensive farming is taking place (Archer et al., 2009).

As mentioned earlier, water resources are subject to a range of stresses, of which climate parameters are only one component. Nowhere is this more critical to take into account than in the Sandveld, where the water user profile changes, and key land uses such as settlements, agriculture, mining and conservation compete for a likely diminishing overall water budget.

In this study, particular care was taken to feed the results back to the key stakeholders in the area, including Potato South Africa, who continue to use such results to inform management recommendations for member farmers in the area. Future planned work in the area will focus on the potential impacts of higher temperatures and rates of evapotranspiration on irrigation requirements by farmers in the area, with further plans to feed such results into revised management plans for the area.

While such results may pose a challenge to potential users of water, close partnerships between scientists, nature conservation and agricultural managers in the area aid in guiding such conversations in a constructive direction.

Sandveld irrigation circles.

6. Agriculture

AN OVERVIEW OF AGRICULTURE IN SOUTH AFRICA

Daleen Lötter

South African agriculture is comprised of mainly two categories – a predominantly subsistence-oriented sector in the rural areas (small scale) and a well-developed commercial (large scale) sector. Subsistence agriculture is often associated with risk and uncertainty. However, it remains a crucial activity for a large part of the South African population.

Agricultural land comprises 100.7 million hectares (81%) of the country's total land area of 122.3 hectares, and encompasses a wide range of crops and products. Of the available agricultural land about 84 million hectares (68.6%) are covered by natural pastures, while the rest, 16.7 million hectares, are under cultivation for crop production. Of the potentially arable land 1.2 million hectares are under irrigation and provide approximately 30% of total agricultural production.

The agricultural sector can broadly be divided into three main branches: animal production, field crops and horticulture. These branches contributed 48,2%, 26,7% and 25,1% respectively to the total gross value of agricultural production for the year 2008/2009, with the poultry meat industry comprising the largest contribution, followed by maize (DAFF, 2009).

The primary agricultural sector fulfils a prominent role in South Africa's economy and is vital to the development and stability of the southern African region. It is a significant provider of employment (8-9% of total employment) and sustaining livelihoods, especially in the rural areas, and a major earner of foreign exchange. Primary commercial agriculture contributes about 2,5% to South Africa's gross domestic product (GDP), but through strong linkages to other sectors of the economy, it is estimated to comprise about 12% of the GDP (DAFF, 2009). Any adverse effects of climate change on agriculture will thus have wide-ranging repercussions for the southern African region.

Global climate change and agriculture

The considerable variation in South Africa's climate – ranging from the dry north-western to the wet eastern regions – strongly influences the distribution of farmland across the provinces, giving rise to diverse crop and livestock farming activities. Agriculture is directly dependent on climatic variables such as temperature and precipitation as these variables dictate crop and livestock selection for a specific locality, as well as cultivar choices and cropping calendars.

Global warming is projected to have significant impacts on climate conditions affecting agriculture, including temperature, carbon dioxide, precipitation and the interaction of these factors (DEADP, 2008). Global climate change is predicted to modify these climatic variables (see Chapter 3), which may alter agricultural productivity and have important implications for the incidence of pests and diseases.

Altered climatic conditions will impose new challenges for various crops, regions and farming systems across the country. This will have consequences for the day-to-day management decisions of the agricultural sector and for broader issues such as food security.

"The primary agricultural sector fulfils a prominent role in South Africa's economy and is vital to the development and stability of the southern African region."

6. Agriculture

Risks to agriculture

Temperature, rainfall and water resources

Temperature dictates crop production, with optimum growth rates under different upper and lower temperature limits in different seasons. The heat unit and chill unit concept depicts this dependence and refers to the period of accumulated maximum/ minimum temperatures above/ below a threshold. A new temperature regime (see Chapter 3) will modify the rate at which heat units and chill units accumulate, affecting growing locations, crop yields, planting and harvest dates, and pest or disease incidence. In addition, increased minimum and maximum temperatures imply an increase in potential evaporation, which is likely to have profound effects on dry-land and irrigated crop production.

Rainfall is critical to agriculture, especially the timing, intensity and distribution of rainfall throughout the growing season. Increased intensity of rainfall (see Chapter 3) will affect both ground and surface water resources.

In South Africa, a semi-arid country where the average evaporation rate exceeds its precipitation, water is a critical limiting factor for agricultural production (see, for example, the Sandveld case study provided in the previous chapter). The agriculture sector accounts for about 60% of water utilisation in South Africa. Changes in water demand and availability will significantly affect farming activities, with western regions predicted to have 30% reduced water availability by 2050. Under these conditions irrigation demand will increase, especially in the affected drier western parts of the country, adding to the pressure on water resources.

Field crops

Maize (a staple of a large proportion of the population), wheat and sorghum are the country's most important grain crops. South Africa is the main maize producer in the SADC region. Prominent commercial maize production areas are to be found in the Free State province, followed by Mpumalanga and North West. Wheat is largely produced in the winter-rainfall areas of the Western Cape, and to a lesser extent in the Free State.

The profitability of maize and wheat production is highly climate dependent. With a 2°C increase in temperature and a 10% reduction in rainfall, profits are projected to be generally reduced by around R500/ha, which is equivalent to a yield reduction of 0.5 t/ha (Schulze, 2007). Wheat-producing regions in marginal areas of the winter rainfall region (see Chapter 3) are expected to suffer losses of 15-60% by 2030-2050, depending on the extent of warming and drying (Midgley et al., 2007).

The greatest impact on production is expected to be in the most marginal areas, where low and irregular rainfall is already experienced. The implications of these projections are significant as many livelihoods depend upon these industries (Midgley et al., 2007).

Horticulture

The horticultural sector includes deciduous fruit, citrus fruit, vegetables, viticulture and subtropical fruit. Income from vegetable production and deciduous fruit (mostly located in the Western and Eastern Cape, with warm, dry summers and cold winters) constituted the largest contribution to gross income from horticultural products in 2008, whereas wine (mostly produced in the Western Cape and along segments of the Orange River in the Northern Cape) was South Africa's top exported agricultural product in 2006.

An increase of 2°C in temperature will cause many agriculturally significant areas of the country to experience a 15-35% increase in heat units, especially on the higher-lying mountainous areas in the southern and eastern parts of the country (Schulze, 2007). Equally, a considerable decrease is predicted in the accumulation of chill units, which is highly sensitive to climate change induced warming. This will have far-reaching implications for the deciduous fruit industry of the Western Cape.

6. Agriculture

Viticulture is expected to be more resilient to warming and drying trends. However, non-irrigated grapevines are expected to suffer slight to severe losses depending on the extent of warming. The anticipated change in chill and heat unit accumulation may bring about shifts in traditional fruit producing areas, gradually giving way to other varieties or crops.

Livestock and pastures

Extensive livestock farming comprises nearly 80% of agricultural land in South Africa. Dairy farming is practiced all over South Africa, whereas sheep farming and most of South Africa's rangelands are to be found in the semi-arid areas of the country. Any further decline in water availability in these water-stressed areas is likely to impact carrying capacity and may lead to severe livestock loss and a decline in overall productivity.

Heat stress is another important factor in livestock production and can cause decreased milk production and poor reproductive performance in dairy cows, with huge economic implications. Conversely, the projected general increase of minimum temperatures might alleviate cold weather stress on livestock as warm nights increase and cold nights decrease.

Predicted changes in climate are expected to:

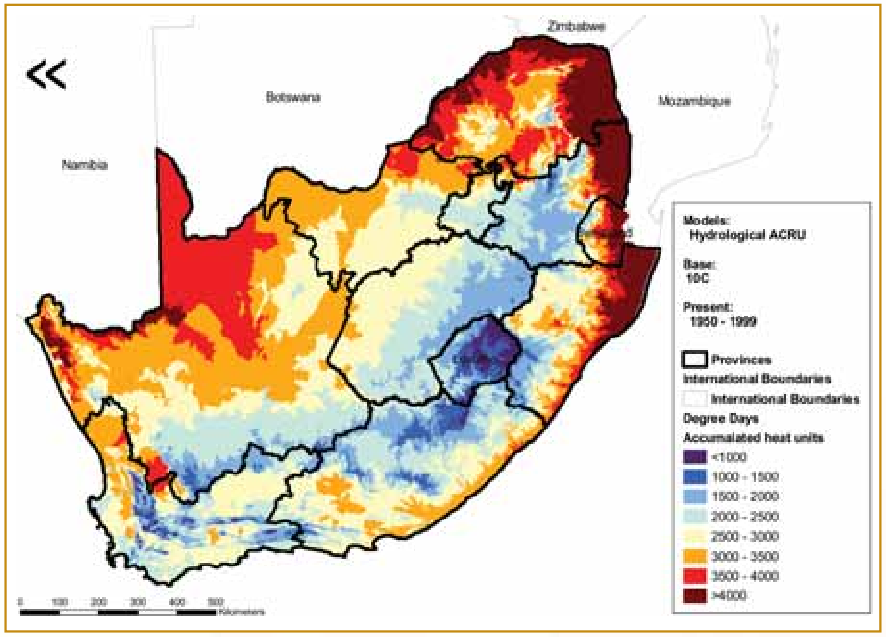
- modify agricultural productivity across different farming regions;
- alter the spatial distribution of climatically suitable growing areas, with certain areas benefiting, while others may find themselves at a disadvantage;
- impose new management practices or adjustment to existing operations;
- result in a shift in agricultural trade patterns; and
- identify new crop opportunities with certain crops having competitive advantages/ disadvantages over others (Schulze, 2007).

Vulnerability

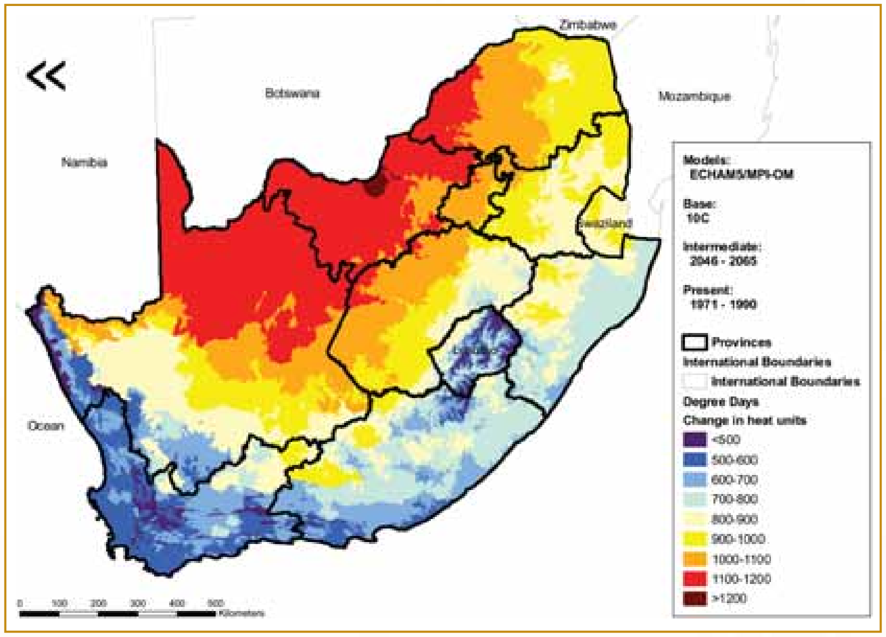
There are various inherent adaptation measures and adjustments that farmers apply in order to be less vulnerable and more resilient in the face of climate change and variability. However, in those areas where agricultural systems are already under stress economically or biophysically, or where crops are nearing climate tolerance thresholds, or where multiple stresses exist, agri-businesses are at highest risk (DEADP, 2008).

Emerging, small-scale and resource-poor farmers are particularly vulnerable to climate change and variability because they have fewer capital resources and management technologies at their disposal. Subsistence farmers often do not have the ability to adapt nor sufficient means to deal with and recover from extreme events such as floods and droughts.

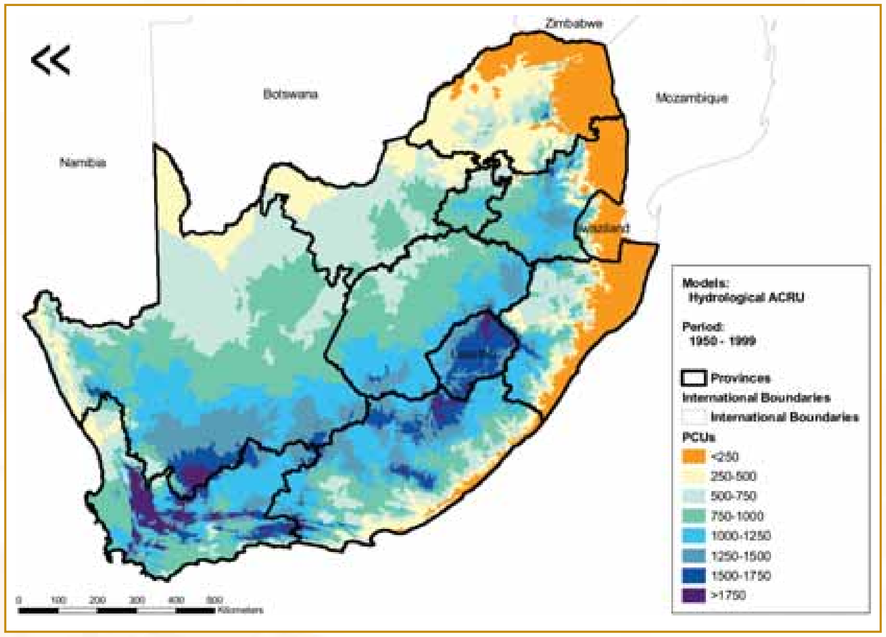
6. Agriculture



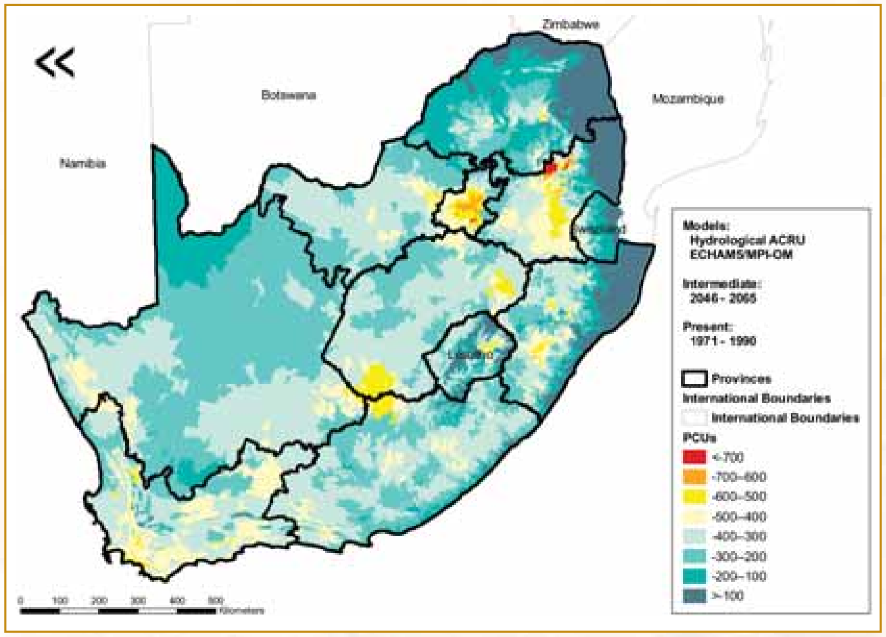
Map 6.1. Accumulated heat units (degree days). Annual (Jan - Dec). Source: R.E. Schulze, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal.



Map 6.2. Intermediate future - present (degree days). Accumulated heat units. Annual (Jan - Dec). Source: R.E. Schulze, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal.



Map 6.3. Accumulated positive chill units. Winter (Apr - Sep). Source: R.E. Schulze, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal.



Map 6.4. Intermediate future - present. Accumulated positive chill units. Winter (Apr - Sep). Source: R.E. Schulze, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal.

Ryegrass pastures against the backdrop of the Outeniqua Mountains.

6. Agriculture

CASE STUDY

GLOBAL CHANGE IMPACTS ON AGRICULTURE AND WATER: SOUTH AFRICA'S GARDEN ROUTE

Daleen Lötter

The Cape Garden Route, situated along the majestic coastline of the Southern Cape, falls mainly under the jurisdiction of the Eden District Municipality. It comprises a range of biologically diverse terrestrial and aquatic ecosystems, mountain ranges, indigenous forests and estuaries.

Frequent severe water shortages, land degradation, alien invasive species and altered climate patterns are putting South Africa's Garden Route under strain, however. Prolonged droughts, followed by devastating floods, have had wide-ranging implications for the agricultural sector, which constitutes a prominent part of the Eden District economy. In addition, surface water resources are already stretched to the limit in coastal catchments, where the demand for water exceeds the available surface water resources. Coupled with the effects of predicted climate change, the pressure on water and land resources is expected to increase. Global change scenarios predict a warmer climate (Figure 6.1) and more irregular and intense rainfall events for the area.

Global change is posing a major threat to agricultural industries in the region, which in turn puts pressure on water and land resources. Increasing the risk are inappropriate land and water management practices applied in certain areas. Multiple economic, ecological and political stresses are placing farmers under immense pressure, contributing to their vulnerability. It has become vital for researchers to investigate the impact of global change on agriculture in the area to identify vulnerable areas and avoid further risk.

Specific risks associated with global change in the region include decreased water security and quality, loss of biodiversity and the incidence of diseases. According to the Department of Water Affairs, the irrigation sector (mostly pastures and vegetables), requires nearly half of the water requirements for the area (Figure 6.2). The region is already experiencing a shortfall in water supply and it is predicted that such a deficit will increase in the future. The dairy industry in particular is vulnerable as water availability affects grazing security and the condition of livestock.

Climate models

Agriculture in the area under investigation is progressively exposed to extreme weather conditions. Projected increases in the frequency and intensity of extreme climate events such as floods and droughts appear likely (see Chapter 3). Emerging farmers, small and resource-poor farmers are particularly vulnerable in that they lack sufficient resources to deal with, and recover from, extreme flood and drought events.

The Wildlife and Environment Society of South Africa (WESSA) initiated a research project to determine the implications of global change for land and water use within the agricultural sector of the Garden Route. The project is partly funded by the Eden District Municipality. Research is driven by concerns that, confronted by global change, farmers and municipalities will tap more water resources and develop more land currently occupied by indigenous vegetation worthy of conservation. The research gains insight into farmers' perceptions of climate change and variability as well as the factors that dictate and drive their adaptation decisions. Farmers' perceptions of climate variability and global change strongly influence their reaction to changing climate conditions. Their adaptation decisions are largely dictated by the economic benefits associated with improved land and water conservation practices.

This case study aims to make key global change science and impact information available to stakeholders such as government departments, municipalities and civil society. It places a strong emphasis on informing these stakeholders about the implications of global climate change for the agricultural sector. The findings of the study will assist stakeholders in their assessment of future pressure on water and land resources under changing climatic conditions, and will hopefully encourage the implementation of more sustainable agricultural practices. Such practices will make the farmers less vulnerable and more resilient to global change, whilst mitigating its potentially devastating effects.

The case study also serves as an example of how decision-makers can apply existing climate risk and vulnerability information to the agricultural sector. The aim is to create greater public awareness around the vulnerability of water, agriculture and biodiversity to global change by means of translating scientific research into a format which is useful for decision-makers on local government level.

Collaboration on the case study between the Western Cape Department of Agriculture, Eden District Municipality, WESSA and the Nelson Mandela Metropolitan University has resulted in multi-institutional data sharing – for the benefit of agriculture and food production in the region.

6. Agriculture

CASE STUDY

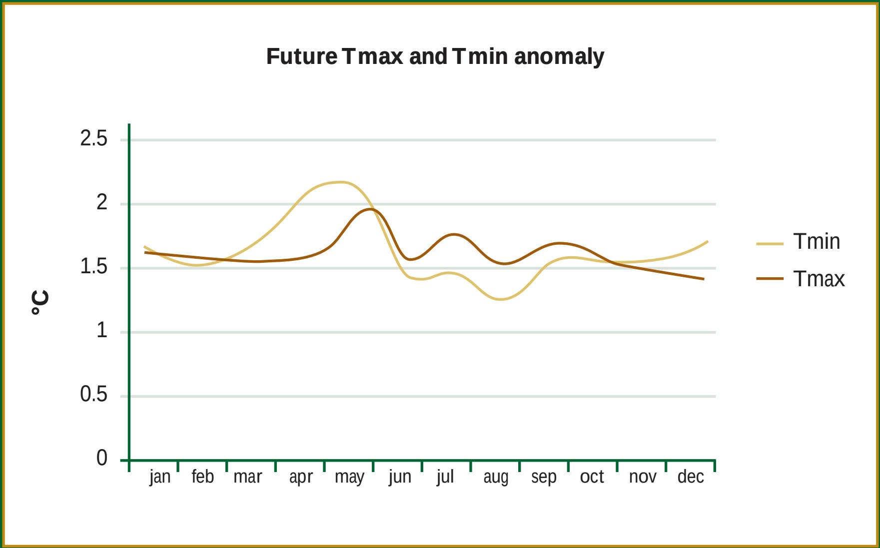


Figure 6.1. Future anomaly of maximum and minimum temperature, Garden Route area. Source: Agro-meteorological weather station network, hosted by the Agricultural Research Council's Institute for Soil, Climate and Water.

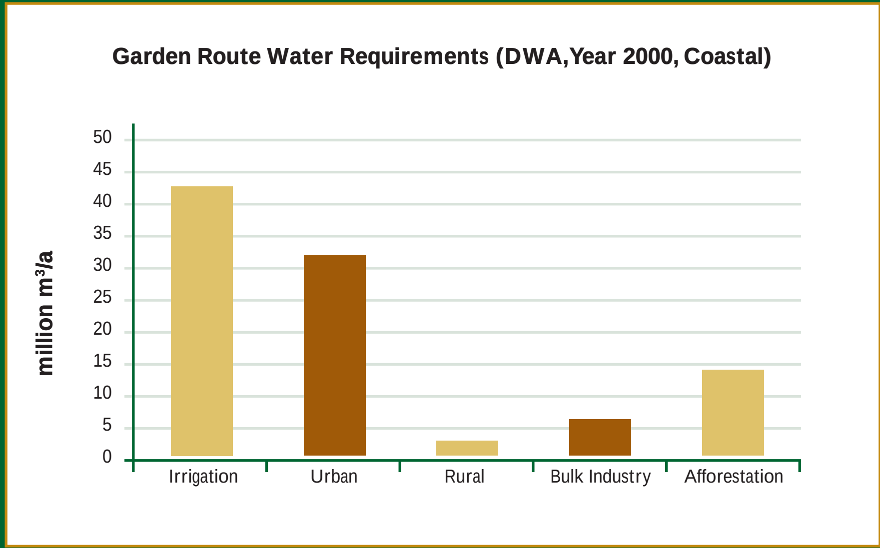


Figure 6.2. The irrigation sector has the largest requirement for water in the coastal catchments of the Garden Route. Source: DWAF 2003

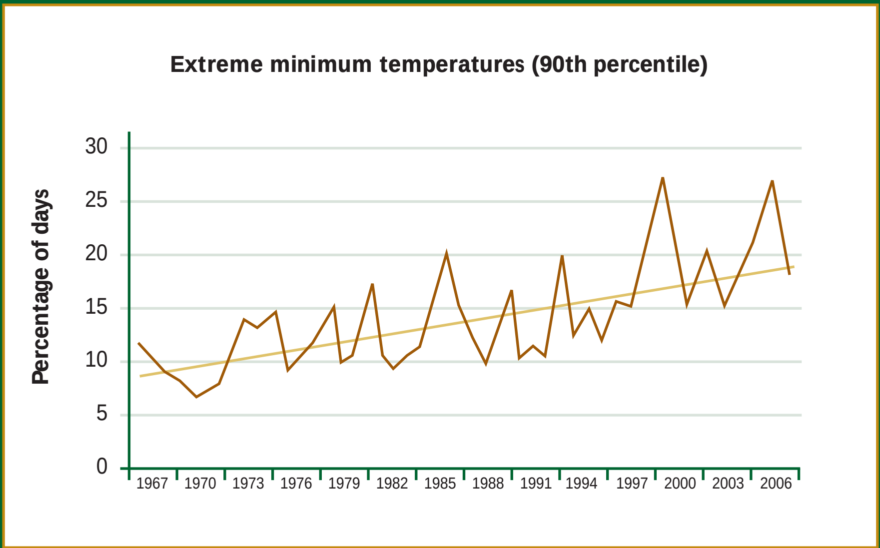


Figure 6.3. Observed minimum temperature (warm nights) increase, Outeniqua research farm. Source: Agro-meteorological weather station network, hosted by the Agricultural Research Council's Institute for Soil, Climate and Water.

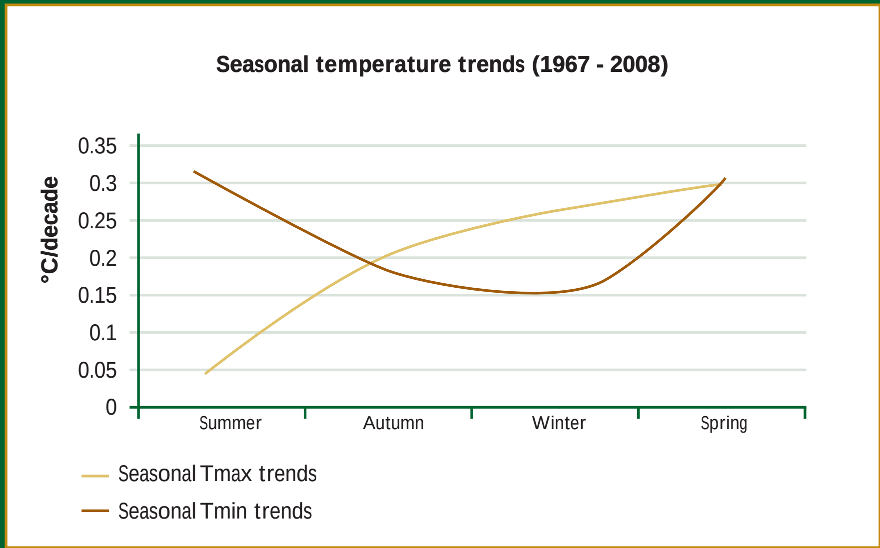


Figure 6.4. Observed seasonal temperature increase, Outeniqua research farm. Source: Agro-meteorological weather station network, hosted by the Agricultural Research Council's Institute for Soil, Climate and Water.

7. Human Health

GLOBAL CHANGE AND HUMAN HEALTH

Jane Olwoch and Caradee Wright

"Health risks from climate change include those directly related to increases in extreme weather events such as heat waves, floods, cyclones, storm surges and droughts, and those due to an increase in pollens, spores and moulds."

The popular traditional belief that human health depends entirely on genetic make-up, behaviour and accessibility to a health facility has been diluted with new and consistent knowledge that environmental and social conditions fundamentally determine human health.

The World Health Organization (WHO) recently estimated that 34% of all childhood illness in the world (compared to 24% of all age illness) and 36% of deaths in children under age 14 are due to modifiable environmental factors. Determining how environmental conditions at different scales change, and how they influence or determine human health is a challenge. It is even more challenging to determine how social, cultural and economic conditions influence the vulnerability of communities, and subsequently their adaptive capacity.

Global warming and climate change may cause environmental and ecological changes that weaken both social and economic systems. Effects of climate change on human health are particularly critical, since climate change itself is a gradual process and its effects on human health are mostly indirect, not easily quantified and their manifestation is complex.

Climate change health risks

Health risks from climate change (see Table 7.1) include those directly related to increases in extreme weather events such as heat waves, floods, cyclones, storm surges and droughts, and those due to an increase in pollens, spores and moulds. Air quality is further threatened via at least three mechanisms: heat-driven increases in ground-level ozone; energy production that results in increases in particulates; and other fossil fuel related air pollutants and changes in aeroallergens.

7. Human Health

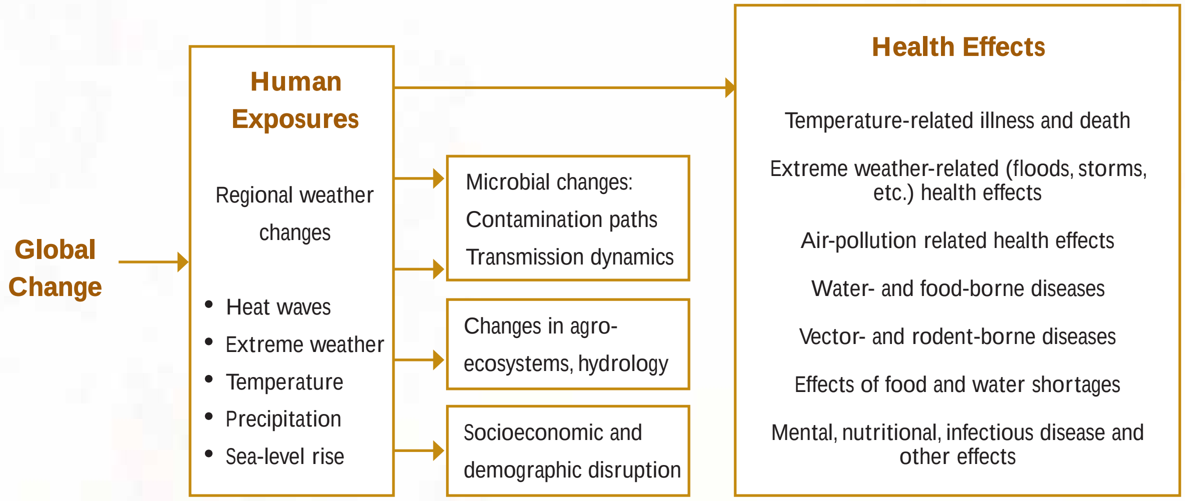


Figure 7.1: Climate change as a modulator of human health: Direct and indirect influences. Source: Redrawn from World Health Organization, Online at: WHO Climate Influences.

Other risks will be from indirect means such as an increase and / or shift in the distribution of vector-borne, water-borne diseases and food-borne infections. More indirect effects will come from decreased food production and associated malnutrition. Weak social and economic stability, inadequate health information and facilities, limited access to and availability of resources and information such as early warning systems, and reduced capacity to respond make the poor, rural South African communities vulnerable to health risks from climate change (Figure 7.1).

For example, malaria kills more than 3 000 children per day in sub-Saharan Africa. Malaria is mainly transmitted in the low altitude areas of the northeastern parts of South Africa – Mpumalanga, Limpopo and northeastern parts of KwaZulu-Natal. An analysis of seven years of malaria data shows a reduction in malaria cases in KwaZulu-Natal, but increases in Limpopo Province, although a range of factors may play a role here (see case study to follow).

Adaptation and mitigation strategies

Adaptation and mitigation strategies are necessary to increase the communities' preparedness and resilience in the light of climate change impacts on health. These include improvement in flood mitigation infrastructure; better early-warning systems and rescue services; sustained behavioural change; a change in housing design and improvement of sanitation infrastructure; as well as sustained public health surveillance; primary health activities for disease prevention; and dissemination of health information.

It is essential to note that a 'multiple benefits' approach should be taken here. As with other sectors, many existing strategies and policies may be merely supported or amended to improve resilience in the face of climate change implications for health, amongst other health outcome priorities.

7. Human Health

Phenomenon	Human health impact	Additional child-specific risks
Fewer cold days and nights	Fewer cold-related deaths	Children will benefit
Increased frequency of warm spells and heat waves	Increased heat-related deaths and illness	Very young at higher risk of death; older children will have more heat stress due to time spent outside during exercise
Increased heavy precipitation events	Increased risk of injury, death, as well as infectious respiratory and skin diseases	Very young vulnerable to hospitalisation and complications from infection
Increased temperatures and rainfall	Reduction in vectors' reproductive and incubation rates as well as parasite infection rates, resulting in an increase in vector-borne diseases	Young children are more vulnerable
Increased areas of drought, wildfires	Increased risk of food and water shortage, malnutrition and infection, concentration of toxic water pollutants, injury and death	Growth retardation, developmental delays
Increased tropical storms and cyclones	Increased risk of injury, death, water-, food-, and vector-borne illness	Children may be more susceptible to injury, post traumatic stress, certain infections
Increased air pollution	Exacerbation of respiratory illness, premature mortality	Children's small airways more susceptible to asthma and infection
Changes in distribution and potency of allergens and mycotoxins	More severe and more prevalent allergies	Allergies, cancer, birth defects
Increased sea level, saltwater intrusion into fresh water	Abrupt coastline change, forced migration, injury, drowning	Disruption of family and school infrastructure, other social disruption

Table 7.1: Major health effects of climate change. Source: Redrawn from Bunyavanich et al., 2003.

"He who has health, has hope. And he who has hope, has everything."
Arabian Proverb

"When it comes to global health, there is no 'them'... only 'us.'"
Global Health Council

7. Human Health

CASE STUDY

ENVIRONMENTAL HEALTH: BRIDGING THE GAP BETWEEN TRADITIONAL HEALTH CONCERNS AND A CHANGING CLIMATE

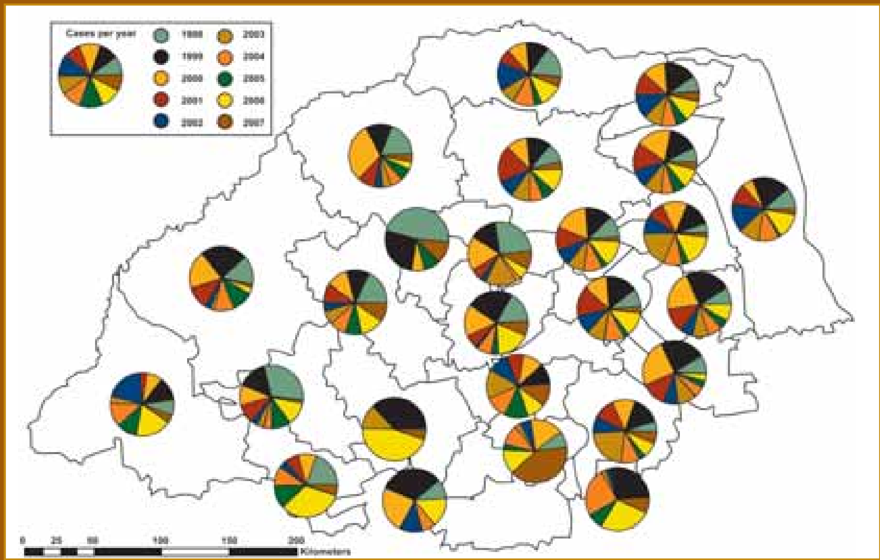
Jane Olwoch and Caradee Wright

Rural communities in Limpopo Province are vulnerable to health risks from global change because they do not have access to adequate health information and services. Adaptation and mitigation strategies are necessary to increase the communities' preparedness and resilience. These strategies include improving early-warning systems and infrastructure to offer protection against flooding. There also needs to be sustained public health surveillance, disease prevention and information dissemination.

For many years, the people of the Limpopo Province in north-eastern South Africa have been at risk of malaria. Subtle changes in climate, particularly warmer temperatures, may worsen this risk.

This University of Pretoria case study investigated changes in climate and malaria incidences in Limpopo Province. Researchers found an association between certain climatic factors and malaria cases. They also highlighted areas where people were most prone to getting malaria. These findings are important for public health services and research into health issues. Planning for future malaria control and anti-malaria programmes should also consider what local people know, believe and do – only then will these interventions prove truly successful.

The case study highlights one of several environmental health risks in South Africa. It has become vital to know more about human behaviour, new technologies, indigenous knowledge and social livelihoods to be able to put effective adaptation and mitigation strategies in place.



Map 7.1. Ten-year variation in malaria cases per municipality in Limpopo Province. Source: Olwoch J M (2010).

"It has become vital to know more about human behaviour, new technologies, indigenous knowledge and social livelihoods to be able to put effective adaptation and mitigation strategies in place."

8. Coastal Areas

THE VULNERABILITY OF THE COASTAL ZONES OF SOUTH AFRICA TO CLIMATE CHANGE

Alan Aldrin Meyer

The coastal zone of South Africa consists of the oceanic region between the coastline and the 200m isobaths (indicated by a black stippled line on Map 8.1).

The physical properties (water temperature and salinity) and circulation features of the coastal zone are markedly influenced and to a large extent determined by the two large-scale ocean currents on either side of South Africa – the Agulhas Current along the east and south coasts and the Benguela Current along the west coast. Any change in the average positions of both currents will impact not only on the water mass[1] properties and circulation[2] of the coastal zone, but also on the coastal zone flora and fauna, and those communities that derive their livelihood from coastal zone goods and services.

Maps 8.1 to 8.4 illustrate the mean shelf circulation regimes, the offshore current systems, and the export and import of water masses across the seaward boundary of the coastal zone. The nurseries and spawning grounds of the commercially most important fish species (sardine, anchovy, horse mackerel, hake and squid) found within the coastal zone are shown on maps 8.2, 8.3 and 8.4. The coastal zone fish species are all dependent on the various coastal currents and enclosed coastal ecosystems for the successful completion of their life cycles.

Predicted changes in the next fifty years

Theoretical, observational and numerical studies all show that the large-scale current systems around South Africa will change in their average physical properties and behaviour in the next fifty years due to anthropogenically induced alterations to the earth's atmosphere. These predicted changes to the large-scale ocean currents will impact on the coastal zone and change the average properties and circulation patterns portrayed on maps 8.1 to 8.4.

Lutjeharms and de Ruijter (1996) showed that the Agulhas Current will exhibit increased meandering[3], which will force the current (on average) further offshore from its contemporary mean position. In the present global climate regime the Agulhas Current is located within 15 km from the shore along the east coast of South Africa 77% of the time. However, perturbations in the form of large intermittent meanders[3] (Natal Pulses – see Box 1 on Map 8.1) force the current's core up to 300 km offshore. The meander modes of the Agulhas Current impact between four to six times a year. Lutjeharms and de Ruijter (1996) suggest that the meander modes will increase in frequency due to global warming and that the current will on average be located further from the coastline. This will impact on the socio-economics of the eastern and southern coastal zones (Figure 8.1).

[1] A water mass is a volume of oceanic water with similar physical properties such as water temperature and salt content, giving the volume of water a specific density, and thus a specific vertical location and behaviour (depth).
[2] Circulation refers to the flow direction and dynamics of a certain water mass.
[3] Meanders refer to lateral deviations from the Agulhas Current's almost linear trajectory along the east coast of South Africa (See Box 1 on Map 8.1 for an example of such meanderings, also known as pulses).

8. Coastal Areas

The western coastal zone, which consists mainly of the Benguela Upwelling System, will exhibit more intense upwelling due to a predicted increase in wind stress over the southern Atlantic on account of global climate change (Lutjeharms et al., 2001). This will induce much cooler sea surface temperatures (SST) along the west coast of South Africa than at present. However, an intensification of the South Atlantic Sub-tropical gyre[4] may also lead to increased atmospheric subsidence[5], fewer clouds, increased insolation[6] and higher air temperature. The latter will result in warming of the surface water, which may negate the increased upwelling and offshore transport of cooler waters.

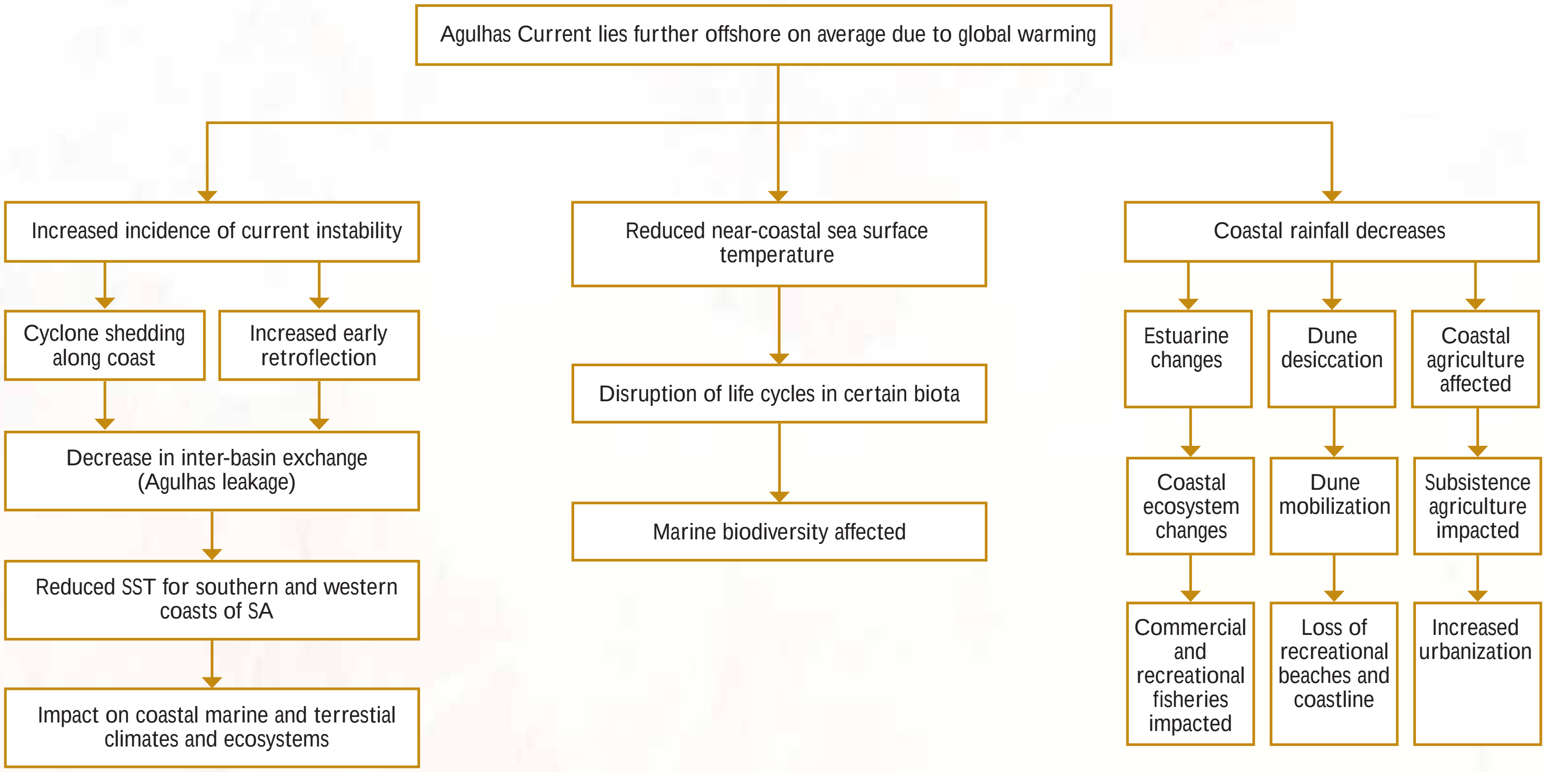


Figure 8.1. Flow diagram of a thought experiment on the possible environmental - and attendant socio-economic - effects along the east coast of South Africa of a substantial seaward shift of the Agulhas Current. Source: Adapted from Lutjeharms and de Ruijter, 1996.

"The coastal zone fish species are all dependent on the various coastal currents and enclosed coastal ecosystems for the successful completion of their life cycles."

[4] Sub-tropical gyre systems are large gyres (circular water flows) that cover the major ocean basins, e.g. the South Atlantic Sub-tropical gyre is the anti-clockwise water flow in between South America and Southern Africa, creating the southward flowing Brasil Current along the eastern coast of South America and the northward flowing Benguela Current along the west coast of South Africa.

[5] Atmospheric subsidence refers to large amounts of air descent.

[6] Insolation is a measure of solar radiation energy received on a given surface area in a given time.

8. Coastal Areas

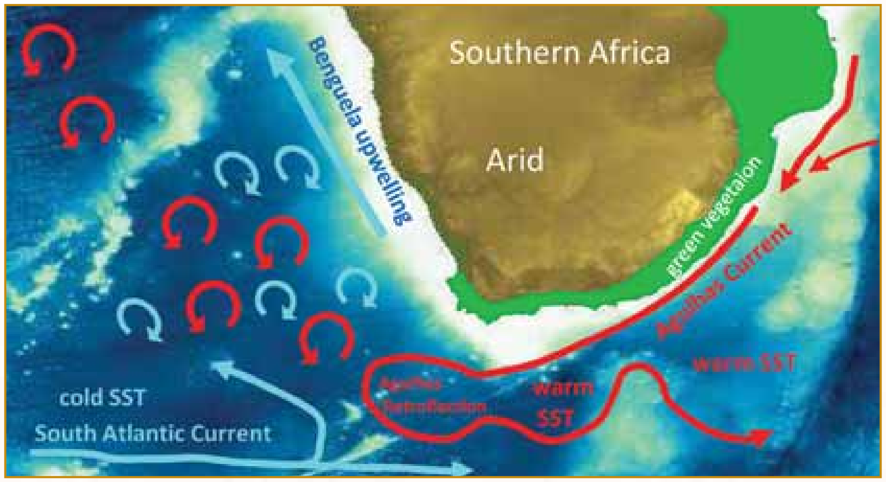
The exchange of large quantities of warm water from the Indian to the Atlantic Ocean (Agulhas Leakage) via the Agulhas Retroflection (see Map 8.1) influences the entire coastal zone of South Africa (see inserted maps 8.2, 8.3 and 8.4). Agulhas Leakage occurs via the intermittent occlusion of the Agulhas Retroflection loop to form the world's largest anti-clockwise vortices (gyres), Agulhas Rings (see Map 8.1 and Figure 8.2 for examples of Agulhas Rings). Each year, between four to eight Rings of varying sizes (200 to 400 km in diameter) are pinched off and advected north-westward into the south eastern Atlantic Ocean along the west coast of South Africa. The Agulhas Retroflection displays a downstream (normal) mode (Figure 8.2a) and an upstream mode (Figure 8.2b).

During the upstream mode the Agulhas Leakage is markedly reduced, which leads to cooler SST for the southern and western oceanic and coastal regimes, compared to during the normal Agulhas Retroflection mode. It has been shown that during Upstream Retroflection, when most of the warm saline Agulhas Current waters are diverted eastward at 25°S, negative SST anomalies are created south and west of South Africa.

A stronger Agulhas Current transport has been predicted due to global warming. The impact of a stronger Agulhas Current on the retroflection mode is still unclear. The models studies of Cai et al. (2007) and Rouault et al. (2009) indicate that the increase in Agulhas Current transport will lead to an associated stronger Agulhas Leakage with more warm Indian Ocean water passing the southern and western coasts of South Africa. The model study of Van Sebille et al. (2009) clearly shows the opposite – that an increase in Agulhas Current transport will lead to a higher frequency of Upstream Retroflections, with a concomitant decrease in Agulhas Leakage.

In either case, the impact of a stronger Agulhas Current will have definite and significant impacts on the coastal zone of South Africa.

a)



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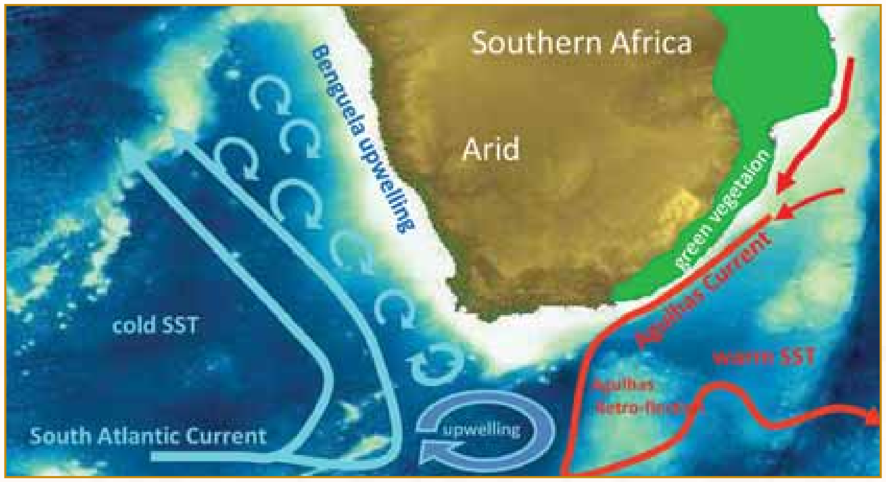
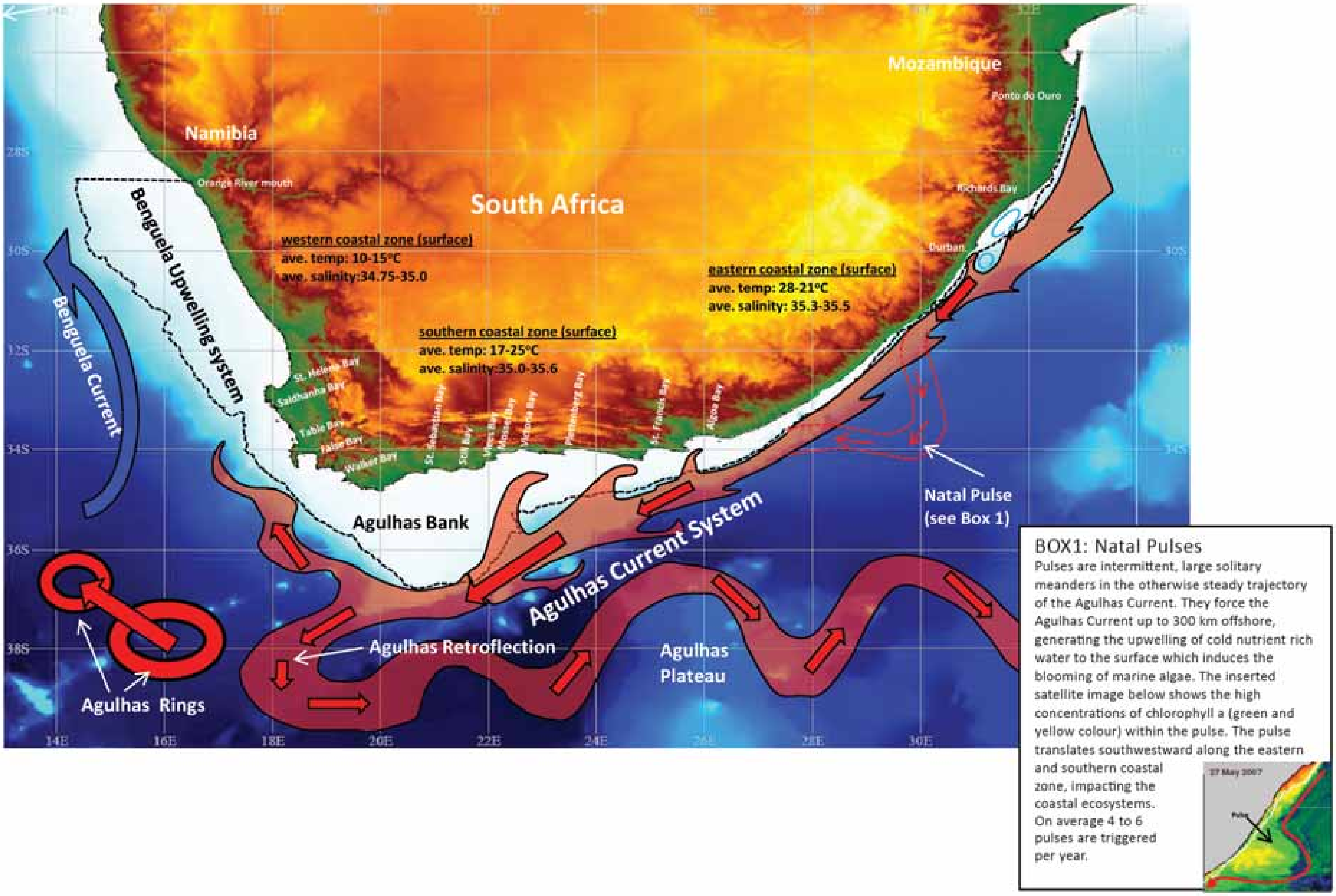


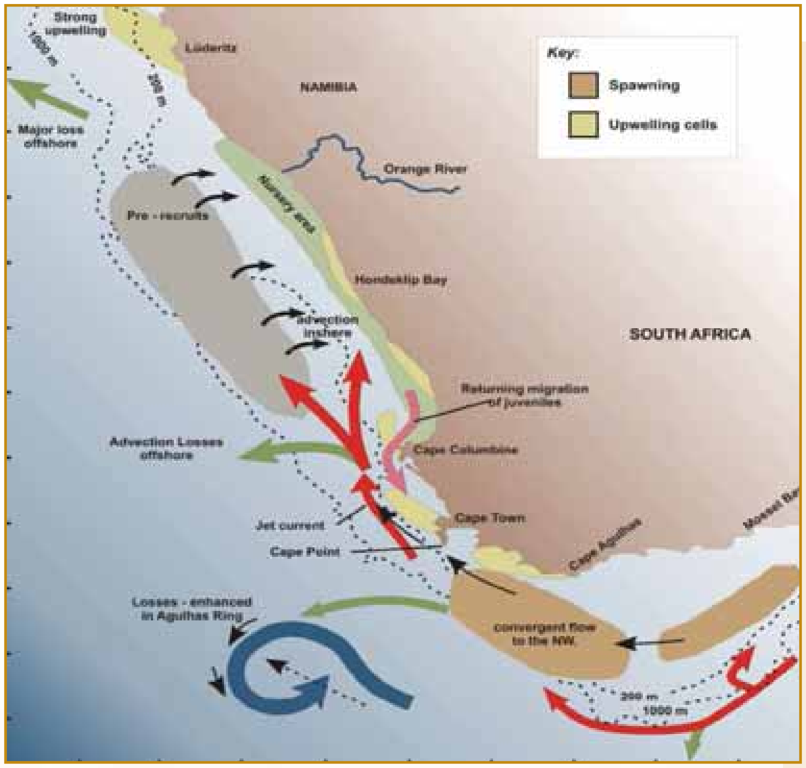
Figure 8.2. Current regimes around South Africa. a) Normal downstream mode of the Agulhas Retroflection, leading to Agulhas Leakages via warm core Agulhas Rings. b) Upstream Retroflection mode leading to a reduction in Agulhas Leakage and cooler SST along the south and west coasts of South Africa. The change in coastal vegetation is indicated for the two modes. Red = warm SST, blue = cooler SST. Source: Derived in part from Lutjeharms (2006).

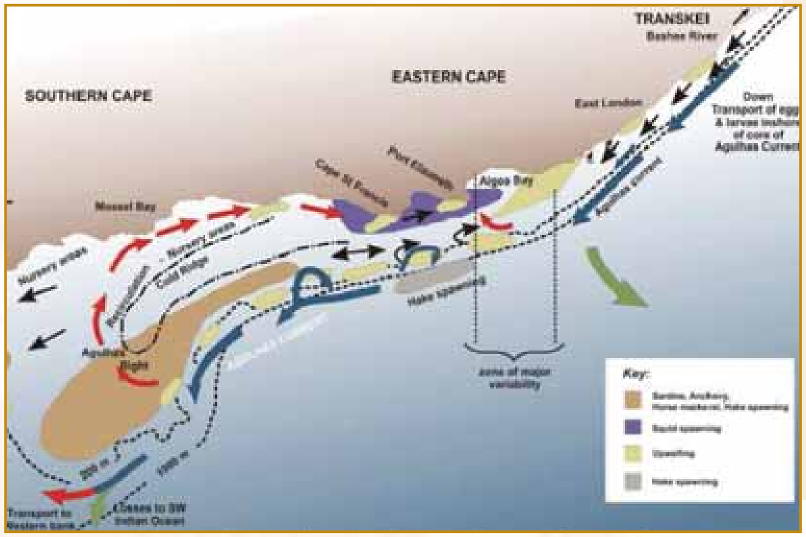
8. Coastal Areas



Map 8.1. The coastal zone of South Africa. Adapted in part from Lutjeharms (2006).

8. Coastal Areas





Adapted from Hutchings et al., 2002; Marine and Freshwater Research, 53, 307-318.

Map 8.2. West Coast nursery ground

Horse mackerel (*Trachurus trachurus capensis*) spawns on east and central Agulhas Bank during austral winter, overlapping onto the inshore west coast nursery during summer. Anchovies spawn on the whole Agulhas Bank peaking during mid-summer. Sardines spawn over similar areas as anchovy with two spawning peaks - early spring and autumn. Most of the eggs and larvae are then transported to the west coast nursery areas via narrow coastal jet currents.

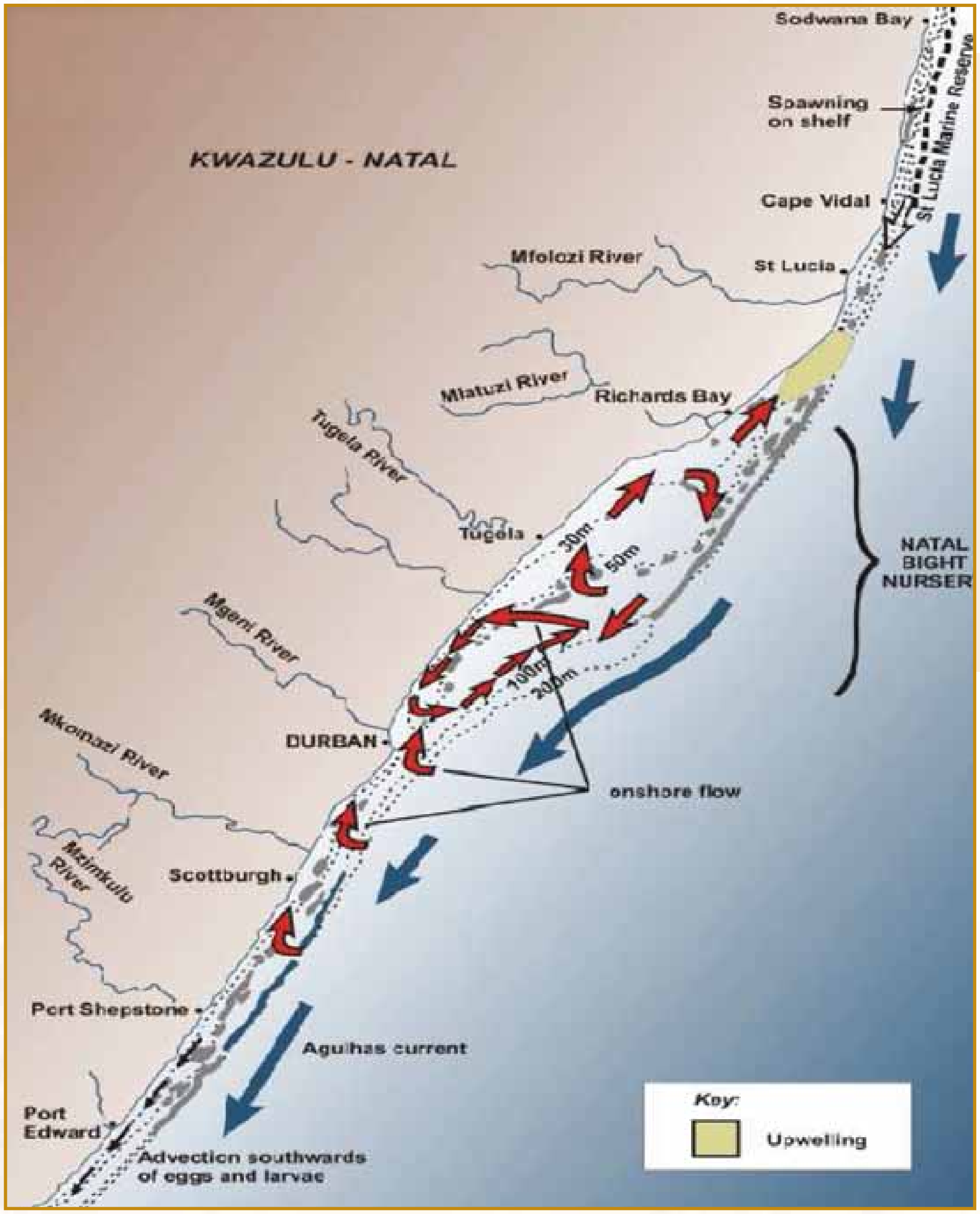
The gadoids *Merluccius capensis* and *M. Paradoxus* (hake), the gempylid *Thyrsites Atun* (snoek) and the clupeid *Etremeus whiteheadii* (round herring) also spawn on the Agulhas Bank, after which larvae drift northwards and inshore to the west coast nursery. A considerable amount of eggs and larvae is lost to the open ocean via Agulhas Current and Agulhas Rings entrainment and offshore Ekman drift.

Map 8.3. Agulhas Bank nursery ground

The Agulhas Bank is both a spawning ground and a nursery area. Species such as the elf, or shad (*Pomatomus saltatrix*) and geelbek (*Atractoscion aequidens*) spawn in September to October. The steenbras (*Lithognathus lithognathus*) spawns in July to August. Squid spawns on the Agulhas Bank during most of the year. All of these species are impacted both by the fast flowing Agulhas Current dynamics and the bottom and surface currents on the Agulhas Bank itself.

The water over the bank varies seasonally. In summer there is a mixture of warm subtropical surface water and cooler bottom waters. The latter is upwelled onto the bank in the easternmost corner of the Agulhas Bank (Port Alfred Upwelling Cell). In winter, westerly winds mix these water masses to depths of 80 to 90 metres. A cold ridge of water, a prominent subsurface feature on the central bank plays an important role in fish life-history strategies. The ridge is associated with elevated phytoplankton concentrations, and dense concentrations of copepods and clupeoid fish eggs.

The Agulhas Current closely follows the eastern Agulhas Bank's shelf edge, and several shear-edge eddies appear to bud off the inner edge of the current at frequent intervals. The counter flow (northeastwards) created by the shear-edge eddies would enable eggs and larvae from shelf edge spawning to be retained on the bank. At the apex of the Agulhas Bank, the Agulhas Current leaves the continent of Africa entirely for the open ocean, and any eggs, larvae or juveniles of shelf species transported in the current have little chance of survival in the open.



Map 8.4. Natal Bight nursery ground

Slinger (*Chrysoblephus puniceus*) is the most important line-fish for the Natal Bight region. The Natal Bight offers opportunities for successful recruitment of slinger, because of a clockwise circulation within the Natal Bight together with upwelling and enhanced phytoplankton levels in the northern extremity of the bight. This creates the necessary conditions for enhanced survivorship of early larvae and juveniles of pelagic spawners by incorporating enrichment, retention and concentration mechanisms.

To the south of the Natal Bight, the shelf is extremely narrow and the Agulhas Current approaches close inshore, driving the inshore currents on the shelf rapidly to the south. Larvae being transported along these narrow shelf regions southwards enter the various estuaries along the east coast or remain in the nearshore zone in order to be retained in the warm subtropical waters. Any warm water species advected with the southward currents into the cooler waters of the western Agulhas Bank region are unlikely to survive.

"A stronger Agulhas Current transport has been predicted due to global warming. The impact of a stronger Agulhas Current on the retroflection mode is still unclear."

8. Coastal Areas

CASE STUDY

POTENTIAL IMPACTS OF CLIMATE CHANGE ON THE COASTAL ZONE: HOW FAR FROM THE SEA SHOULD WE BE?

André Theron, Gerhardus Diedericks, Ashton Maherry and Marius Rossouw

As shown in Chapter 3, continuously rising concentrations of "greenhouse" gases in the atmosphere lead to global warming and climate change. The effects of these rising concentrations are already detectable, mainly in terms of thermal variables and, in particular, global mean air temperature.

The increase in surface temperatures leads to an increase in sea levels through the interaction of various processes such as thermal expansion of the oceans and melting of glaciers. It is predicted that climate change may also bring greater storm intensities. This makes coastal settlements vulnerable, especially considering that coastal zones are densely populated and growing rapidly.

Coastal resources are expected to be affected by a number of consequences of climate change, namely higher sea levels, higher sea temperatures, changes in precipitation patterns and sediment fluxes from rivers, altered oceanic conditions as well as changes in storm tracks, frequencies and intensities.

Extreme storm events

Since 2005, the KwaZulu-Natal coastline has been experiencing a particularly high number of extreme storm events. These storms caused coastal erosion and flooding along the coast. However, some parts of the coast experienced more erosion than others. It is important to determine which parts of the coast are more vulnerable than others under present conditions.

Another important issue to predict is how areas that are already vulnerable to erosion may become more prone to damage in the future due to the effects of climate change. It is well known that the prime factors leading to damages in the past and increased risk in the future, are developments located too close to the sea. Thus, there is a need to determine safe areas, which requires prediction of future shoreline locations. Studying the risks due to climate change in coastal areas will aid design and safe location of new developments and infrastructure, and will also help to identify other adaptation options for existing developments that are at risk. In this first phase of the Atlas project, only some of the effects of the predicted rise in sea-level and potential increase in storminess are considered in predicting the vulnerable areas along the coast.

One of the impacts of sea level rise is that waves will reach further inland than at present, which implies that present coastal development setback lines[1] (of which few exist) have to be adapted. Additional factors which determine the location of setback lines are storm wave runup elevations and how far the shoreline will retreat due to erosion, which are, in turn, affected by the amount of sea-level rise that is expected and the predicted increases in storminess.

Realistic scenarios

Thus, as part of our climate change research, realistic scenarios of sea-level rise and potential increases in wave heights were determined, as well as preliminary calculations of the resulting effects on erosion and runup. Therefore, the first step in calculating setback lines is to determine the maximum point that storm waves can reach, which is known as runup. The second step is to determine if a beach is "stable" or eroding in the long term. Another factor that needs to be considered is the degree of erosion that can occur during a storm. The output of this study is predicted runup lines including the effects of long-term erosion due to sea-level rise.

Coastal areas within Table Bay near Cape Town were selected to illustrate how such runup calculations can be used to highlight present and future vulnerable areas. Runup data were collected by the CSIR following the 2008 storm and some of these runup lines are presented in Map 8.5. The coastal topography for the Table Bay area, which is required to map areas susceptible to wave runup (by means of a Geographical Information System - GIS), was provided by the Cape Metropolitan Council.

The impacts of climate change on wave runup at the site are illustrated by calculating the runup levels with increased sea levels of 0.5m, 1m and 2m. The most severe impact is with a sea level increase of 2m, and a 10% increase in the storm wave heights. Map 8.6 illustrates what the combined impacts of shoreline erosion and a higher wave runup could mean for a 0.5 m rise in sea level and a 1-in-20-year sea storm.

Shoreline erosion depends on a number of factors – some operate on a large scale and others are of a local nature. This study highlighted that the local effects are very important. For example, simply choosing a presently higher contour line to represent a future shoreline is insufficient. More realistic wave runup and erosion prediction techniques are required as illustrated in the maps.

[1] A coastal development setback line is a line landward of which fixed structures (such as houses and roads) may be built with reasonable safety against the physical impacts of the coastal processes (such as sea storms, wave erosion and runup).

8. Coastal Areas

Requirements to further improve on the predictions of future shorelines and safe setback distances include:

- Improved understanding of interconnected sea state and coastal/ physical processes (e.g. the interaction between sea-level rise and changing storm intensities); and
- A coastal model that reliably predicts the changes of the beach profile.

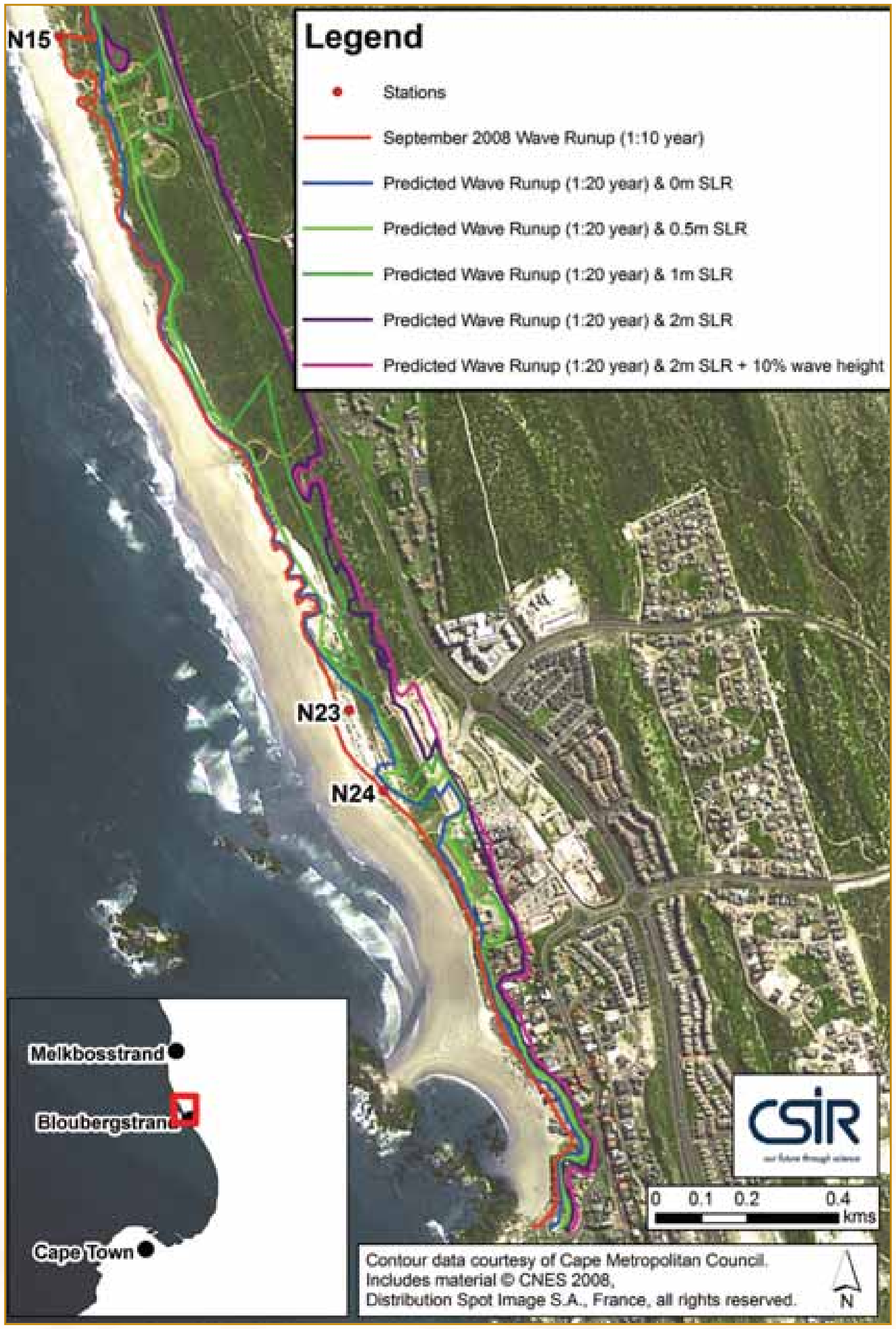
The predicted setback lines will be useful for anybody involved in coastal zone management, municipalities and city planners as well as developers and home owners – in fact anyone living close to the sea. They will be able to use the information from this study to better plan future developments and, hopefully, to develop the coast according to natural cycles and manage coastal development in a sustainable manner.

The calculation of future setback lines will demarcate safe coastal areas as well as those that are at risk of being eroded, and infrastructure or areas that are vulnerable to the effects of sea-level rise. For example, an erosion setback line determined to be safe from present coastal conditions (i.e. present seawater levels and storm intensities) cannot be expected to remain safe under more extreme climate-changed conditions (i.e. raised seawater levels and/or more stormy sea conditions). The determination of setback lines that are safe in the long term needs an acknowledgement and quantification of risks, mobilisation of resources, solid policy guidelines and planning, as well as appropriate legislation.

Planning of adaptation options can further be enhanced with information about realistic scenario modelling, regional connectivity modelling and calculation of regional sediment budgets, as predicting the actual response of the coast to climate change will depend on the holistic understanding of its effects on the coastal system.

The determination of setback lines for the entire South African coastline will require a characterisation of the coast and expected future sea states - for example how erosion resistant the coast is (e.g. is it sandy or rocky) as well as the local coastal topography (contour lines up to 12 metres above sea-level and seafloor depth contours to 20 metres below sea-level).

"The calculation of future setback lines will demarcate safe coastal areas as well as those that are at risk of being eroded, and infrastructure or areas that are vulnerable to the effects of sea-level rise."



Map 8.5. Illustration of predicted effects of climate change on coastal runup lines near Blaauberg. Source: Theron, Diedericks, Maherry and Rossouw, CSIR (2010).

Map 8.6. Illustration of predicted combined effects of potential shoreline erosion with Bruun's rule and higher wave runup for a 0.5 m rise in sea level and a 1-in-20-year sea storm on the Blaauberg coast. Source: Theron, Diedericks, Maherry and Rossouw, CSIR (2010).

9. Biodiversity

BIODIVERSITY: A TREASURE TROVE OF SPECIES

Guy Midgley

An immensely rich species diversity is found in South Africa. With a land surface area of 1,1 million km^2 – representing just 1% of the earth's total land surface – South Africa contains almost 10% of the world's total known bird, fish and plant species, and over 6% of the world's mammal and reptile species.

South Africa is world-renowned for exceptionally high levels of biodiversity, both because of very high numbers of "indigenous species" (species that are typical of a region), but also "endemic species" (indigenous species found only in South Africa, or even small areas within South Africa, such as on a single mountain range).

South Africa has biodiversity values that are well above the global average. It is also remarkable that many of the country's ecosystems have intact communities of animals and plants, in spite of significant land cover changes that have taken place over the past few centuries (see Chapter 11 to follow).

These changes have, however, resulted in significant and imminent threats to many of our ecosystems and species that will require careful management and decision making in order to avoid unintended loss of biodiversity. We are increasingly realising that biodiversity provides the country with a unique resource base for many services that are derived from ecosystems, which importantly, include the significant earnings from nature-based tourism.

How might climate change affect biodiversity in South Africa?

It is important to point out that climate change is likely to be a gradual change that will interact with some already serious changes underway, such as land use for farming, mining, housing and needs of a modern and developing society. Climate change also, however, includes possible "thresholds" that cause large impacts for relatively small changes (biodiversity and ecosystem services are possibly the best understood example of such a phenomenon).

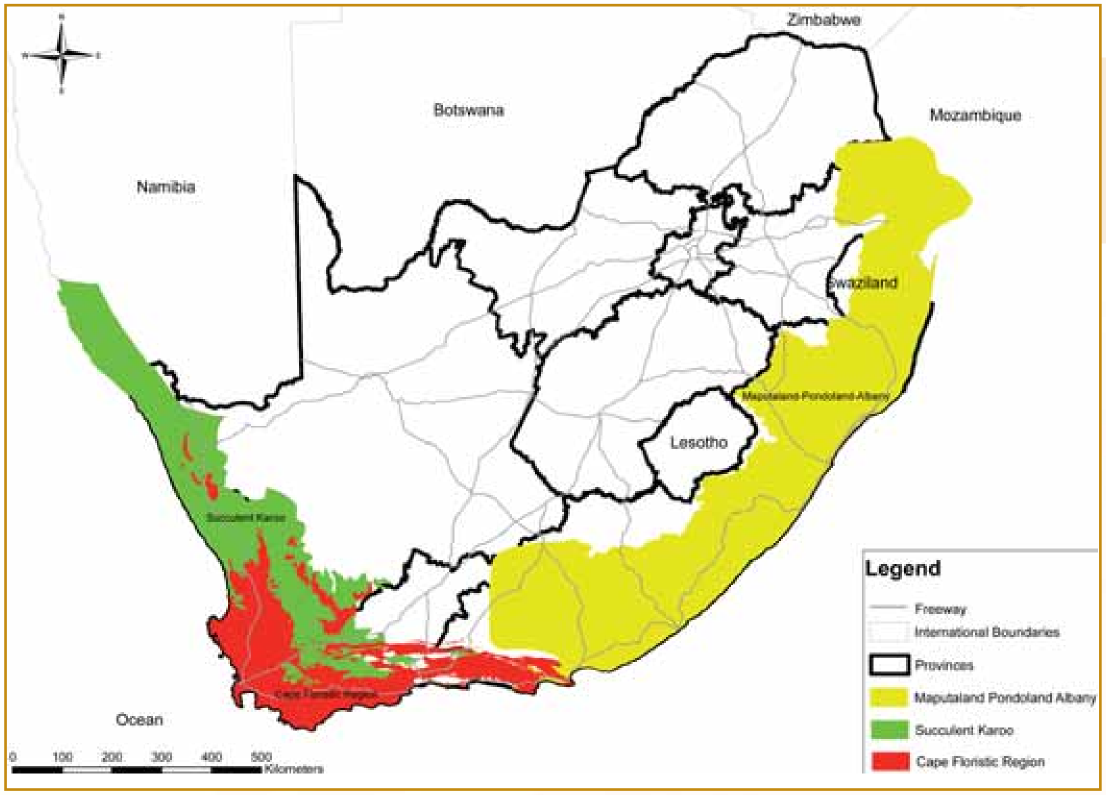
The most concerning implications of such changes for biodiversity are likely to be in the west of South Africa, where particularly rich biodiversity "hotspots" are at risk of climate conditions becoming too harsh for the continued survival of some of their endemic species. In the east, where rainfall changes are uncertain, it is important that natural biodiversity provides crucial ecosystem services such as the protection of soil from erosion due to extreme rainfall events, and ensuring the flow of clean water into rivers and streams.

A natural asset base providing life-supporting services

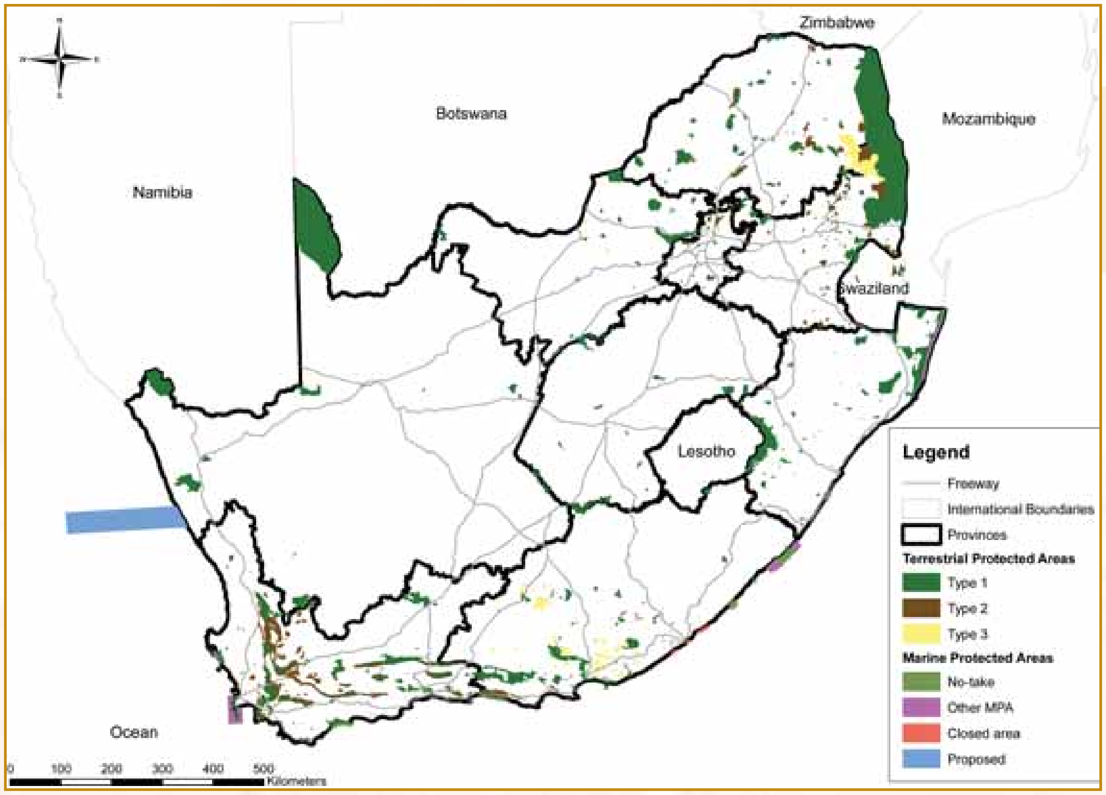
Much work remains to be done to assess these risks and their implications, both for conservation and for people who depend on this biodiversity. It is clear that the people likely to be affected first, and most seriously, by such changes are those that depend on key species and ecosystems for their well-being. These might include farmers of indigenous crops such as rooibos tea, harvesters and gatherers of endemic species for medicinal use, and poor rural communities that rely on natural biodiversity to supplement their earnings and food sources.

What is clear is that biodiversity is important to all South Africans, and this natural asset base provides life-supporting services to the full economic spectrum of South Africans. It is critical that we benefit from the new knowledge synthesized in Biodiversity GIS (BGIS), both alone and linked to the South African Risk and Vulnerability Atlas to guide us in our appreciation of, and drive to preserve this resource for today's and tomorrow's South Africans.

9. Biodiversity



Map 9.1. Hotspots of endemism. Source: SANBI, 2004



Map 9.2. South African terrestrial and marine protected areas. Source: SANBI, 2004

9. Biodiversity

CASE STUDY

ADAPTING TO GLOBAL CHANGE IN A DIVERSE LANDSCAPE: THE KRUGER TO CANYONS BIOSPHERE RESERVE

Claire Davis, Emma Archer, Rebecca Maserumule, Nikki Stevens and Lee-Ann Sinden

The Kruger to Canyons study area (K2C) was designated as a Biosphere Reserve under UNESCO to preserve the integrity of the conservation areas while improving the livelihoods of the people who live within its borders. One of the consequences of conservation initiatives in the past has been the economic underdevelopment of rural areas adjacent to conservation areas. Being home to a substantial portion of the bird and mammal species in South Africa, K2C displays a substantive topographic and climatic diversity, and is the site of multiple stressors. This makes it an excellent subject for considering how global change impacts might be successfully managed in a diverse landscape.

The case study is focused on the highly diverse land use area of K2C where a range of stakeholders are active, including Bushbuckridge Municipality, South African National Parks, Mpumalanga Parks Board, the previously named Department of Water Affairs and Forestry (DWAF) and a range of civil society initiatives.

By incorporating state conserved land, communally managed nature reserves, communally grazed areas, former homeland type dense settlement areas, commercial agriculture, private conserved areas, commercial forestry and provincial conservation, the area is highly appropriate to demonstrate the potential benefits of more accessible information on global change projections and risk and vulnerability planning around potential impacts for the area.

Global change may already be occurring

Previous studies indicate that global changes in the area may already be occurring. Key areas of critical impact include water supply and quality; commercial agriculture; forestry (including the reversion of commercial forestry in certain areas); health; commercial rangeland management; communal agriculture and livestock; and conservation management at the landscape scale (Kruger National Park).

Part of the K2C area comprises former homeland areas (see Chapter 4), with an accordant backlog of service delivery and infrastructure as well as a considerable health risk and disease burden (60% HIV infection rate and chronic lifestyle diseases such as strokes, diabetes and heart attacks). These communities have a high dependence on natural resources that provide a free or cheap alternative to other commercial commodities. These resources are already under increasing pressure from changing environment conditions, which could increase these rural communities' vulnerability to future global change.

This study will draw on the findings of a significant amount of research that has already taken place in the area. There is a keen desire amongst diverse stakeholders to access global change information (for example, the use of such information to inform the Bushbuckridge Municipality IDP), as well as to interactively develop an understanding of what global change implies for critical sectors in the area.

It is hoped that the outputs of this project will include diverse stakeholder planning and decision-making for the area – directly informed by global change predictions – and improved resilience of such sectors under global change.

10. Commercial Forestry

COMMERCIAL FORESTRY AND CLIMATE CHANGE

Michele Warburton

Commercial forestry plantations occupy approximately 1.1% of South Africa's land surface area, with the largest forestry plantation areas falling within Mpumalanga and KwaZulu-Natal. Three primary species are grown in these commercial forestry plantations, of which pines and eucalypts are dominant, with wattle grown to a lesser extent. Depending on the end use of the tree, the rotation length can vary from 7 to 30 years.

Plantation forestry is an important contributor to the South African economy. In 2008, exportation of forestry products generated R14.8 billion in foreign exchange. Activities such as paper manufacturing, pulp milling, sawmilling, certain furniture, pole and fibreboard manufacturing, charcoal and woodchip production, as well as mining timber provision rely on the raw materials from commercial forestry.

What are the potential impacts of climate change on the commercial forestry sector?

The different tree species grown in South Africa have different climatic constraints (such as mean annual precipitation and mean annual temperature) which determine where they can be grown. Thus, given projected climate change, in certain areas species currently grown may need to change, while in other areas it may no longer be climatically suitable to undertake commercial forestry. On the other hand, areas that are at present not climatically suitable for commercial forestry may in the future become climatically suitable, due to climate change.

To date, little is known about how trees will respond to elevated atmospheric CO_2 levels. For example, the growth rates of forests could change, which may impact significantly on forest management and timber markets, requiring an adjustment in forestry policy and planning. What is known is that the forestry species grown in South Africa are most sensitive to rainfall, and that the hybrids of both eucalypts and pines are relatively more robust to changes in climate than commonly grown species.

Looking to the future of the commercial forestry sector

There remains much work to be done on understanding the impacts of climate change on both commercial and indigenous forestry. Current commercial forests make extensive use of exotic species, a practice that may influence biodiversity and other climate change sensitive factors such as excessive water use and soil properties. However, forestry offers opportunities for effective, low cost, sustainable methods of removing carbon from the atmosphere.

Given the relatively lengthy rotation of commercially grown forest species, the time frames for which decisions need to be made, and the sensitivity of the industry to climate, it is crucial to develop a greater understanding of the impacts of climate change on the forestry sector and implementing appropriate adaptation.

“Forestry offers opportunities for effective, low cost, sustainable methods of removing carbon from the atmosphere.”

11. Land Use

LAND TRANSFORMATION

Caesar Nkambule

Land-use and land-cover changes are so extensive that, on a global scale, they may significantly affect key aspects of earth system functioning.

These changes have a direct impact on biotic diversity worldwide (see Chapter 9), contribute to local and regional climate change – as well as to global climate warming – and are the primary source of soil degradation (Tolba et al., 1992). By altering ecosystem services, they affect the ability of biological systems to support human needs (Vitousek et al., 1997). Such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political disturbances, interacting with, for example, certain of the factors and trends described in Chapter 4 (Kasperson et al., 1997).

Human-induced land-use change includes deforestation, desertification (often as a result of overgrazing and excessive exploitation of vegetation), agricultural expansion and soil erosion. Modification in land use affects several land-surface characteristics such as canopy area and the resistance of vegetation to transpiration.

Climate change and land-use change, as two global ecological changes predicted for the future, also affect each other (Dale, 1997), partly through the process of land-atmospheric feedbacks. Rainfall, for instance, may be linked to the albedo of the underlying surface, and by the contrast in albedo between bare soil and vegetation. By removing vegetation, atmospheric subsidence would increase, and thereby potentially reduce rainfall.

Changes in land cover can alter the reflectance of the Earth's surface and cause local warming or cooling. Generally, as albedo increases, surface temperatures decline. Desertification may occur when overgrazing of savanna vegetation alters surface albedo and surface water budget, thereby changing the regional circulation and precipitation patterns (Dale, 1997).

Bare soil can also increase the amount of suspended dust that, in turn, causes radiative cooling and a decline in precipitation. This provides a positive feedback loop, as drier conditions are less likely to sustain the return of vegetation (Taylor, 2002). Such a phenomenon is of critical importance in understanding the significance of the impacts which may be triggered by either climate change or land-use/land-cover change. As mentioned earlier, land-use or land-cover change may lead to evaporation and decreased rainfall, exacerbating land-use and/or land-cover change due to positive feedback. Land-use activity may thus contribute to climate change – changes in land-cover patterns are one way in which the effects of climate change are expressed (Dale, 1997).

Land-use and land-cover changes (Map 11.1) are attributed to factors such as human population, technology, markets and policies. Land use refers to the management regime humans impose on a site, whereas land cover refers to the status of the vegetation at a site. Thus, land cover denotes the physical state of the land including the quantity and type of surface vegetation, water and earth minerals, while land use describes the human employment of land, including settlement, cultivation, pasture, rangeland and recreation (Meyer and Turner, 1994).

As shown in Chapter 3, at the global scale, human activities influence the greenhouse effect by releasing greenhouse gases into the atmosphere and by changing the patterns of carbon storage through land-use activities (Figure 11.1).

"We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect." - Aldo Leopold

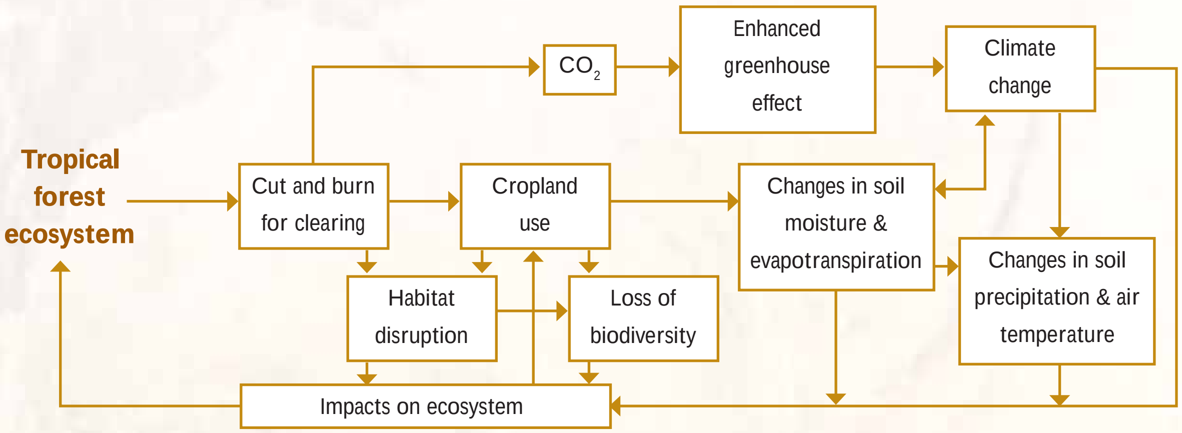
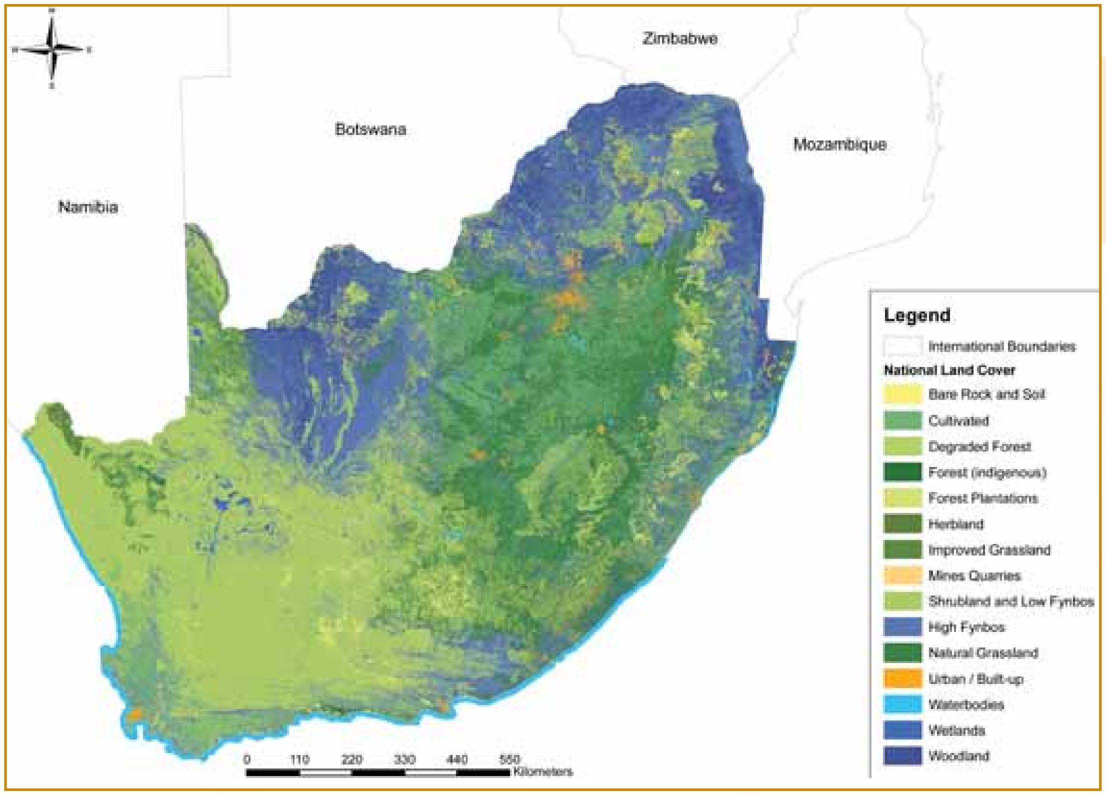


Figure 11.1. The links of environmental change. Source: Adapted from www.aag.org.

11. Land Use



Map 11.1. Land cover in South Africa. Source: SANBI.

Figure 11.1, for example, explains a situation where a forest is cleared to make way for cropping. Burning of the forest releases CO_2 into the atmosphere, contributing to the greenhouse effect, and cropping releases CO_2 stored in the soil. The change in land cover affects the evapotranspiration rate as well as the reflectance of the Earth's surface.

Land-use/cover change and climate change have a cumulative impact on natural resources. Land-use/cover change results in habitat loss and destruction of ecosystems, while climate change may result in areas becoming unsuitable for habitation by certain species (See Chapter 9), possibly threatening the existence of those species. Again, land-use changes such as forest clearance for agriculture, or reclamation of wetlands for construction are themselves likely to be dependent upon future climate – crops may fail if the climate changes, and coasts may be inundated by a rising sea-level; as shown in previous chapters.

Within Southern Africa land degradation is widely regarded as a severe and widespread environmental problem. Furthermore, South Africa is one of the top 25 countries in the world in terms of biodiversity, with a greater part of its biodiversity occurring on agricultural land than in current conservation areas. Due to the expansion of cropland or urban areas, some of that biodiversity will be lost in the near future (see Chapter 9) (Jonas et al., 2006).

Land transformation in South Africa is defined by the Department of Environmental Affairs' State of the Environment as "The conversion of land usually from natural habitat to human uses such as agriculture or settlements" (Fairbank et al., 2000). The State of the Environment estimates that approximately 18% of South Africa's natural land cover is transformed, mainly by cultivation (10.46%), degradation of the natural cover (4.47%), urban land use (1.51%), and forestry (1.41%) (Department of Environmental Affairs, 2009). Chapter 4 indicates significant trends of in-urban migration, indicating that the current increase in land transformation, and its accordant challenges, is likely to continue.

"Land-use and land-cover changes determine, in part, the vulnerability of places and people to climatic, economic or socio-political disturbances."

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