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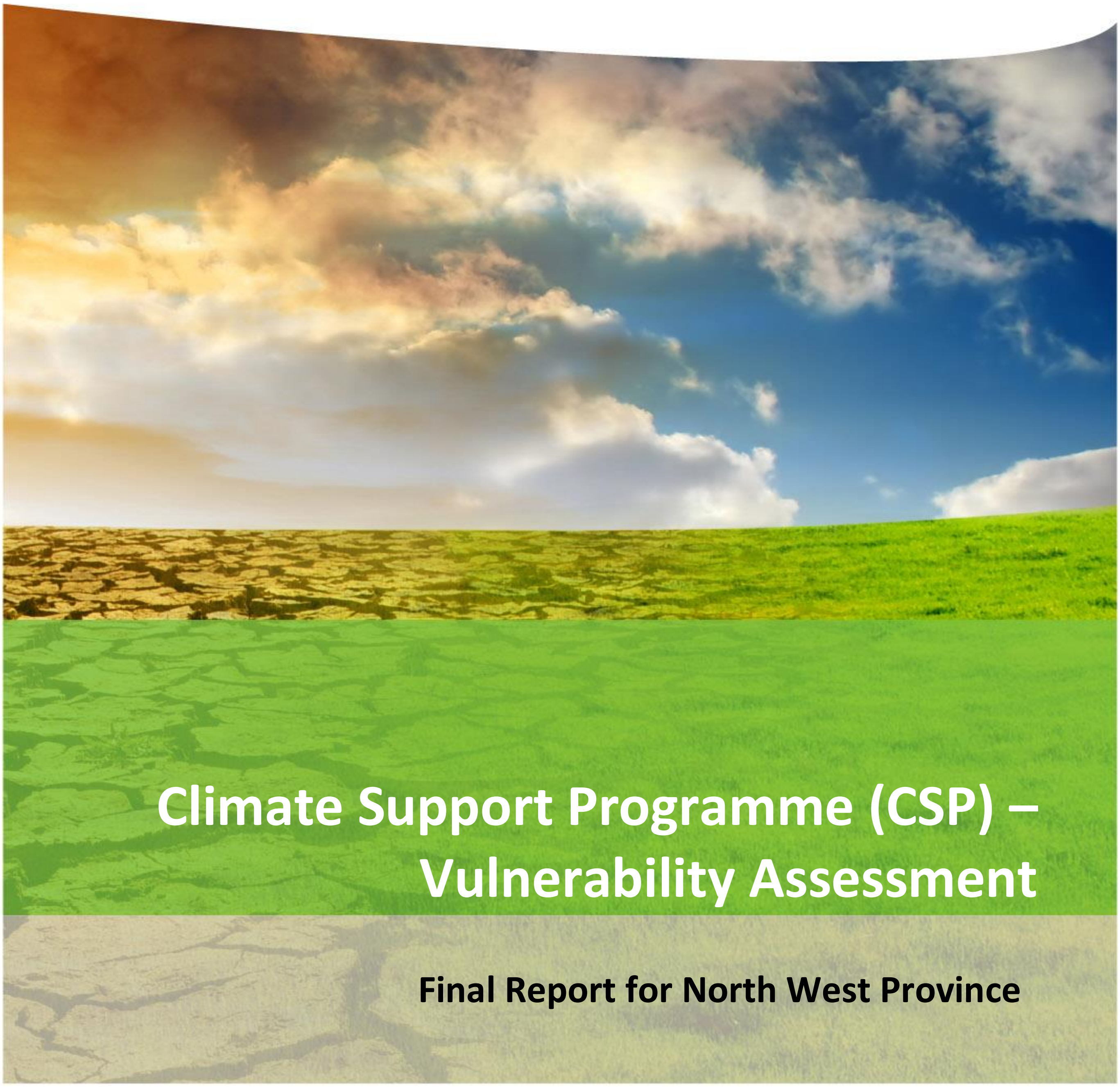
Department:
Rural, Environment and Agricultural Development
North West Provincial Government
REPUBLIC OF SOUTH AFRICA



Climate Support Programme (CSP) – Vulnerability Assessment

Final Report for North West Province

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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ABBREVIATIONS AND ACRONYMS

AMD – Acid Mine Drainage
AR4 – Fourth Assessment Report
AR5 – Fifth Assessment Report
BoD – Biochemical Oxygen Demand
BSP – Biodiversity Sector Plan
CBA – Critical Biodiversity Areas
CCDM – Climate Change and Disaster Management
CMA – Catchment Management Agency
CSIR – Council for Science and Industrial Research
CSP – Climate Support Programme
DACE – (NW) Department of Agriculture, Conservation and Environment
DACERD – (NW) Department of Agriculture, Conservation, Environment and Rural Development
DAFF – Department of Agriculture, Forestry and Fisheries
DARD – (NW) Department of Agriculture and Rural Development
DEA – Department of Environmental Affairs
DEDECT – (NW) Department of Economic Development, Environment, Conservation and Tourism
DOE – Department of Energy
DRDLR – Department of Rural Development and Land Reform
DST – Department of Science and Technology
DWA – Department of Water Affairs
DWS – Department of Water and Sanitation
ECL – Environmental Critical Levels
EMF – Environmental Management Framework
GCM – General Circulation Models
GIZ–Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH
GVA – Gross Value Added
IPCC – Intergovernmental Panel on Climate Change
IRP – Integrated Resource Plan
LTAS – Long Term Adaptation Scenarios
MuSSA – Municipal Strategic Self-Assessment
NCCC – National Climate Change Committee
NFEPA – National Freshwater Ecosystem Priority Areas
NW – North West Province
NWA – National Water Act
NWPG – North West Provincial Government
NWPTB – North West Parks and Tourism Board
NWSDF – North West Spatial Development Framework
PDP – Provincial Development Plan (for North West)
RCP – Representative Concentration Pathways
READ – Department of Rural, Environment and Agricultural Development
RHP – River Health Programme

SADC – Southern African Development Community
SALGA – South African Local Government Association
SANBI – South African National Biodiversity Institute
SARVA – South African Risk and Vulnerability Atlas
StatsSA – Statistics South Africa
VA – Vulnerability Assessment
WCWDM – Water Conservation and Water Demand Management
WMA – Water Management Area
WUA – Water User Associations

1. Executive Summary

South Africa's North West province has already started grappling with the impacts of climate change, and available climate science indicates that the impacts are likely to increase and intensify in decades to come. The primary channel through which climate change is impacting the province (and South Africa as a whole) is through water availability, and thus water becomes a crucial lens through which to study climate change in this part of South Africa. Changes in water directly affect agriculture and animal husbandry (or livestock rearing), critical sectors in the North West. Indirectly, it also affects the biggest revenue-generator in the province – mining. Efforts are already underway in the North West province to better understand the nature and extent of the current and future impacts, as well as to help the province better prepare for climate change.

In building an impactful climate adaptation strategy for North West province, a critical first step is to identify key areas of vulnerability. While climate change is a global phenomenon and has impacts across the continent, region, country, and province as a whole, certain sectors within the province are more vulnerable to the changes due to their nature – specifically, due to their sensitivity or level of response to climate change, and to their current ability to cope with changes, i.e. their adaptive capacity. In terms of exposure to climate change, credible, publicly available climate science allows for an understanding of climate change indicators (temperature and rainfall trends) at the level of the province. Climate modelling of a higher resolution, e.g. at the Municipality or District Municipality Level, is fraught with uncertainty and diminished levels of confidence. Hence for the purpose of ascertaining climate vulnerability of key sectors in North West province, this assessment has relied on exposure data and projections at a province-wide scale. However, it must be noted that as high-resolution climate modelling improves and becomes more accessible, it will likely be possible to identify varied exposure across North West's province's major physical features and sub-climatic or micro-climatic zones.

The Long Term Adaptation Scenarios (LTAS) project suggests that the region within which North West province is located is likely to face a potential increase in temperatures by as much as 2.5°C by 2035, and 1-3°C between 2040 and 2060 (or even 2-5°C in the high-end scenarios), and by 3-6.5°C between 2080 and 2100 (or as much as 5-8°C in the high-end scenarios).

Assessing climate change sensitivity and exposure of each key sector allows for a picture of climate risk (potential impacts) to develop. When this is combined with the sector's adaptive capacity in the province, it allows for a richer understanding of sectoral climate change vulnerability to emerge. **The current assessment reveals that the sectors in North West province displaying greater climate change vulnerability, in relative terms compared to other sectors, are agriculture, ecosystems (terrestrial and aquatic), rural livelihoods, and the mining sector.**

The table below summarizes the findings of the vulnerability assessment for the province.

	Sensitivity	Exposure		Risk		Adaptive Capacity		Vulnerability	
		Short Term	Long Term	Short Term	Long Term	Short Term	Long Term	Short Term	Long Term
Terrestrial	Med	Med	High	Med	High	Low	Med	Med	High
Aquatic	High	Med	High	High	High	Med	Med	Med	High
Rural	High	Med	Med	Med	High	Med	Low	Med	High
Urban	Med	Low	Med	Low	Med	Med	Med	Low	Med
Agriculture and Farming	High	Med	High	Med	High	Med	Med	Med	High
Mining	Med (indirect)	Med (Indirect)	Med (Indirect)	Med (Indirect)	High (Indirect)	Low	Med	Med (Indirect)	High (Indirect)
Tourism	High	Med	Med	Med	Med	Med	Med	Med	Med
Water Supply	High	Med	High	Med	High	Low	Med	Med	Med
Energy Supply	Med	Low	Med	Low	Med	Med	Med	Med	Med
Transport	Low	Low	Med	Low	Low	Low	Med	Med	Med
Public Health and Safety	Med	Med	Med	Med	Med	Low	Med	Med	Med
Extreme Weather / Disaster	High	Med	High	Med	High	Med	Med	Med	Med

The high climate vulnerability of these sectors is a matter of great concern for North West Province. North West produces 18% of South Africa's total maize, a crop whose yields have been shown to be highly sensitive to rainfall changes (Blignaut et al., 2009). In particular, small-scale farmers in North West are likely to experience revenue losses if rainfall decreases markedly (Benhin, 2006). Given the province's major role in maize production and cattle ranching, impacts of climate change in the agriculture sector in North West have national implications.

The relatively high vulnerability of rural livelihoods – predominantly based on agriculture and livestock – is also a matter of significance for North West province, where a large percentage of people reside in rural areas and rely mostly on natural resources for subsistence (DRDLR, 2013a). According to the 2011 census, over 20% of people in North West were illiterate, and the province had the third lowest annual average household income of all provinces in the country – both factors that contribute to low adaptive capacity in the face of climate change (StatsSA, 2012).

North West's ecosystems – both aquatic and terrestrial – are also highly vulnerable to climate change. The province already has one critically endangered ecosystem (the western sandy Highveld grassland), one endangered ecosystem (the Vaal-Vet sandy grassland), and eight vulnerable ecosystems. Grasslands in particular are at risk from climate change, with an increased likelihood that warmer temperatures and higher carbon dioxide levels in the atmosphere will support the growth of wooded plants and trees, edging out grasses. The savanna biome is less vulnerable to climate change but nevertheless likely to see changes in range and in the level of ecosystem services being provided.

The extractives sector (mining) contributes nearly a fourth of North West's total economy, with platinum being one of the main products and the province produces a quarter of South Africa's gold. The sector accounts for 15% of the province's total employment. It is a critical pillar of the province's economy. While the sector is not directly impacted by changes in temperature and rainfall in the way that ecosystems and agriculture are, the sector's water dependency and the effect of heat on working conditions makes this sector susceptible to climate change as well.

While all the sectors examined as a part of this assessment display varying degrees of vulnerability to climate change, the potential impacts on some – either as a function of sensitivity or as a result of low adaptive capacity – are higher than others in relative terms. The priority sectors described here (agriculture, rural livelihoods and settlements, ecosystems, and extractives), having emerged out of the research conducted for this climate vulnerability assessment report, will become the focus of the next stage of the project – the development of adaptation strategies based on best practices and consultation with stakeholders in North West province.

However, to the extent that stakeholders in the North West express particular concern for sectors that did not emerge as highly vulnerable in this specific analysis, and if they identify a desire to develop adaptation strategies for those additional sectors, those additions will be reflected in the subsequent report, i.e. a Climate Change Adaptation Strategies Report for the North West.

2. Introduction to this Report

This report is the product of the initial stage of secondary research and stakeholder engagement in a three-province project aimed at developing climate change adaptation strategies at a provincial level. The objective of the five-month project, funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and facilitated by the South African Department of Environmental Affairs (DEA), is to develop a province-specific climate change adaptation strategy which focuses on approaches that should be taken in high-vulnerability sectors in the province to develop adaptive capacity to current and projected impacts of climate change. Thus the project will culminate in a climate change adaptation strategy report for North West province, to be developed in the second phase. However, to inform the development of such strategies and to first identify focus areas for action, the first phase of the project has produced this sectoral climate change vulnerability assessment for North West province.

2.1. Project objectives

The overall objective of the project is to provide a sound understanding of current and future climate change risks in key sectors within three of South Africa's provinces, namely the North West, Mpumalanga and Limpopo provinces. The focus of this report is on assessing climate change vulnerability for North West Province, in an effort to highlight sectors of relatively greater vulnerability. Building on this report, the second stage of the project will produce a report providing guidance to decision-makers in the North West province on optimal strategies for improving adaptive capacity in key sectors of high vulnerability.

The ultimate goal of the project is to create a shared knowledge-base for key stakeholders in North West Province on both the impacts the province faces from climate change as well as adaptation strategies that could protect natural capital, livelihoods of local communities, and the resources underpinning economic activity in climate-vulnerable sectors of importance to the province.

An allied objective, important to the funding agency, is to strengthen governance capacity in the province to understand the content and processes involved in vulnerability assessments and strategy-building, such that the provincial government gains the ability to itself engage in these processes in the years ahead at different levels, e.g. to conduct future municipal level or industry level or species level climate change vulnerability assessments.

2.2. Project Methodology

2.2.1. Understanding Vulnerability

In understanding and unpacking climate change vulnerability, the project aligned closely with concepts and overall guidance provided in South Africa's National Climate Change Response White Paper. This entails identifying the concepts of climate sensitivity, exposure, climate risk, adaptive capacity, and vulnerability along the lines of the Intergovernmental Panel on Climate Change (IPCC)'s

Fourth Assessment Report (2007). In spite of the recognition that the Fifth Assessment Report (AR5) has adopted marginally different definitions of climate vulnerability, with a revised nomenclature of the constituents of vulnerability, the project team believes that the overall approach towards conducting vulnerability assessments does not undergo a radical shift within the IPCC AR5 paradigm. Moreover, the changes encapsulated within AR5 are so recent that climate change practitioners have not yet reached consensus on whether – and if so how – the design and implementation of vulnerability assessments should be modified. Given the body of knowledge and practice that exists on vulnerability assessments, and the predominance of the AR4 approach within existing knowledge and practice, this report adheres to the overall concepts and definitions within IPCC AR4. To this end, the understanding of climate change vulnerability is summarised as follows – ‘The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes, where vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. Detailed information on these and other concepts are provided in Section 2 of this report.

Within this understanding, the methodology used to assess climate change vulnerability includes the following key components:

- **SENSITIVITY:** This element assesses whether a built, natural or human system is directly or indirectly affected by or susceptible to changes in climate conditions (e.g., temperature and precipitation) or specific climate change impacts (e.g., sea level rise, increased water temperature). If a system would undergo changes as a result of climatic changes and variability, it is considered sensitive to climate change. In other words, sensitivity refers to the extent to which a given system can be affected /impacted by a particular climatic change. Sensitivity is about the inherent qualities and characteristics of an entity or system, and is an internal feature. In the case of this vulnerability assessment, the inherent features are the biophysical characteristics of the sectors or sub-sectors in the North West, which influence how they respond to changes in temperature or rainfall.

- **EXPOSURE**: Climate exposure assesses whether a built, natural, or human system is likely (probable) to face climate change, and if so assessing the magnitude and rate of change based on future projections. In other words, the extent to which a given system will be subject to or come into contact with a climate change impact – in this case, increased temperatures and changes in rainfall patterns.

- **ADAPTIVE CAPACITY:** Assessing the ability of built, natural and human system associated with a given planning area to accommodate changes in climate with minimum disruption or minimum additional cost. In other words, the element of adaptive capacity assesses the extent to which a system is able to exploit opportunities and resist or adjust to change. Adaptive capacity is often estimated based on proven historical ability of the system to cope with the climatic changes in question. And from a futuristic perspective, it is assessed through proxies such as levels of education and income and, in this case, programs or policies being put in place to help the sector cope with changes in a positive manner.

Under this framework, climate change risk is a combination of hazard exposure and climate sensitivity. Climate change vulnerability is then a result of the interaction between climate change risk, and adaptive capacity. This broad approach is consistent with current practice within the South African Government (such as a recent climate change risk and vulnerability assessment for rural settlements).

The table below provides a list of the selected sectors and sub-sectors that this vulnerability assessment focuses on as per the project terms of reference:

Table 1: List of key sectors and sub-sectors for North West Province

Sector	Sub Sector
Ecosystems	Aquatic (rivers, lakes, wetlands)
	Terrestrial (biodiversity, forests, invasive species)
Livelihoods	Rural
	Urban
Economic Activity	Agriculture / Farming
	Tourism
	Extractives
Infrastructure and Utilities	Water Supply
	Energy Supply
	Transportation
Public Health and Safety	Human Health (diseases etc.)
	Disasters resulting from extreme weather (wild fires, floods, drought)

For each variable in the methodology – i.e. climate sensitivity, exposure (and thereby risk), adaptive capacity, values have been assigned (low / medium / high) based on existing secondary climate literature and intelligence-gathering in the North West province. The assigned values help reflect the short term (2015-2020) and the long term (2020-2040 or mid-century) horizons with respect to sensitivity, exposure and adaptive capacity of systems in the North West Province. This has enabled us to identify the sectors of greatest vulnerability in order to develop interventions with intent focus on priority areas in the adaptation strategies report that will follow.

Evidence Base

For the Vulnerability Assessments the project team relied heavily on the findings of the Long Term Adaptation Scenarios (LTAS) project, including the sector reports from Phase One. The climate vulnerability data contained in these report forms the basis of the literature review, and has been used as the starting point for the analysis. Although the project had limited resources (8 consultant-days, or 64 hours, for the vulnerability assessment in each province), the project team supported by the DEA officials put an effort to collect and collate as much information as possible. Moreover, the limited resources mean that to commission a new climate modeling and downscaling process for North West province is beyond the scope of this short assignment. However, since the LTAS project resulted in the generation of a wealth of climate model downscaling and the results are recent, high quality, and representative, its findings have been incorporated into this assessment. Additionally, the project team has supplemented with evidence from the IPCC's AR5, from relevant studies carried out by CSIR (such as the Climate Change Handbook for Northeastern South Africa), from the South African Risk and Vulnerability Atlas (SARVA) (Archer et al., 2010), and other publicly accessible, credible, peer-reviewed published studies on climate change in South Africa and southern Africa more broadly.

The project team, with valuable assistance and guidance by the province, consolidated and reviewed available province-specific climate change impact studies that the provincial governments were able to provide access to. Similarly, the project team has examined existing, publicly accessible vulnerability assessments of the key sectors at the national level – including agriculture, water and sanitation, health, rural development, and human settlements. However, the preliminary data search demonstrated that high quality studies relating to the provinces are somewhat scant in the public domain. Thus, where necessary due to lesser available province-specific reports and analysis, the project team relied on extrapolations of credible, peer-reviewed materials at the national scale.

2.3. Adaptation vs Mitigation

It must be noted that the methodology described above is aimed at assessing sector vulnerability to climate change. The ultimate objective is to suggest strategies that the North West province can develop further and use to facilitate adaptation of the vulnerable sectors to the projected risks. In this regard, it is useful to clearly articulate the difference between mitigation and adaptation. Although both involve sets of actions motivated to address climate change, they differ in terms of focus. Figure 1 below, provides a summary definition of climate change mitigation and adaptation. The aim is to help readers of this document to appreciate the different meanings in order to facilitate a focused discussion on matters relevant to climate *adaptation* in the North West Province, per the overall objectives of the project.

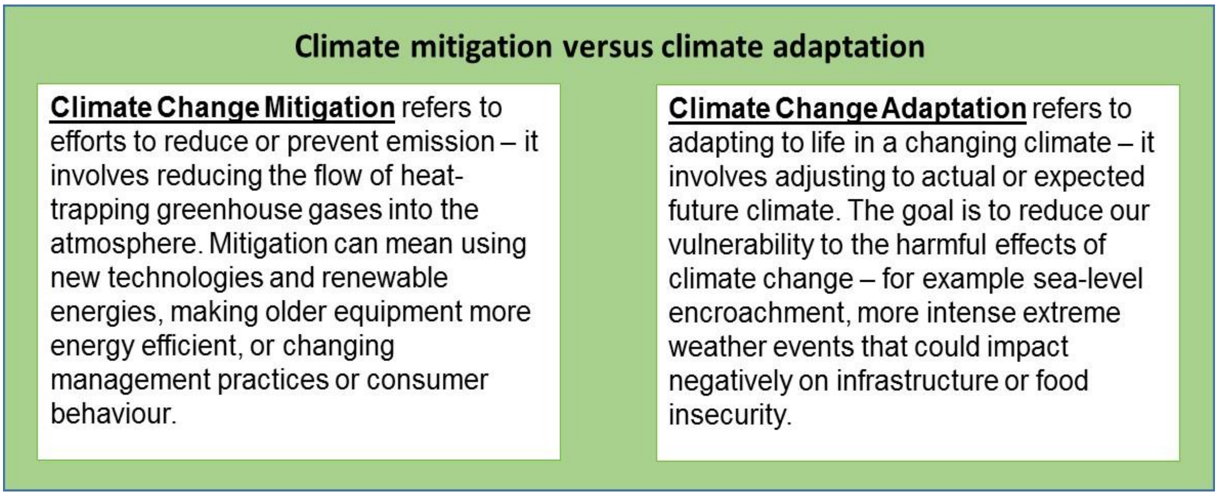


Figure 1: Mitigation vs Adaptation (Definitions adapted from Global Greenhouse Warming.com)

This climate vulnerability assessment report concerns itself with understanding sensitivity, exposure and adaptive capacity of the environment to extreme climate changes in North West province. In short, climate change mitigation strategies are beyond the scope of this project.

2.4. The Study Context: North West Province

The North West province of South Africa is landlocked and the capital of the province is Mahikeng. It shares borders with the Gauteng province in the east, the Limpopo province in the north east, Botswana in the north, the Free State province in the south, and the Northern Cape Province in the west. The province consists of four district municipalities and 19 local municipalities. It is predominantly rural with most of the people relying on agriculture for their livelihoods. The four district municipalities are as follows (see figure below):

- Bojanala Platinum District Municipality
- Ngaka Modiri-Molema District Municipality
- Dr. Ruth Segomotsi Mompati District Municipality
- Dr. Kenneth Kaunda District Municipality

Major towns include Mahikeng, Brits, Klerksdorp, Lichtenburg, Potchefstroom, Rustenburg and Vryburg.

The 2014 mid-year population estimates issued by the Statistics SA (2014) indicate that there are approximately 3.67 million people residing in the province. Nearly 43% live in the eastern Bojanala Platinum District Municipality, and a further 24% live in the Ngaka Modiri-Molema District Municipality (READ, 2014). According to the 2011 Census, the outflow of 167,367 was more than offset by inflow to result in a nett inflow of approximately 31,000 people (READ, 2014).

The North West province is predominantly rural, with around 60% of the population living in rural areas and the rest in urban areas. The rural population is mainly dependent on agriculture for livelihoods. According to the headcount measure of poverty by Statistic SA (2014), the North West has a higher proportion of people living in poverty (50. 5%) than the national average (45.5%).

The province is semi-arid and contains mainly savannah and grassland vegetation. Climate plays an important role in determining the availability of resources, the natural landscape and vegetation types. There is a wide variation in climate across the province.

Figure 2: District Municipalities in the North West province (READ, 2014)

The economy of the province is mainly natural resource based, with the main contributor being the mining sector (33.6%). About 50% of the world's platinum is mined in the province with other minerals such as gold, diamonds, chrome, vanadium, granite, slate, limestone, dimension stone, nickel, silica, manganese, phosphate, fluorspar, and zinc also featuring strongly. General government services account for 12.1% of the economy, financial services, real estate and business services account for 11.1%, with agriculture, forestry and fishing accounting for just 2.1% of the economy in the province. However, the province represented more than 20% of maize production in the country in 2009/2010 (DAFF, 2011a). It also accounts for 12% of beef production in the country (DAFF, 2011b). Other agricultural products being farmed in the province include livestock, sunflower seeds and oils, nuts, citrus, and tobacco. Potchefstroom, Rustenburg and Vryburg are the major mining and agricultural areas. The province also has a substantial number of game farms. Economic activities have a major influence on the environment because of their reliance on natural resources (e.g. water, land, energy, vegetation, livestock and wildlife) to create wealth and employment. In general, areas of high economic activity experience the most severe environmental problems (e.g. Rustenburg and Brits).

3. Climate Change Science and Uncertainty

3.1. Dealing with Uncertainty in Climate Change Science

Climate science is a complex field, involving a large number of variables that influence how the earth's atmospheric system functions and reacts. Despite the fact that a great deal is known about the climate system and the types of impacts that climate change can result in, there are still some uncertainties that prevent us from knowing with one hundred percent certainty the impacts that will take place, including timelines, and specific locations. This assertion applies to most climate change studies, including those conducted in South Africa, and is applicable in the North West Province. However, not having one hundred percent certainty is no reason to ignore what climate science able to tell us with a significant degree of likelihood and probability.

A large amount of information is available in South Africa on the causes of climate change and what its effects are likely to be in North West Province. With careful consideration, this provides ample evidence to guide decision makers in the Province about what must be done to respond to possible climate changes. Indeed, it is helpful for policy makers to understand uncertainties and probabilities involved so that they can take these into account when using scientific input to inform decisions. For instance, decisions on allocation of available water resources, given the competing needs between industrial, domestic and agricultural uses, should factor in uncertainty associated with water availability of lack due to climate shifts.

An example of such uncertainty is projected rainfall trends in the North West. As captured in LTAS, even though a very clear increase or decrease in future rainfall is difficult to project, rainfall anomalies for the North West are largely expected to lead to a drying trend (DEA, 2013a). With this in mind, the reality is that a number of critical sectors that rely on the availability of adequate water in the North West must not only start planning for a future where water availability is uncertain, but one where the chances of drying and lower water availability are relatively greater than the chances of increased water availability. Water sector strategies developed for the future must, in other words, be strategies to deal with uncertainty.

3.1.1. Language Adopted by the IPCC to Describe Confidence about Facts (IPCC, 2010)

In assessing the state of knowledge about climate change, scientists have developed a careful terminology for expressing uncertainties around both statements of fact about a current situation and statements about the likelihoods of various future outcomes. This terminology reflects mathematical probability. Typically, these probabilities and statistical levels of confidence are expressed in the following way:

- "Very high confidence" = *At least* 90 percent chance of being correct
- "High confidence" = About 80 percent chance of being correct
- "Medium confidence" = About 50 percent chance of being correct
- "Low confidence" = About 20 percent chance of being correct

- “Very low confidence” = *Less than* 10 percent chance of being correct

For the purpose of achieving common understanding in this vulnerability assessment report, the above terminology is useful in the analysis. The scientific literature reviewed for this report is credible, peer reviewed science, and much of the literature utilizes the same terminology in order to emphasize what we know enough to act on.

3.2. Current and Future Climate – A National Level Snapshot (Archer, 2010)

Climate is regarded as the long-term average of weather conditions. There is a great deal of diversity in climate conditions across different regions of South Africa, and even within each region there is large inter-annual variability (i.e. differences in climatological conditions in different years). This is a challenge for weather prediction, seasonal forecasting, and for climate change projection.

South Africa is located latitudinally between 35° S and 22° S, and thus 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 result, the western half of South Africa has a semi-arid climate. As is common in the subtropics, rainfall patterns over the country display well-pronounced intra-annual and inter-annual variability. 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 coast to have a warm and humid climate, whilst the cold Benguela current along the west coast contributes makes the region arid.

South Africa has a warm climate, and much of the country experiences average annual temperatures of above 17°C. 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 regions of the Northern Cape. The oceans surrounding South Africa have a moderating influence on the temperatures along coastal areas. The warm Agulhas current makes the east coast significantly warmer than the west coast, where the cold Benguela current and upwelling result in lower temperatures.

[1] Atmospheric pressure systems are one of several factors that influence South Africa’s climate. Pressure systems are the result of air flowing from an area of high pressure to an area of low pressure. Air pressure depends on the temperature and the density of the air. Hot air rises and thus the pressure is low, while cold air sinks so pressure is high. Air pressure at the equator is low (hot air). At latitude 30° South, the upper air is cool and begins to sink earthwards, causing higher surface pressure, i.e. the sub-tropical high. At latitude 60° very cold polar air forces the warmer air in front of it upwards and the air pressure is reduced. At the poles, due to the cold dense air, the air pressure is high. The movement of air from a high-pressure cell towards a low-pressure cell is influenced by the rotation of the earth which deflects the winds to the left of their direct path in the southern hemisphere and to the right in the northern hemisphere. In the southern hemisphere, where South Africa is situated, high pressure belts occur between 25º and 30º south latitude during the winter and low-pressure systems that occur during summer.

Table 2: South Africa's Seasonal Climate Characteristics (CSIR, 2010)

SEASONAL CLIMATE CHARACTERISTICS			
Summer (December-January-February)	Autumn (March-April-May)	Winter (June-July-August)	Spring (September-October-November)
This is the most important rainfall season for the central and northern interior of South Africa. Heat-induced thunderstorms frequent the South African interior, being most abundant over the eastern escarpment and Highveld areas.	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). The Cape interior regions receive significant amounts of rainfall during autumn from cloud bands that occur to the west of the most well-pronounced regions of subsidence.	Weather is characterised by sunny days, clear skies and cold nights. Frost is common especially over the higher altitude parts of South Africa. Cold front systems bring rain to the south-western Cape and the Cape south coast. On occasion this cold front intrudes northwards and brings "cold snaps", and in extreme cases causes snowfall to occur over the Free State and the Highveld regions of Gauteng and Mpumalanga.	Spring is characterised by the onset of rainfall over the interior regions of South Africa, with the first of the significant falls of rain typically occurring over KwaZulu-Natal before spreading deeper into the interior. 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.

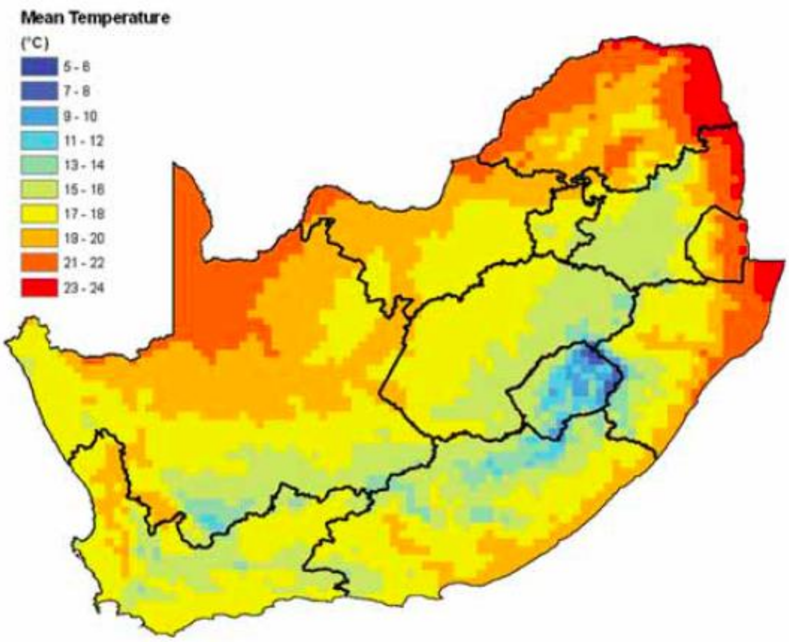


Figure 3: Historic Average Annual Temperature (Celsius) over South Africa, Historic Average (1961-1990) (Archer et al., 2010 (SARVA)) [Note that this map is provided by way of indicating historic averages, i.e. temperatures in the "normal" range, prior to climate change-induced rise of average temperature.]

Rainfall over South Africa is highly variable in space, and there exists a west-east gradient in rainfall totals. 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 southwestern Cape and Cape south coast areas, which similarly result from orographic forcing when moist frontal air is transported inland.

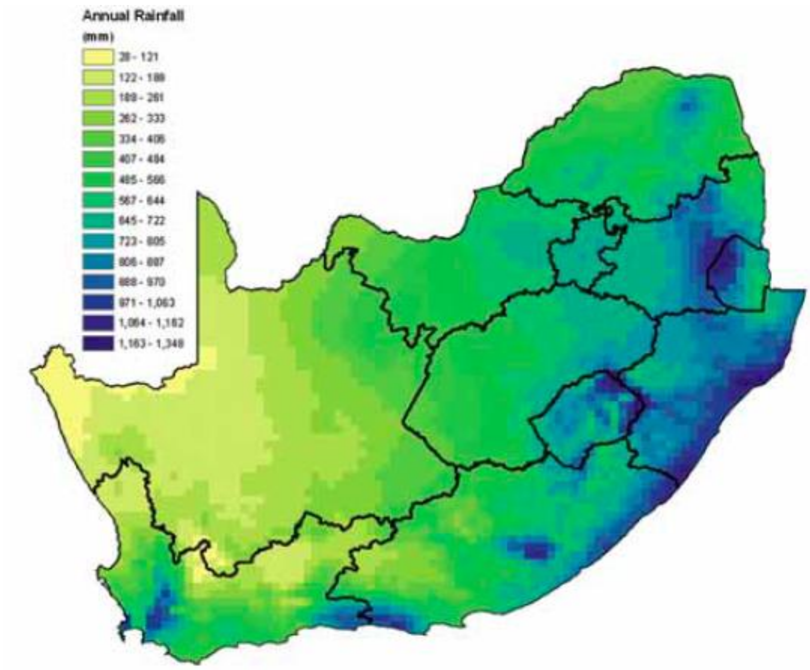


Figure 4: Historic Average Annual Rainfall Totals (mm) over South Africa, Historic Average (1961-1990) (Archer et al., 2010 (SARVA) [Note that this map is provided by way of indicating historic averages, i.e. precipitation in the "normal" range, prior to climate change-induced rise of average rainfall.]

Climate modelling conducted for the South African Risk and Vulnerability Atlas (SARVA) (Archer et al., 2010) indicates some broad future trends at the country-scale. The model projects an increase in the median temperature of more than 3°C over the central and northern interior regions of South Africa by 2100. 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.

Over the same time period (by 2100) 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. 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. Statistical downscaling results indicate that the median duration of dry spells for the mid-21stcentury may be expected to increase along the western and northern margins of South Africa between spring and autumn, compared to1961-1990.

Downscaled climate change modelling of the change in the annual number of consecutive dry days undertaken for SARVA (Archer et al., 2010) suggests that in the near term (2021 – 2050) there will be an increased drying and associated risk of drought in the western and north eastern parts of the country, becoming more pronounced in the long term (2071 – 2100). What is critical to note, however, is that the model projections also indicate a large range of probabilities, which is significant and suggests that in some parts of the country (particularly the southern and eastern cape) the direction of change is not certain, and may alter over the near term and long term.

3.3. Current and Future Climate - A Provincial Level Snapshot

Current and future climate projections for North West are discussed below in Chapter 4, section 4.3.

The maps below capture the present-day temperature and rainfall profile of the North West province.
Mean annual temperatures tend to be highest in the northern regions of the province.

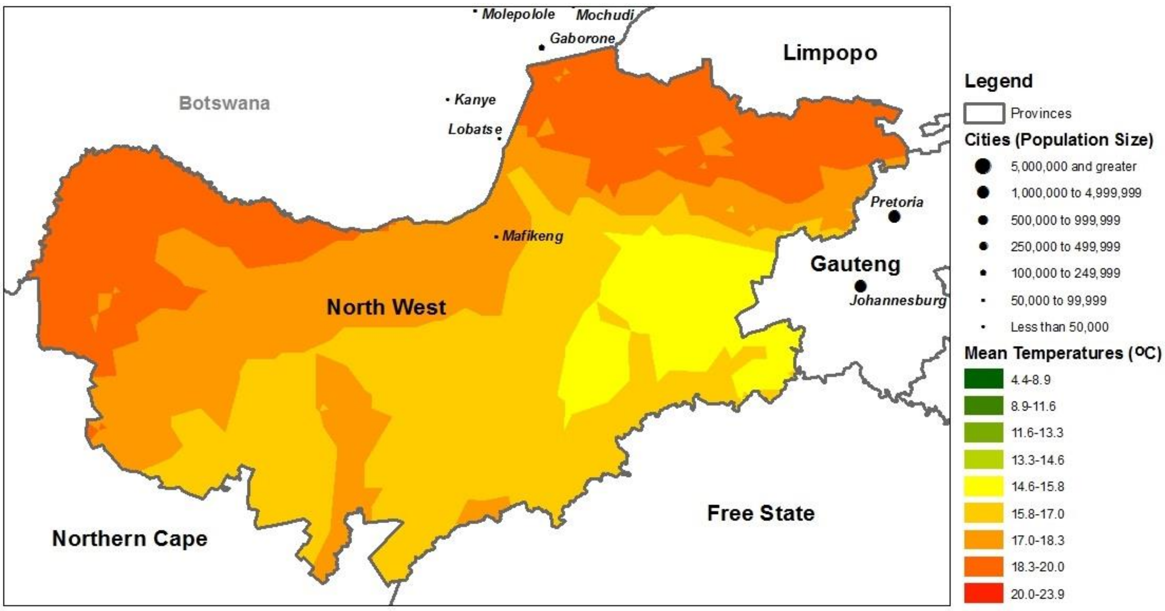


Figure 5: North West Mean Annual Temperature in Degrees Celsius (Data Source: WorldClimate 2015)

Mean annual Precipitation tends to increase towards the eastern regions of the province.

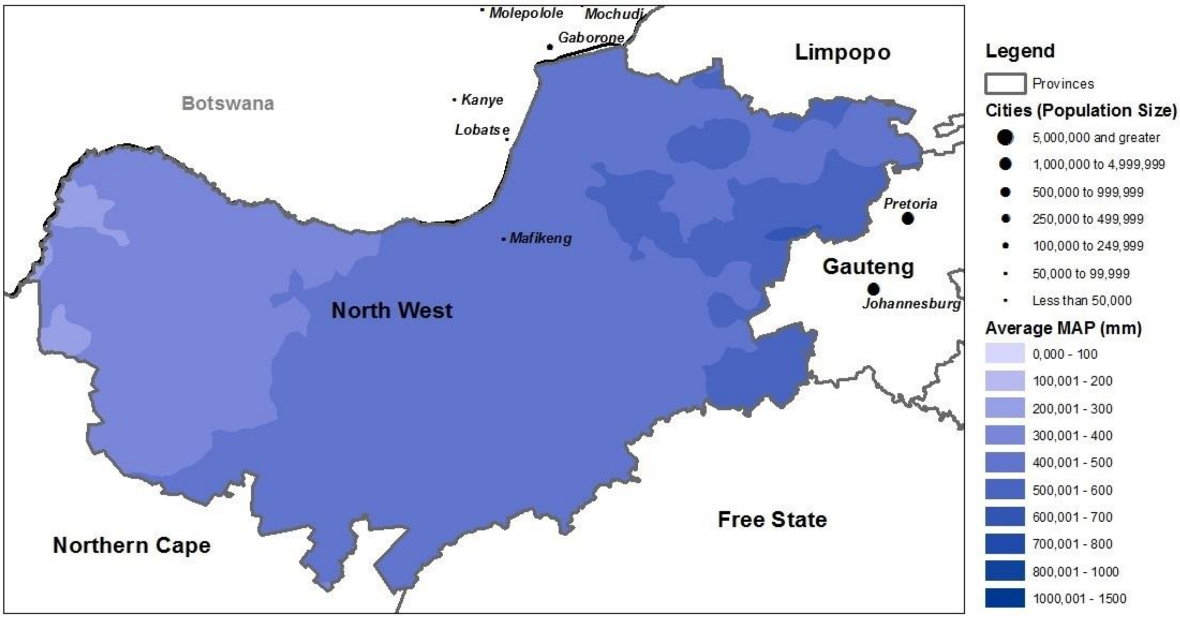


Figure 6: North West Mean Annual Precipitation in millimetres (Data Source: WorldClimate 2015)

These temperature and rainfall pictures are likely to change in the future. The Long Term Adaptation Scenarios (LTAS) project suggests that the region within which North West province is located is likely to face a potential increase in temperatures by as much as 2.5°C by 2035, and 1-3°C between 2040 and 2060 (or even 2-5°C in the high-end scenarios), and by 3-6.5°C between 2080 and 2100 (or as much as 5-8°C in the high-end scenarios). LTAS projects decreased rainfall over the North West in the long term, but rainfall projections in the LTAS project remain within the realm of present-day variability (i.e. they do not show a statistically significant departure from current patterns). Other studies suggest that there may be moderate future increases in rainfall in the region, attesting to the uncertainty in model projections for this region of Southern Africa within the existing body of knowledge. However, what emerges out of such uncertainty is that the region is likely to experience greater variability in rainfall, and will almost certainly witness an increase in evaporation rates, implying a drier future even in the presence of greater rainfall and heavy rainfall events.

3.4. Uncertainty Involving Climate Impacts in South Africa

The major climate features that dominate South Africa are shown below. They have a geographic influence on different parts of the country, as well as being drivers of climate variability.

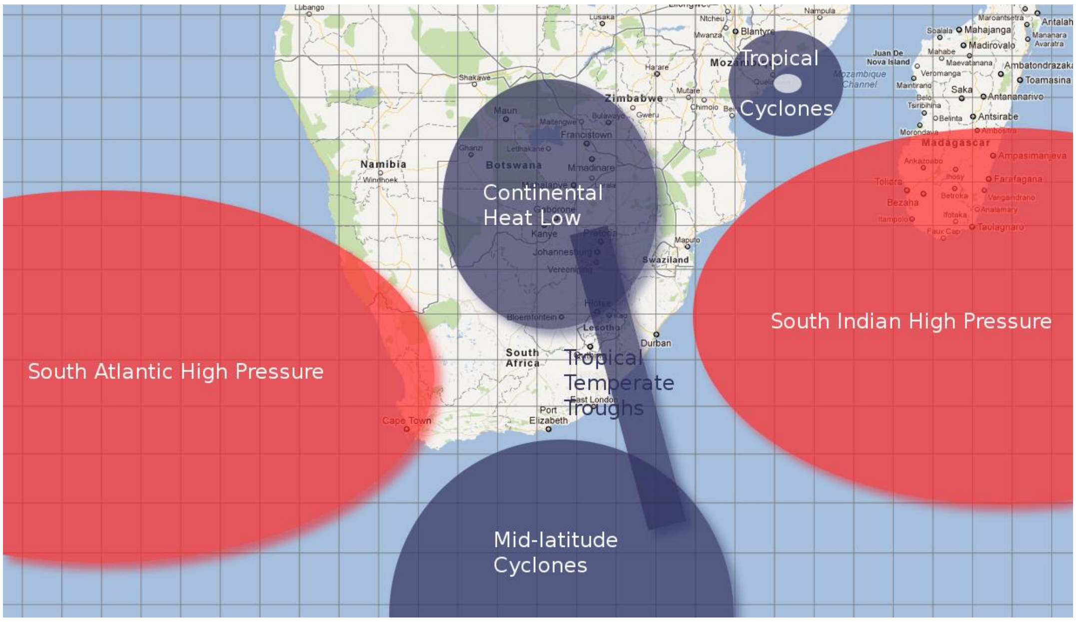


Figure 7: Major Climate Systems influencing South Africa[2]

The interaction of these climate features with seasonal solar and temperature variation drive the seasonal and inter-year precipitation patterns across the country.

The most commonly used method for determining the impacts of climate change is to use General Circulation Models (GCMs), which allow the simulation of most of the key features of climate on a global scale. GCMs use a very high spatial resolution (typically 250 km^2 grids or units). At this scale GCMs are less accurate in their projections, particularly about rainfall, which is influenced by several localized factors including physical relief. Therefore, to assess local or provincial impacts from climate scale, outputs from the GCMs are often downscaled to an appropriate resolution. The process of downscaling involves the interpretation of results from GCM models in relation to local climate factors and dynamics. [**Note:** the scope of the current project does not permit commissioning of a large scale GCM downscaling. However, Chapter 4 of this report provides current and future climate change/ vulnerability scenarios based on credible, peer reviewed climate science as captured within South Africa's Long Term Adaptation Strategies (LTAS) program. The LTAS is also informed by extensive, high quality climate modeling and GCM downscaling.

The LTAS project's results can be encapsulated in three main categories of findings:

1. **There is a clear increasing trend in temperatures across South Africa, and temperatures are projected to rise more in the interior regions than on the coast.**
2. **There is ambiguity about rainfall trends across South Africa, with implications for the northern provinces of South Africa that total annual rainfall could either increase over time with climate change, or it could also decrease. Depending on the type of downscaling**

[2]Pegasys Strategy and Development, Internal Background Document for LTAS Water Sector Report

used (statistical versus dynamical) and the specific climate scenario used for downscaling, results imply that wet season (winter) rainfall is likely to increase overall, but there is also the possibility of a decrease of precipitation. There is, however, significant uncertainty in these findings and statistically there is no significant departure from current rainfall variability patterns.

3. **Even in a potential future with higher rainfall totals, the increase in temperature suggests an increase in evaporation, thus even if rainfall increases, conditions may get drier and water availability may decrease overall.**

Specifically, GCM downscaling for the LTAS program provided the following findings:

- Across South Africa, surface air temperature shows a general warming across the board, but most strongly in the interior regions. Warming is expected to be around 1°C increasing to around 3°C in the northern interior by the middle of the current century. By the end of the century the rate of warming is expected to be even greater, depending on the level of future greenhouse gas emissions.

- Changes in temperature will lead to changes in evaporation from soil, plants and water surfaces).

- Through 2065, annual temperature will increase by an estimated 1.5 to 2.5 °C along the coastline and by approximately 3.0 to 3.5 °C in the interior. This is largely due to the moderating influence of the ocean on temperature. Towards the end of the century, temperature change will become more rapid, with projected increases of 3.0 to 5.0 °C along on the coast and more than 6.0 °C in the interior.

- Annual variability is expected to increase in the northern parts of the country and decrease in the south.

Maximum and minimum temperatures are also important indicators of climate change, and they additionally influence evaporation rates. GCMs downscaled for LTAS indicated the following in relation to January and July maximum and minimum temperatures:

- Through 2065, January maximums are expected to increase by 2 to 3°C with an east to west gradient. July minimums are also expected to increase by 2 to 3 °C but with a more south to north gradient. Most of the country will experience an increase in the inter-annual variability of the July minimum temperature. Towards the end of the century, January maximums are expected to increase by 4°C in the east and more than 6°C in the northwest. July minimums are expected to decrease by less than 4°C along the southwest coast and more than 6°C in the interior. The rate of change will increase markedly in the second half of the century. Variability in January maximums is expected to increase by more than 30% in the central and northern interior and decrease by up to 30% along the west coast.

In comparison to temperature trends, the precipitation projections from GCM downscaling are not as clear regarding rainfall trends. Even though there exists some uncertainty about future rainfall patterns in South Africa, some high level implications can certainly be drawn from what is known. Some of the reasons for the uncertainty is the interaction of the various forces that shape rainfall across South Africa, and the non-linear nature of the results of the interactions. Another layer of uncertainty results from different modeling approaches pointing to slightly different outcomes.

The mid-latitude cyclones cause the cold fronts that produce rain during winter in the Western and Southern Cape, while the South Atlantic High shifts southward to cause dry weather during summer in the western parts of the country. The effects of the South Atlantic High are expected to strengthen under a warming climate, thereby driving the mid-latitude cyclones southwards, with a possible reduction in winter rainfall. Generally, the number of rain days is expected to decrease in the western parts of the country, whereas localized orographic rainfall in the coastal mountains is expected to increase year round.

However, the interaction between the tropical temperate troughs, the South Indian High and the Continental Low results in moist air being channeled into the central interior and east coast during summer. This is combined with local convective rainfall along the east and south coast. Tropical cyclones occasionally affect the northeastern region in summer, whereas the highpressure anti-cyclone results in dry winters in the eastern and interior parts of the country. Total summer rainfall, number of rain days and rainfall intensity are all expected to increase under a warming climate.

While many of the models reflect the trend of wetting in the eastern parts and some drying in the west of the country, a couple of the models reflect a strong drying trend across the country. This has an important implication for the climate change predictions by shifting the range of possible climate futures to include a much dryer future across the country. While this does raise the level of uncertainty in South Africa's possible climate futures for now, what it means is that any South African climate assessment and strategy must consider a much more challenging climate scenario and be better prepared for a broader range of potential climate outcomes.

The bottom line is that in creating adaptation strategies (in the follow-up report), the next stage of the project must develop strategies that address an environment of increasing temperature in North West province, and take into account the possibility of a drier future, but must build into them the likelihood of greater variability and unpredictability in rainfall, including both more heavy, intense precipitation events and longer dry spells and increased water stress (CSIR, 2010).

3.4.1. Types of Impacts from Changing Climate Indicators

The reason changes in temperature and rainfall (i.e. exposure) are considered as a factor in climate risk is because of the range of consequences they can produce in a climate system and on terrestrial, aquatic, and marine systems. **Error! Reference source not found.** below summarizes the types of impacts possible (DRDLR, 2013a)

CHANGE IN CLIMATE VARIABLE	TYPE OF CHANGE	IMPACT
Temperature Rise	Increased number of warm and very hot days, and increased daily maximum temperatures	• Increased evaporation impacting on the availability of surface water; • Soil degradation due to increased acidity, nutrient depletion, declining microbiological diversity, lower water retention, and increased runoff; • Positive or negative impacts on crops' growing seasons, yields, and growing range. Some crops – especially fruits – require a chill factor (a period of cold) in the winter to have a good harvest; • Increased incidence of heat waves and associated health conditions for human and livestock health, such as heat stress. Heat especially impacts the health of the particularly old and young or those already suffering from other illness; • Increase in concentration and range of pests and pathogens that are human and livestock disease vectors (carriers), such as mosquitos and ticks; • Increased risk of drought conditions, and of wildfires, plus associated damage to crops, property, and infrastructure.
Change in Rainfall	Increased number of consecutive dry days	• Decreases in runoff and streamflow and an increased risk of drought, affecting crop production, food security, and rural livelihoods; • Reduced streamflow (a particular threat for communities dependent on surface water); • Loss of soil moisture affecting crops and increased risk of soil erosion due to wind; • Increased risk of veld-fires and resultant threat to property, grazing, and crops;
	Increased number of wet days and/or increase in extreme (heavy) precipitation events	• Increased risk of floods and consequent damage to property, crops, and loss of life; • Water logging of soil which can affect crops; • Increased risk from water borne diseases, particularly after flood events; • Damage to bulk infrastructure such as irrigation systems; • Damage to property and crops from winds associated with violent storms; • Increase in lightning events which can damage crops and cause loss of life;
	Variability or change in the timing of precipitation	• Rain-fed agriculture, which relies on the timing of rains for planting and harvest, is particularly at risk; • Less predictability impacts the management of water resources in catchments and for large water infrastructure, with implications for water supply reliability.

Table 3: Types of Impacts Possible (DRDLR, 2013a)

Explanation of the Intergovernmental Panel on Climate Change's (IPCC) Climate Change Scenarios

In this report about climate change vulnerability in North West province, readers will find various references to climate change scenarios used by the Intergovernmental Panel on Climate Change (IPCC) to project a range of potential future climate change impacts, depending on various factors (the IPCC is the world's leading body of climate scientists from over a hundred countries, who synthesize and endorse the best available science on climate change). Scenarios help compare research findings of different groups, by creating a common framework for the projections – including starting conditions, historical data, and key trends. While these scenarios (used to run computer models to predict likely outcomes) have technical names, the underlying futures they represent can be described as below.

Representative Concentration Pathways (RCPs)

Representative Concentration Pathways are different scenarios used by global climate scientists in the latest report from the IPCC - the Fifth Assessment Report (AR5) in 2014. Each pathway indicates a different trajectory of global emissions, i.e. a different concentration of greenhouse gases as an outcome, plus a different approach or path to getting there over time. These scenarios help give us a better understanding of what is likely to happen down the line depending on when we act to reduce emissions and by how much. (NOTE: Radiative forcing refers to the change in energy levels in the atmosphere).

- RCP 8.5: Radiative forcing of 8.5 watts/square meter in 2100; rising greenhouse gases; 1370 parts per million of carbon dioxide equivalent in the atmosphere. *Temperature rise of ~4.9 degrees C by 2100.*
- RCP 6: Radiative forcing of 6 watts/square meter in 2100; stabilizing greenhouse gases; 850 parts per million of carbon dioxide equivalent in the atmosphere. *Temperature rise of ~3.0 degrees C by 2100.*
- RCP 4.5: Radiative forcing of 4.5 watts/square meter in 2100; stabilizing greenhouse gases; 650 parts per million of carbon dioxide equivalent. *Temperature rise of ~2.4 degrees C by 2100.*
- RCP 2.6 (or RCP3PD): Radiative forcing of 3 watts/square meter before 2100, peaking and then declining to 2.6 watts/square meter in 2100; greenhouse gases that rise and decline; 450 parts per million of carbon dioxide equivalent in the atmosphere. *Temperature rise of 1.5 degrees C by 2100.*

Older IPCC Scenarios

The 2007 IPCC Fourth Assessment Report (AR4) relied on slightly different scenarios, which are still seen in a great deal of climate science literature. The futures these scenarios represent are:

- A1F1: Population of ~7 billion in 2100; very high economic growth; very high energy use from fossil fuels; low land-use change. *Temperature rise of ~4.5 degrees C by 2100* (close to RCP 8.5).
- A1B: Population of ~7 billion in 2100; very high economic growth; very high energy use but balanced between all fuel sources – fossil and non-fossil; low land-use change. *Temperature rise of ~3 degrees C by 2100.*
- A1T: Population of ~7 billion in 2100; very high economic growth; very high energy use but primarily from non-fossil fuel sources, i.e. low-carbon energy; low land-use change. *Temperature rise of ~2.5 degrees C by 2100.*
- A2: Population of ~15 billion in 2100; medium economic growth; high energy use but from a mix of different fuels without a dominant source; medium levels of land-use change. *Temperature rise of ~4.5 degrees C by 2100.*
- B1: Population of ~7 billion in 2100; high economic growth with tertiary sectors dominating; low energy use due to efficient technologies; high land use change (more afforestation). *Temperature rise of ~2 degrees C by 2100* (close to RCP 4.5).
- B2: Population of ~10 billion in 2100; medium economic growth; medium energy use from a variety of sources, but more clean energy; medium land use change. *Temperature rise of ~2.5 degrees C by 2100*(close to RCP 6).

4. Climate Change and Development – A Provincial Snapshot

4.1. Current and Projected Development in the North West Province

In addition to climatic factors (which determine exposure), current and future development patterns in the province contribute significantly to what makes the province (and regions within it) susceptible to the impacts (i.e. sensitivity). Development also increases the capacity of the province and relevant sectors to cope with the changes, and thereby understanding development trends is also key to understanding current and future resilience (adaptive capacity). Various development plans within the province, as well as development plans at the national level that have implications for the province, are instructive in developing this understanding.

The North West Spatial Development Framework: The North West Spatial Development Framework of 2010 has identified interventions in a number of zones in the province. As can be seen from the discussion below, the zones include zones of high economic activity, rural areas, and environmentally sensitive areas. The identified zones are as follows:

- **Zone 1: Main Economic Growth Areas for prioritised development spending.** In order to reach and maintain a 6% growth rate, resources and collaborative government action should be concentrated on maintaining and growing the economy. It is thought that the current transport and tourism corridors should be reinforced. As far as transport corridors are concerned, in addition to the current Platinum, Treasure and Western Corridors, there is a proposed new corridor from Potchefstroom through Ventersdorp, Coligny, Lichtenburg to Mafikeng to Botswana to promote North-South interaction to markets and mobility.

  The spatial development framework sees substantial growth in agricultural, mining and manufacturing sectors. In his 2015 State of the Province Address, the premier announced that Agriculture is at the top of the province's economic development strategy, followed by Culture, Arts and Tourism. As far as the agricultural sector is concerned, the spatial development framework envisages, among other things, targeted institutional support for small-scale farmers with limited expansion of irrigation, including better utilisation of the Taung irrigation scheme. The deterioration of water quality of Hartbeespoort Dam is of concern to the irrigation farmers in the region. The strategy also envisages support for movement towards more diversified production systems. Sustainable resource management is also emphasized.

  Investment in new mining opportunities in the Bojanala Platinum and Dr Kenneth Kaunda Districts is envisaged. It is noted that provincial government, in conjunction with relevant role-players should put the necessary measures in place to address the environmental rehabilitation of closed mining areas and the alternative uses of such land for agricultural or industrial purposes.

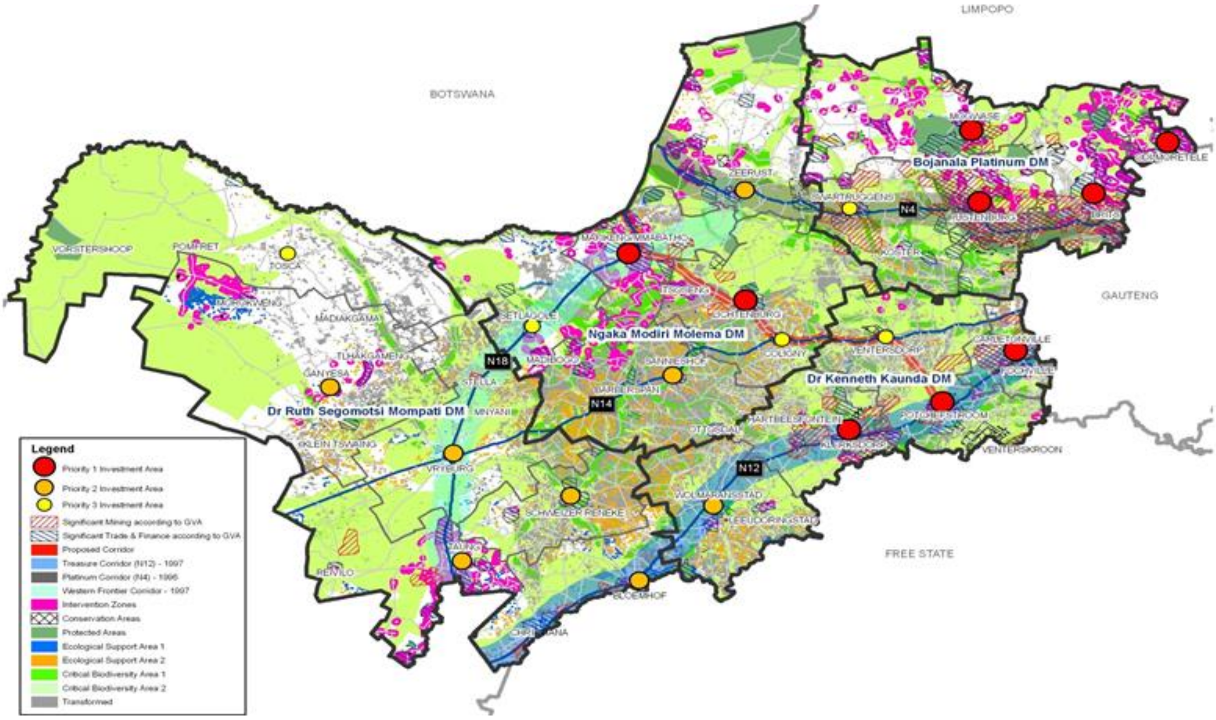


Figure 8: Development Strategies for the North West province (NWPG, 2008)

- **Zone 2: Social Inclusion Areas representing areas for investment in people rather than places**. Zone 2 is rural-focused and promotes the concept of social inclusion by promoting and strengthening overlaps in economic activity and poverty to address high levels of spatial fragmentation and exclusion

- **Zone 3: Stimulating and kick-starting New Potential Growth Nodes.** Zone 3 will identify and focus on the emergence of potential new nodes where spatial overlaps between areas of economic activity and areas of poverty occur.

- **Zone 4: Environmentally Sensitive Zones.** This zone will largely concentrate on future sustainable development approaches in terms of sustainable development spending. Under this zone, four category areas have been identified: ***Category 1:*** Protected Areas; ***Category 2*****:** Critical Biodiversity Areas (irreplaceable sites; important sites; terrestrial ecological corridors; aquatic ecological corridors; special habitats; critical wetlands; critical estuaries; critical sub-catchments; critically endangered ecosystems; endangered ecosystems); ***Category 3:*** Other natural areas; ***Category 4:*** Areas where no natural habitat remains.

The North West Provincial Development Plan 2030: The North West Provincial Development Plan has identified a number of sectors for growth in the province, and these include agriculture, mining, construction and infrastructure, renewable energy, tourism and others.

The gross value added (GVA) growth targets for the province towards 2030 are shown in the table below. In simpler terms, this means that the table shows the goals that the province has set for itself in terms of the annual average growth of major sectors and the current and projected revenue from the sector to the province in millions of Rand.

Table 4: Average Annual GVA in millions of Rand, and Growth Rate 2030 (PDP, 2013).

Sector	Historical Annual Average Growth Rate (2000 – 2010)	2010	Target Average Annual Growth Rate (2010 – 2030)	2030
Agriculture	2.0%	R 3.39	8.5%	R 17.31
Mining	0.1%	R 54.97	2.5%	R 90.08
Manufacturing	2.5%	R 7.18	8.7%	R 38.07
Electricity	1.9%	R 2.12	9.1%	R 12.09
Construction	8.2%	R 3.46	8.0%	R 16.12
Trade	3.4%	R 15.81	6.1%	R 51.67
Transport	5.0%	R 10.79	5.6%	R 32.07
Finance	6.0%	R 19.47	6.5%	R 68.23
Community Services	2.9%	R 28.55	6.0%	R 91.57
TOTAL / AVERAGE	2.7%	R 145.73	5.40%	R 417.22

Even though the mining sector is not tipped to grow very quickly to 2030, it will remain one of the largest contributors towards the GVA of the province.

4.2. Current Climate Variability

Rainfall in the North West province is highly variable both in time and regionally (READ, 2014). On average, the western part of the province receives less than 300mm of rain per annum, the central part around 550mm, while the eastern and south-eastern parts receives over 600mm. The highest rainfall occurs in the summer months between October and April; rainfall is very low in winter. A large proportion of rain occurs as thunderstorms with heavy gusts of wind, lightning, hail and flash-floods. The province is considered to be semi-arid (annual rainfall totals approximately 539mm) (DACE, 2008). Droughts and floods occur regularly at both provincial and local scales, and play a significant role in almost every aspect of the social, economic and ecological environment within the province. Evaporation exceeds rainfall in most parts of the province, and as a result the North West province relies heavily on ground water resources to meet its needs.

There are wide seasonal and daily variations in temperature, with very hot weather in summer (daily average high temperatures of 32ºC in January) and mild to cold weather in winter (average daily minimum in July is 0.9ºC) (DACE, 2002). There is a high variance between minimum and maximum temperatures; daily maximums range from 17 to 31ºC in the summer (October to April) and 4 to 20ºC in the winter (May to September) (DACE, 2008).

4.3. Future Climate Change Scenarios and Projections

The climate-water zones reflected in the figure below were developed as part of the draft water sector climate adaptation strategy of DWA, and are defined according to the institutional boundaries of the Water Management Areas (WMAs), grouped according to climate and water characteristics. This figure is helpful to understand which climate-water zone the North West province falls under, Zone 3.

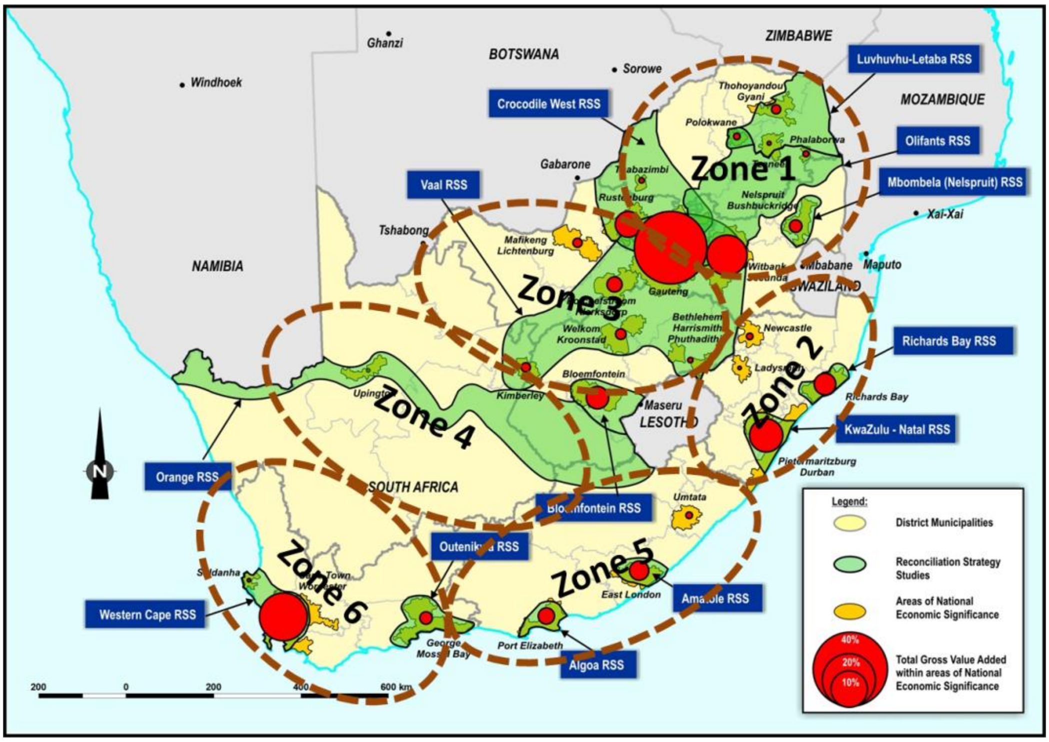


Figure 9: Climate zones in relation to key economic areas and their existing water supply systems (DEA, 2013b)

The zones – which were also used in all the LTAS climate change studies -- are as follows:

- **Zone 1:** the Limpopo, Olifants and Inkomati WMA in the northern interior.
- **Zone 2**: the Pongola-Uzimkulu WMA in KwaZulu Natal in the east.
- **Zone 3:** the Vaal WMA in the central interior.
- **Zone 4:** the Orange WMA in the north-west.
- **Zone 5:** the Mzimvubu-Tsitsikamma in the south-east.
- **Zone 6:** the Breede-Gouritz & Berg Olifants WMAs in the south-west.

The North West province falls mainly within Zone 3, with some portions falling within Zone 4. Future climate predictions for temperature and rainfall for Zone 3 are shown in the figure below from the LTAS study, and then summarised in the sub-sections that follow.

The figure below is a depiction of future temperature and rainfall projections for the North West province under the RCP8.5 scenario (i.e. highest temperature rise). The grey points show the median figures of the projections. What this implies is that while temperature in the province is expected to rise significantly over the historic baseline, rainfall projections do not change significantly from the current trends (and the direction of rainfall change is indeterminate).

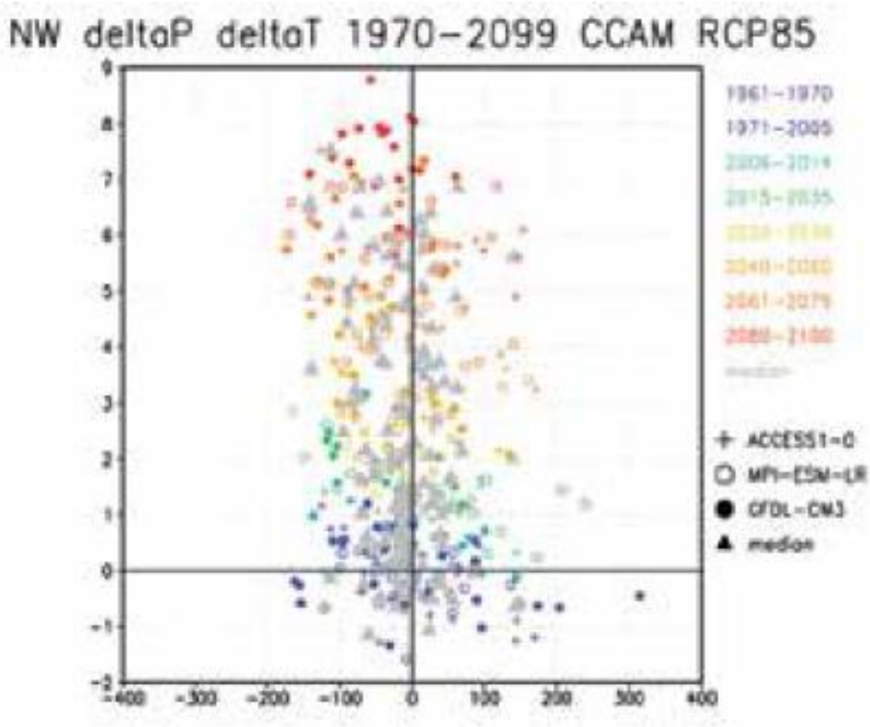


Figure 10: Projected Annual Temperature (degrees Celsius, x-axis), and rainfall (mm, y-axis) for the period 1971-2099 relative to the 1971-2005 baseline climatology, for the six CCAM downscaling under the RCP8.5 scenario. For each year, the median of the ensemble of projected changes is shown in grey (DEA, 2013a)

4.3.1. Temperature

The LTAS study (DEA, 2013a) shows the following climate change impacts on temperature, for Zone 3:

- For the near future (2015-2035), annual temperature anomalies under the A2 and RCP8.5 scenarios are drifting outside the present day climatological regime of North West, reaching values of 1 to 2.5ºC
- For the mid-future period (2040-2060) temperature anomalies of between 1 and 3ºC (2 to 5ºC) are projected in the A2 scenario (RCP8.5).
- Drastic increases in annual average temperature of 3 to 6.5ºC (5 to 8ºC) are projected over zone 3 (North West) for the period 2080-2100 relative to the baseline period under the A2 (RCP8.5) scenario.
- The RCP4,5 future implies significantly reduced increases in temperature, with annual anomalies remaining below 4ºC in the far future (2080-2100). There are indicators of general but modest drying, with negative annual rainfall anomalies projected that are somewhat larger in amplitude than any of those simulated under present day conditions.

4.3.2. Rainfall

The LTAS study (DEA, 2013a) shows the following climate change impacts on rainfall, for Zone 3:

- Rainfall anomalies projected for North West exhibit a drying pattern under both the A2 scenarios and RCP 8.5, though the projected rainfall anomalies remain within the realm of present day climate (DEA, 2013a).
- A summary from UNICEF (2011) of the regional climate impacts across South Africa on key climate variables for the distant future is shown in the table below, it shows a moderate increase in annual average rainfall for the North West province.

  As noted above, the table below captures future projected changes in South Africa's provinces due to climate change. The North West province is identified as part of the Interior region, and as evident below the table summarizes the changes expected in average annual temperature (expected to increase), total annual average rainfall (which could see a moderate increase), the intensity of rainfall (expected to show large variability), and the total days with no rainfall (not much change).

Table 5: Summary of Projections in Changes to Key Regional Climate Variables for the Distant Future across South Africa (UNICEF, 2011).

	Average annual temperature & number of 'hot' days and nights	Total annual average rainfall	Rainfall intensity, and number of heavy rainfall events annually	Total days with no rainfall (p.a.)
North-East (Limpopo, Mpumalanga, Gauteng)	Moderate increase	High increase	High increase	Moderate decrease
Interior (Free State, North West)	High increase	Moderate increase	High variation (increase in some areas, decrease in others)	Little/no apparent change
West (Western Cape, Northern Cape)	Slight increase	High decrease	Moderate/high decrease	Moderate increase
South-East (Eastern Cape, KwaZulu-Natal)	Slight increase	High increase	High increase	Moderate decrease

- Unlike temperature, where there is a strong warming trend, with rainfall available information the trend is inconclusive trend. However, rainfall is expected to be more variable, as shown in the figure below.

  The map below, from the Department of Rural Development and Land Reform, shows what several climate models (GCMs) indicate about changes in rainfall variability in the future through mid-century (2046-2065). Most of the province (as based on current borders) is likely to see changes in rainfall, and in several cases the variance could mean less rainfall.

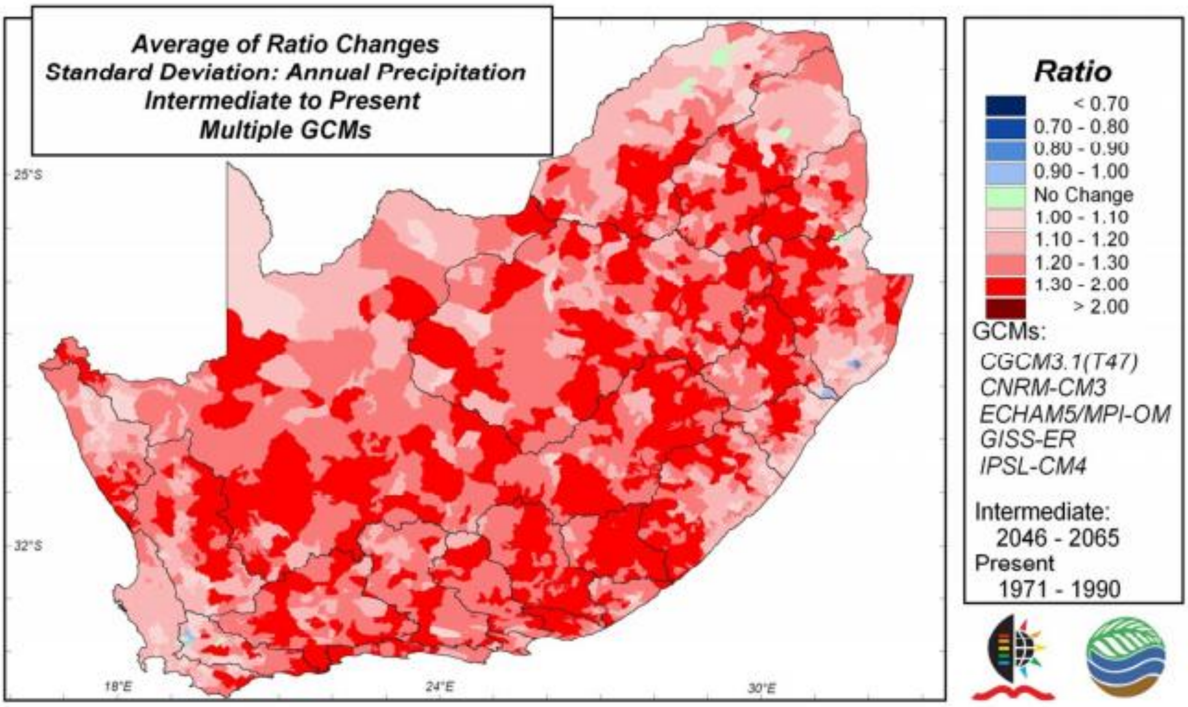


Figure 11: Changes in Rainfall Variability (DRDLR, 2013a)

5. Climate Vulnerability Assessment

Listed in the table below are the key sectors and sub-sectors that this vulnerability assessment will focus on:

Table 6: List of key sectors and sub-sectors for North West

SECTOR	SUB SECTOR
Ecosystems	Aquatic (rivers, lakes, wetlands)
	Terrestrial (biodiversity, forests, invasive species)
Livelihoods	Rural
	Urban
Economic Activity	Agriculture / Farming
	Tourism
	Extractives
Infrastructure and Utilities	Water Supply
	Energy Supply
	Transportation
Public Health and Safety	Human Health (diseases etc.)
	Extreme Weather / Disasters (wild fires, floods, drought)

In the discussions below, an analysis for climate sensitivity, exposure (and thereby risk), adaptive capacity for both the short term (2015-2020) and long term (2020-2040 or mid-century) will be conducted. The assessment will be on a basis of assigning values of low / medium / high based on what existing climate literature and our intelligence-gathering in the province indicate. This will enable identifying the areas or sectors of greatest vulnerability in order to focus more intently on those priority areas and tailor adaptation strategies for them going forward.

Climate change has the potential to adversely affect the economy, natural resources and society. Changes to both weather patterns and longer-term climate will induce changes, and the exposure faced by the economy and people to climate and weather-related risks will increase. Warmer temperatures, for example, will affect crop selection for agriculture, habitat suitability for wildlife, water availability for mining, energy usage by urban populations and the spread of diseases. In terms of energy and water supply, the North West province will be affected by the implementation of the Integrated Resource Plan for Electricity (IRP 2010-2030) (DOE, 2013) and updates to the National Water Resources Strategy; both of these could affect the cost and variability of these commodities and force changes to the way in which services are provided in the province (READ, 2014).

5.1. Ecosystems

5.1.1. Terrestrial (biodiversity, forests, invasive species)

5.1.1.1. Introduction

The diversity of the North West ranges from the majestic Magaliesberg mountain range in the east to unique dolomitic springs, eyes and sinkholes dotted in the bushveld and savannah plains in the central region to the arid plains of the Kalahari in the far western region. The province is primarily covered by savannah biome with its associated bushveld vegetation (71%) and to a lesser extent the grassland biome, which contains a wide variety of grasses typical of arid areas. In the grassland areas, water flow regulation is one of the most important ecosystem services necessary for economic development.

At a finer scale, there are a total of 61 provincially-determined vegetation types, or ecosystems types, which are nested within the 41 nationally recognised vegetation types (SANBI, 2011 in READ, 2014).

There are approximately 2,221 plant species, 120 mammals, 480 birds, 34 amphibians and 123 reptiles in the province. Several species are endemic to the province (READ, 2014). The map below shows the distribution of the main biomes in South Africa, and it is clear that the primary biomes in the North West are savannah and grasslands.

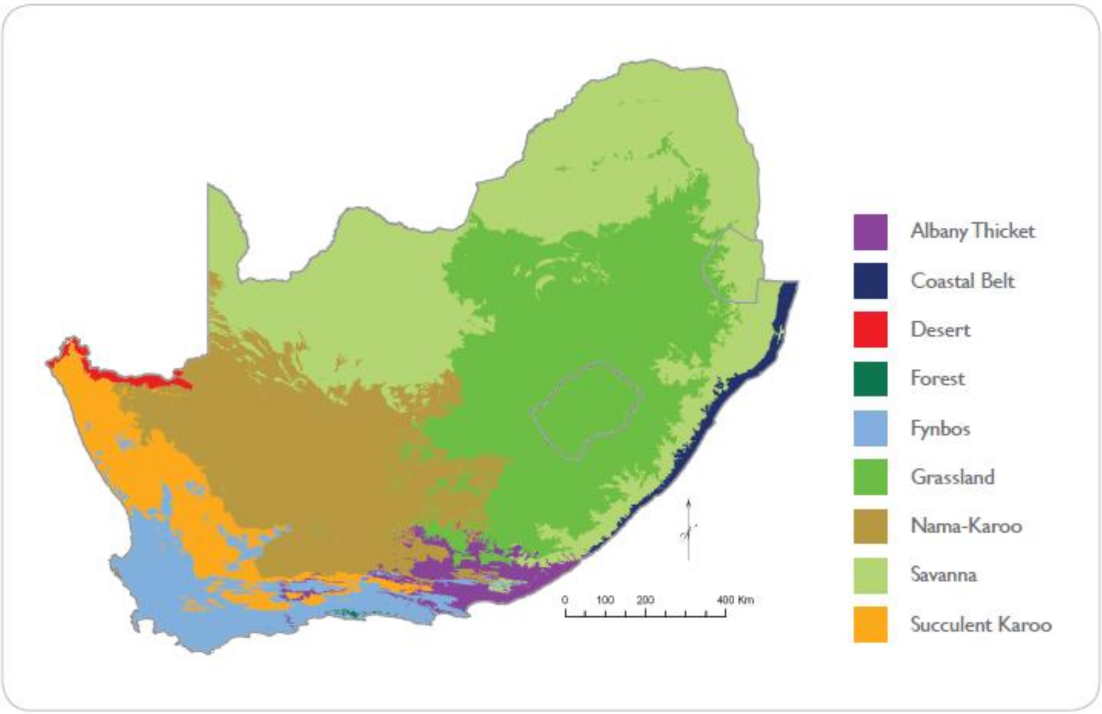


Figure 12: South Africa's Biomes (DEA, 2013d)

The map below is from the North West Biodiversity Conservation Assessment and it shows the various vegetation types spread across the province.

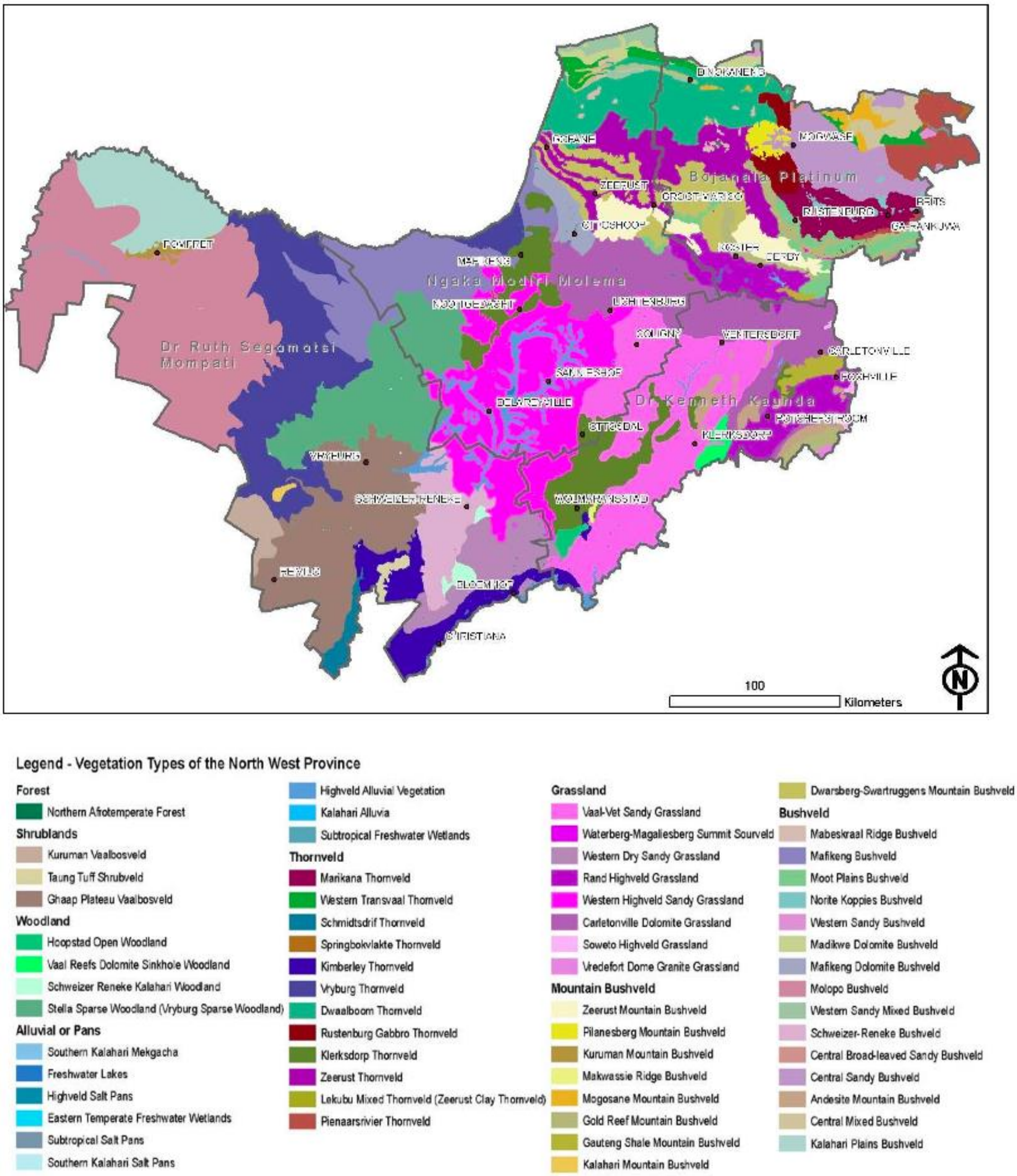


Figure 13: North West Vegetation (North West Biodiversity Conservation Assessment Technical Report)

Risk and Vulnerability

Risk

- **Sensitivity: Medium**

  The main biomes in the North West are savannah and grasslands. The sensitivity of savannah to temperature is generally low; savannah plants are not predicted to be overly sensitive to increases in temperature as savannah seedlings can germinate at a wide range of high temperatures. However, savannah plants have been shown to be sensitive when temperatures reach extreme highs, and they are also susceptible to rainfall variability (since savannah seeds need frequent rain during their germination stage).

  Grassland biomes are sensitive to temperature and rainfall changes. Furthermore, since grassland is important for groundwater recharge, the sensitivity of grassland to climate change is important (VA Workshop, 2015).

  Temperature forests are sensitive to changes in rainfall, with less rainfall leading to some species of plants drying out. This is an issue in the Magaliesberg region of the North West province (VA Workshop, 2015).

- **Exposure:**

  In the North West, the lack of recent historical warming represents a divergence from the projections of the climate models (READ, 2014). Nonetheless, if projections hold true, significant temperature rises can be expected (such as levels described in section 4.3.1 above).

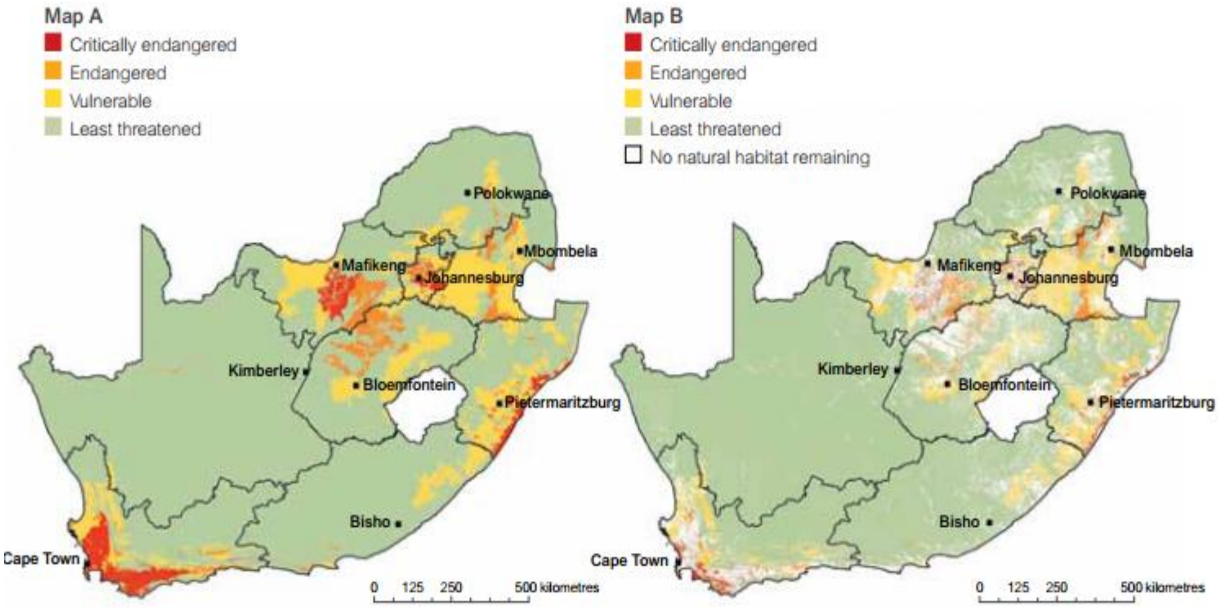
  - **Short Term: MEDIUM**
    In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that the ecosystem is exposed to is not significant. However, even current day changes are already having an impact on the ecosystem (as described below), thus the short term exposure is assessed as medium level exposure.

    A new dataset of land cover for 2010 is currently being processed, but based on a new broad land cover classification, the preliminary analysis indicates that, in the North West province, only 55,6% of the land remains untransformed, 10,2% of the landscape that has been degraded in the past now appears as natural, while 34,4% has been transformed and 0,21% degraded (READ, 2014). It must be noted that land-use techniques[3] in the province are poor (VA Workshop, 2015). Eleven of the 61 vegetation types have been classified as threatened in terms of their ecosystem status. Eastern bushveld and south-eastern grasslands (along the Platinum Belt and Treasure Corridor) are experiencing high rates of current transformation

[3] "Land use is characterised by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it" (FAO/UNEP, 1999) (http://www.fao.org/nr/land/use/en/)

and options for achieving conservation goals are rapidly decreasing. Savannah has been transformed due to land-use activities, and there has been loss of species diversity within the savannah biome. Furthermore, there is little grassland left and little protection of grassland. Finally, air pollution has been impacting on the moisture, i.e., resulting in the drying out of forests (probably afrotemporate forest in the Magaliesberg). This, in turn, has led to growth of alien invasive species (VA Workshop, 2015).

The maps below show how all ecosystems in the North West province (which is a component of the overall national map) have been denuded, included those identified as vulnerable, endangered, and critically endangered.



Our threatened land-based ecosystems: Most of our threatened ecosystems are found near big cities, productive croplands and coastal areas, where large amounts of natural habitat have been lost. Map A shows the original footprint of terrestrial ecosystems. Map B shows what remains of those ecosystems today, with the white areas showing where natural habitat has been irreversibly lost.

Figure 14: Threatened Land-Based Ecosystems (SANBI, 2013)

- **Long Term: HIGH**

Rainfall change and variability is very likely to affect vegetation in tropical grassland and savannah systems with, for example, a reduction in cover and productivity simulated along an aridity gradient in southern African savannah in response to the observed drying trend of about 8 mm/yr since 1970 (IPCC).

For the grassland biome, there is a consistent message of potential significant change and loss of habitat due to climate change, and the possible increase in tree cover due to lengthened growing season and CO_2 fertilization. In addition, this region is likely to increase in importance as a habitat for animal diversity, and thus the conservation response in the region will be critical. Furthermore, the ingress of woody plants into the grassland biome has major implications for water delivery from highland catchments.

For the North West, according to projections under LTAS, the savannah biome is likely to expand with its geographic range partly replacing grassland (DEA, 2013d) (see figure below). Although the climate envelope suitable for savannah is likely to expand significantly in the future, and specific savannah species are likely to benefit, this does not necessarily benefit existing habitats and species assemblages. The increase in the savannah biomes implies a change in suitability of the habitat for certain grassland species, resulting in range reductions or localisation of some species, or mass extinctions of those species with limited geographic ranges. Shifts in biome conditions imply cascading effects, such as changes to hydrological cycles, which then impacts on people. An expansion of the savannah biome could make more areas suitable for game ranching, and thus impacts on other industries (READ, 2014).

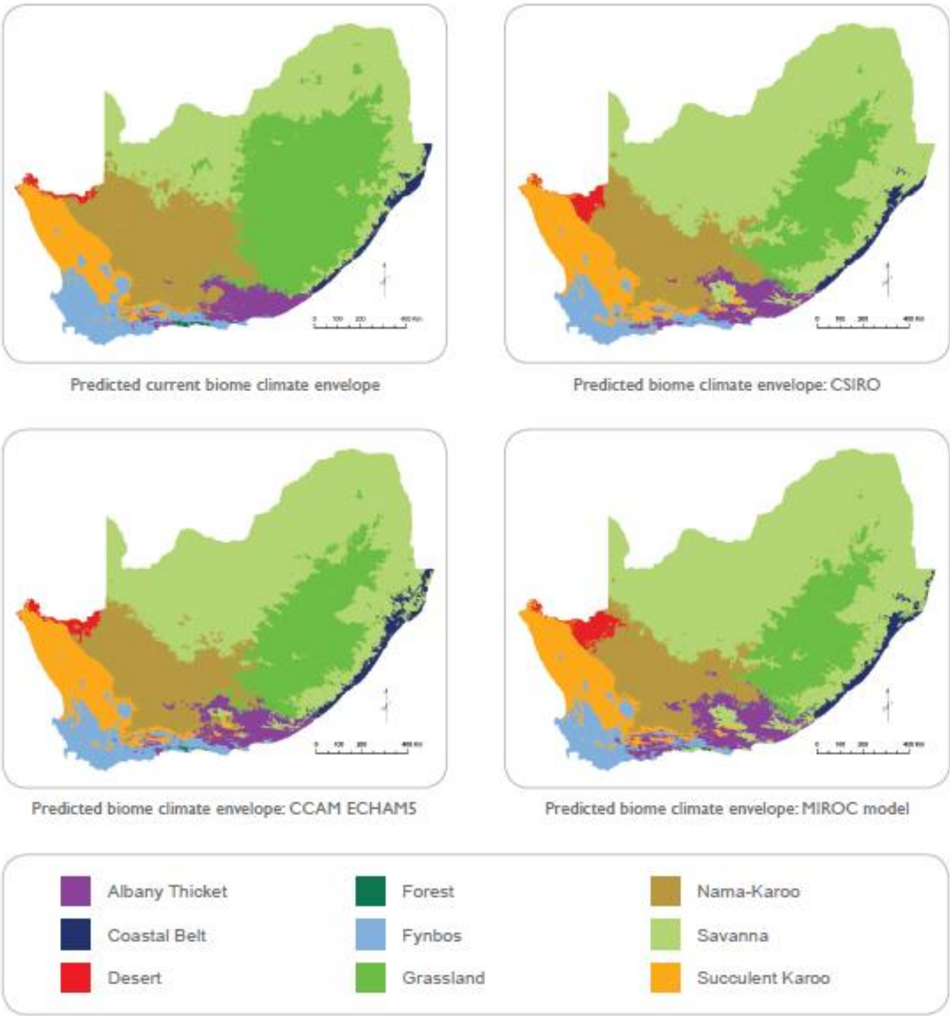


Figure 15: Projections of bioclimatic envelopes under mechanistically downscaled climate scenarios, looking ahead to approximately 2050. CSIRO represents a wetter future, MIROC a drier future, and ECHAM5 an intermediate rainfall future (DEA, 2013d)

Overall, the modelled loss of species richness is lower than projected in earlier work on animal species (DEA, 2013d). Range shift projections for South Africa indicate a low risk for significant bird range shifts that result in species loss as a result of climate change (temperature and rainfall alone) (see figure above), though in a few areas this risk is high, for example in the central interior (DEA, 2013d). The map below projects that bird species richness will be lost the most in the western region of the North West province.

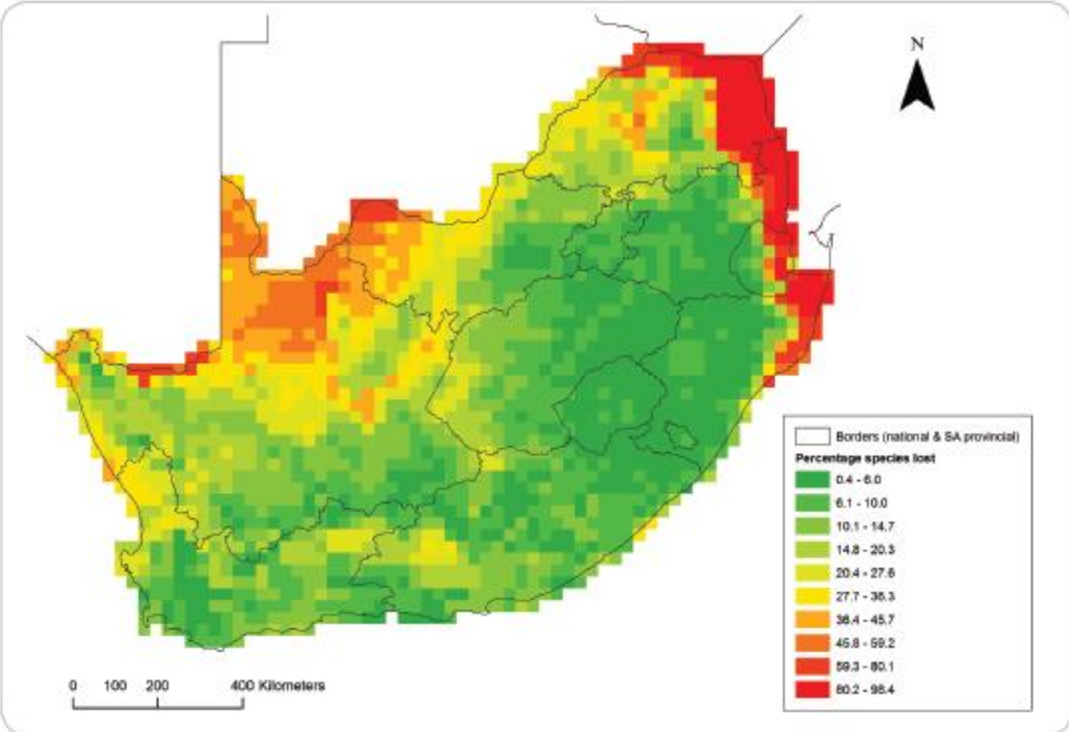


Figure 16: Predictions of Bird Species Richness Loss for South Africa under mechanistically downscaled climate scenarios, looking ahead to approximately 2050. This is based on range modelling of 623 terrestrial bird species (DEA, 2013d)

The potential impacts of loss of biodiversity in the province are as follows (DACE, 2008 and READ, 2014):

- The loss of biodiversity will lead to the loss of critical ecosystem services that support the province's economy and others that are required for human survival (for example, pollination of commercial crops, eco-tourism, rangeland protection, sourcing and purification of water resources)
- Biodiversity loss sparks a negative spiral of progressive ecosystem deterioration and further biodiversity loss due to destabilisation of the integrity of the ecosystem. Habitat loss, fragmentation, bush encroachment, invasive alien infestations and species losses are all a consequence of a reduction in biological variability. Furthermore, an additional identified challenge is the increase in alien

invasive species which, in turn, will lead to increase in fires since alien invasive species are more prone to fire (VA Workshop, 2015)

- There is growing concern about the health consequences of biodiversity loss, due to dependence on productions and services provided by biodiversity and healthy ecosystems (for example, a source of traditional and modern medications). Growing evidence also indicates that the loss of biodiversity and habitat destruction can increase the incidence and distribution of infectious diseases affecting plants, animals and humans, largely due to the removal of predators of disease vectors or the loss of hosts to dilute pathogen transmission
- Loss in quantity and quality of water resources
- Decreased carrying capacity for domestic livestock
- Soil erosion

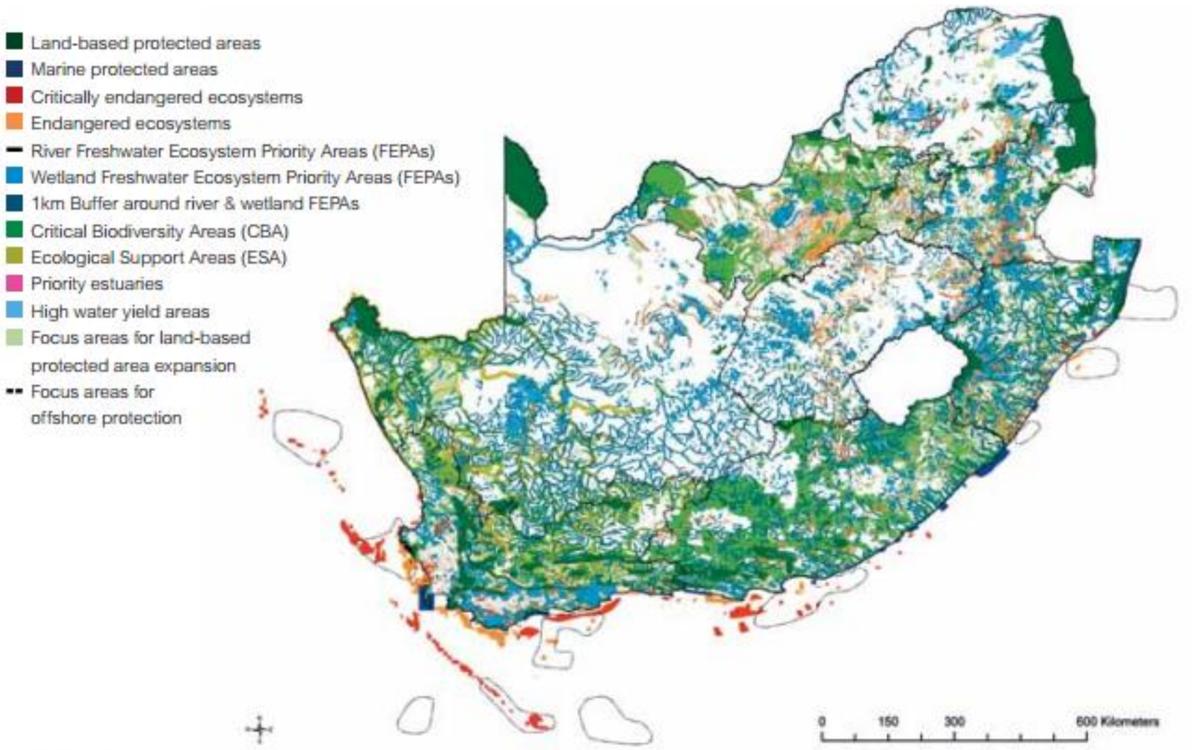
- **Risk:**
  - **Short Term: MEDIUM**
  - **Long Term: HIGH**
    - Savannah – Medium-High (based on stakeholder input in VA Workshop, 2015): Land transformation means that viable ecosystem will be depleted; this will result in desertification and ecosystem fragmentation
    - Grassland – Medium-High (based on stakeholder input in VA Workshop, 2015): There is no buffer capacity around protected areas, that is, human impact leads to loss of resilience in protected areas
    - Afrotemperate Forest (Magaliesberg) – High (based on stakeholder input in VA Workshop, 2015).

Vulnerability

- **Adaptive Capacity:**
  - **Short Term: LOW**
    - Highveld grassland types remain virtually unprotected (IFPRI, 2011). Grassland parks should be included in the adaptive strategy (VA Workshop, 2015)
    - Central bushveld savannah is very poorly protected (DEA, 2013d).
    - The province does not have an up and running biodiversity information system, which means there is little data with which to conduct an assessment. Provincial authorities struggle to make decisions related to the environment in the absence of good or at least some biodiversity data. (DACE, 2008)

▪ The poor institutional environment, lack of capacity and political will to implement environmental policies and legislation is viewed by stakeholders as the largest threat to biodiversity (DACE, 2008).

The map below is an indication that the important steps of identifying areas for protection and conservation have already taken place at the national level, and that these must be translated into planning at the provincial level. In the North West, there are several areas designated as Critical Biodiversity Areas, focus-areas for land-based protected area expansion, endangered ecosystems, and wetland freshwater ecosystem priority areas.



Smart planning: Biodiversity priority areas are grouped into different categories. These aren't mutually exclusive and in many cases overlap. Where categories overlap, it emphasises the significance of an area in terms of its biodiversity and the need to keep that area in good ecological condition.

Figure 17: Biodiversity Priority Areas (SANBI, 2013)

▪ **Long Term: MEDIUM**

Long term adaptive capacity is dependent on implementation of programmes and plans. A few of these are highlighted below.

▪ **Systematic Biodiversity Planning:**

The North West completed the *North West Biodiversity Conservation Assessment* in 2009, which was used to inform the development of various spatial planning tools in the province, including the North West Protected Area Expansion Strategy, various local municipal Spatial Development Frameworks including provincial SDF and a number of Environmental Management Frameworks. The assessment will also feed into the 2014 North West Biodiversity Sector Plan (BSP) which is currently under development and will be completed by November 2015.

The BSP will not just look at the vegetation types as information of Critical Biodiversity Area designations, but will also take into consideration the species locality data that has been collected as part of the 2013 North West Biodiversity Inventory project. Biodiversity inventories for plants, mammals and birds have been generated for all district municipalities in the North West (READ, 2014).

The North West also compiled an Environmental Outlook 2013 Report, which highlights the major challenges to the environment, and flags particular issues. Climate change is also dealt with in this report.

The Provincial Development Plan identifies a phased approach for the province to achieve environmental sustainability (PDP, 2013).

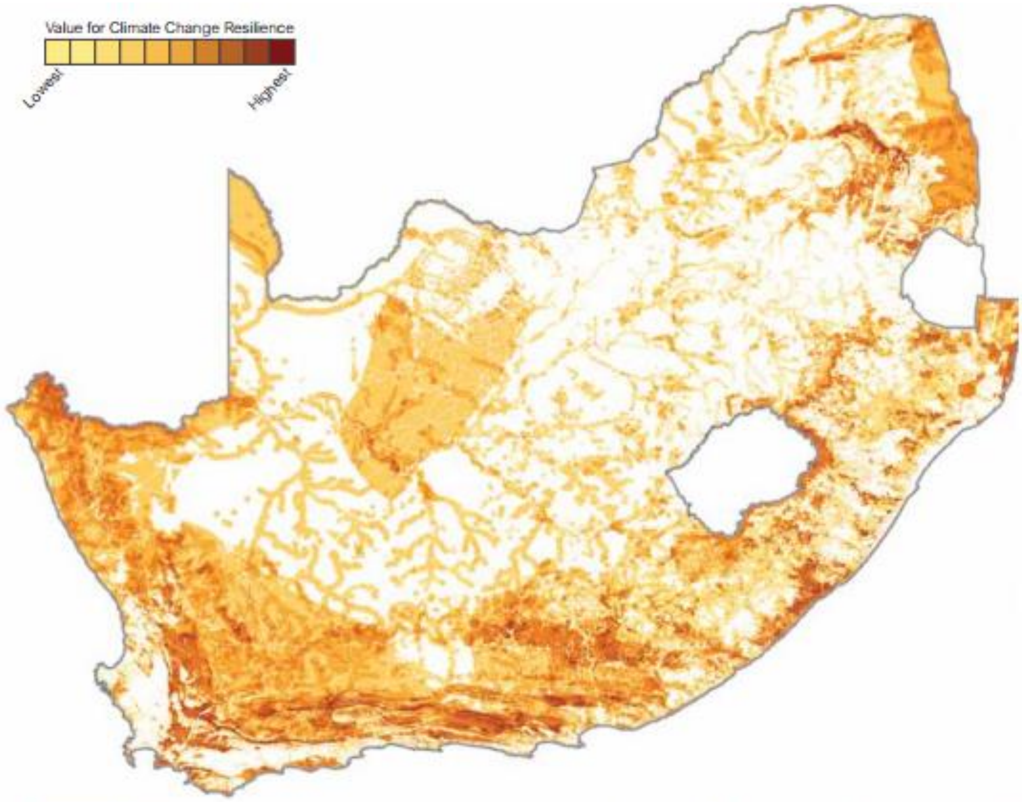
An Environmental Management Framework is a study of biophysical and socio-cultural systems of a geographically defined area to secure environmental protection of the area. These are typically decision-support tools, for example, to guide decision-making during an Environmental Impact Assessment (EIA) process. There are a number of EMFs for the province, including the Madibeng EMF, Rustenburg EMF, the Magaliesberg Protected Area EMF, the Vredefort Dome EMF, and the Tlokwe Local Municipality EMF. EMFs currently in development include the Greater Taung Local Municipality EMF and the Dr. Kenneth Kaunda District Municipality EMF.

- **Protected Area Expansion:**
  The 2009 NPAES set a target for the North West to extend the area under protection to 11% of the province by 2030. The Vaal Grassland focus area on the border of Gauteng was identified as a priority area to conserve the last remaining unfragmented areas of Dry Highveld Grassland. Greater efforts are required to expand the areas under formal protection and these should aim to protect priority biodiversity areas (CBA 1) to meet the national targets (READ, 2014).

  The province is looking at expansion of protected areas, and three sites are being considered (VA Workshop, 2015). The 2009 Biodiversity Conservation Assessment

(DACERD, 2009) indicates the potential expansion of a number of existing nature reserves and conservation areas under provincial control, including (READ, 2014):

- Proposed Heritage Park development which is envisaged to link the Madikwe Game Reserve with the Pilanesberg National Park
- Possible expansion of Vaalkop Dam Nature Reserve to link with Pilanesberg and Borakalalo National Parks as well as Madikwe Game Reserve
- Conservation of some of the intact Norite hills within the Magaliesberg area
- Addition of 22,000ha to the protected area network through biodiversity agreements and stewardship programmes (READ, 2014).



Places of resilience: Decision makers now have a single map which draws together information on nature's resilience-building scaffolding, which can then be prioritised for management and conservation purposes. These areas need to be considered in land-use planning, environmental impact assessments, protected area expansion, and working with industry sectors to minimise their spatial footprint and other impacts.

Figure 18: Places of Resilience (SANBI, 2013)

- **Inherent Adaptive Capacity:** As per the figure (map), scientists have identified features in the landscape that are likely to help build resilience for biodiversity in an area, that is, helps to maintain stable landscapes[4]. This information can then be

[4]These include river corridors and buffers of natural vegetation along rivers; corridors of natural vegetation along the coast; areas that incorporate temperature, rainfall and altitude gradients; areas with a high proportion of plant species that are unique to that place; south-facing slopes and kloofs that can give refuge for species needing to move away from hotter, more exposed aspects of the surrounding landscapes; habitats that have not been carved up and fragmented into small islands in a sea of urban sprawl or cultivated lands.

used for management and conservation purposes, including land-use planning, environmental impact assessments, protected area expansion, and working with industry partners to minimise spatial footprints and other impacts (SANBI, 2013). However, as the figure above indicates, the North West province does not have many natural features that help to maintain stable landscapes. Indeed, Figure 15 (the map above) shows these natural resilience features for South Africa, but unfortunately there are very few such areas in the North West.

- **Vulnerability:**
    - **Short Term:MEDIUM**
    - **Long Term:HIGH**
        - Savannah – Medium (VA Workshop, 2015)
        - Grassland – High (VA Workshop, 2015)
        - Afrotemporate forests – High (VA Workshop, 2015)

5.1.2. Aquatics (rivers, lakes, wetlands)

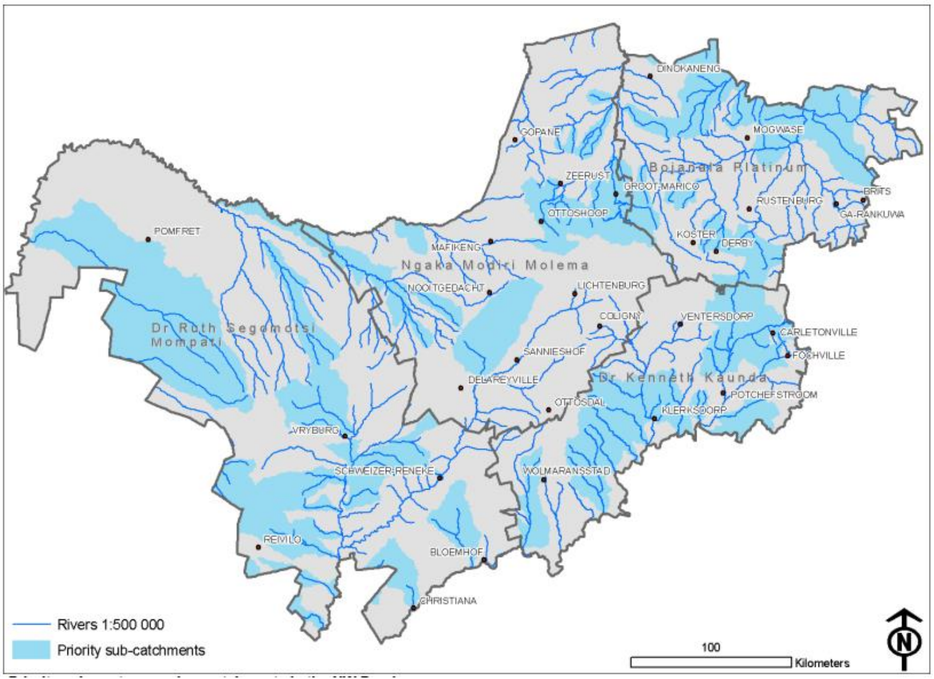
5.1.2.1. Introduction

Water is considered a key limiting factor to development. The Western part of the province is arid (< 300mm per year); the central part is semi-arid (500mm per year); and the eastern part is moderate (600mm per year). The North West province relies heavily on groundwater resources, particularly the more rural areas. Groundwater quality in the North West province is relatively good, though there is a fluctuating trend within each catchment over the years (READ, 2014).

In the North West, ground and surface water are integrated as inter-dependant; groundwater flowing to the surface as dolomitic eyes or springs is the source of several major rivers (Groot Marico, Mooi, Schoon Spruit and Molopo). Water quality and quantity issues affecting groundwater also have implications for surface water (DACE, 2008).

There are four Water Management Areas (WMA) in North West, namely the Crocodile (West) and Marico, Upper Vaal, Middle Vaal and Lower Vaal. The Middle and Upper Vaal WMAs extend beyond the NW provincial boundary. Most rivers are non-perennial, flowing with seasonal rainfall. Larger rivers are concentrated in the wetter eastern and southern portions of the province (Crocodile, Hex, Elands, Mooi, Vaal, Harts). Molopo is the only major river in the drier north-west (DACE, 2008).

The figures below show the distribution of river systems as well as pans and wetlands in North West province. This provides a spatial picture of where the aquatic ecosystems lie in the province.



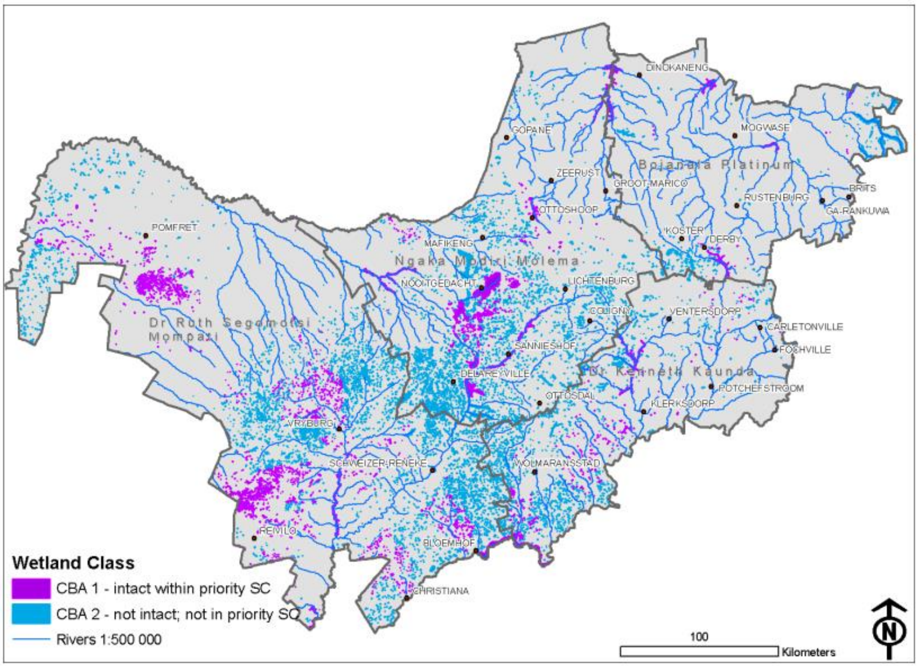


Figure 19: Priority Sub-Quaternary River Catchments (upper) and Distribution of Wetlands and Pans in the NW Province (DACE, 2008)

There is scarcity of water in the North West due to its non-perennial nature. The quantity of water flowing is affected by:

- Abstraction of groundwater impacting on quantity flowing from dolomitic eyes
- Construction of dams and reservoirs resulting in changes in river and lakes systems
- Inter-basin transfer of water which has major flow ramifications

The pressures on availability of water in the province in the provinces are as follows (READ, 2014):

- Population numbers
- Climate
- Nature of economic activities taking place

A steady increase in population, coupled with growth in the mining and industrial sectors and continued reliance on agriculture will result in the need for increased abstraction of water and the need to upgrade wastewater related infrastructure (READ, 2014).

The Vaal River (lower) provides much of the irrigation needs in the south, while the Crocodile and Marico rivers provide water to some of the eastern and central parts of the province. In addition, the Vaal River system supplies water to 60% of the economy including the mines/industries of Mpumalanga, the bulk of Eskom's power stations, the urban areas of Gauteng, the North West and Free State goldfields, iron and manganese mines in the Northern Cape, Kimberley, several small towns along the river and irrigation schemes. It will also soon provide water to the Waterberg coal fields in Lephalale. The Vaal system overlaps with the Crocodile West River System (DEA, 2013b).

Water use (from surface water) in the North West province mirrors the national perspective, with irrigation being the main consumer of water (62%), followed by the urban sector (18%) and mining and industrial sectors (12%). Due to high intensity of water use in the Crocodile West-Marico WMA, the CMA faces challenges in the following:

- Reconciling and managing the requirement for water, taking into account water transfers from the Upper Vaal WMA
- Managing the water quality impacts associated with effluent discharge, urban runoff and mining in the Crocodile River catchment

Up to 80% of the water used in rural and agricultural communities is from groundwater sources, particularly in the arid western region. The main pressures on groundwater in the province are due to the depletion of the resource and impacts on water quality. (SA WRC, 2013).

In the North West, the most prominent wetland is Baberspan, a Ramsar site which is recognised as a wetland of international importance (internationally recognised bird habitat).

5.1.2.2. Risk and Vulnerability

Risk

- **Sensitivity: HIGH**

  Changes in temperature and rainfall patterns have significant effects on aquatic ecosystems. These include the following: Stress / Impacts on physiology of aquatic life (due to increased temperature); changes in species range due to temperature shifts. There is projected deterioration in water quality due to increased salt concentrations in dams, wetlands and soil/plant systems from enhanced evaporation rates. Increase in temperature results in eutrophication (VA Workshop, 2015). Increased periods of drought mean less water is available to dilute wastewater discharges and irrigation return flows resulting in reduced water quality and associated downstream health risks to aquatic ecosystems.

- **Exposure:**

  - **Short Term: MEDIUM**
    In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that the ecosystem is exposed to is not significant. However, even current day changes are already having impacts on aquatic ecosystems in the North West (as described below), thus the short term exposure is assessed as medium level exposure. The province is already pressured in terms of water availability and water quality impacts (VA Workshop, 2015). Few rivers (20%) are in good ecological condition, while the majority of rivers in NW (58%) are in a moderately modified state. 6% of rivers are considered largely modified and 1% seriously modified. Some rivers could not be assessed due to lack of information (READ, 2014)

    Even though the North West is well-endowed with regard to pans and wetland features – the 2009 Biodiversity Conservation Assessment identified 5,340 wetlands and 6,600 pans – these wetlands and pans are under threat from mining, agriculture and urban expansion resulting in the loss of wetland ecosystem functioning and form. This is evident in the central and north east region where many wetlands are heavily modified. An estimated 18% and 38% respectively of wetlands and pans are considered moderately modified and heavily-to-critically modified. Approximately 44% of the wetlands and pans remain in a largely natural or good condition (READ, 2014).

    The impacts on water currently include the following (DACE, 2002):

    - Expansion of population and urbanisation add pressure on water resources through increased abstraction of water.

    - The need to provide acceptable living conditions results in the construction of infrastructure and modification of river channels (READ, 2014). Dams affect the flow of water in rivers, increase sedimentation, affect the natural flow of water in rivers, increase sedimentation, and affect the natural migration pathways of fish. The stagnation of water may also result in the growth of bacteria (READ, 2014).

- The availability of water is impacted on by the effects of alien plants (e.g. blue gums and poplars) in river catchments. There is a loss of habitats and biodiversity, due to invasion by alien plants and fish (such as largemouth bass).
- There is degradation of aquatic ecosystems and their functioning, due to pollution, destruction and modification of wetlands, pans, rivers and karst ecosystems, eutrophication and the proliferation of alien plants species (e.g. water hyacinth) (READ, 2014).
- There is declining water quality from salinization, acid mine drainage, industrial effluent and storm water runoff in urban areas. The mining industry impacts on water availability and water quality. This pressure is not expected to decrease (VA Workshop, 2015). It is important to note that an increase in rainfall leads to an increase in AMD.
- The loss of natural habitat results in loss of natural water purification (water purification is enhanced through the diversity of riverine and wetland plant species and microbes) (READ, 2014). Increase in costs to provide water of acceptable quality.
- Current supplies of water appear to be fully allocated, necessitating the supplementation of sources in the future. Low recharge rates of groundwater limits the viability of this resource. Furthermore unsustainable use, or any deterioration in groundwater resources, will impact in rural areas which are heavily dependent on groundwater. The province may also be looked at in the future to supply the Waterberg coalfields, even though the province is already on the brink of a water deficit (READ, 2014).

- **Long Term: HIGH**
  - Climate predictions show that precipitation in the area will either decrease, remain the same or increase. There may be flooding in some parts of the area, and variability is thus important (DEA, 2013a). The pressures on the sector are not expected to decrease.
  - Specific areas of high risk where cumulative negative climate change impacts are likely to occur (including increased evaporation, decreased rainfall and decreased runoff) include the central western parts (DEA, 2013b).
  - In the Crocodile West Reconciliation Study and Vaal reconciliation study, no climate change considerations were found in the Reconciliation Report (DEA, 2013b).

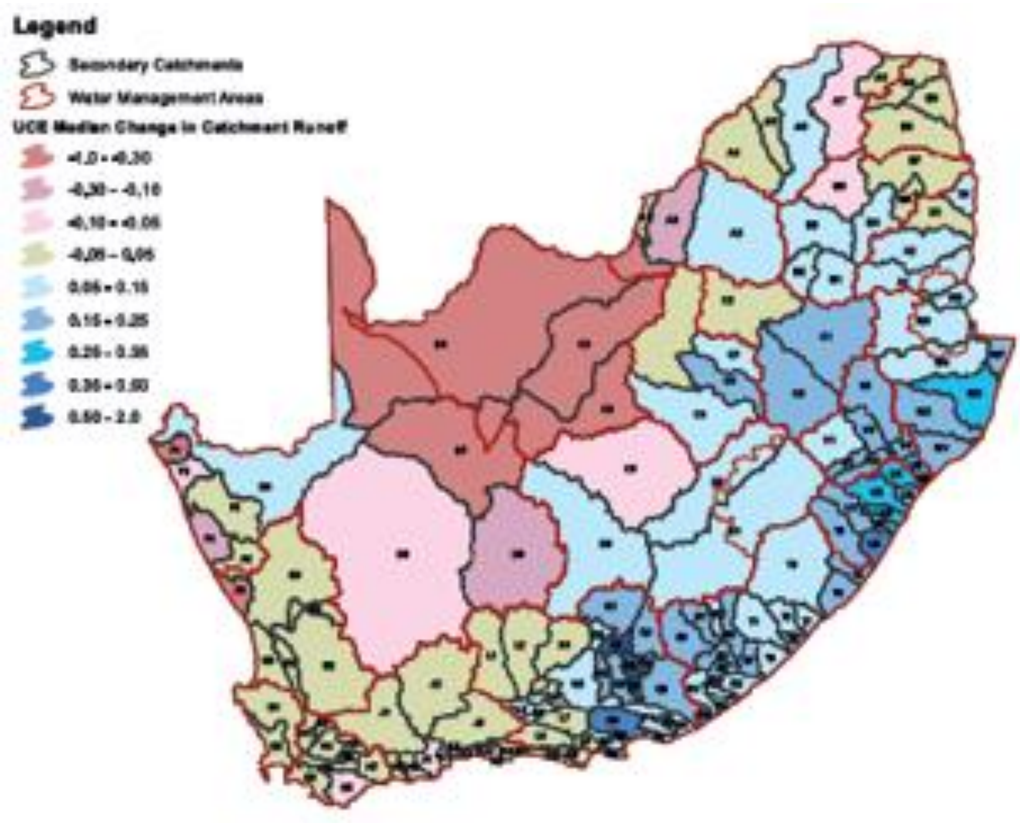


Figure 20: Median Impact of Climate Change on the Average Annual Catchment Runoff for the period 2040-2050 relative to the base scenario average for 1990-2000 for all secondary catchments in South Africa derived from a Hybrid Frequency Distribution (HFD) analysis of all possible global circulation model (GCM) outputs (+6000 scenarios) for an Unconstrained Emissions Scenario (UCE) (DEA, 2013b)

- **Risk:**
  - **Short Term: HIGH**
  - **Long Term: HIGH**
    - Lack of integrated planning will lead to increasing scarcity in an already water-stressed province. Increasing water scarcity means reduced dilution of pollution (VA Workshop, 2015).
    - Reduced flow of water will reduce the amount of oxygen, resulting in loss of filtration capacity (VA Workshop, 2015).
    - Increase in rainfall may lead to an increase in AMD, which will further impact on water quality in an already water-stressed province.

<u>**Vulnerability**</u>

- **Adaptive Capacity:**

- **Short Term: MEDIUM**
  - The North West Biodiversity Conservation Assessment Report (DACERD, 2009) identifies Critical Biodiversity Areas (CBAs), which inputs into multi-sectoral planning and decision-making tools. The aquatic CBAs for the province as well as the Ecological Support Areas for the province are shown as in the figures below.

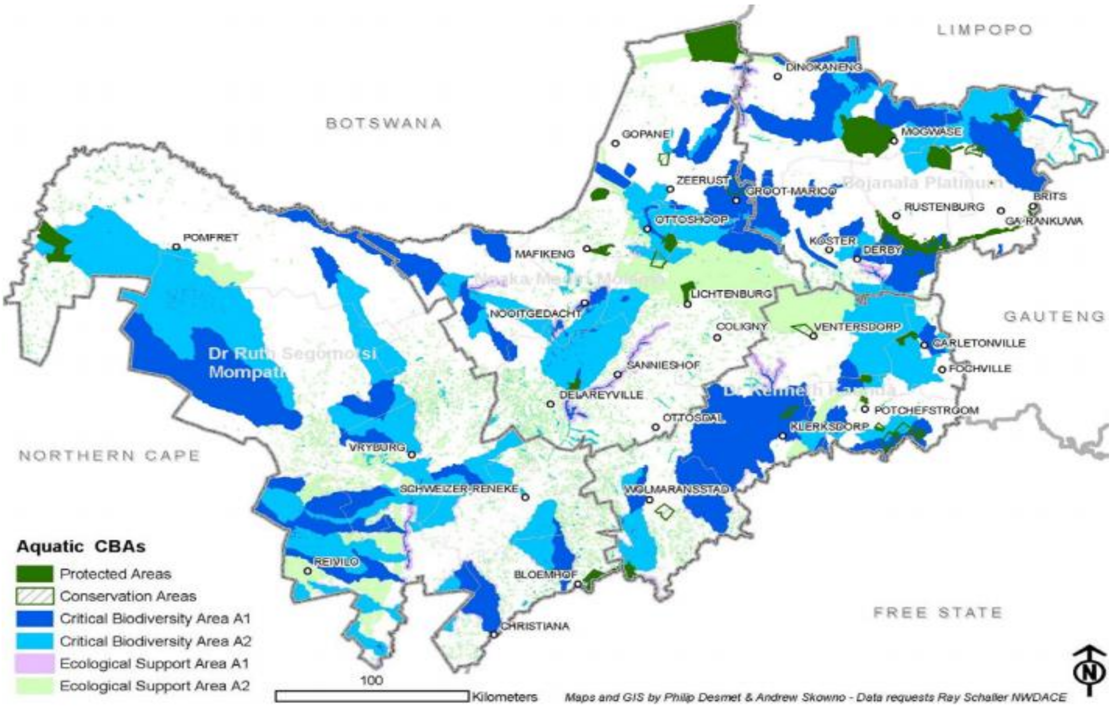


Figure 21: Aquatic CBAs for the North West province (DACERD, 2009)

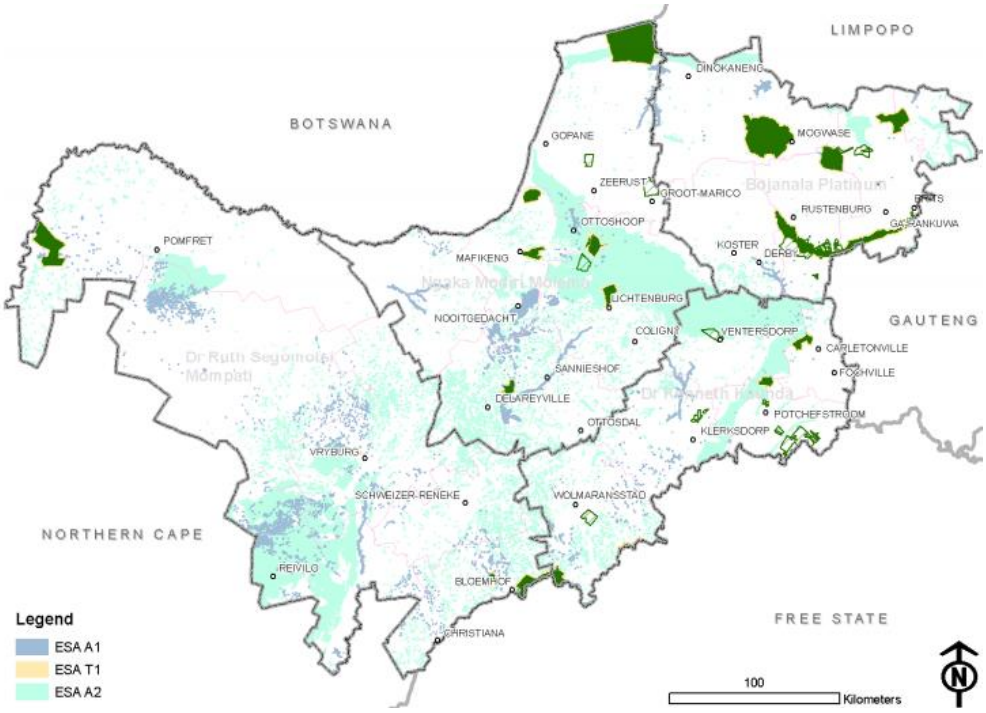


Figure 22: Ecological Support Areas for the North West province (DACERD, 2009)

- The Department of Environmental Affairs under the Working for Water banner is working on a process to remove invasive alien plant species, including in parts of the North West province (DEA, 2013b) This has several benefits, including maintaining natural biodiversity, improving water security and creating jobs.
- River Health Programmes (RHP): The Groot Marico River forms part of the River Health Programme (RHP) that was developed in response to the need for monitoring, assessing and reporting on ecological status of river ecosystems (PDP, 2013). The province's river health programme is, in fact, one of the oldest and most well-established in the country.
- A number of dam remediation programmes have been undertaken to improve the water quality, such as for the Hartbeespoort and Roodeplaat Dams (DWA, 2013)

- **Long Term: MEDIUM**

Long term adaptive capacity is dependent on implementation of programmes and plans. A few of these are highlighted below.

Planning: The North West completed the *North West Biodiversity Conservation Assessment* in 2009, which was used to inform the development of various spatial planning tools in the province, including the North West Protected Area Expansion

Strategy, various local municipal Spatial Development Frameworks including provincial SDF and a number of Environmental Management Frameworks. The assessment will also feed into the 2014 North West Biodiversity Sector Plan (BSP) which is currently under development and will be completed by November 2015.

There are a number of EMFs for the province, including the Madibeng EMF, Rustenburg EMF, the Magaliesberg Protected Area EMF, the Vredefort Dome EMF, and the Tlokwe Local Municipality EMF. EMFs currently in development include the Greater Taung Local Municipality EMF and the Dr. Kenneth Kaunda District Municipality EMF.

Reconciliation Studies (by DWS): The Department of Water and Sanitation's (DWS) Reconciliation Strategy studies are designed to quantify water resources availability (yield) and demand (including environmental water requirements) to provide information about future water allocation strategies and the need for new supply infrastructure to meet the demand in the future. The Reconciliation Studies should consider climate change impacts as well.

For the North West province, the sustainable use of water resources is addressed in the Water Provisioning and Water Management Plan which aims to achieve a sustainable balance between water availability and water supply for the long term. The study assessed district municipalities in the North West and reported significant water losses occurring in the domestic and irrigation sectors and suggestions to address the problems including WCWDM, relining of irrigation canals, review of irrigation budgets, water allocation mechanisms and pricing, water reuse and recycling, especially for mining operations and rainwater harvesting. The ultimate outcome of the implementation of the Water Provisioning and Water Management Plan will include cooperation and collaboration between different spheres of government and implementing agents within the water sector as well as an efficient monitoring and control system (READ, 2014).

The North West Groundwater Master Plan is a guiding document that will be used to define tasks for groundwater management in the province. The Master Plan provides a detailed description of each groundwater unit and provides background information on the functioning of the systems. The plan further provides information in terms of utilisation, protection, management, control and data or information management (READ, 2014).

- **Catchment Management Agencies (CMAs) & Water User Associations (WUAs):** As part of Integrated Water Resource Management and management of water at catchment levels, the DWS establishes CMAs to perform WRM functions at a catchment level. The Limpopo-North West CMA was meant to be established in 2014, integrating the previous Limpopo and Crocodile West and Marico Water

Management Areas (WMA) together with the Luvuvhu catchment from the previous Luvuvhu-Letaba WMA. The National Water Act also prescribes the establishment of WUAs to manage water at a local catchment level. Former irrigation boards (21 in the province) are to be transformed into WUAs taking into cognisance the need for a broader stakeholder representation. However, challenges around functionality abound, and the WUAs require support in terms of finance, governance, skills and institutional management (READ, 2014).

- **National Freshwater Ecosystem Priority Areas (NFEPA):** The NFEPA project was established as a response to the degradation of freshwater ecosystem conditions and associated biodiversity and provides guidance on rivers, wetlands and estuaries, including which ones, should remain in a near-natural condition to support the water resource protection goals of the National Water Act (Act 36 of 1998) (NWA). The project also informs the expansion of the protected area network. Thus, priority ecosystems have been identified for the North West which reflect both the water resource importance and the linked biodiversity importance (READ, 2014).
- **River Health Programme:** The River Health Programme was developed in response to the need for monitoring, assessing and reporting on the ecological status of rivers. Programmes such as this will gain in importance over time with an increase in competing uses for limited water resources (READ, 2014).
- The Department of Water and Sanitation has a number of programmes dealing with water quality, including Acid Mine Drainage programmes, and a programme that aims at implementing charges (fees) for Waste Discharges.

- **Vulnerability:**
  - **Short Term: MEDIUM**
  - **Long Term: HIGH**

5.2. Livelihoods

5.2.1. Rural

5.2.1.1. Introduction

Currently, 46% of population (45% of households) live in tribal or traditional areas and 9% of the population (9% of households) on farms (READ, 2014). Rural communities depend on agriculture. Thus, climate change adaptation is especially important in rural areas since people rely on natural resources. For many rural communities in the province, where food security is a major problem, fishing provides a source of protein. Women are among the most vulnerable to climate change since they depend on natural resources such as wood for energy and clean water for usage in households.

5.2.1.2. Risk and Vulnerability

Risk

- **Sensitivity: HIGH**

  Changes in temperature and rainfall patterns have significant effects on rural livelihoods, which are heavily reliant on ecosystems and natural resources (which, in turn, are typically climate sensitive). Effects that indicate climate sensitivity include the following: Changes in water availability, temperature-related changes in water quality (PH, biochemical oxygen demand (BoD)), temperature related stress on plants and animals, changes (increase / decrease) in crop yields, decline in human productivity at higher ambient and body temperatures. There is also evidence that extreme events place pressure on social networks, because it becomes more onerous to maintain social reciprocity under higher levels of resource stress. Production and income activities are likely to be significantly affected by climate change and increased climate variability by 2050 at least, particularly in rural areas where changes in rainfall directly affect agriculture and natural resources that underpin many production and income activities.

  In the map below, the Department of Rural Development and Land Reform identified sensitive municipal wards across the country. Combining the indicators of sensitivity for rural human settlements (physical water scarcity by major river basin, irrigated agricultural land, terrain slope index, growing period, net primary production (rain-fed), net primary production (irrigated), major perennial rivers, ground water availability, land degradation index, crop diversification index and ecological resilience), highly sensitive municipal wards are found in the North West province as per the figure below (DRDLR, 2013b).

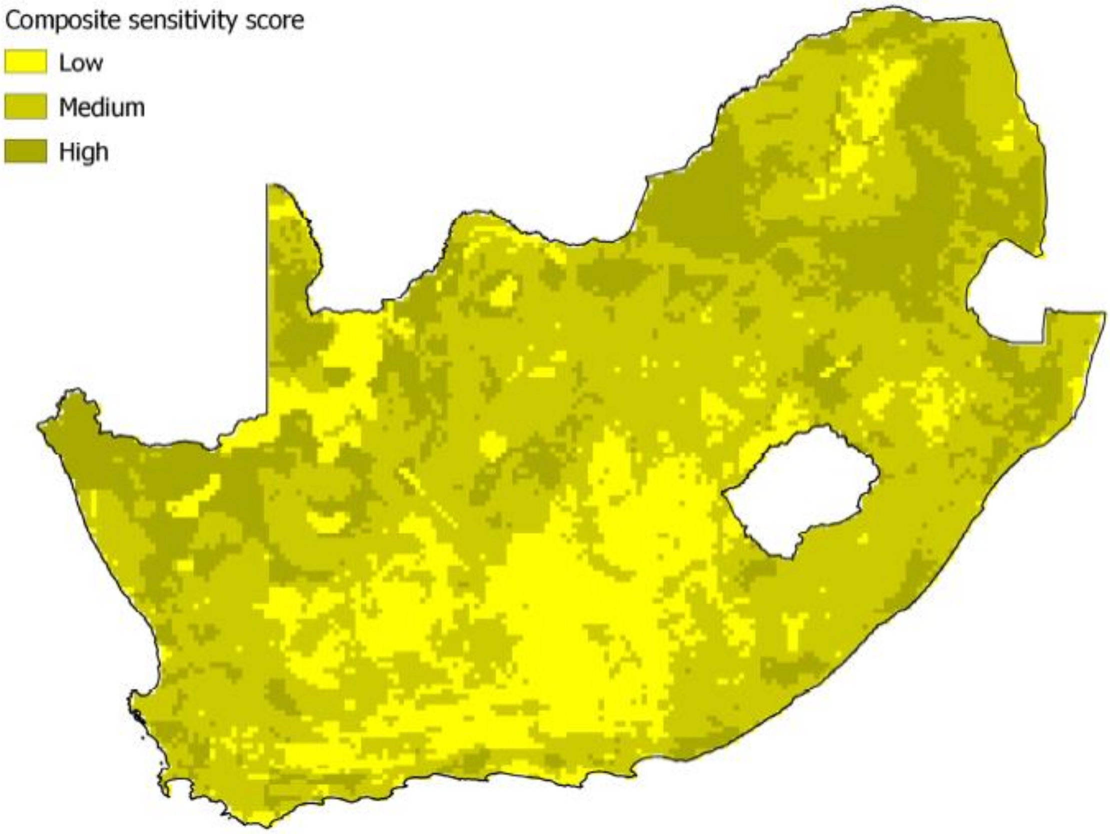


Figure 23: Sensitivity of Rural Dwellers to Climate Change (DRDLR, 2013b)

- **Exposure:**
  - **Short Term: MEDIUM**

    In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that rural livelihoods are exposed to is not significant. However, even current day variability already has impacts on rural livelihoods in the North West, thus the short term exposure is assessed as medium level exposure.

    In certain areas of the North West, adolescents are already moving away from farm work due to doubts about the long-term viability and dominance of rain-fed farming as a livelihood strategy. This could lead to higher unemployment and migration. Migration is a problem, particularly in areas where there are few work opportunities (UNICEF, 2011)

  - **Long Term: MEDIUM**

    Climate change may impact on children, and particularly girls, as they have to travel greater distances to fetch water in areas where water availability is reduced – particularly in areas where households are already experiencing inadequate access to water sources (UNICEF, 2011)

When the indicators (temperature change, annual precipitation change, climate extremes index, sea-level rise, ocean acidification and changes in aridity index) are combined into a single composite map, municipal wards in the North West receive a medium score in terms of exposure in the figure below, with some also designated as low (DRDLR, 2013b).

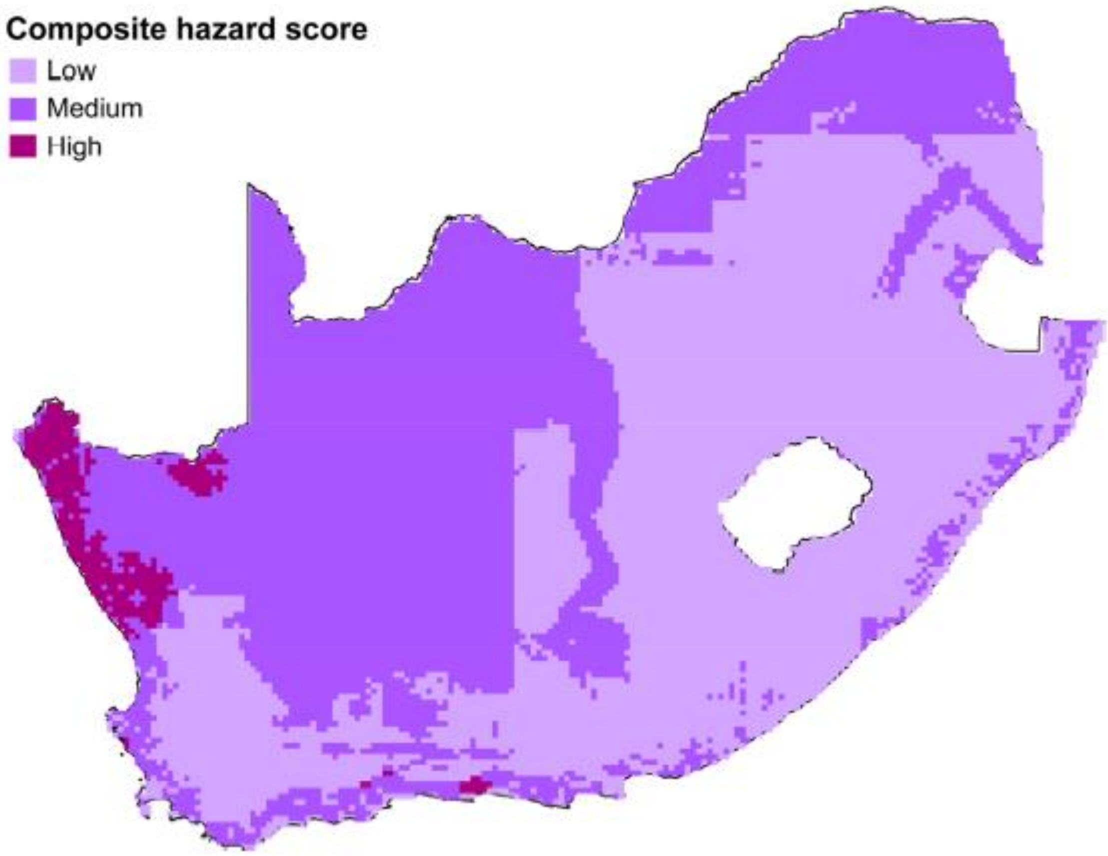


Figure 24: Hazard/Exposure of Rural Dwellers to Climate Change (DRDLR, 2013b)

- **Risk:**
    - **Short Term: MEDIUM**
    - **Long Term: HIGH**

<u>**Vulnerability**</u>

- **Adaptive Capacity:**
    - **Short Term: MEDIUM**

Rural areas generally have less capacity to adapt to climate change since adaptive capacity is linked to social and economic development. In Mantsie village of the Lehurutshe district in the North West province, households are responding to the impacts of regular drought and an unpredictable rainy season by adopting the practice of petty trading, an activity in which children, particularly girls, are likely to be more involved. Others are investing in poultry or livestock trading, enabling them to enhance income security. Thus, people are moving away from rural agriculture (UNICEF, 2011).

- **Long Term: LOW**

Long term adaptive capacity is dependent on implementation of programmes and plans. A few of these are highlighted below:

National Initiatives: Provinces with large rural populations such as the North West are the most socially vulnerable to climate change. Communities dependent on subsistence farming and grants for survival are particularly socially vulnerable to climate change. Fetsa Tlala is an integrated government framework that seeks to promote food and nutrition security and to address structural causes of food insecurity. The initiative is aimed at implementing the food production pillar of the National Policy to maximize cultivation of food by putting 1 million hectares of land under production by 2018/19 production season. It is expected that beneficiation of One Million Hectares programme will in the main accrue to the indigent and vulnerable sections of the society (DAFF, Fetsa Tlala Production Plan 2014/2015). In the context of increasing water scarcity, it is not clear whether this kind of programme (and others from within the province) will provide the necessary results in the province.

In addition, the Department of Housing and Human Settlements is looking at a National Climate Change Strategy (VA Workshop, 2015).

Provincial Initiatives: The Provincial Development Plan advises that the main land uses of mining, manufacturing and agriculture must occur in a co-ordinated fashion to ensure optimal use of land, and a sustainable and healthy existence with human settlements. This will be achieved by establishing integrated settlements in locations where the use of land is appropriate to the area, it is accessible and not remote from existing neighbourhoods and urban centres which provide job opportunities and social facilities, and where planning is already in place for the provision of bulk infrastructure services. There have been a number of challenges to establishing integrated human settlements, but the provincial government has outlined priority actions in response to these challenges. The project needs to be supported by a co-operative and coordinated approach by all relevant departments (READ, 2014).

SALGA and Municipality Initiatives: The South African Local Government Association (SALGA) has prioritised climate change planning for the municipalities for 2015-2016 (VA

Workshop, 2015). Furthermore, some municipalities in the North West province such as the Tlokwe have plans for a climate change strategy.

- **Vulnerability:**
  - **Short Term:MEDIUM**
  - **Long Term: HIGH**

Although the physical impacts of climate change will be felt most in western half of the country, in terms of vulnerability this will be outweighed by the biophysical sensitivity and lack of adaptive capacity among rural communities. The North West province is among the most vulnerable provinces per the figure below (DRDLR, 2013b)

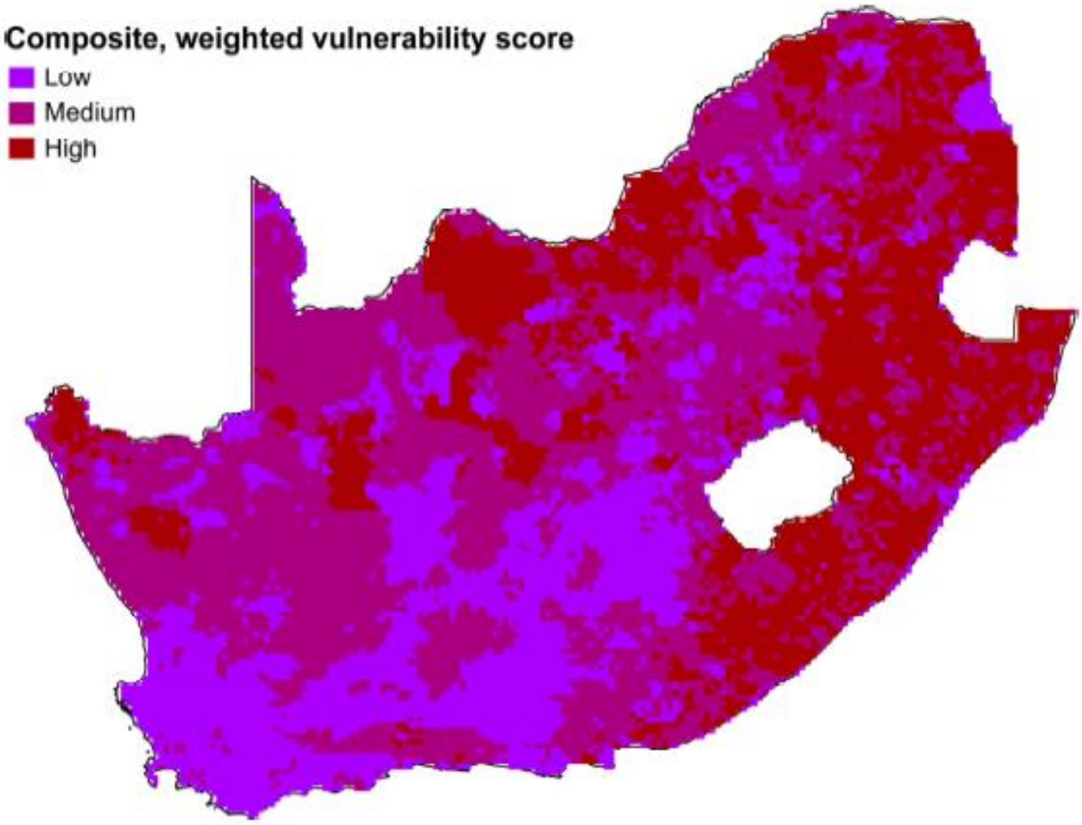


Figure 25: Vulnerability Score for Rural (DRDLR, 2013b)

5.2.2. Urban

5.2.2.1. Introduction

In contrast to rural settlements, urban settlements in the North West are not as vulnerable, especially due to higher adaptive capacity. Nevertheless, urban areas will also be impacted negatively by climate change.

The North West province has had a positive net migration in recent years, with more people coming to the province than leaving (READ, 2014). Urbanisation to the larger towns is also quite common. Thus, if these trends continue urban settlements will be very important population centres in the future, and their vulnerability to climate change will become increasingly important to study.

5.2.2.2. Risk and Vulnerability

<u>**Risk**</u>

- **Sensitivity: MEDIUM**
  Changes in temperature and rainfall patterns have several effects on urban livelihoods, especially those that rely on natural resource base. However, in contrast to rural livelihoods, urban livelihoods are less sensitive to change in temperature or rainfall. Thus, sensitivity is assessed as medium level sensitivity in the urban setting. Changes to urban livelihoods induced by climate change include changes in water availability, temperature-related stress on plants and animals, decline in human productivity at higher ambient and body temperatures.

  Climate change has the potential to reduce available water resources through reduced rainfall and higher evapotranspiration in mainly the western parts of the country, and also to increase consumption patterns due to temperature increase. This is likely to increase the risk of water shortages, and raise the cost of providing water by relevant authorities. Moreover, changes in temperature might lead to further stress on water supply owing to power demand for cooling systems.

- **Exposure:**

  - **Short Term: LOW**
    In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that urban livelihoods are exposed to is not significant.

  - **Long Term: MEDIUM**
    Evidence from South Africa indicates that increasing frequency and intensity of extreme rainfall will result in a higher risk of flooding episodes in urban areas (which already happen, but will increase further), and drought-induced water shortages and fire risk. Extreme events such as heat waves are expected to increase in frequency and severity,

with increased risk of mortality among the elderly and sick, and the risk of fire in informal settlements (Midgley et al., 2007).

- **Risk:**
    - **Short Term: LOW**
    - **Long Term: MEDIUM**

__Vulnerability__

- **Adaptive Capacity:**

  Due to the relative availability of financial and infrastructure resources in urban settings, adaptive capacity in urban areas tends to be stronger than in rural settings.

    - **Short Term: MEDIUM**
    - **Long Term: MEDIUM**

      Long term adaptive capacity is dependent on implementation of programmes and plans. As mentioned earlier in the report, the South African Local Government Association (SALGA) has prioritised climate change planning for the municipalities for 2015-2016 (VA Workshop, 2015). Some municipalities in the North West province already have plans for a climate change strategy, like Tlokwe.

Vulnerability:

- **Short Term: LOW**
- **Long Term: MEDIUM**

In general, due to higher adaptive capacity and economic differentiation, urban areas have less vulnerability to climate change risks. With greater population pressures and a growing burden on urban infrastructure, this picture may change in coming decades.

5.3. Economic Activity

The province has the 4th largest GDP (5.7%) in the country. The economy of the province mainly consists of mining, agriculture and manufacturing, with some tourism.

5.3.1. Agriculture and Farming

5.3.1.1. Introduction

The North West is considered to be an important contributor to the South African food basket with approximately 43,9% of the province categorised as 'arable' land (PDP, 2013).

There is a dualistic agricultural economy comprising of a well-developed commercial sector and a predominantly subsistence sector in communal areas. The province has the following characteristics:

- Agriculture in the eastern, wetter parts of the province is mostly livestock and crop faming
- The central and southern regions are dominated by wheat and maize farming
- Livestock and wildlife farming occurs in the semi-arid western parts of the province

There are three major irrigation schemes in the Crocodile, Vaal and Harts Rivers (DACE, 2002)

Small-holder farmers constitute 70 percent of the farming population of the province. Inappropriate land uses have degraded land and reduced farming capacity.

In 2010, the North West province produced 22% of the maize produced in the country. The maize industry in South Africa contributes to food security in both South Africa and the SADC region (DAFF, 2011a). Maize production covers 58% of the cropping area in Southern Africa and 50% of the maize in the SADC region is produced in South Africa. South Africa is the major source of food in the region. Adverse climate impacts on agriculture in South Africa may therefore destabilise the region (Durand, 2006).

Fishing is mostly for recreational purposes, though it is an important protein source in communities vulnerable to shortages. NW province has been involved in development of small-scale agricultural fisheries in conjunction with communities using dams. Similar projects are underway by the Department of Water and Sanitation (DWS) for the aquaculture of fish in the ponds of sewage works.

The agricultural sector presents great challenges regarding the availability and use of water. If irrigation is to be expanded in the province, the province will need to use water more efficiently (PDP, 2013).

5.3.1.2. Risk and Vulnerability

Risk

- **Sensitivity: HIGH**

  CROPS:

  Changes in temperature and rainfall patterns have significant effects on agriculture, given that crop growth and range is directly affected by (and a function of) temperature and rainfall. The distribution of rainfall and timing of rainfall patterns are also important, since farming is seasonal (VA Workshop, 2015).

  Dryland crops are sensitive to climate change while irrigated crops are less sensitive (VA Workshop, 2015). In a study by Blignaut et al. (2009) on agriculture production's sensitivity to changes in climate in South Africa using data between 1970 and 2006, it was found that for the North West, there is a highly significant statistical relationship between crop production and rainfall. A 1% change in rainfall should lead to a more than 1% change in maize production. Furthermore, there is a strong negative relationship between temperature and rainfall in the province.

  ANIMALS:

  Intensive cattle farming, that is, keeping of livestock at high stocking densities in confinement has a low sensitivity to climate change, whereas cattle that roam freely on the veld have a medium sensitivity to climate change (VA Workshop, 2015)

  GENERAL:

  Changes in water availability for humans, plants, and animals, temperature-related changes in water quality (PH, biochemical oxygen demand (BoD)), temperature related stress on plants and animals, changes (increase / decrease) in crop yields, changes in species range due to temperature shifts, decline in human productivity at higher ambient and body temperatures.

Exposure:

- **Short Term: MEDIUM**

  In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that agriculture is exposed to is not significant. However, even current day variability already has big impacts on agriculture in the North West (as described below), thus the short-term exposure is assessed as medium level exposure.

  CROPS:

  Between 1970 and 2006, there has been a decrease in rainfall in the North West of around 11.3% and an increase in temperature of around 2.3%. Variance around rainfall has been increasing, implying increasing unpredictability. If it becomes warmer in the future, and rainfall continues to decrease, then the major maize producing regions will be susceptible to marked reductions in crop production.

CATTLE:

In 2004, subsistence farmers owned 5,6 million head of cattle, 41% of the national total of 13,8 million. These individuals are extremely vulnerable to change in climate, and given the small scale of their operations and the limited access they have to open markets, the value of their animal production is not adequately captured in macro-economic datasets.[5]

- **Long Term: HIGH**

CROPS:

If it becomes warmer in the future, and rainfall continues to decrease, then the major maize producing regions will be susceptible to reductions in crop production.

  - The LTAS predicts a range of potential impacts from climate change on maize yields. The impact could range from a reduction in total national yield by 25% to even a potential increase by 10% (DEA, 2013c). This is showcased in the figure below.

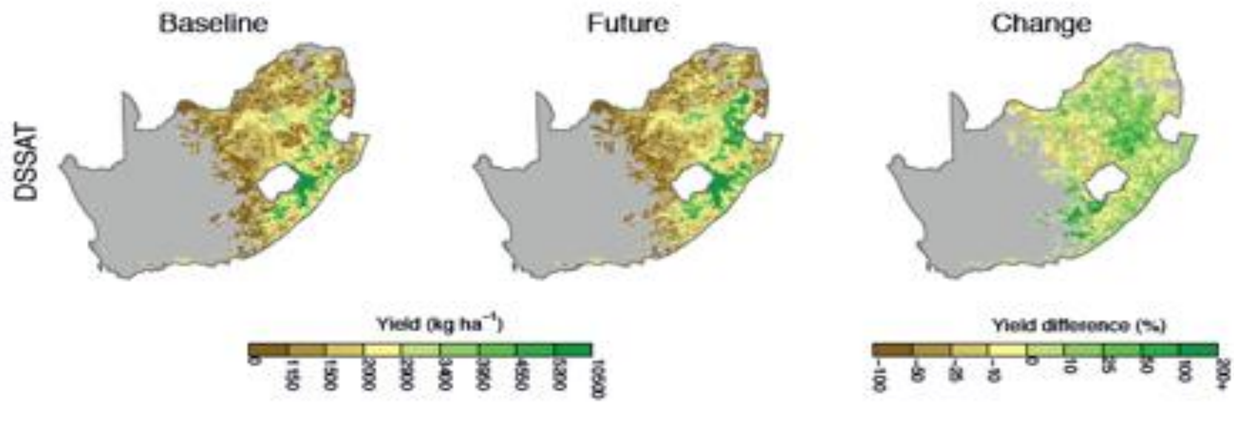


Figure 26: Median Change in Crop Yields for Rain-Fed Maize by Mid-Century (DEA, 2013c)

In a study on three maize-growing districts (Lichtenburg in the North West, Kroonstad in the Free State, and Middelburg in Mpumalanga), examining the effect of climate change on maize production, all three GCMS predictions indicate a decrease in maize production for the three districts, with the most alarming results for Lichtenburg in the North West (CEEPA, 2006). In the future, only in 7

[5] https://www.environment.gov.za/sites/default/files/docs/implications_climatechange_foragriculture.pdf

out of 10 years will there be a certainty of maize harvesting of more than between 556 and 822 kg/ha which is much lower than the rule of thumb of one ton/ha to break even, per the study. Thus, maize production in Lichtenburg may not be economical in the future. Given that about 57% of this district is cultivated, the majority of which is under maize production (90%), there is a definite warning sign (CEEPA, 2006).

- The exposure of crops is also dependent on the type of crops being grown. For instance, GMO (genetically modified organism) wheat helps to conserve soil moisture (VA Workshop, 2015).
- It is important to note that over the past 2-3 decades there have been challenges with: i) profitability with regard to crop production in the North West province; and ii) the failure to use sound agricultural practices in both large scale and small scale farming, including overstocking of land and cropping on marginal soils. In this context, any climate change impacts will negatively impact production and ultimately have an impact on profitability and land (VA Workshop, 2015).

CATTLE:

Feedlot cattle are adversely affected by high temperatures, relative humidity, solar radiation, and low wind speeds. Tolerance levels have likely been reached in the North West. It is expected that temperature tolerance thresholds will be exceeded in the North West towards the end of the century (DEA, 2013c)

An increase in temperature means an increase in diseases for cattle, while an increase in rainfall means an increase in external parasite risk (VA Workshop, 2015).

Beyond the feedlots, the vast majority of cattle in the province are actually herds that graze in the open. Thus they are more vulnerable to temperature impacts. They graze on the veld, and thus ecosystem impacts on grasslands and savanna have implications for the cattle as well. As veld quality is diminished due to higher temperatures and changes patterns of lignification, and as rainfall variation changes growth rates and grass quality, lowered vegetative growth makes cattle more vulnerable.

- **Risk:**
  - **Short Term: MEDIUM**
  - **Long Term: HIGH**

Vulnerability

- **Adaptive Capacity:**

- **Short Term: MEDIUM**

  It is important to note that farmers are continuously adapting to changing conditions (VA Workshop, 2015). For example, Farmers have already adapted their cultivar of choice of maize in seasons with late rains to ultra-short seasoned varieties, or are using sunflowers as an alternative crop. However, these cultivars – owing to their complex genetic development – require good management in terms of fertilisation and pest control and are not very drought-resistant. They are prone to developing leaf burn (Durand, 2006). While alternatives such as sorghum and millet can be grown, these are not the staple and there is resistance to this (CEEPA, 2006).

  Currently, there is an indication that the planting window is shifting to a week or so later in the season, and farmers are increasing using fields with marginal crop production for other purposes such as grazing (CEEPA, 2006**).**

  Rainfall efficiency: Conservation farming practiced by South Africa farmers include minimum tillage, strip cropping, building contour terraces and contour ploughing (Durand, 2006).

  Grants: government grants are helping households which otherwise depend solely on agriculture to be more resilient to climate change impacts (VA Workshop, 2015)

  DAFF: The Department of Agriculture, Forestry and Fisheries has a number of initiatives to promote adaptive capacity:

  - DAFF's Extension Officers provide information on sound agricultural practices (VA Workshop, 2015)
  - There is a level of Disaster Risk Management being implemented, which provides suggested strategies to small scale farmers. However, there are resource challenges as far as this is concerned (VA Workshop, 2015). DAFF's Climate Change and Disaster Management Directorate deals with both disaster management and climate change, with a major focus on reduction and prevention, avoidance, mitigation and preparedness. It had implemented an early warning system for extreme weather warnings to farming communities, and is carrying out research, awareness and education campaigns and training to strengthen responses and risk management. There is a lack of capacity in disaster risk management. Furthermore the workshop also identified that there are resource issues (VA Workshop, 2015).
  - DAFF is promoting the use of indigenous cattle breeding (VA Workshop, 2015)
  - DAFF is running a project for the use of alternative crops, but there is resistance to this (VA Workshop, 2015)
  - The department promotes the stocking of areas according to norms for cattle (VA Workshop, 2015)

- **Long Term: MEDIUM**

  Long term adaptive capacity is dependent on implementation of programmes and plans. A few of these are highlighted below.

  Irrigation requirements are expected to remain constant between 2005 and 2030 in the Crocodile West River catchment. (DEA, 2013b). Adaptive capacity is low in the NW due to high dependence on agriculture, high unemployment rates, high HIV prevalence and low levels of infrastructure development (IFPRI, 2011). Furthermore, there is very little buffering capacity within the adaptation of the (maize) crop itself. Nevertheless, the development of the Department of Agriculture, Forestry and Fisheries (DAFF)'s Climate Change Sector Plan gazetted in 2013 forms the basis to ensure that activities related to the elements of Climate Smart Agriculture, Forestry and Fisheries (Vulnerability, Adaptation, Mitigation and Food Nutrition Security) are scaled up and addressed. SANBI was accredited as South Africa's National Implementation Entity to the Adaptation Fund in 2011. The main aim of the NIE is to deliver tangible results through the implementation of projects that address climate change adaptation in vulnerable communities in South Africa.

  In addition, the National Department of Agriculture, Forestry and Fisheries (DAFF) is coordinating the implementation of Early Warning System and conducting awareness programmes on the impact of climate change. The Early Warning Unit in the Climate Change and Disaster Management (CCDM) unit of DAFF is compiling and disseminating monthly advisories to the farming communities. DAFF is also participating actively in the National Climate Change Committee (NCCC) under the Department of Environmental Affairs. The DAFF prepared a discussion document on "Climate Change the agricultural sector in South Africa" in an attempt to bring together concepts relating to climate change and the possible effects. This will serve to inform decision makers on current perceptions and follow-up action. Through its current involvement in climate change activities, the DAFF is playing an important and proactive role.[6]

  In the North West province, there is a detailed North West Agricultural Master Plan (AMP), adopted in 2010. It has a comprehensive programme to strengthen and grow the sector in the province.

  There is however no specific provincial climate change plan for the agricultural sector, and this has been identified as a need. The province does have a land care programme which aims at educating communities and individuals to adopt an ecologically sustainable approach to the management of South Africa's environmental and natural resources. It has been identified that more research as well as funding and personnel is needed as far

[6]DACERD. *Climate Change* (pamphlet provided by READ)

as climate change work is concerned. Furthermore, implementable strategies are required (VA Workshop, 2015).

Both in the short term and long term, adaptive capacity is also being built by a range of READ activities. For instance, READ has long promoted the use of indigenous breeds of cattle and has distributed bulls at subsidized rates to farmers. READ has also invested in developing alternative crops that are climate-smart, such as amaranth, quinoa, millet etc. READ conducts research into rangeland management and stocking densities to ensure better resilience to changing climatic factors.

It is important to note that even with the development of climate-smart technologies and appropriate management practices that research supports as building adaptive capacity, what is most important is that farmers adopt such practices. If farmers do not change their approach in the face of changing climatic conditions, agriculture sector adaptive capacity will not increase significantly.

- **Vulnerability:**
  - **Short Term: MEDIUM**
  - **Long Term: HIGH**

5.3.2. Tourism

5.3.2.1. Introduction

Existing tourist attractions in the province include the entertainment complex at Sun City; the Pilanesberg and Madikwe Reserves; the Cradle of Humankind and Taung Heritage Site; Vredefort Dome; Birding Routes (Molopo, Borakalalo, etc); the Magaliesberg area and Crocodile River catchment initiatives; and the National Highveld Park situated west of Tlokwe (PDP, 2013). The tourism sector is dependent on water quality, thus, protection of water quality as well as an adequate quantity of water is critical for tourism and conservation.

The North West province has two national parks (Pilanesberg and Borakalalo) and 12 provincial reserves. The most significant cross-boundary protected areas are the Magaliesberg Protected Environment, which is shared with Gauteng province; Cradle of Humankind World Heritage Site, which is shared with Gauteng; and the Vredefort Dome World Heritage Site, which is shared with the Free State province. The total size of formally protected areas is 297,500ha which amounts to approximately 2,84 % of the province. This includes national parks, provincial nature reserves, private nature reserves and protected natural environments (e.g. Magaliesberg). This falls below the 20% of each vegetation type, river type and wetland type (READ, 2014).

Game farms play an important role in conservation in the province. The farms add approximately 290,000ha (approximately 3%) to the conservation estate (READ, 2014). There are also 24 conservancies in the province. The species being conserved on these game farms are predominantly antelope such as kudu, duiker and steenbok. Other animals such as sable, Cape buffalo, gemsbok, eland, red hartebeest, blue wildebeest and even black rhinoceros also occur in the province. The North West province has some of the largest traders of wildlife in South Africa, who trade both nationally and internationally, bringing much-valued foreign exchange to the province (DACE, 2002).

5.3.2.2. Risk and Vulnerability

<u>Risk</u>

- **Sensitivity: HIGH**

  Changes in temperature and rainfall patterns have significant effects on tourism, given the sector's heavy dependence on biodiversity and ecosystems, which are in turn highly sensitive to temperature and rainfall. Effects that indicate climate sensitivity of tourism include the following: Changes in water availability for humans, plants and animals; temperature related stress on plants and animals; and changes in species range due to temperature shifts.

- **Exposure:**

  - **Short Term: MEDIUM**

In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that tourism is exposed to is not significant. However, even current day variability already has significant impacts on tourism in the North West, as a result of impacts on biodiversity and vegetation (discussed earlier in this report in a separate section). Impacts on biodiversity have impacts on game animal habitat, altering their surroundings, thus the short term exposure is assessed as medium level exposure.

- **Long Term: MEDIUM**

  As far as tourism is concerned, there are uncertain biodiversity effects on flora and fauna in terms of species composition and health. (Golder, 2011). However, ecosystem impacts are significant.

  North West Parks and Tourism Board perceives that climate change does affect the province, mainly through dry seasons becoming longer and below average rainfall. Higher temperatures may result in decreased tourism.

  Game farming is affected in a similar way to cattle farming (see above) (VA Workshop, 2015).

- **Risk:**
  - **Short Term: MEDIUM**
  - **Long Term: MEDIUM**

<u>Vulnerability</u>

- **Adaptive Capacity:**
  - **Short Term: MEDIUM**

    The tourism industry is well organised in terms of communication and the grouping of various bodies within the industry. However, relationship between government departments and private tourism industry is not as robust and transparent as in past years, and climate change issues are not discussed at various levels within the sector.

    The parks are involved in projects such as reducing fire frequencies and reviewing animal-stocking plans, including game removals to ease pressure on vegetation. The province as a whole is actively concerned with the impact of climate changes on the tourism sector, in terms of the impacts on biodiversity and ecosystems.

  - **Long Term: MEDIUM**

There are a number of initiatives for conservation of national parks. There are 14 reserves under the management of the North West Parks and Tourism Board (NWPTB); and 8 community park forums have been established comprising of traditional leaders, business, municipalities, youth and CPA members. The main focus of community meetings revolve around how communities relate to the reserve (DEA, 2014).

Although, the North West Parks and Tourism Board has not compiled or implemented any formal mitigation and adaptation plans and strategies, the province is looking at expansion of protected areas, with three sites being looked at for expansion of parks and protected areas (VA Workshop, 2015).

- **Vulnerability:**
  - **Short Term: MEDIUM**
  - **Long Term: MEDIUM**

5.3.3. Mining

5.3.3.1. Introduction

Mining is the mainstay of the province, generating 34% of the province's GDP and a quarter of its jobs. The platinum mining area is mainly between Brits and Rustenburg, while gold mines are found between the Klerksdorp to Potchefstroom area. The electricity consumption of the province is due to the electrical energy-intensive mining and related industrial sector. Approximately 63% of the electricity supplied to the province is consumed in its mining sector.

Mining requires water and it thus impacts on the water in the province. The large consumption of water by the mining industry is exacerbated by the fact that the activities occur mostly in the water scarce parts of the province, compelling mines to use water as efficiently as possible.

5.3.3.2. Risk and Vulnerability

<u>**Risk**</u>

- **Sensitivity: MEDIUM**

Climate change impacts on the mining sector are mainly indirect (VA Workshop, 2015)

Changes in temperature and rainfall patterns have some effects on mining, because temperature affects the working conditions of miners, and rainfall affects water availability for mining operations. Furthermore, mining impacts on water quality through effluent discharge and AMD impacts. Mining thus places significant quality and demand pressures on the province's water resources and this is important in the context of water scarcity.

Most mines need large volumes of water for production and also discharge of waste products as effluents into rivers and other surface waters. If available water declines in the future due to climate change impacts, the mining sector's impact on water also becomes important. For example, mining wastes, such as overburden, waste rock or slimes all have a negative impact on the aquatic environment. Furthermore, mining at depth cannot be conducted safely below dolomite aquifers, and the standard practice of the industry is to dewater such aquifers for safe operations. Many local aquifers have become depleted because of this. Depletion of surface water resources within the province as a result of mining activities is difficult to differentiate from the depletion of the ground water, as information on the individual components of a mine's water balance are generally not measured.

- **Exposure:**

  - **Short Term: MEDIUM**

    INDIRECT: In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that mining is exposed to is not significant. However, even current day variability already has impacts on mining in the North West (including operational efficiency of existing mines), thus the short term exposure is assessed as medium level exposure.

    The issues raised below provide a discussion of water and the mining sector in the context of the fact that the NW province is a water-stressed province. Climate change impacts may thus further exacerbate already difficult conditions (VA Workshop, 2015).

    There have been claims of the depletion of the aquifers in the vicinity of deep mining operations in the Klerksdorp area, impacting on water availability for other users. In addition, in a community satisfaction survey done by G3 Business Solutions and the University of the North West, farmers accused Lonmin of, "amongst other things… stealing water from the Buffelspoort dam, and that the boreholes had dried up as a result of mining operations." (Bench Marks Foundation). Finally, the perforation of impermeable dykes by the mining sector can lead to changes in the flow of direction of underground water. This may also lead to the pollution of water and the decanting of polluted water into surface streams through fountains. The perforation of dykes may also cause a drop in the water table with dire consequences for farmers and communities depending on wells and boreholes.

  - **Long Term: HIGH**

    INDIRECT: Again, the long-term impacts for the mining sector revolve around the discussion of availability of water and the impact of the mining sector on scarce and stressed water resources in the province (VA Workshop, 2015).

For the Crocodile west catchment, the mining industry water requirements were very hard to obtain (DEA, 2013b). Climate models do not provide a high level of certainty about whether rainfall in the North West province is likely to increase, decrease, or stay roughly the same in the future. However, in either scenario, there are significant impacts for the mining sector. With less rain, and potentially drier conditions, the sector will face the challenge of finding adequate water for its operations. With more rain, the challenge of Acid Mine Drainage (AMD) is likely to be exacerbated. Thus, with potentially increased rainfall in zone 3 region, there will be a resulting potential increase in ingress and decant. While there are technically feasible options to mitigate the effects of AMD, there may be long-term challenges (DEA, 2013b).

- **Risk:**
    - **Short Term: MEDIUM**
    - **Long Term: HIGH**

__**Vulnerability**__

- **Adaptive Capacity:**
    - **Short Term: LOW**
    Given scarce water resources, the mining sector's impact on water resources is critical. It is thus important to look at what is in place currently:
        - The National Environment Management Act of 1998 requires pre-mining assessment of social and environmental impacts and implementation of environmental management plans throughout the life of the mining operation (DST, 2011). This is aimed at minimising environmental risk and repairing damage. The closure of a mine is dependent on achievement of specified environmental targets for the return of biodiversity, ecosystem function, land use options, aesthetics and environmental health (DST, 2011)
        - One piece of research found a lack of capacity at local and district government levels to independently monitor the impact of mining on surface water, and a lack of awareness among communities in the area of the potential risk. Implats in its annual report states that insurance companies are refusing to insure their tailings facilities in the area. Discussions with risk assessors also indicate that insurers are reluctant to insure against potential disasters posed by waste facilities (Bench Marks Foundation).
        - All the mines in the Rustenburg area report in some detail about their consumption of water and energy and about their management of waste and of substances that

are being pumped into the atmosphere. However, there are many hydrological and geological issues not covered in either their reports or by national legislation or international conventions. This is particularly true for issues that will take a long time to become obvious, including the impact on underground water of the dewatering of aquifers, the perforation of dykes, the disturbing of faults, etc (Bench Marks Foundation).

- **Long Term: MEDIUM**

  Adaptive capacity in the long term for the mining sector revolves around implementation of long-term programmes to make mining more environmentally sustainable in terms of water resources:

  - Acid Mine Drainage Projects: There is a provision of R39 billion in the *Sustainable Development through Mining* programme being undertaken by CSIR for rehabilitation of abandoned mines.

  - The 2010 report to the inter-ministerial committee on Acid Mine Drainage[1] identified that there existed risks owing to the flooding of the mines and decant of AMD to the environment. In order to mitigate some of the impacts, a generic approach to the management of the identified risks were proposed:

    - Decant prevention and management: water levels to be held at or below the Environmental Critical Levels1 (ECLs) by pumping of water.
    - Ingress control: by preventing the recharge of the shallow groundwater above the mine void by the canalisation of surface streams, the sealing of surface cracks and mine openings and a number other measures.
    - Water quality management: AMD is still being produced and will require treatment through active, passive and in situ treatment technologies.

  - Implementation of Waste Discharge Charges

- **Vulnerability:**

  - **Short Term: MEDIUM (INDIRECT)**

  - **Long Term: HIGH (INDIRECT)**

[1]*Mine Water Management in the Witwatersrand Gold Fields with special emphasis on acid mine drainage, Report to the inter-ministerial committee on acid mine drainage, December 2010*

5.4. Infrastructure and Utilities

5.4.1. Water Supply

5.4.1.1. Introduction

The North West is a water scarce province. The Vaal River (lower) provides much of the irrigation needs in the south, while the Crocodile and Marico rivers provide water to some of the eastern and central parts of the province. Both mining and agriculture require significant amounts of water and therefore water resources have to be imported from other basins as well. Many communities also rely on groundwater for consumption and irrigation (PDP, 2013).

The availability of water is a key factor for any future development in the North West province. Thus, both water security and water quality are key to provincial development (PDP, 2013).

5.4.1.2. Risk and Vulnerability

<u>Risk</u>

- **Sensitivity: HIGH**

  Changes in temperature and rainfall patterns have significant effects on water supply, given the sector's direct relationship with the quantity and quality of water or the lack thereof. Effects that indicate climate sensitivity of water supply include the following: Changes (increase / decrease) in water availability, changes in water quality as a result of warmer temperatures (such as a decline in biochemical oxygen demand (BoD) or slight decrease in PH levels, salinization and sedimentation), changes in spatial / geographic distribution of water, disruption of water infrastructure by climate change related extreme weather events**.**

- **Exposure:**

  - **Short Term: MEDIUM**

    In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that water supply is exposed to is not significant. However, even current day variability already has big impacts on water supply in the North West (as described below), thus the short term exposure is assessed as medium level exposure.

    <u>DEMAND FOR WATER:</u> The province is currently a water scarce province and water shortages are likely to occur by 2020 (based on current growth in consumption and demand), particularly in the western and north western parts of the province if

interventions are not put in place (PDP, 2013). Water resources are drying quickly due to higher temperature and less rainfall (VA Workshop, 2015).

WATER SUPPLY INFRASTRUCTURE AND LOSSES: A reduction of rainfall in an already water-stressed province like the North West is compounded by huge water losses that many water schemes suffer due to lack of technical capacity, decaying infrastructure and lack of proper operation and maintenance capacities. Water infrastructure is ageing and proper management and maintenance remains a challenge (PDP, 2013). Distribution losses associated with irrigation supply in the Crocodile West catchment are as high as 50% (DEA, 2013b).

Per the map below, in the North West province the percentage of non-revenue water is high in the areas for which there is data available for the province.

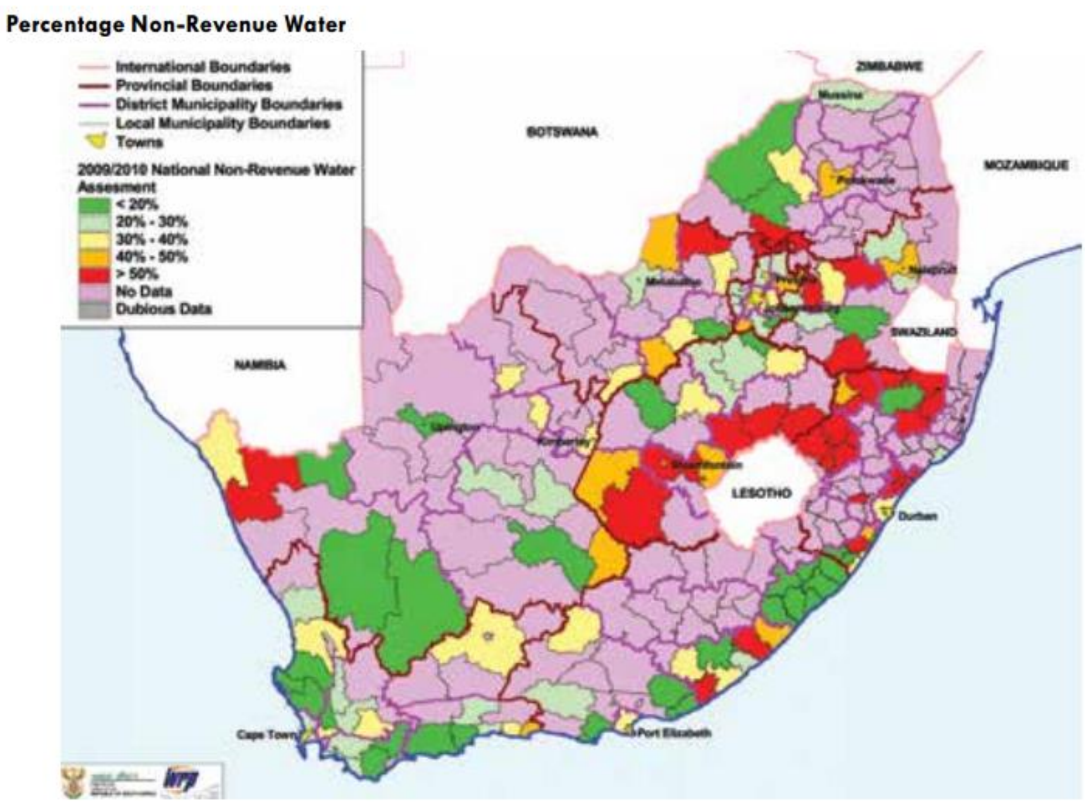


Figure 27: Percentage Non-Revenue Water (DWA, 2013b)

Permanent and reliable access to water in the North West province remains a challenges in many communities, often leading to households having to incur additional costs to source water. The figure below shows that while areas of the province are well-serviced, there are also areas that require attention. Over R734 million is required to deal with water backlog in the North West alone (DWA, 2013).

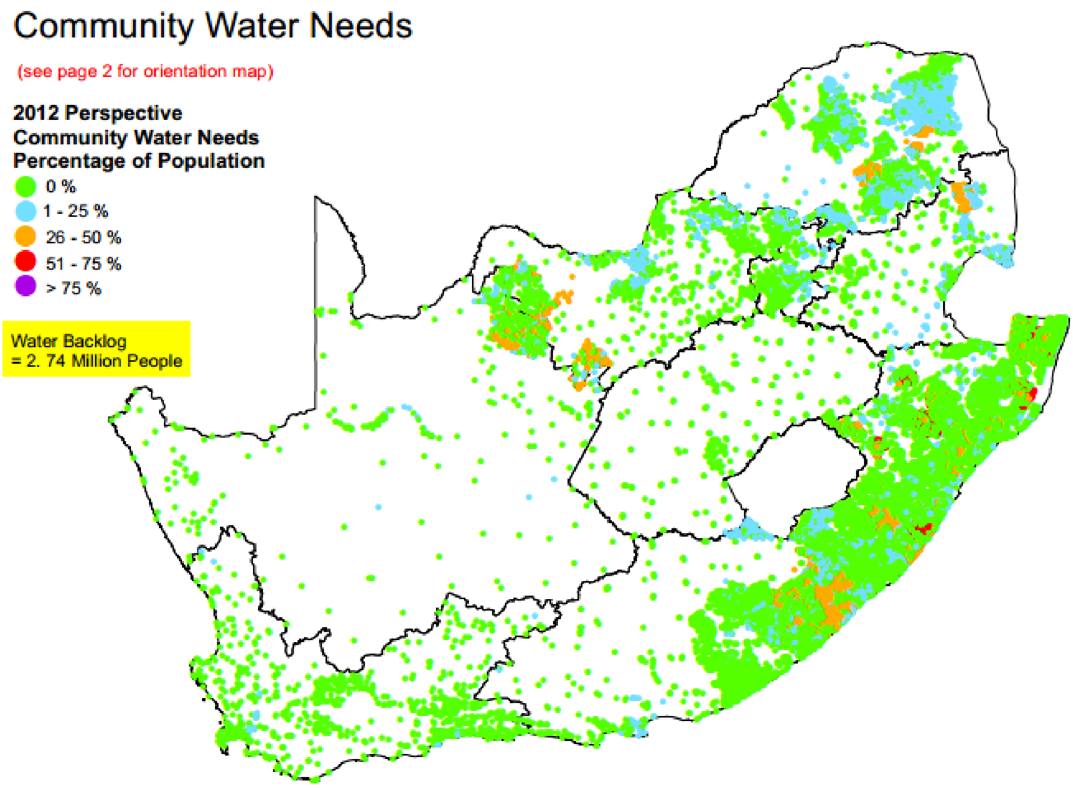


Figure 28: Community Water Needs (DWA, 2013b)

DWA uses a Municipal Strategic Self-Assessment (MuSSA) to check the overall business health of municipality / Water Service Authority and identify key areas of vulnerability. Sixteen key areas of service vulnerability within a WSA were assessed, including water services development planning, management skill levels, staff skill levels, technical staff capacity, water resource management, water conservation and demand management, drinking water quality, wastewater / environmental safety, infrastructure asset management, operations and maintenance of assets, financial management, revenue collection, information management, organisational performance, water service quality and customer care (DWA, 2013b).

Based on this, the vulnerability of the North West province is very high, as shown in the figure below. All but one of the municipalities are marked as highly vulnerable.

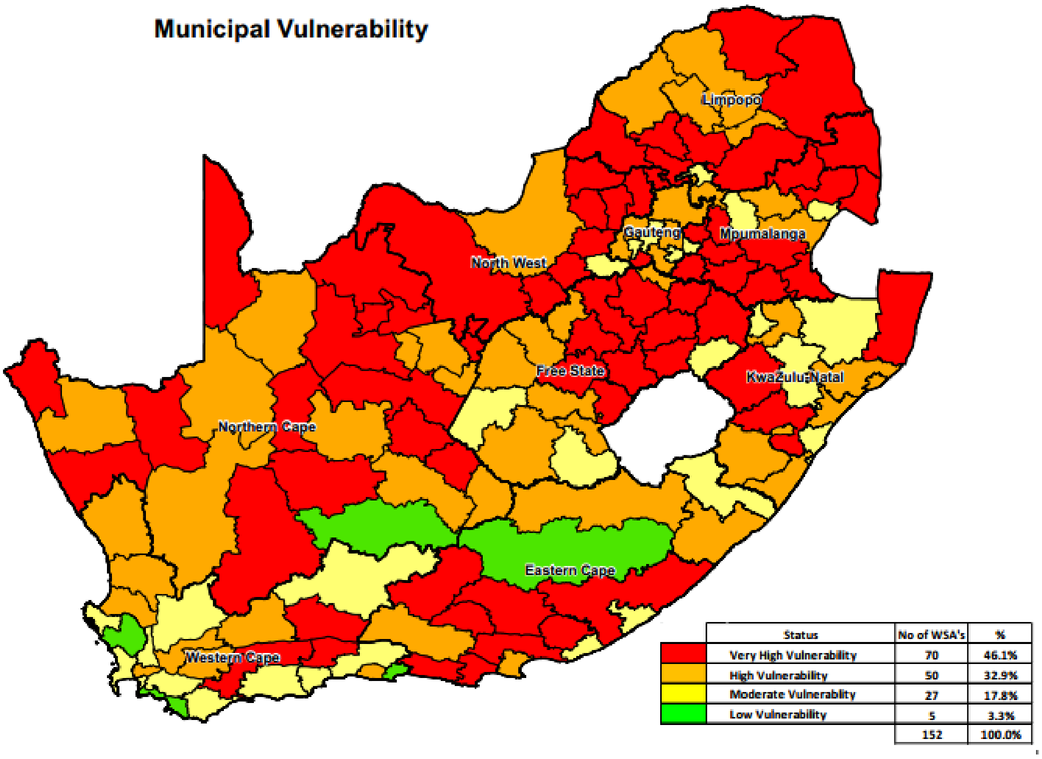


Figure 29: Municipal Vulnerability in South Africa – Water Services (DWA, 2013b)

WATER QUALITY: The province is not only depleting its precious water reserves, but suffers from an additional problem - that of pollution of groundwater. This includes high levels of dissolved mineral levels, nitrates and fluoride concentrations in certain areas, caused by both natural and human-induced factors including mining and industrial activities, agriculture and domestic use.

The simulated flow data for the Crocodile (West) river catchment shows that a large quantity of return flow from urban and mining developments reaches the Crocodile catchment from effluent discharges originating in the Vaal, which significantly impact on the water quality of receiving streams and impoundments (DEA, 2013b).

- **Long Term: HIGH**

  DEMAND FOR WATER: In the Crocodile West catchment, scenarios with regard to population growth, economic growth, socio-economic changes and possible transfers of water are presented in the Reconciliation Study report. It is anticipated that the current development trends will continue for the foreseeable future with strong growth in the urban / industrial / mining sectors. Large new developments related to mining, power and petro-chemicals industries are also being planned in the neighbouring Mokolo catchment, with the expectation that water could be supplied from or via the Crocodile River (DEA 2013b). Population growth will take place via two avenues: childbirth and migration, while economic growth is expected to continue at above the national average. Socio-economic changes and improvements in service delivery also play a role in the water demand for the area (DEA, 2013b). The province is potentially facing a water crisis in the long-term, and water will become more expensive as it becomes scarcer. Furthermore, the deterioration in water quality as a result of industrial, farming and household activities will further exacerbate the situation (VA Workshop, 2015).

  Though climate change considerations were not found in the Crocodile West reconciliation study report, the catchment relies heavily on return flows from the Vaal – this would become insufficient should there be increased demand in the area (DEA, 2013b). In the Vaal River catchment, there is a prediction of a deficit after 2035 (DEA, 2013b). Furthermore, increased rainfall could exacerbate the phenomenon of AMD (DEA, 2013b).

  INFRASTRUCTURE: Existing dams are dimensioned on historical hydrological records (dam size and safety), and will not necessarily be able to deal with future climate conditions. Climate change needs to be included as a factor to be taken into account when assessing the safety of current dams and in the design of new structures.[7]

- **Risk:**
  - **Short Term: MEDIUM**
  - **Long Term: HIGH**

Vulnerability

- **Adaptive Capacity:**
  - **Short Term: LOW**

    There are a number of initiatives currently for dealing with water issues, and they include the following (VA Workshop, 2015):

[7] https://www.environment.gov.za/sites/default/files/docs/implications_climatechange_foragriculture.pdf

- Water Conservation and Demand Management (WCWDM)
- Water Restrictions
- Early Warning Systems
- Awareness Programmes
- Groundwater recharge strategies
- Rainwater harvesting
- Removal of Alien Invasive Plant

- **Long Term: MEDIUM**

  Long term adaptive capacity is dependent on implementation of programmes and plans. A few of these are highlighted below.

  - Implementation of Water Management Plans will enhance adaptive capacity in the long-term. These include initiatives outlined in the National Water Resource Strategy II (VA Workshop, 2015).
  - There is a National Climate Change Strategy for Water Resources which will be implemented for provinces as well (VA Workshop, 2015).
  - The role out of the Catchment Management Agencies (CMA) should result in regionalised databases of water quality and River Health Programme data (Kalule-Sabiti and Heath, 2008)
  - Ground water monitoring programme: Little data collection is being done on a regional level in the North West province, particularly around groundwater. There is limited information regarding the ground water toxicity and the percentage of non-compliances with guidelines. Furthermore there is no database of ground water pollution incidences which would service various national and even multilateral reporting requirements (e.g. The Community Right To Know Principle enshrined in the Kyoto Protocol on Climate Change). Furthermore, no cooperative agreements exist currently between various organisations such as DWS, Local Government, mining houses, etc to collect data and supply it in the required format so that the North West province can undertake the required ambient monitoring programme.
  - Working for Wetlands Programme (VA Workshop, 2015): Approximately 50 interventions are implemented under the Working for Wetlands programme in the North West province every year. For example, in the Rustenburg area, numerous degraded wetlands associated with the Hex and Crocodile River systems have been successfully rehabilitated by addressing common drivers of wetland degradation (READ, 2014).

- A number of dam remediation programmes have been undertaken to improve the water quality, such as the Hartbeespoort and Roodeplaat Dams (DWA, 2013)

- Municipal Asset Maintenance Programme to decrease water loss: A number of Water Service Authorities in South Africa do not budget sufficiently for asset maintenance and replacement. Given this, DWS is currently developing an infrastructure management strategy, tools and processes to assist WSAs to ensure that their assets are properly managed and maintained (DWA, 2013).

- Supply of water:
  In the North West, the first phase of the R1,2 billion Pilanesberg scheme is being implemented. The project is being developed in conjunction with mines and will provide a further 100Ml of water per day for the benefit of municipalities and mines.

  Rand Water BG3 pipeline – which is Sub-Saharan Africa's largest water pipeline, running from the Vaal Dam to its Zoekfontein Plant (which is 8,6km away) – was launched in June 2013 and will augment raw water capacity and accommodate the region's projected water growth in water demand to 2030 (DWA, South Africa Yearbook 2013/2014).

  In addition to the current Municipal Grant Funding (MGF), Equitable Share allocation and Regional Bulk Infrastructure Grant (RBIG)[8], DWS is also instituting a Municipal Water Infrastructure Grant (MWIG) which aims to assist WSAs to provide water services to consumers currently without a basic water supply, particularly those in rural areas, though the facilitation, planning, acceleration and implementation of various projects (through DWS's Interim/Immediate Water Supply Programme) (DWA, 2013b).

- **Vulnerability:**
  - **Short Term: MEDIUM**
  - **Long Term: MEDIUM**

5.4.2. Energy Supply

5.4.2.1. Introduction

The North West is the fourth largest electricity consumer in South Africa and consumes approximately 12% of the available electricity.

[8]Over 16,000 households will benefit from the R52 million Makapanstad and Mathibestad Bulk Water project, which aims to address water shortages in the villages of Moretele Local Municipality in the North West (South Africa Yearbook 2013/2014).

In the North West province, urban areas rely predominantly on electricity to meet most of their energy needs. The majority of households in non-urban areas use wood and paraffin (as an alternative to electricity) for cooking purposes, and candles for lighting. However, the reliance of rural communities on fuel-wood exerts pressure on the environment to meet demand. This is particularly evident in the immediate vicinity of settlements, where deforestation can occur (DACE, 2002). There is a need to improve access to electricity in the province. However, coal-powered energy is water intensive and is intensive in terms of greenhouse gas emissions.

5.4.2.2. Risk and Vulnerability

Risk

- **Sensitivity: Medium**

  Changes in temperature and rainfall patterns have significant effects on energy supply, given the sector's usage of water (for both electricity generation and cooling), and the relationship to temperature (in very high temperatures there is heavy demand for cooling, and in low temperatures there is heavy demand for heating). Effects that indicate climate sensitivity of water supply include the following: Changes (increase / decrease) in water availability for cooling in power plants; increased levels of cooling needed in extremely warm temperatures; disruptions in energy supply from climate change-related extreme weather events; increase in demand for air conditioning in warmer temperatures.

  Electricity production in South Africa (coal) is water-intensive. A warmer climate may reduce the efficiency of power production for many existing fossil fuel and nuclear power plants because these plants use water for cooling. The colder the water, the more efficient the generator. Thus, higher air and water temperatures could reduce the efficiency with which these plants convert fuel into electricity. Therefore projected changes in water availability for cooling in power plants, increased levels of cooling needed in extremely warm temperatures, increase in demand for air conditioning in warmer temperatures will exacerbate disruptions in energy supply from climate change related extreme weather events. Changes in energy demand will likely affect greenhouse gas emissions, but the net effect depends on which energy sources are used for electricity and heating.[9]

  Climate change is likely to both increase electricity demand for cooling in the summer and decrease electricity, natural gas, heating oil, and wood demand for heating in the winter. New infrastructure investments may be necessary to meet increased energy demand, especially peak demand during heat waves.

- **Exposure:**

  - **Short Term: LOW**

[9] http://www.epa.gov/climatechange/impacts-adaptation/energy.html

In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that energy supply is exposed to is not significant. Nonetheless, increased storms and flash floods will impact on energy supply infrastructure (VA Workshop, 2015).

- **Long Term: MEDIUM**
  Increased storms and flash floods will continue to impact on energy supply infrastructure (VA Workshop, 2015).

  Indirect: Economic growth as well as more frequent and severe heat waves will likely increase the demand for electricity in North West.[10] At the same time, reduced water supplies due to decreased rain and/or increased temperature and evaporation could further stress water resources in the country.

- **Risk:**
  - **Short Term: LOW**
  - **Long Term: MEDIUM**

Vulnerability

- **Adaptive Capacity:**
  - **Short Term: MEDIUM**
    South Africa is looking at diversifying its energy production away from coal, which could help reduce the stress on water resources, particularly since climate change impacts may result in further drying in parts of the country. The RustMo1 Solar Farm is a 7MW Solar Photovoltaic power generation facility located in Buffelspoort, 22km outside the City of Rusternburg, and is the first renewable energy project in the North West province. It was launched in 2013. Other interventions that are helping to reduce (water-intensive) energy use include the following (VA Workshop, 2015):
    - Solar energy / energy-saving bulbs/devices
    - Awareness campaigns on energy savings
    - Energy Audit
  - **Long Term: MEDIUM**

    The North West province has developed a renewable energy strategy, which aims to improve the environment, reduce the contribution to climate change, and alleviate

[10] Higher temperatures will lead to increased use of air conditioners, though it is important to note that most of the province is rural.

energy poverty. A number of renewable energy supply options have been developed for the province (DEDECT, 2012).

- **Vulnerability: MEDIUM**

5.4.3. Transportation

5.4.3.1. Introduction

5.4.3.2. Risk and Vulnerability

Risk

- **Sensitivity: LOW**

  Changes in temperature and rainfall patterns have some effects on transportation, albeit not highly significant ones (unless inland navigation on rivers is a key element). Effects that indicate climate sensitivity of transportation include the following: Roads and bridges buckling and cracking in warmer temperatures, disruption of transportation infrastructure by climate change related extreme weather events, increase in heavy rainfall can cause erosion of dirt roads, landslides causing road blockages

  Climate change is projected to increase the frequency and intensity of extreme weather events. Higher temperatures can cause pavements to soften and expand. This can create rutting and potholes, particularly in high-traffic areas and can place stress on bridge joints. Exposure to flooding and extreme temperature events shortens the life expectancy of highways and roads. On the other hand, drought in some areas of South Africa could increase the likelihood of wildfires that reduce visibility and threaten roads and infrastructure.

- **Exposure:**

  - **Short Term: LOW**

    In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that transport infrastructure is exposed to is not significant.

    Nevertheless, South Africa currently has a large unpaved road network that is impacted by increases in rainfall and existing paved road network that needs to be adapted to projected increases in temperature (Chinowsky et al., 2012).The quality of the road infrastructure is also impacted by floods (VA Workshop, 2015). Although the road network in the province is well developed and includes some key highways, the quality of many of the roads is deteriorating and wide scale investments are required to improve conditions (PDP, 2013).

  - **Long Term: MEDIUM**

In the longer-term there will be deterioration of infrastructure (VA Workshop, 2015). **T**he potential cost of climate change on roads could be increasingly reduced in the latter decades if a pro-active adaptation strategy is taken. The benefits from adapting road infrastructure proactively include savings from decreased maintenance on unpaved road infrastructure, decreased vulnerability to climate change impacts, and a more robust and reliable road infrastructure system. By adapting unpaved road infrastructure to paved infrastructure, there are fiscal savings as well as additional benefits including less maintenance from extreme events, increased connectivity of roads year-round, and higher traffic and freight volumes.

The figures below show the decadal cost for each province for the median climate scenario from adapting and not adapting. The cost for the North West province in the "No Adapt" scenario is lower than for most other provinces. The adaptive advantage is particularly high for the North West, among other provinces, per the figure below (Chinowsky et al, 2012).

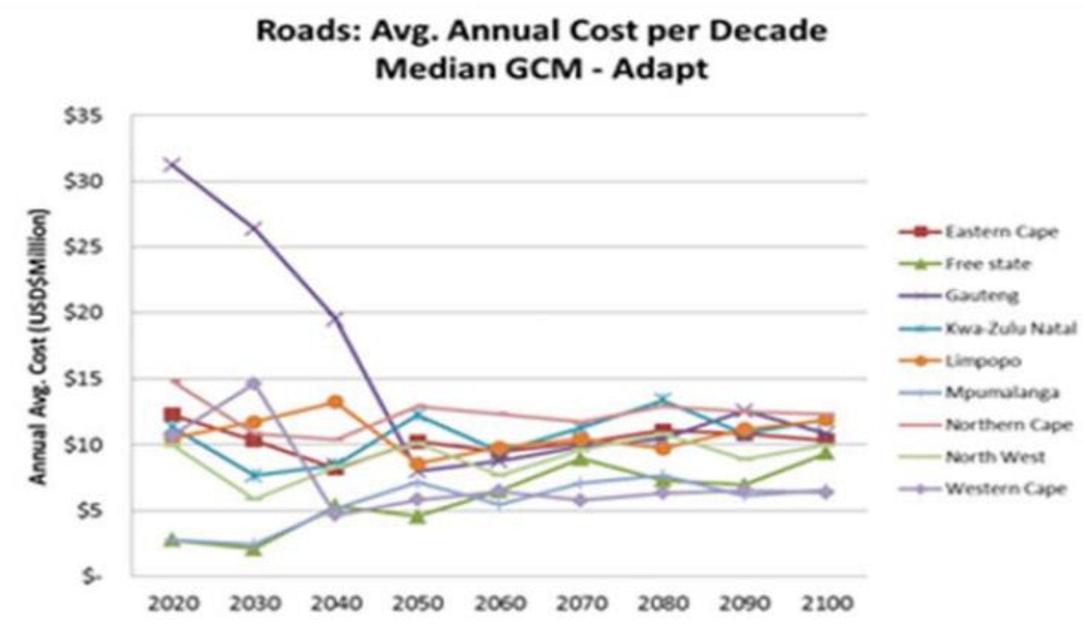


Figure 30: Decadal Cost for Road Infrastructure, Median GCM, Adapt (Chinowsky et al., 2012)

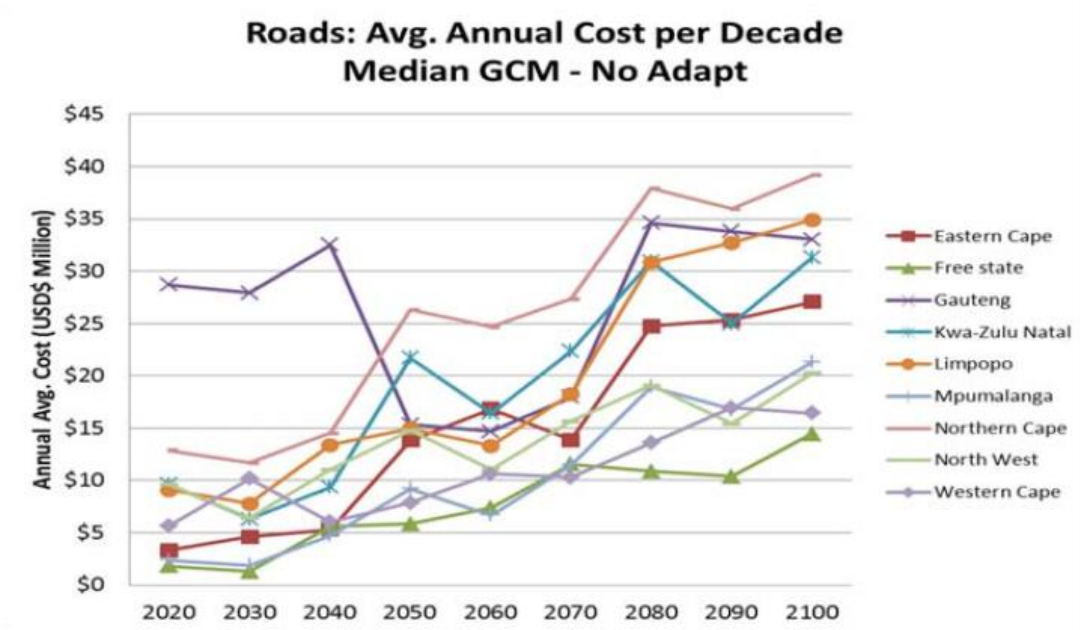


Figure 31: Decadal Cost for Road Infrastructure, Median GCM, No Adapt (Chinowsky et al., 2012)

Risk:

- **Short Term: LOW**
- **Long Term: LOW**

Vulnerability

- **Adaptive Capacity:**
  - **Short Term: LOW**
    - There are a number of ongoing upgrade projects underway. For example, recently, a contract was awarded by the North West provincial government for the upgrade of 54,8km of gravel roads in the Ganyesa area, north west of Vryburg by May 2016.[11]
    - Introduction of Rapid Road Transport means improvement in roads and more people using public transport (VA Workshop, 2015).
  - **Long Term: MEDIUM**

[11]http://www.engineeringnews.co.za/article/mr-infrastructure-awarded-north-west-road-infrastructure-upgrade-contract-2014-12-11

The National Infrastructure Plan envisages unlocking the economic opportunities in the North West province through investments in road, rail and transmission infrastructure, among other things.

Introduction of Rapid Road Transport means improvement in roads and more people using public transport (VA Workshop, 2015).

The implementation of Disaster Management Plans will improve adaptive capacity in the long-term (VA Workshop, 2015).

- **Vulnerability: :MEDIUM**

5.5. Public Health and Safety

5.5.1. Human Health and Safety (diseases, etc)

5.5.1.1. Introduction

Climate change impacts human health in a wide variety of ways. Changes in temperature disturb the thermal equilibrium of the body, creating more physiological stress that can exacerbate existing chronic conditions such as heart and respiratory conditions (leading to increases in heart attacks, strokes, chronic obstructive pulmonary disease etc.). High temperatures lead to more dehydration and heat exhaustion as well as heat strokes. Drought also could lead to dehydration, lowered food security (due to less access to adequate nutrition), an increase in water-borne disease (from more users using limited water supplies, increasing the risk of contamination). Similarly, after floods triggered by extreme rain there could be more water borne diseases due to effluent overflow. Certain pests thrive more (extend their range or their lifecycle, reproducing at a more prolific rate) in warmer temperatures, and could cause more food borne diseases or lower food security through crop damage.

5.5.1.2. Risk and Vulnerability

<u>Risk</u>

- **Sensitivity: MEDIUM**

  Changes in temperature and rainfall patterns have several effects on human health and safety, in particular because ambient temperature affects the human body's functioning, and also because the range and populations of disease-carrying pathogens is often related to temperatures that create favourable conditions for such organisms. Effects that indicate sensitivity of the health sector to changes in temperature and rainfall include: Heat related illnesses and exacerbation of chronic illness; spread of diseases due to changes in vector / carrier range (from temperature shifts); changes in food and water-borne diseases (due to impacts of warmer temperature on pathogen reproduction or lifecycle). Diseases/conditions such as skin cancer, heart conditions, dehydration, heat-stroke, zoonotic diseases and respiratory illnesses are also sensitive to temperature / rainfall changes (VA Workshop, 2015). The pattern of increasing extreme rainfall events and rising temperature favour the geographical expansion of the borders of vector borne diseases such as malaria, dengue fever and yellow fever (DEA, 2013e). There are a range of impacts associated with extreme weather, as indicated in the table below.

  Table 7: Impacts of Extreme Events on Health (DEA, 2013e)

Floods and Storms	Drought	Fire
• Increased or decreased vector (e.g. mosquito) abundance (e.g. if breeding sites are washed away). • Increased risk of respiratory and diarrhoeal diseases. • Drowning. • Injuries. • Health effects associated with population displacement. • Impacts on food supply. • Mental health impacts.	• Changes in abundance of vectors that breed in dried up river beds. • Food shortages. • Illness. • Malnutrition. • Increased risk of infections. • Death (starvation). • Health impacts associated with population displacements.	• Burns and smoke inhalation. • Soil erosion and increased risks of landslides. • Increased mortality and morbidity. • Increased risk of hospital and emergency admissions.

In areas where effective adaptation responses are lacking, the food habits of people may change. For example, people may substitute their consumption, production and ecological systems in response to climate change and development pressures. Similarly, a decline in income could result in a decline in food expenditure, thus substituting less nutritious food or consuming less. This could negatively impact on childhood development.

- **Exposure:**

  - **Short Term: MEDIUM**

    In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the change that the health sector is exposed to is not significant. However, given that climate variability already has some effects on the sector (e.g. patterns of diseases and heat related illnesses), the exposure level is assessed as medium even for the short term.

  - **Long Term: MEDIUM**

    Some of the health risks resulting from or aggravated by climate variability in South Africa over the next few decades include heat stress; vector-borne diseases (such as malaria, dengue fever and yellow fever); 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. Malaria is projected to spread within regions bordering current malaria areas, which are presently too cold for transmission.

    In the rural areas in the North West province, one in three children displays marginal vitamin A status, 20% are anaemic and 10% are iron-deficient (DACE, 2002). It is estimated that in 2010, around a quarter of children in the North West province lived in households that experienced hunger (PDP, 2013). In rural areas where subsistence agriculture is prevalent, there is greater likelihood of drought linked to higher temperature and unpredictable rainfall. This is likely to have particularly acute effects where child hunger is already significant.

At present, there are a number of contributors to air quality challenges in the province, including mining in open areas, mining tailings disposal sites, crop agriculture, denuded land, industrial and manufacturing activities, on-road mobile sources, household fuel combustion, waste-burning and biomass burning (DEDECT, 2011). Rising temperatures and greater numbers of hot days and nights, particularly in inland provinces such as the North West, might see deteriorating air quality. Compounded by issues of air pollution, these pressures could negatively affect children's respiratory health and development. In rural areas, poor air quality could induce respiratory diseases, such as asthma and TB. With a possible increase in veld fires, the quality of air could be reduced leading to health problems and contributing to poor ambient air quality in the province (DACE, 2009).

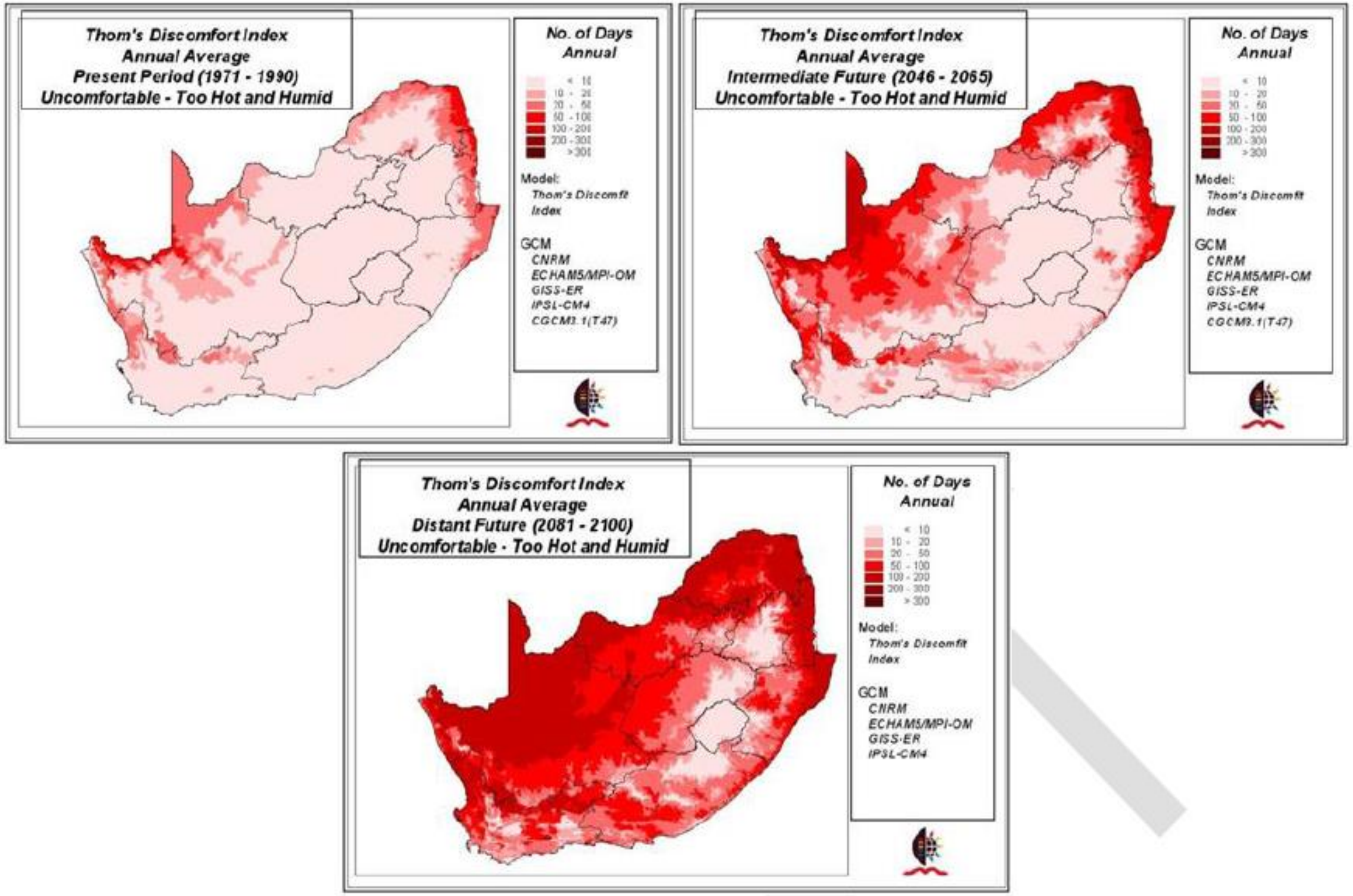


Figure 32: Thom's Discomfort Index (DEA, 2013c)

Incidence of heatstroke are likely to be exacerbated by deteriorating levels of water due to evapo-transpiration. Furthermore, increases in average temperatures and extreme events are projected to induce heat stress, increase in morbidity, and result in respiratory and cardiovascular diseases (DEA, 2013e).

The North West province reports no or a small number of malaria infections. The incidence of malaria may rise where higher rainfall is combined with higher temperatures. Similarly the prevalence of water, air and vector-borne diseases like bilharzia, diarrhoea and cholera will increase in areas where higher levels of rainfall (in terms of intensity, distribution and annual average) are projected, principally where this coincides with inadequate access to sanitation.

- **Risk:**
    - **Short Term: MEDIUM**
    - **Long Term: MEDIUM**

<u>**Vulnerability**</u>

- **Adaptive Capacity:**
    - **Short Term: LOW**

      Health infrastructure in the North West province is currently unprepared to deal with malaria outbreaks, given the historically low prevalence in the area (UNICEF, DEA, 2011).

      There are number of initiatives underway that impact on adaptive capacity in the short-term. They include (VA Workshop, 2015):

        - The War on Poverty
        - The Working for Fire programme
        - The Working for Water programme
        - The Provincial Disaster Management Strategy
        - Advisory Forums
        - Outbreak Response Teams
        - Disaster Early Warning Systems

    - **Long Term: MEDIUM**

      The adaptive capacity of the health sector is dependent on better health infrastructure in the future and implementation of health, nutrition and poverty alleviation programmes.

      The Provincial Air Quality Management Plan (2009) identifies a number of interventions to improve air quality, including i) Air Quality Management Capacity Development; ii)

Information Management; iii) Identification and Regulation of Industrial Polluters; iv) Electrification where fuel burning is widespread; v) Reducing Transport emissions within the province; vi) Understanding, Creating Awareness, and Managing agricultural and biomass burning. It also recognises that climate change issues should feed into provincial and local strategic interventions (DACE, 2009).

There are number of other plans / programmes including (VA Workshop, 2015):

- The Department of Health's National Climate Change and Health Adaptation Plan
- National School Nutrition Programme
- Environmental Health Programme

- **Vulnerability:**
    - **Short Term: MEDIUM**
    - **Long Term: MEDIUM**

5.5.2. Extreme Weather / Disaster (wild fires, floods, droughts, etc)

5.5.2.1. Introduction

Droughts and floods occur regularly in the province.

5.5.2.2. Risk and Vulnerability

Risk

- **Sensitivity: HIGH**

  Changes in temperature and rainfall patterns have significant effects on the occurrence and intensity of climate related disasters, given that temperature and water are key components of such disasters. Effects that indicate climate sensitivity of weather disasters include the following: Flooding and combined sewer overflows (due to increase in heavy precipitation events); droughts (due to decrease in overall precipitation, including in localized areas); more dryness in the bush / scrub, with greater chances of wild fires (due to increase in temperature and evaporation). Other impacts include intense lightning (VA Workshop, 2015).

- **Exposure:**
    - **Short Term: MEDIUM**

    In the short-term period (which this study defines as 2015-2020), temperature rise and changes in rainfall are within the range of current day climate variability. Therefore the incidence of expected disasters in this timeframe is not significant. However, given that climate variability already has some effects on the sector (e.g. record heat waves and an increase in veld fires), the exposure level is assessed as medium even for the short term.

The fire frequency in the east of the province is quite intense, as indicated in the figure below.

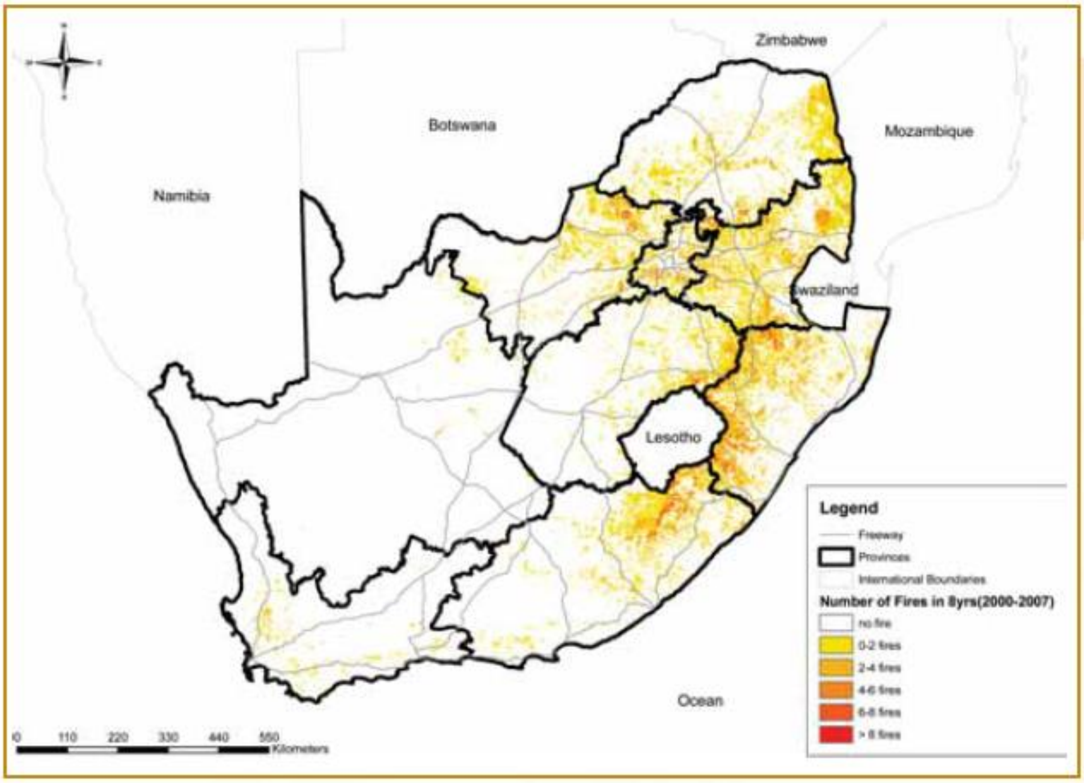


Figure 33: Fire Frequency in South Africa (Archer et al., 2010 (SARVA))

- **Long Term: HIGH**
    - Future increases in storm flow events are simulated over much of the Northwest of the country.
    - Fire regimes typical of several of South Africa's dominant ecosystems such as grasslands and savannah are projected to show a greater frequency.

- **Risk:**
    - **Short Term: MEDIUM**
    - **Long Term: HIGH**

<u>**Vulnerability**</u>

- **Adaptive Capacity:**

- **Short Term: MEDIUM**

  The North West is actively building and developing a Provincial Disaster Management Centre in Mafikeng to cover droughts, severe weather conditions, floods, veld fires and diseases (NDMC 2014).

- **Long Term: MEDIUM**

  The following projects have been identified for disaster risk reduction (DARD, 2011) in the longer term:

  a. VELDFIRES
     - Construction of fire belts for areas prune to veld fires
     - Supply/ Subsidisation of equipment to combat veld fires
     - Training
     - Formation of Fire Protection Associations
     - Fodder banks
     - Contingency Funds

  b. DROUGHT
     - Repairs/Construction of Water reticulation systems
     - Debushing/Restoration of Environment/Pastures
     - Camping division systems/infrastructure
     - Fodder banks
     - Contingency Funds

  c. FLOODS
     - Relocation from flood prone areas
     - Contours/Earth dams
     - Vaccinations
     - Fodder banks
     - Contingency Funds

  d. EARLY WARNING
     - Cell phone system (SMS) for all hazards
     - Satellite Fire Detection System

  e. STRUCTURE
     - Implement effective structure on District level.

- **Vulnerability:**
  - **Short Term: MEDIUM**
  - **Long Term: MEDIUM**

5.6. Summary of Climate Impact Risk and Vulnerability Assessment Findings

Table 8: Summary of Climate Impact Risk and Vulnerability Assessment Findings

	Sensitivity	Exposure		Risk		Adaptive Capacity		Vulnerability	
		Short Term	Long Term	Short Term	Long Term	Short Term	Long Term	Short Term	Long Term
Terrestrial	Med	Med	High	Med	High	Low	Med	Med	High
Aquatic	High	Med	High	High	High	Med	Med	Med	High
Rural	High	Med	Med	Med	High	Med	Low	Med	High
Urban	Med	Low	Med	Low	Med	Med	Med	Low	Med
Agriculture and Farming	High	Med	High	Med	High	Med	Med	Med	High
Mining	Med (indirect)	Med (Indirect)	Med (Indirect)	Med (Indirect)	High (Indirect)	Low	Med	Med (Indirect)	High (Indirect)
Tourism	High	Med	Med	Med	Med	Med	Med	Med	Med
Water Supply	High	Med	High	Med	High	Low	Med	Med	Med
Energy Supply	Med	Low	Med	Low	Med	Med	Med	Med	Med
Transport	Low	Low	Med	Low	Low	Low	Med	Med	Med
Public Health and Safety	Med	Med	Med	Med	Med	Low	Med	Med	Med
Extreme Weather / Disaster	High	Med	High	Med	High	Med	Med	Med	Med

6. Conclusion: Hotspots and Priority Areas for Building Adaptive Capacity

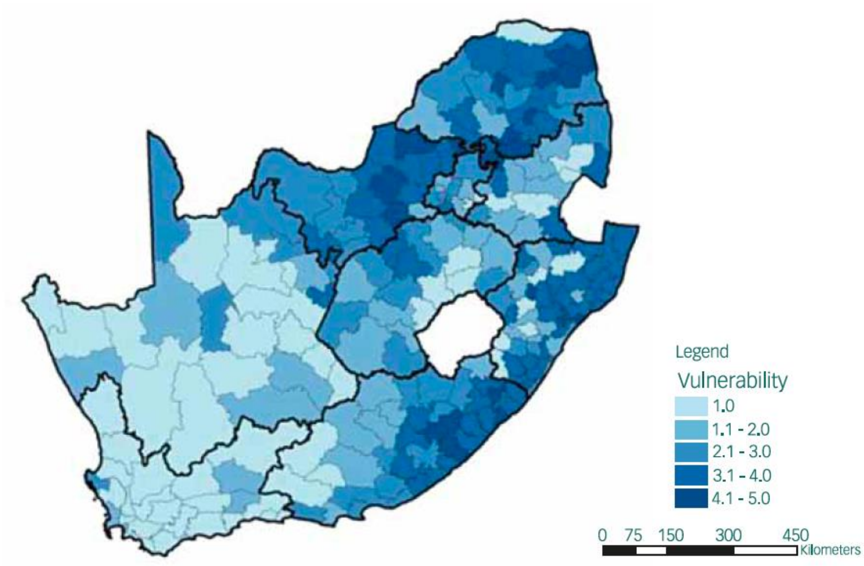
From a sectoral standpoint, the literature review and analysis in this report (further validated by provincial stakeholder workshops) points to the following sectors as priority areas for building adaptive capacity:

- **Agriculture and animal husbandry**
- **Rural livelihoods and settlements**
- **Terrestrial and aquatic ecosystems**
- **Extractives (mining)**

While the scope of the current project has always been to operate on a province-wide scale (and the constraints of resources and time available to this project – a mandate to cover three provinces in five months – also necessitate that the study take place only at the province level), it is important to note that as the province moves forward with its work on climate change adaptation in the key sectors identified it must allocate resources based on geographic need and vulnerability as well. There is a critical need for sub-provincial climate vulnerability assessments and for future resources to be dedicated to identifying geographic hotspots in relation to the specific sectors.

Prior to findings from such localized studies, it is possible to examine human existing vulnerability data for the province and surmise that climate change vulnerability may mirror, or at least overlap to a great extent, the areas that are already vulnerable due to low adaptive capacity overall (for instance, based on income levels, education levels, the presence of informal housing, access to water, sanitation, and electricity etc.).

One such recent nation-wide effort allows for a spatial view of which municipalities in North West that may have the greatest vulnerability to climate change. The report identified North West as having four of South Africa's twenty most vulnerable municipalities in the context of climate change – Moretele, Moses Kotane, Distobotla, and City of Matlosana (Financial and Fiscal Commission, 2012). In the table below (which lists all twenty municipalities), the four municipalities from the NW are identified with the codes NW 371, NW 375, NW 384 and NW 403 respectively (the last four in the list of top twenty).



Source: Calculated using WorldClim[14] (past-present data) and the CCFAS[15] (future, spatially downscaled predictions) global climate databases.

Figure 34: Index of Vulnerability to Climate Change for South African Municipalities (Financial and Fiscal Commission, 2012)

Table 9: Twenty Most Vulnerable Municipalities in South Africa to Climate Change (Financial and Fiscal Commission, 2012)

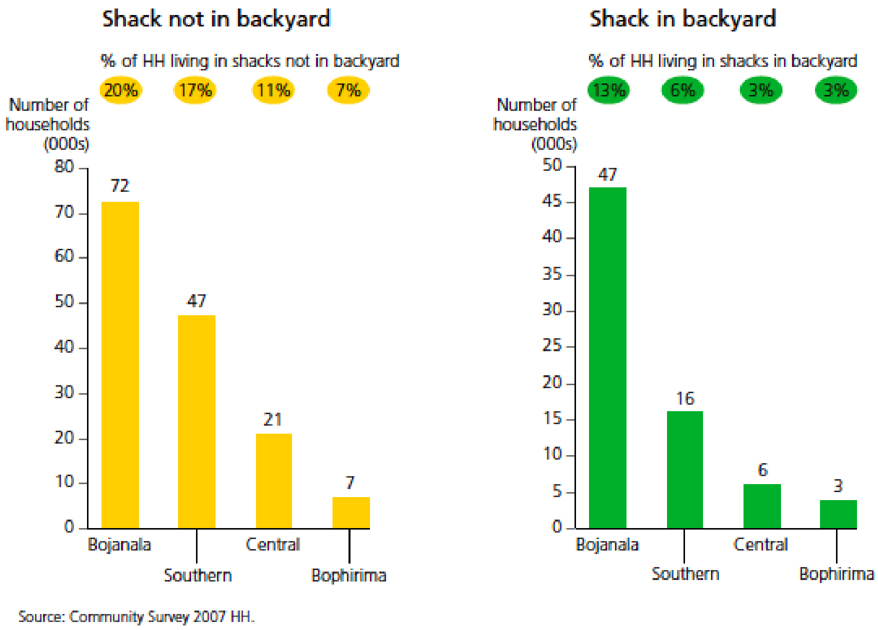
Municipality Name	Municipality Code	Municipality Type	Municipality Name	Municipality Code	Municipality Type
Mnquma	EC122	B4	Thulamela	LIM343	B4
Intsika Yethu	EC135	B4	Aganang	LIM352	B4
Engcobo	EC137	B4	Ephraim Mogale	LIM471	B4
Port St Johns	EC154	B4	Elias Motsoaledi	LIM472	B4
Ntabankulu	EC444	B4	Fetakgomo	LIM474	B4
Indaka	KZN233	B4	Thembisile	MP315	B4
Mandeni	KZN291	B4	Moretele	NW371	B4
Maphumulo	KZN294	B4	Moses Kotane	NW375	B4
Greater Giyani	LIM331	B4	Ditsobotla	NW384	B3
Greater Letaba	LIM332	B4	City of Matlosana	NW403	B1

The study found that levels of vulnerability in general are higher amongst households and communities who are resource-poor and presently lack adequate shelter or access to services. Climate vulnerability – especially in relation to health and safety as well as water supply and disaster risk – often correlates with such overall human vulnerability.

Within North West, one of the proxies for identifying this target group for building adaptive capacity is whether a household lives in informal settlements (such as in shacks that are not within their own backyard) or in formal housing structures (Housing Development Agency, 2012). This proxy metric flags Bojanala and Dr. Kenneth Kaunda (Southern) municipalities as areas with greater human vulnerability, and thus key areas for associated climate change vulnerability as well.

Figure

Figure 35: Households Living in Shacks, by Municipality in North West (Housing Development Agency, 2012)



The identification of these areas provides a helpful starting point towards identifying geographic vulnerability hot spots.

As this effort moves into the adaptation strategies phase, focus will be on the high priority sectors identified by this project, but the strategies will also take into account geographies with higher vulnerability where greater resources may need to be deployed when the provinces create implementation plans for the strategies.

In concluding, it is important to note that a lot of work is already being done in North West – both in the public and private sectors as well as in academia – on climate change vulnerability. Relative to some other provinces, North West has more capacity on climate change and has trained, skilled, and empowered individuals working on the issue in various capacities. Thus even though there are several vulnerable sectors in North West, there is a strong and growing knowledge base and adaptive capacity emerging in the province. This should be harnessed and strengthened so that activities already underway can be scaled up. Similarly, there are a lot of initiatives in North West that are not climate change focused but nevertheless address overall vulnerability and poverty in the province. The success of such efforts will also contribute to reducing climate change vulnerability and strengthening the economic and human resilience to climate change across the board in coming decades.

References

Archer, E., Engelbrecht, F., Landman, W. *et al*. (2010). *South African risk and vulnerability atlas (SARVA)*, CSIR and DST, Pretoria. http://www.rvatlas.org/download/sarva_atlas.pdf

Bench Marks Foundation. *A Review of the Corporate Social Responsibility Programmes of the Platinum Mining Industry in the North West Province.* http://www.bench-marks.org.za/research/Rustenburg%20platinum%20research%20summary.pdf

Benhin, J. 2006. *Climate Change and South African Agriculture: Impacts and Adaptation Options,* CEEPA Discussion Paper No. 21, CEEPA, University of Pretoria, South Africa. https://static.weadapt.org/knowledge-base/files/1426/5370f181a5657504721bd5c21csouth-african-agriculture.pdf

Blignaut, J., Ueckermann, L. and Aronson, J. 2009. *Agriculture Production's Sensitivity to Changes in Climate in South Africa,* South African Journal of Science. http://www.sajs.co.za/sites/default/files/publications/pdf/4-28-1-PB.pdf

CEEPA. 2006. *Climate Change and Crop Water Use and Productivity in South Africa,* CEEPA Policy Note No. 28 August 2006 (Climate Change and African Agriculture)

Chinowsky, S., Schweikert, E. Strzepek, L., Strzepek, R., Kwiatkowski, P. 2012. *Infrastructure and Climate Change: Impacts and Adaptations for South Africa*, WIDER Working Paper, No. 2012/105.

CSIR. 2010. *A Climate Change Handbook for North-Eastern South Africa*. CSIR, Pretoria. http://www.csir.co.za/nre/coupled_land_water_and_marine_ecosystems/pdfs/Davis_2010.pdf

Durand, W. 2006. *Assessing the impact of climate change on crop water use in South Africa*, CEEPA Discussion Paper No. 28, CEEPA, University of Pretoria, South Africa. http://www.ceepa.co.za/uploads/files/CDP28.pdf

Department of Agriculture, Forestry and Fisheries (DAFF). 2011a. *Maize Market Value Chain Profile 2011/2012.*

Department of Agriculture, Forestry and Fisheries (DAFF). 2011b. *A Profile of the South African Beef Market Value Chain 2011.*

Department of Energy (DOE). 2013. *Integrated Resource Plan for Electricity (IRP) 2010-2030: Update Report 2013*

Department of Environmental Affairs (DEA) (2014). *South Africa's Implementation of the 5th World Parks Congress Outcomes. Preliminary Report Durban to Sydney, 2003-2014.*

Department of Environmental Affairs (DEA). 2013a. *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Trends and Scenarios for South Africa.* Pretoria, South Africa.

Department of Environmental Affairs (DEA). 2013b. *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Change Implications for the Water Sector in South Africa.* Pretoria, South Africa.

Department of Environmental Affairs (DEA). 2013c. *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Change Implications for the Agriculture and Forestry Sectors in South Africa.* Pretoria, South Africa.

Department of Environmental Affairs (DEA). 2013d. *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Change Implications for the Biodiversity Sector in South Africa.* Pretoria, South Africa.

Department of Environmental Affairs (DEA). 2013e. *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Change Implications for Human Health in South Africa.* Pretoria, South Africa.

Department of Rural Development and Land Reform (DRDLR). 2013a. *Climate Change Risk and Vulnerability Assessment for Rural Human Settlements* (July 2013). http://www.ruraldevelopment.gov.za/phocadownload/spatial_Planning_Information/Climate_Change/Latest_Risk_and_Vulnerability_july_2013_09072013.pdf

Department of Rural Development and Land Reform (DRDLR). 2013b (April). *Draft Document: Climate Change Risk and Vulnerability Assessment for Rural Human Settlements.* http://www.ruraldevelopment.gov.za/phocadownload/draftvulnerability_assessment_1204131_psc.pdf

Department of Science and Technology (DST). 2011. *Observations on Environmental Change in South Africa.*

Department of Water Affairs (DWA). 2013. Speech by Minister of Water and Environmental Affairs, Mrs Edna Molewa, at the North West Provincial Service Delivery Summit, Rustenburg, 04 July 2013.

Department of Water Affairs (DWA). 2013b. *Strategic Overview of the Water Sector in South Africa*.

Department of Water Affairs. *South Africa Yearbook 2013/2014.*

Financial and Fiscal Commission. 2012. *Submission for the 2013/14 Division of Revenue.* *http://www.gov.za/sites/www.gov.za/files/Submission%20for%20the%202013-14%20Division%20of%20Revenue%203-%20pdf%20reduced2.pdf*

Golder Associates. 2011. *Baseline Assessment. Vulnerability and Impact of Climate Change on Major Tourism Attractions and Activities.*

Housing Development Agency. 2012. *North West: Informal Settlements Status.*http://www.thehda.co.za/uploads/images/HDA_Informal_settlements_status_North_West.pdf

IFPRI. 2011. *Mapping the South African Farming Sector's Vulnerability to Climate Change and Vulnerability. A Subnational Assessment.*

IPCC (Intergovernmental Panel on Climate Change). 2010. *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*", July 2010. https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf

IPCC (Intergovernmental Panel on Climate Change), R.K. Pachauri and A. Reisinger, eds. 2007. *Synthesis Report – Contribution of Working Groups I, II, and III to the Fourth Assessment of the Intergovernmental Panel on Climate Change.* Geneva.

Kalule-Sabiti, M. and Heath, R. 2008. *Underground Water as a Key Resource and the Associated Environmental Challenges in North West Province of South Africa*.

Midgley, G., Chapman, R., Mukheibir, M., Tadross, M., Hewitson, B., Wand, S., Schulze, R., Lumsden, T., Horan, M., Warburton, M., Kgope, B., Mantlana, B., Knowles, A., Abayomi, A., Ziervogel, G., Cullis, R. and Theron, A. 1997. *Impacts, Vulnerability and Adaptation in Key South African Sectors. An Input into the Long Term Mitigation Scenarios Process.* ERC, University of Cape Town

(North West) Department of Agriculture, Conservation and Environment (DACE). 2009. *Provincial Air Quality Management Plan. 4 February 2009*

(North West) Department of Agriculture, Conservation and Environment (DACE). 2008. *North West Province Environment Outlook: A report on the State of the Environment 2008 (NWO)*

(North West) Department of Agriculture, Conservation and Environment (DACE). 2002. North West Province State of the Environment Report. Overview 2002.

(North West) Department of Agriculture, Conservation, Environment and Rural Development (DACERD) 2009. *North West Provincial Biodiversity Conservation assessment Technical report, Version 1.2. March 2009. NW DACERD. Mmabatho*

(North West) Department of Agriculture, Conservation, Environment and Rural Development (DACERD). 2008. *Provincial Integrated Waste Management Plan* (PIWMP).

(North West) Department of Agriculture and Rural Development (DARD). 2011. *Identification of Disaster Risk Reduction Projects in the Province*

(North West) Department of Economic Development, Environment, Conservation and Tourism (DEDECT). 2012. *Renewable Energy Strategy for the North West Province.*

(North West) Department of Economic Development, Environment, Conservation and Tourism (DEDECT). 2011. *Emission Inventory for the North West Province 2011.*

(North West) Department of Rural, Environment and Agricultural Development (READ). 2014. *North West Environment Outlook Report 2013*. North West Provincial Government. Mahikeng.

(North West) Department of Rural, Environmental and Agricultural Development. 2014. *Disaster Management Plan 2014/2015*.

North West Planning Commission. 2013. *Provincial Development Plan, 2030*.

North West Provincial Government (NWPG). 2010. *North West Provincial Spatial Development Framework. 2010*

North West Provincial Climate Change Vulnerability Assessment Workshop (VA Workshop). 2015. *Climate Change Vulnerability Assessment Workshop (VA Workshop).* 20th March 2015, Potchefstroom Agricultural College, Alex Holm Hall.

South African National Biodiversity Institute (SANBI). 2013. *Life: The State of South Africa's Biodiversity 2012.* SANBI, Pretoria.

Statistics South Africa (StatsSA). 2014. *Poverty Trends in South Africa. An examination of absolute poverty between 2006 and 2011.*

Statistics South Africa (StatsSA). 2012. *Statistical Release (Revised) P0301.4 Census 2011.*http://www.statssa.gov.za/publications/P03014/P030142011.pdf

UNICEF. 2011. *Exploring the Impact of Climate Change on Children in South Africa.* Pretoria: UNICEF, South Africa.