



LONG TERM ADAPTATION SCENARIOS

TOGETHER DEVELOPING ADAPTATION RESPONSES FOR FUTURE CLIMATES

SUMMARY FOR POLICY-MAKERS



environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

giz

On behalf of



Federal Ministry for the
Environment, Nature Conservation
and Nuclear Safety

of the Federal Republic of Germany

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LONG-TERM ADAPTATION SCENARIOS
FLAGSHIP RESEARCH PROGRAMME (LTAS)

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High-level/key messages emerging from LTAS Phase I (completed in June 2013)

The project is part of the International Climate Initiative (ICI), which is supported by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.



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INTRODUCTION

The Long Term Adaptation Scenarios Flagship Research Programme (LTAS) aims to respond to the South African National Climate Change Response White Paper (NCCRP, para 8.8) by developing national and sub-national adaptation scenarios for South Africa under plausible future climate conditions and development pathways (see Figure 1). This is a complex task which requires the projection of climate change impacts for key sectors, and an evaluation of their socio-economic implications in the context of the development aspirations of these sectors. The process is being followed in two phases to build a sub-national and national 'scenarioscape' within which adaptation to climate change will occur. In addition, the process will assess the extent to which the regional and international context might influence the national adaptation response.

During its first phase, summarised here, the LTAS developed a consensus view of climate change trends and projections, summarised key impacts and identified potential response options in primary sectors, namely, water, agriculture and forestry, human health, marine fisheries, and biodiversity, as defined by the NCCRP and stakeholders. The information and results presented focus on the likely impacts of climate change as well as adaptation needs and response options for primary sectors in South Africa.¹



Figure 1. At sub-national level the LTAS process covers the six hydrological zones in South Africa developed for use by the National Water Adaptation Strategy process. These zones are based on Water Management Areas (WMAs) and grouped according to their climatic and hydrological characteristics. They can thus be appropriately modelled and analysed for impacts on the water sector, and related indirect effects on other sectors.

CLIMATE TRENDS AND SCENARIOS FOR SOUTH AFRICA²

The LTAS climate scenario technical work analysed recent trends in climate, and synthesised a range of potential future climate conditions that plausibly could occur in South Africa over three time frames (2015–2030, 2040–2060 and 2080–2100). Due to the variety of emissions scenarios employed by climate modellers, climate projections have been gathered into two main groups, namely unmitigated (unconstrained) and mitigated (constrained) future energy pathways. Observed climate trends for South Africa from 1960 to 2010 were analysed and related to modelled trends for the same period to begin identifying possible strengths and weaknesses in current modelling approaches.

Observed climate trends for South Africa (1960–2010)

Over the last five decades the following climate trends have been observed in South Africa.

- The rate of temperature change has fluctuated, with the highest rates of increase occurring from the middle 1970s to the early 1980s, and again in the late 1990s to middle 2000s.
 - **Rainfall** has shown high inter-annual variability, with smoothed rainfall showing amplitude of about 300 mm, about the same as the national average.
 - Annual rainfall trends are weak overall and non-significant, but there is a tendency towards a significant decrease in the number of rain days in almost all hydrological zones. This implies a tendency towards an increase in the intensity of rainfall events and increased dry spell duration.
 - There has also been a marginal reduction in rainfall for the autumn months in almost all hydrological zones.
 - Extreme rainfall events show a tendency towards increasing in frequency annually, and especially in spring and summer, with a reduction in extremes in autumn.
 - Overall, rainfall trends are similar in all the hydrological zones, with rainfall being above average in the 1970s, the late 1980s, and mid to late 1990s, and below average in the 1960s and in the early 2000s, reverting to the long-term mean towards 2010.
- Mean annual **temperatures** have increased by at least 1.5 times the observed global average of 0.65°C reported by the Fourth Assessment Report (AR4) of the International Panel on Climate Change (IPCC) for the past five decades.
 - Maximum and minimum daily temperatures have been increasing annually, and in almost all seasons. A notable exception is the central interior (zone 3, Vaal), where minimum temperatures have been increasing less strongly, and some decreases have been observed.
 - High and low temperatures (i.e. hot and cold extremes) have respectively increased and decreased in frequency in most seasons across the country, particularly in the western and northern interior.

¹ The basis for this summary for policy-makers (Phase I) can be found in the LTAS Phase I full technical reports. The sector specific technical reports are specified in footnotes where relevant.

² See LTAS full technical report: Climate Trends and Scenarios for South Africa.

Strengths and weaknesses of model simulations of the recent historical climate (1960–2010)

Modelled climate data were compared with observed climate trends (1960–2010) to explore how well climate models have simulated observed trends. Findings suggest that some key climatic processes relevant for South Africa may not yet be adequately represented by either or both the general circulation models (GCMs) or the downscaling methods currently in use.

- Observed temperature trends are more closely matched by modelled simulations than are rainfall trends.
- Observed temperature trends since 2000 have not increased as steeply as projected by model simulations, a tendency noted in the Fifth Assessment Report (AR5) of the IPCC.
- Observed temperature trends in the central interior (zone 3, Vaal) are flat, but modelled trends are significantly positive, matching all the other zones.
- The observed reductions in autumn rainfall are not reproduced by the models, and the models tend to show opposite trends.

Projected rainfall and temperature changes for South Africa (to 2050 and beyond)

Climate projections were simulated over southern Africa using both statistical and dynamic downscaling of the output of AR4 (A2 and B1 emissions scenarios) and AR5 (RCPs 8.5 and 4.5) representing unmitigated (A2 and RCP8.5) and mitigated (B1 and RCP4.5) future energy pathways. In addition, a pattern scaling method, using a two dimensional atmospheric model of the Massachusetts Institute of Technology (MIT) Integrated Global System Model was used employing 450ppm CO₂ stabilisation as a mitigated scenario, contrasted with an unmitigated pathway.

Climate change projections for South Africa up to 2050 and beyond under unmitigated emission scenarios include:

- All modelling approaches project warming trends until the end of this century, but most approaches project the possibility of both drying and wetting trends in almost all parts of South Africa.
- Very significant warming, as high as 5–8°C, over the South African interior by the end of this century. Warming would be somewhat reduced over coastal zones.
- A general pattern of a risk of drier conditions to the west and south of the country and a risk of wetter conditions over the east of the country.
- Many of the projected changes are within the range of historical natural variability, and uncertainty in the projections is high.
- Effective global mitigation action is projected to reduce the risk of extreme warming trends, and to reduce the likelihood of extreme wetting and drying outcomes by at least mid-century.
- High resolution regional modelling suggests even larger benefits of effective global mitigation by the end of this century, when regional warming of 5–8°C could be more than halved to 2.5–3°C.
- Overall, there is far greater certainty in temperature than in rainfall projections.

Projected climate futures for South Africa (2015–2035, 2040–2060 and 2070–2090)

Four broad climate scenarios could usefully represent plausible climate outcomes over the coming century given the two main groups of emissions scenarios namely unmitigated (unconstrained) and mitigated (constrained) future energy pathways.

South Africa's climate future from 2025 and beyond can be described using four broad climate scenarios at national scale, with different degrees of change and likelihood that capture the results of global mitigation action and the passing of time:

1. warmer (<3°C above 1961–2000) and wetter, with greater frequency of extreme rainfall events.
2. warmer (<3°C above 1961–2000) and drier, with an increase in the frequency of drought events and somewhat greater frequency of extreme rainfall events.
3. hotter (>3°C above 1961–2000) and wetter, with substantially greater frequency of extreme rainfall events.
4. hotter (>3°C above 1961–2000) and drier, with a substantial increase in the frequency of

drought events and greater frequency of extreme rainfall events.

- The effect of strong international mitigation responses would be to reduce the likelihood of scenarios 3 (hotter/wetter) and 4 (hotter/drier), and increase the likelihood of scenarios 1 (warmer/wetter) and 2 (warmer/drier) during the course of this century. These scenarios can be further elaborated in terms of rainfall projections at sub-national level for the six hydrological zones (see Table 1).

Table 1. Rainfall projections for South Africa's six hydrological zones.

Scenario	Limpopo/Olifants/Inkomati	Pongola-Umzimkulu	Vaal	Orange	Mzimvubu-Tsitsikamma	Breede-Gouritz/Berg
1: warmer/wetter	▲ spring and summer	▲ spring	▲ spring and summer	▲ in all seasons	▲ in all seasons	▼ autumn, winter and spring
2: warmer/drier	▼ summer, spring and autumn	▼ spring and strongly summer and autumn	▼ summer and spring and strongly autumn	▼ summer, autumn and spring	▼ in all seasons, strongly summer and autumn	▼ in all seasons, strongly in the west
3: hotter/wetter	Strongly ▲ spring and summer	Strongly ▲ spring	▲ spring and summer	▲ in all seasons	Strongly ▲ in all seasons	▼ autumn, winter and spring
4: hotter/drier	Strongly ▼ summer, spring and autumn	▼ spring and strongly summer and autumn	▼ summer and spring and strongly autumn	▼ summer, autumn and spring	▼ all seasons, strongly in summer and autumn	▼ all seasons, strongly in the west

IMPLICATIONS FOR THE WATER SECTOR³

- Climate change impacts on South Africa are likely to be felt primarily via effects on water resources. Projected impacts are due to changes in rainfall and evaporation rate, but hydrological modelling approaches are essential for translating these into potential water resource impacts.
 - Preliminary projections for national runoff range from a 20% reduction to a 60% increase by as early as mid-century based on an unmitigated emissions pathway. Across the country, this ranges from increases along the eastern seaboard and central interior to decreases in much of the Western and Northern Cape. If global emissions are constrained to stabilise at 450 ppm CO₂, these changes are projected to lie between a 5% decrease and a 20% increase in annual runoff.
 - Under all four future climate scenarios, a higher frequency of flooding and drought extremes is projected, with the range of extremes exacerbated significantly under the unconstrained global emissions scenario. Under a **wetter future** climate scenario, significant increases in runoff would result in increased flooding, human health risks, ecosystem disturbance and aesthetic impacts. **Drier future** climate scenarios would result in reduced surface water availability, but would not exclude the risk of extreme flooding events.
 - Areas showing highest risks in extreme runoff related events (and flooding conditions) include KwaZulu-Natal, parts of southern Mpumalanga and the Eastern Cape. Specific areas at risk to increased evaporation, decreased rainfall and decreased runoff include the south-west and western regions, and to some extent the central region and the extreme north-east.
- Adaptation responses and research requirements**
- Because of the critical importance of water in the South African economy, the country has a sophisticated water resources technical and planning capacity which has been founded on a good understanding of the rainfall variability. This capacity is a key capability for adaptation planning going forward.
 - At present, specific provisions for climate change adaptation have been made in very few of the water resources planning tools. There are some early attempts that have simulated simple scenarios of changed surface water supply in reconciliation studies.⁴
 - Development aspirations in South Africa will likely be influenced by opportunities and constraints that arise from climate change impacts on the water sector. Key decisions would benefit from considering the implications of a range of possible climate-water futures facing South Africa. This is because the current modelling of future climate is uncertain with respect to rainfall variability and seasonality change, but more certain with regard to warming projections.
 - A scenario-based approach is therefore a viable way forward with respect to exploring adaptation options for the water sector. Given the substantial uncertainty over rainfall scenarios neither drier nor wetter scenarios can be excluded.
 - Under a **wetter future** scenario, trade-offs in water allocation between sectors are likely to be less restrictive, providing greater scope

³ See LTAS full technical report, Climate Change Implications for the Water Sector in South Africa.

⁴ Reconciliation studies are one of the primary tools for assessing the use of, and future requirements for, water in South Africa and how these can be 'reconciled' with the available sources through various strategies.

for urban-industrial economic growth and water provision for an intensive agricultural production model.

- Under a drier future scenario**, significant trade-offs are likely to occur between developmental aspirations, particularly in terms of the allocation between agricultural and urban-industrial water use, linked to the marginal costs of enhancing water supply. These constraints are most likely to be experienced in central, northern and south-western parts of South Africa, with significant social, economic and ecological consequences through restricting the range of viable national development pathways.
 - Adaptation response strategies for the water sector could be usefully identified at distinct governance levels. At **national scale** the development of a strategic intent and an enabling framework for adaptation would help to ensure a coherent national response. At **sub-national or system scale** key institutions could usefully engage in prioritising and allocating resources to interventions that take cognisance of adaptation imperatives. At **sub-catchment or municipal scale** the design of local implementation actions would be facilitated by responding to local challenges, resources and capacities.
 - The following priority functions would be beneficial to the Department of Water Affairs: policy review for enabling flexible frameworks; flexible and robust infrastructure planning; resources directed at maintaining critical ecological infrastructure in vulnerable systems; institutional oversight to ensure water-related institutions build adaptive management
- capacity; effective information management and maintenance of monitoring and evaluation systems; and sustainable and locally accessible financial management.
- Research** and focused monitoring would be valuable for: supporting the development of tools, approaches and case studies of the way in which water planning may consider long-term climate change; understanding the way in which climate driven changes in water resources availability or demand may constrain or enable different development pathways in different parts of South Africa, particularly for agricultural production and energy generation; and exploring the implications of long-term hydrological change on the ecological reserve (including the appropriate definition of the reserve) and associated issues of catchment management approaches that are needed to maintain the ecological reserve⁵ in different systems so that it continues to provide clean water and other ecosystem services to society.

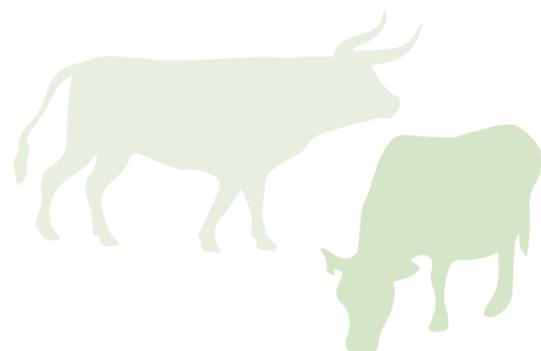


⁵ The 'Ecological Reserve means the quantity and quality of water required to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource'. This is an allocation of water to sustain a river ecosystem so that it continues to provide the desired ecosystem services, such as water supply and quality, flow regulation and aquatic productivity, to society.

IMPLICATIONS FOR THE AGRICULTURE AND FORESTRY SECTORS⁶

Climate change impacts

- Climate change impacts are projected to be generally adverse for a wide range of agricultural activities over the next few decades, with some possible exceptions. Many of these adverse impacts would be significantly reduced under a constrained emissions scenario as well as with the implementation of appropriate adaptation responses, with large potential avoided damages by as early as 2050.
- Under a **warmer/wetter** climate scenario, a modest increase of 4–6% in irrigation demand is projected, with limited implications for the agriculture sector. For catchments along the eastern seaboard, an increase in evaporation is projected to be offset by the increase in precipitation, with no change in irrigation demand. Increases in irrigation demand in the range of 15–30% are plausible under a **hotter/drier** future climate scenario and would present substantial risk for the sector. This would have important cross-sectoral implications due to the high proportion of surface water allocated to agriculture in South Africa.
- Spatial shifts in the optimum growing regions for many key crops such as wheat, barley, maize, sorghum, soybeans and sugarcane, and pasture/rangeland grasses such as *Eragrostis curvula* and Kikuyu are likely to occur. For example, under unconstrained emissions scenarios, western maize production areas are likely to become less suitable for maize production and areas suitable for viticulture in the western and southern Cape could be substantially reduced or shift to higher altitudes and currently cooler, more southerly locations.
- Projected impacts on yields of rain-fed crops include a -25% to +10% change in maize yield. Global mitigation efforts to achieve CO₂ stabilisation at 450 ppm would reduce this range of impact to a -10% to +5% change in yields. Similar results have been obtained for other crops such as wheat and sunflowers.
- Crops with strong tropical affinities, such as sugarcane, may increase in yield given the warmer/wetter projections in the tropical north-east of South Africa under the unconstrained emissions scenario.
- However, the annual mating index of eldana – one of the most serious sugarcane pests in South Africa – is projected to increase throughout the climatically suitable area for sugarcane by ~10% along the east coast to >30% further inland by 2050 at the latest.
- It is possible that some adverse impacts on rain-fed crops will be offset by the positive impacts of higher atmospheric CO₂ levels, but there is no local research available to quantify this.
- Climate change-induced changes in plant and animal diseases and insect distribution would adversely affect both crop and livestock production, and



- animal health. Warming alone has the potential to significantly increase the area subject to damage by both chilo – a key pest of major tropical crops and sugarcane – and codling moth – a key pest of several high value temperate fruit types, including apples, pears, walnuts and quince.
- In the medium- and longer-term, under a warmer/wetter climate scenario the total area of potentially suitable land for commercial plantation afforestation (including *Eucalyptus*, *Pinus* and *Acacia* species) in KwaZulu-Natal, Mpumalanga and the Eastern Cape Provinces is projected to increase due to the wetting trend over the eastern seaboard and adjacent areas.
- Climate change impacts on livestock have been less studied than those on key crops. However, studies do indicate a possible increase in heat stress as a result of climate change. Heat stress has known effects such as reducing milk yields in dairy cattle, and influencing conception rates across virtually all breeds of livestock. Furthermore, projected decreases in rainfall and hence herbage yields will result in negative health impacts for livestock.

- Results generated with projected future climate scenarios over South Africa display a marked increase in thermal discomfort on more days of the year, and especially in summer months. This will have serious implications for the productivity of agricultural labour especially under hotter/drier climate scenarios.

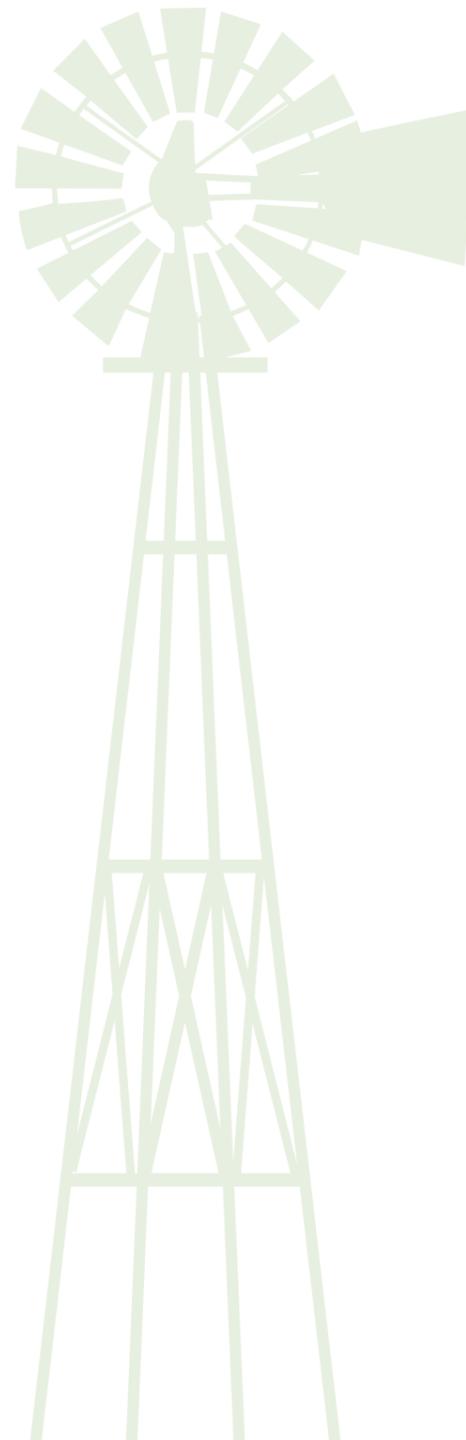
Adaptation responses and research requirements

- Adapting agricultural and forestry practices in South Africa requires an integrated approach that addresses multiple stressors, and combines indigenous knowledge and experience with the latest scientific insights.
- Potential adaptation responses in the agriculture sector range from national level strategies that relate, for example, to capacity building in key research areas, extension, and consideration of water resource allocation, to local level responses, which may be specific to agriculture production methods and local conditions.

- Ecosystem-based Adaptation** approaches use biodiversity and ecosystem services in an overall adaptation strategy and include the sustainable management, conservation and restoration of ecosystems to maintain and increase the resilience, and reduce the vulnerability of ecosystems and people in the face of adverse effects of climate change (CBD 2009).
- Community-based Adaptation** approaches empower people to plan for and cope with climate change impacts by focusing on community led processes grounded in the priorities, needs, knowledge and capacities of communities (Chesterman and Hope, 2011, in Midgley et al., 2012).
- Conservation Agriculture** approaches aim to achieve resource-saving agricultural production with acceptable profits, and high and sustained production levels while conserving the environment. The three core principles are: minimum mechanical soil disturbance to maintain minerals within the soil, stop erosion and prevent water loss; maintaining permanent organic soil cover for growth of organisms within the soil structure; and crop rotation with more than two species (FAO 2007).
- Climate Smart Agriculture** approaches are designed to identify and implement sustainable agricultural development for climate change. They integrate the economic, social and environmental dimensions of sustainable development by jointly addressing food security and climate challenges based on three main pillars: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or eliminating greenhouse gas emissions (FAO, 2013).
- Agroecology** approaches include recycling nutrients and energy on the farm rather than introducing external inputs; integrating crop and livestock management practices; diversifying species and genetic resources in agroecosystems over time and space; and focusing on interactions between production components and productivity across the agricultural system.

⁶ LTAS full technical report, Climate Change Implications for the Agriculture and Forestry Sectors in South Africa.

- As an overall adaptation strategy, benefits would be gained from best management practices based on the principles of ecosystem⁷ and community-based⁸ adaptation, conservation agriculture⁹, climate-smart agriculture¹⁰ and agroecology¹¹. Such practices include restoring and rehabilitating ecosystems, working landscapes and other open spaces to optimise them for future climatic conditions; minimising soil disturbance, maintaining soil cover, maximising water storage, multi-cropping and integrated crop and livestock production to optimise yields; sequestering carbon, and minimising methane and nitrous oxide emissions.
- Diversification in the agriculture sector is especially important in areas of projected decreases in rainfall and/or shifting rainfall conditions. Furthermore, climate advisory services could usefully communicate key messages from the latest available science in an appropriate format to government, agri-business (e.g. seed companies), extension services and farmers. This could include processes that support civil society to interpret and respond to such messages.
- The latest scientific insights combined with indigenous knowledge and experiences will need to continually provide improved answers on when, where, and how to adapt to climate change, especially regarding greater rainfall variability and its impacts on crop production.
- The agriculture sector would benefit from a holistic assessment of adaptation related future research needs that consider the full range of plausible climate scenarios. Such an assessment could distinguish needs at a range of scales of implementation and identify adaptation needs for specific agricultural activities at local level.



IMPLICATIONS FOR HUMAN HEALTH¹²

Climate change impacts¹³

- Health risks in South Africa that climate change would aggravate over the next few decades include heat stress, vector-borne diseases (such as malaria, dengue fever and yellow fever), extreme weather events, air pollution, communicable diseases (such as HIV/AIDS, TB and cholera), and non-communicable diseases (such as cardio-vascular and respiratory diseases). Climate change could also have deleterious effects on mental and occupational health, and its adverse impacts would be worsened by food insecurity, hunger and malnutrition.
- Increases in average temperatures and episodic extreme events (e.g. heat waves) resulting from a changing climate would have increasingly significant direct impacts on human health, especially for unmitigated hotter future climate scenarios. For example, high temperatures are known to induce heat stress and increase morbidity and mortality rates, and to result in respiratory and cardiovascular diseases.
- Alterations in climatic factors may lead to changes in the distribution of vectors such as mosquitoes, which will change the distribution of diseases like malaria. However, malaria is currently more strongly impacted by non-climatic factors, including effective management actions.
- Health impacts from extreme weather events can be immediate (e.g. death), long-term (e.g. impacts on crop yields), direct (e.g. injuries as a result of a landslide) or indirect (e.g. changing vector abundance through habitat destruction or creation, migration), and are difficult to project with the current knowledge base. An increase in the frequency/intensity of dry spells and flood events especially under hotter future climate scenarios would result in compromised food availability, food access, and food utilisation, all factors that lead to food insecurity.
- Climate change will impact on air quality in South Africa by affecting weather and thereby negatively influencing criteria pollutants such as particulate matter (PM), sulphur dioxide, ozone, carbon monoxide, benzene, lead and nitrogen dioxide.
- Climate change can impact on non-communicable diseases (such as cardiovascular and respiratory diseases) directly (e.g. by increasing temperatures and air pollution concentrations) and indirectly (e.g. by adversely impacting on agricultural yields and resulting in food insecurity).
- The transmission of cholera is linked to rainfall and temperature (air and sea surface) in South Africa and is likely to be affected by climate change-induced changes in rainfall and temperature regimes, especially under hotter future climate scenarios.
- Climate change will disrupt social and biophysical life support systems (e.g. displace communities, destroy homes, and result in loss of life). This will have serious implications on mental and occupational health (e.g. agricultural labourers productivity) and human well-being.

¹² See LTAS full technical report, Climate Change Implications for Human Health in South Africa.

¹³ The relationship between climate change impacts and health risks is not yet well understood. In particular, research is not at a stage where the health impacts stemming from climate change can be accurately projected spatially and temporally. As a result, LTAS Phase I adopted a narrative, theoretical approach to analysing the likely impacts of climate change on human health in South Africa.

Adaptation responses and research requirements

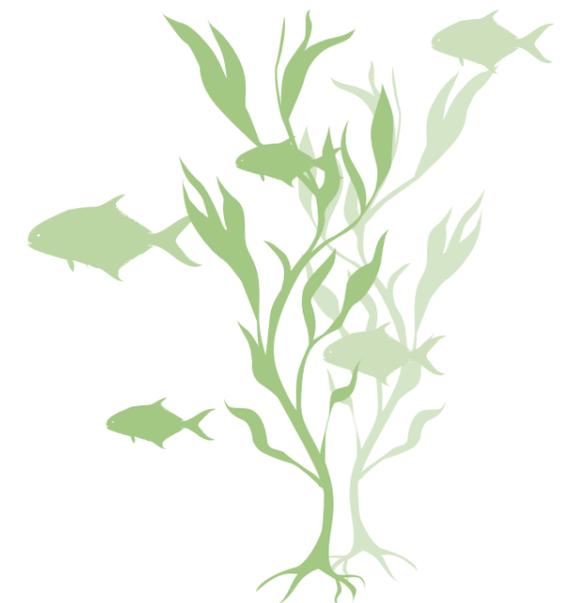
- Vulnerability assessments, increased surveillance, increased access to data and multi-sectoral cooperation are critical components of adaptation strategies which feature in the South African National Climate Change and Health Adaptation Plan.
- South Africa's National Climate Change Response Policy has advocated the following adaptation measures: reducing certain criteria pollutants (e.g. sulphur dioxide); developing and strengthening existing public awareness campaigns; developing heat-health action plans; improving biosafety; developing a spatial and temporal health data capturing system; and integrating food security and sound nutritional policies into all adaptation strategies moving forward.
- Models and/or methodologies exist to begin projecting the impacts of climate change on some of South Africa's key health risks, in particular heat stress, cholera and malaria, with the modelling of the latter being the most robust. However, the relationship between climate change impacts and key health risks is not yet well understood for South Africa.
- Research is not yet at a stage where the health impacts stemming from climate change can be accurately projected. Non-climatic factors need to be considered in such projections as these factors play a significant role in the transmission/spread of disease.
- The Department of Health, in collaboration with the World Health Organisation (WHO), is in the early stages of developing the first vulnerability assessment of the health sector in South Africa. This could be expanded to include vulnerability and risk assessments of specific diseases to climate change, and impact modelling (including consideration of non-climatic factors) to determine risk factors and health impacts which need to be addressed through adaptation.



IMPLICATIONS FOR MARINE FISHERIES¹⁴

Climate change impacts

- Projecting climate change impacts on marine fisheries is difficult because of the complex relationships between species distribution patterns, variations in their abundance, distribution and productivity, and the impacts of overfishing and other stressors.
- Effective modelling is limited by incomplete information on the functioning of the biological resources and even more critically on the physical changes in the oceans. In particular, most of the global biophysical models currently in use do not simulate the salient features in the oceans around South Africa.
- Climate-related changes in wind, upwelling, sea surface temperature, productivity, oxygen levels, storm frequency, precipitation, freshwater flow and runoff patterns, may all have impacts on estuaries, inshore and offshore ecosystems. These changes are likely to affect resource and habitat diversity, resource abundance, fish behaviour and physiology, resource catchability, fish size and fishing opportunities and success, which in turn will affect commercial and subsistence fishing livelihoods and recreational fisheries and their associated industries.
- Several marine species have already shifted their geographic ranges as a result of climate variability and change.
- Accelerated sea level rise, changes in river flows and increased frequency of high-intensity coastal storms and high water events pose a significant risk to estuarine, inshore and offshore fisheries with potential impacts on linefish, prawns and squid. Sea level rise may reduce estuarine nursery habitat, and decreased rainfall may cause temporarily open estuaries to close more frequently or even permanently, impacting on linefish.
- On a regional scale, KwaZulu-Natal and west coast estuaries are likely to be the most affected from a structural and functional perspective especially under wetter climate scenarios. Offshore catches of important linefish (squaretail kob and slinger) may decrease if freshwater flow inputs are not maintained to key systems such as the Thukela banks, especially under drier climate scenarios.
- Tropical species may move southwards in response to warming temperatures resulting in an expansion of the subtropical region. In contrast, temperate regions may contract, with coastal species being affected by changes in upwelling, related extremes in temperatures, reduced runoff



¹⁴ LTAS full technical report, Climate Change Implications for Marine Fisheries in South Africa.

and habitat loss ultimately leading to a decrease in temperate species diversity and abundance.

- Stocks under intense exploitation pressure (such as temperate linefish species) are likely to be more vulnerable to the effects of climate change than optimally exploited populations. This is because overfishing may result in reduced genetic variability, which may negatively affect the possibilities of an evolutionary response to climate change and the ability of depleted stocks to recover.
- Impacts on offshore fisheries depend on distinct scenarios of change in the oceans linked to wind patterns and offshore currents. Currently there is limited understanding of the mechanisms involved and an incomplete ability to model these changes.
- Increased storm activity under a changing climate would significantly impact on fishing activity by reducing the number of viable sea fishing days, and damaging shore-based off-loading facilities and fishing vessels.

Adaptation responses and research requirements

- Although many resources are overexploited, management action can lead to stock recovery. Key elements in securing resource sustainability in the long term include robust stock assessments, effective data management and science-based management action grounded in the realities of resource abundance.
- Adaptation strategies should centre on sound integrated ecosystem-based management approaches including Integrated Coastal

Management and the Ecosystem Approach to Fisheries Management (to complement the current single species approach).

- Sustainable fishing levels and practices, and appropriate spatial management, including climate-resilient marine protected areas (MPAs), would be valuable as key elements in South Africa's climate change response strategy. This would support the maintenance of genetic variability to secure genetic potential to adapt to change.
- Policies could usefully consider promoting diversification of activities and income generation to enhance social resilience in the face of uncertainty and variability, particularly for vulnerable coastal and fisher communities.
- Key modelling capacity is required to move beyond the current uncertain projections for key fisheries resources under future climate change. In particular a focused effort is required to develop plausible scenarios of physical oceanographic and coastal habitat change. The impacts of unsustainable fishing and climate change interact in a number of ways and should not be treated as separate issues.
- Experimental work on key species would be valuable to understand their adaptive capacity, and to improve projections of the impact of future climate change. The direct and indirect impacts of ocean acidification need to be quantified. Additional research on the socio-economic linkages from climate change impacts on the fisheries sector to other sectors is a priority.

IMPLICATIONS FOR THE TERRESTRIAL BIODIVERSITY SECTOR¹⁵

Climate change impacts

- Healthy ecosystems interlinked with working landscapes and other open spaces form the ecological infrastructure of the country and provide the foundation for clean air and water, fertile soil and food (DEA, 2013). Ecosystems in South Africa are under pressure from land use change and related processes causing degradation, as well as invasive alien species. Accelerated climate change (resulting in increasing temperature, rising atmospheric CO₂ and changing rainfall patterns) is exacerbating these existing pressures.
- South Africa consists of nine terrestrial biomes, geographical areas comprising a number of ecosystems with related plant and animal groups and similar disturbance regimes, most importantly wildfire.
- Well-functioning ecosystems provide natural solutions that build resilience and help society adapt to the adverse impacts of climate change.¹⁷ Sustainably managed and/or restored ecosystems help in adapting to climate change at local or landscape level.
- When combining the threats of climate change, rising atmospheric CO₂ and land use change, the following biomes are most vulnerable and in need of strong protection, restoration and/or research to ensure adaptation benefits for all South Africans and in particular vulnerable communities under future climate conditions.

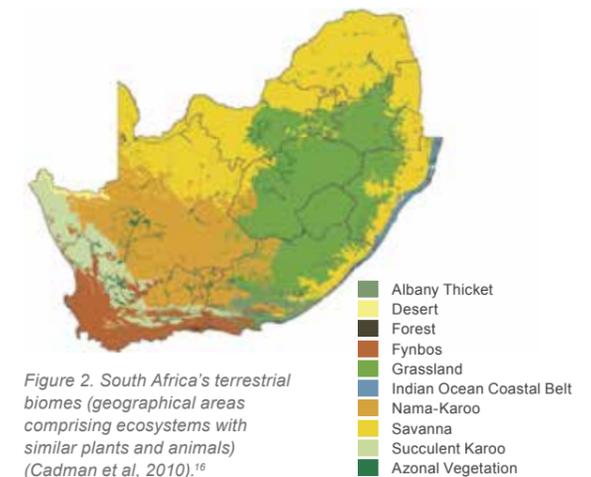


Figure 2. South Africa's terrestrial biomes (geographical areas comprising ecosystems with similar plants and animals) (Cadman et al., 2010).¹⁶

- Highest priority for action: **Grassland and Indian Ocean Coastal Belt.**
- High priority for action: **Fynbos and Forest.**
- Medium priority for action: **Nama Karoo and Succulent Karoo.**
- For grassland, significant change and loss of habitat is projected due to climate change. This is likely to be related to the high altitude of the biome and its susceptibility to warming effects, and the possible increase in tree cover, due to a lengthened growing season and increased CO₂ fertilisation. The savanna biome, on the other hand, is projected to expand with its geographic range partly replacing grassland.

¹⁵ See LTAS full technical report: Vulnerability Assessment of Climate Change Impacts on South African Biomes.

¹⁶ Azonal vegetation is not discussed in this factsheet as its highly fragmented nature prevented it from being included in the vulnerability assessment conducted during the LTAS Phase I process.

¹⁷ This includes, for example, buffering communities from extreme weather events; reducing erosion and trapping sediment; increasing natural resources for diversifying local livelihoods; providing food and fibre; and providing habitats for animals and plants which offer safety nets for communities during times of hardship.



- Desert is projected to expand at the expense of other biomes under all climate scenarios and particularly under the high risk climate scenario.
- The invasion of woody plants (alien and indigenous) into the grassland biome has major implications for conservation and the delivery of ecosystem goods and services to people, notably water delivery from highland catchments and grazing, as well as ecosystem processes such as wildfire.
- In addition to “a biome-based approach” to understanding climate change impacts on biodiversity, species-based projections, and related monitoring efforts provide a sensitive methodology for focused ongoing assessments of the rate and trajectory of ecosystem change, and the effectiveness of adaptation interventions.
- Birds are potential indicators of climate responses because they are highly mobile and sensitive to changes in habitat and climate. High potential rates of loss of indigenous bird species richness are projected in the central interior, an area identified as at risk from desert biome expansion. The north-eastern boundary of South Africa, from northern KwaZulu-Natal, along the border with Mozambique, and along the Limpopo basin represents an even greater risk for loss of bird species richness.

Adaptation responses and research requirements

- To increase the resilience of biodiversity and ecosystem service delivery under future climate conditions synergies could be developed during adaptation planning and implementation between biodiversity, poverty reduction and development objectives.
- Authorities should focus on mainstreaming the potential of biodiversity and ecological

infrastructure for achieving adaptation and development benefits across sectors into policy planning and implementation.

- Ecosystem-based Adaptation and expansion of protected areas using climate-resilient approaches offer two adaptation response options for the biodiversity sector that are appropriate for achieving increases in the climate resilience of biodiversity and maintaining and/or enhancing ecosystem service delivery. These two approaches should be adapted as necessary to build the resilience of ecological infrastructure to support economic sectors and livelihood activities
- Adaptation responses in the Grassland region will be critical for preventing loss of bird species richness; and for maintaining water supply from highland catchments, grazing services for local communities and ecosystem processes such as wildfire.
- The appropriate and specific types of local action required would need to be further defined in biome specific adaptation plans. This would include stakeholder engagement and a focus on implementation at local level prioritising multi-benefit, low-cost approaches; integrating adaptation and mitigation responses; and making use of indigenous knowledge.
- Biome adaptation plans and their implementation, would contribute to building climate-resilience at the biome level, and provide support to adaptation in other sectors such as water, agriculture and forestry, and human health through ensuring continued supply of ecosystem services. These plans, however, need to be mainstreamed across sectors for adaptation benefits to be realised.
- Vulnerability assessment data should be integrated with spatial data related to ecosystem service delivery, and translated at local level

based on user-specific vulnerabilities and needs to inform biome adaptation plans. Research and assessment would be important for developing mainstreaming products, tools and communication pathways (including decision-making and spatially referenced tools and information) so that information also informs other local development plans.

- Priorities for future research include the development of a predictive understanding of the rates of spread of invasive plants (including rising atmospheric CO₂), changes to fire regimes under climate change conditions, and developing achievable goals and measurable criteria for assessing the success of Ecosystem-based Adaptation and protected area expansion in increasing the resilience of biodiversity and maintaining ecosystem services under future climate conditions.
- It must be noted that changes projected for the end of this century under an unmitigated emissions scenario require careful consideration and further modelling in order to assess the risks they present for biodiversity and ecosystem services.

Overall conclusion and linkages

- Global climate model ensembles summarised for South Africa suggest a significant benefit from effective mitigation responses (global CO₂ stabilisation at between 450 and 500 ppm) relative to unconstrained emission pathways by as early as mid-century.
- Even under effective international mitigation responses, significant socio-economic implications are expected for vulnerable groups and communities in South Africa under both wetter and drier climate futures. These implications would largely be felt through impacts on water

resources, such as changes in water resource availability and a higher frequency of natural disasters (flooding and drought), with cross-sectoral effects on human settlements, disaster risk management and food security.

- Substantial increases in irrigation demand are plausible under a hotter and drier scenario presenting substantial risk for the sector, and with important cross-sectoral implications due to the high proportion of surface water allocated to agriculture in South Africa. In both wetter and drier futures, a higher frequency of flooding and drought extremes is expected with cross-sectoral effects on human settlements, disaster risk management and food security.
- The potential for ecological infrastructure to provide adaptation benefits and assist in achieving development aspirations across sectors could be mainstreamed into policy planning and implementation. This will work towards building the resilience of South Africa’s natural systems, working landscapes and open spaces to support economic sectors and local livelihoods under future climate conditions.
- Multi-sectoral collaboration is needed in conducting research and in developing and implementing adaptation plans.



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