Technical Analysis to Support the Update of South Africa's First Nationally Determined Contribution: Adaptation Component




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Date: 1 July 2021

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Key definitions from the IPCC AR5 glossary (IPCC 2014, page 1757 – 1776)

Risk: The potential for consequences [= impacts] where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as a probability of occurrence of hazardous events or trends multiplied by the impacts of these events or trends occur. Risk results from the interaction of vulnerability, exposure and hazard.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In the IPCC report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Sensitivity: Factors that directly affect the consequences of a hazard. Sensitivity may include physical attributes of a system (e.g. building material of houses, type of soil on agriculture fields), social, economic and cultural attributes (e.g. age structure, income structure).

Coping capacity: The ability of people, institutions, organizations and systems, using available skills, values, beliefs, resources and opportunities, to address, manage and overcome adverse conditions in the short to medium term (e.g. early warning systems in place).

Adaptive capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (e.g. knowledge of alternative farming methods).

Impacts: Effects on natural and human systems. In the [IPCC] report, the term impacts are used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. The impacts of climate change on geophysical systems, including floods, droughts and sea-level rise, are a subset of impacts called physical impacts.

1 Introduction

1.1 Background

The adaptation component of the Nationally Determined Contributions (A-NDC) is one of the primary vehicles under the Paris Agreement which is meant to share individual country efforts and commitments on adaptation. For the present 21st century, adaptation has become a key climate change response as it is now well-established that, in the case where emission reductions are unlikely to take place at the necessary magnitude and rate, the climate system is bound to change. This is despite individual country efforts in the reduction of greenhouse gas emissions.

In 2015, the Department of Environment Forestry and Fisheries (then the Department of Environmental Affairs) undertook the work of the Intended Nationally Determined Contributions (I-NDC) under the technical support of the CSIR. The output of the exercise was South Africa's first NDC accompanied by a technical report which outlined the methodology used. This work builds on the effort to update the findings of the INDC, improve the methodology for costing of the adaptation needs while aligning the risk and vulnerability approach with the national adaptation framework and guiding information for the nationally determined contributions (NDC).

1.2 Design of the A-NDC template for adaptation

The adaptation component (A-NDC) of the nationally determined contributions (NDC) follows the guidelines of the African Group of Negotiators and draws further guidance from the Department of Environment Forestry and Fisheries (DEFF) and the project steering committee. Table 1.2-1 presents a breakdown of the project components, their goal as well as a summary of the methodology along with comments on progress as reflected in this technical report.

Table 1.2-1: Breakdown of the project components, their goal as well as a summary of the methodology

Elements/ Activities	Goals	Assumptions / Methodologies	Comments on (Phase 1 and 2) progress
National risk and vulnerability mapping and vulnerability matrices	**Goal 1:** Quantify the physical climate hazards for the key sectors of the economy as driven the change in rainfall and temperature extremes for the climatological periods 2011 - 2040 **Goal 2:** Consider extreme climate indices and develop sector-specific climate-based risk and vulnerability matrices.	National	Goal 1 and Goal 2 completed
Assessment of adaptation needs.	**Goal 3:** Implement and test the methodology developed in the INDC and demonstrate through a detailed assessment of the adaptation needs across strategic sectors in line with adaptation priority sectors in the NCCRP	Damage costs associated with high impact climate events (wildfires, storms, droughts and floods), including both direct and downstream costs were calculated. These were estimated for the present-day climate and for the near future under low and moderate mitigation scenarios. Emission scenarios considered are RCP 8.5 (low mitigation) The costs estimated are in terms of the 10th, 50^{th} and 90^{th} percentiles of annual costs occurring within the periods of interest. Annual costs were calculated for 2021-2030 and 2021-2040. Sectors covered; Water, Agriculture, Forestry, Settlements, Biodiversity, Disaster Risk Reduction (DRR)	Review and documentation of an updated methodological approach completed.
Prioritisation of adaptation responses	**Goal 4:** Report on adaptation priorities, goals and measures	The approach is a synthesis of the national level adaptation interventions that should be applied across each of the key sectors for	Phase 1 work for **Goal 4** completed.

Elements/ Activities	Goals	Assumptions / Methodologies	Comments on (Phase 1 and 2) progress
	and future adaptation interventions. Identify adaptation investments from official annual reports covering the years 2010 – 2015.	the period 2020-2025 and 2025-2030.	
Government sectoral policies:	**Goal 6:** Report on the current state of adaptation response in the public sector and present a summary of an inventory to be used to assess how the country (across all spheres of government) is planning for adaptation	Undertake the mapping exercise of the current state of adaptation and develop a national inventory of sectoral policies.	All **Goal 6** completed
Alignment of outputs of Task 1 to Task 4 with key national adaptation policies	**Goal 7:** validation of the alignment of the outputs of Activities 1 to 4 within the key national climate change policy landscape and stakeholder mapping.	desktop-based research and stakeholder engagement	Almost all of **Goal 7** achieved but without stakeholder engagement
Analysis of sector growth profiles and cost estimates	**Goal 9**: Evaluation of the sectoral growth projects' direct benefits, related to the use of the goods or services produced. **Goal 10**: quantification and acknowledgement of the national adaptation and resilience efforts.	Conduct an economic analysis of sectoral growth. This will include analysing the GDP contribution of the priority sectors. Data on historic adaptive finance distribution and likely future period's trends of equity on public and private adaptation financing is depicted.	Completed

1.3 Climate Risk and Vulnerability Assessments – Conceptual framing and definitions

The need for climate and risk vulnerability assessments have been growing, including its requirement under various policies and plans (such as the National Climate Change Response Policy (DEA, 2011), the draft Climate Change Bill, the draft National Climate Change Adaptation Strategy and the Disaster Management Amendment Act 16 of 2015). Due to the use of different approaches by these assessments, evaluating and aggregating across them has been problematic. The national government of South Africa, under the custodianship of the Department of Environment, Forestry and Fisheries (DEFF), has thus established a common framework, the draft National Climate Risk & Vulnerability (CRV) Assessment Framework (DEFF, 2020a) to enable a more integrated approach to climate adaptation.

The CRV Assessment Framework is structured around three practical steps: (1) **Scoping**, which unpacks the purpose and context; (2) **Planning**, which determines the depth of assessment; and (3) **Assessing** which delves into the components of conducting an assessment.

The latest conceptual framing from the Assessment Report form (AR5) (2014) of the Intergovernmental Panel on Climate Change (IPCC) specifies risk as a core concept and vulnerability a component of risk. The risk associated with experiencing climate impacts thus result from the interaction of climate hazards, exposure and vulnerability. The vulnerability component is determined by the sensitivity and adaptive capacity of those exposed to certain climate hazards (see Figure 1.3-1)

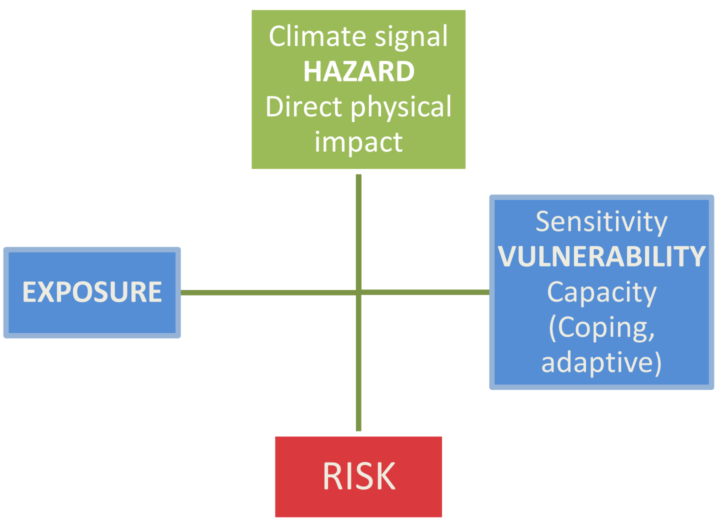


Figure 1.3-1: The components of climate vulnerability and climate risk in IPCC AR5

A hazard may refer to the climate signal (i.e. an extreme event or a trend) as well as climate-related direct physical impacts such as floods, erosion and landslides (Draft National Climate Risk and Vulnerability Framework, 2020 (DEA, 2020a)). Climate vulnerability provides an explanation for the difference in impacts experienced by different receptors equally exposed to a climate hazard, like a drought or coastal inundation. Interventions which enable adaptation to, or reduction of climate risk should thus either reduce exposure and/or reduce vulnerability – the latter, by reducing sensitivity and/or increasing capacity. This framework thus provides a common approach for developing and reviewing assessments for the different sectors that will enable a more integrated approach to climate adaptation.

2 Climate indices

2.1 Overview of the climate over South Africa and its projected changes

Most of South Africa's rainfall occurs during the summer months (De Coning, 2013; Roffe et al., 2019). The rainfall is characterised by a strong gradient with the western parts of the country generally drier than the eastern parts (see Figure 2.1-1 (a)). Whilst the inter-annual variations of the rainfall is influenced by remote drivers such as ENSO (Mason and Jury, 1997), its occurrence is dependent on the availability of moisture that is transported onto the landmass from the South-West Indian Ocean (SWIO) (Cook et al., 2004; Dyson, 2015; Ndarana et al., 2020). This moisture transport is facilitated by ridging South Atlantic Ocean high-pressure systems (Engelbrecht et al., 2015; Ndarana et al., 2018). Moisture that ends up in the South African domain may also originate from the Tropical south-east Atlantic Ocean (Reason and Smart, 2015) and Equatorial Indian Ocean (D'Abreton and Tyson, 1995). Then, when the moisture is transported into the country by these means, weather systems that provide lifting mechanisms are required to cause rainfall (Doswell III et al., 1996). These include cut-off low-pressure systems (Singleton and Reason, 2007; Favre et al., 2013), upper air westerly troughs (Favre et al., 2013), tropical temperature troughs (Fauchereau et al., 2009; Ratna et al., 2013; Hart et al., 2010; Macron et al., 2014), tropical lows which contribute to rainfall in the Limpopo River basin (Malherbe et al., 2012; Rapolaki et al., 2019) and tropical cyclones (Malherbe et al., 2014). All these systems occur during the summer, except the cut-off lows, which occurs during all seasons. Frontal winter rainfall occurs in the far west and southwest coast of the South Africa (Weldon and Reason, 2014), while the south-eastern coast is an all-season rainfall region (Engelbrecht et al., 2015) [see Figure 2.1-1 (b)].

Downscaled CCAM rainfall patterns for future climates exhibit a similar general structure but with increases in some areas of the Limpopo and Mpumalanga provinces [Figure 2.1-1(c)]. Not only would future changes in the weather systems discussed above (Engelbrecht et al., 2011) have an impact on these changes in rainfall over the country in general, they would significantly contribute to increases in the frequency of occurrence of the extreme events in the South African domain (DEA, 2015). This has profound implications for climate change adaptation, particularly for water and energy infrastructure, as shown in the previous iteration of the NDC (DEA, 2015). Changes in rainfall may also lead to extreme events such as droughts, which have dire implications for the agricultural production and water resources sectors, in particular.

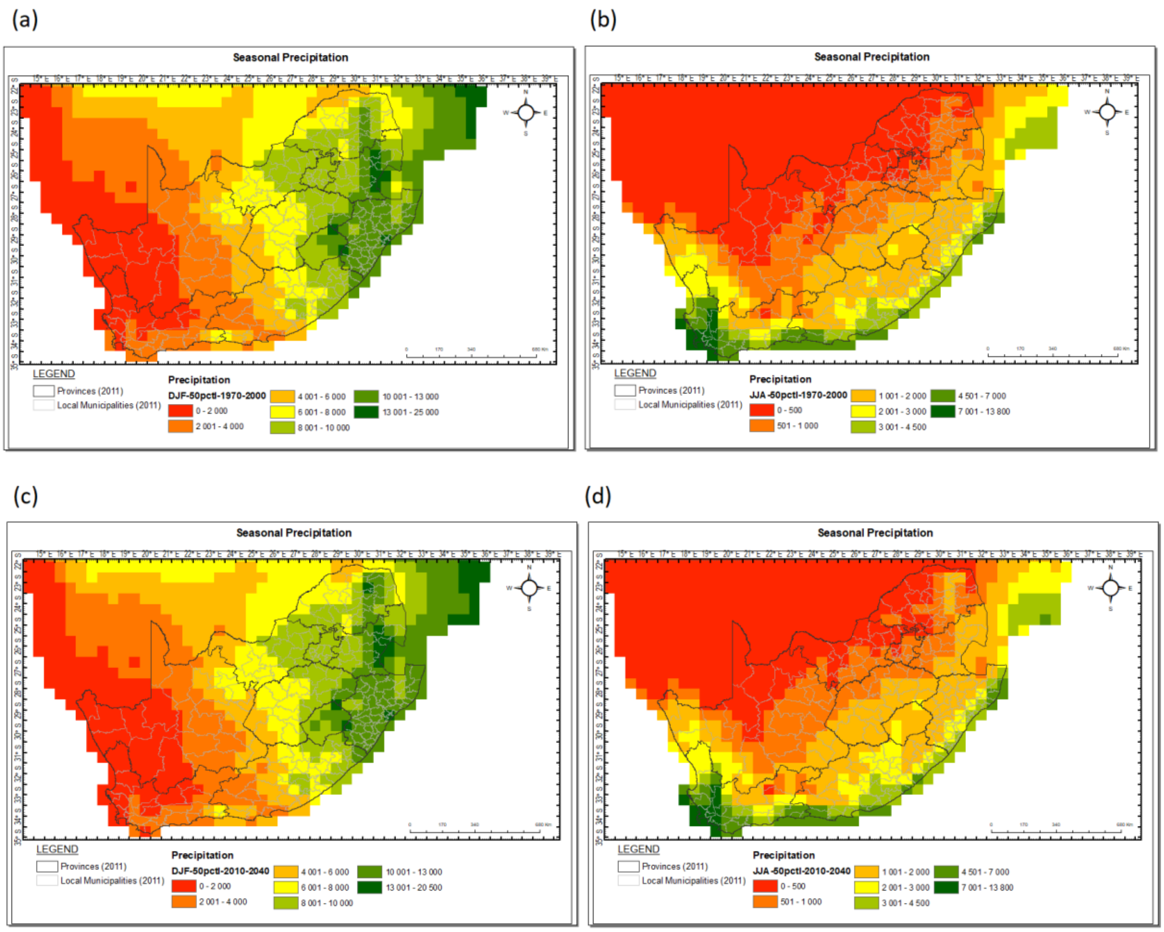


Figure 2.1-1: Precipitation patterns produced by CCAM downscaling runs for (a) DJF and (b) for the timeslab 1970 – 2000. (c) and (d) are the same for (a) and (b), respectively but for the 2010 – 2040 timeslab.

Temperature variations over South Africa are also deeply seasonal with higher temperatures experienced during the summer and lower temperatures experienced during the wintertime, as frontal systems migrate northward during the latter (Tyson and Preston-Whyte, 2000). In the context of climate change one of the important issues about temperature is that it is increasing globally (IPCC, 2007) and is doing so more rapidly over Africa and southern Africa, in particular (Engelbrecht et al., 2015a). It is also a robust climate change signal. Increases in maximum temperatures are shown in, which may as high as 6°C across the interior of the country (Engelbrecht et al., 2015a; Mbokodo et al., 2020). These increases in maximum temperatures have been shown to lead to increases in heat waves over South Africa (Mbokodo et al., 2020) (Figure 2.1-2: Same as in Figure. As previously stated, these extreme events have implications for climate change adaptation, in particular for the health and agricultural sectors. Changes in minimum temperatures (Shown in Figure 2.1-3: Same as in Figure) also have implications for the agricultural sector as will be seen in the discussion below.

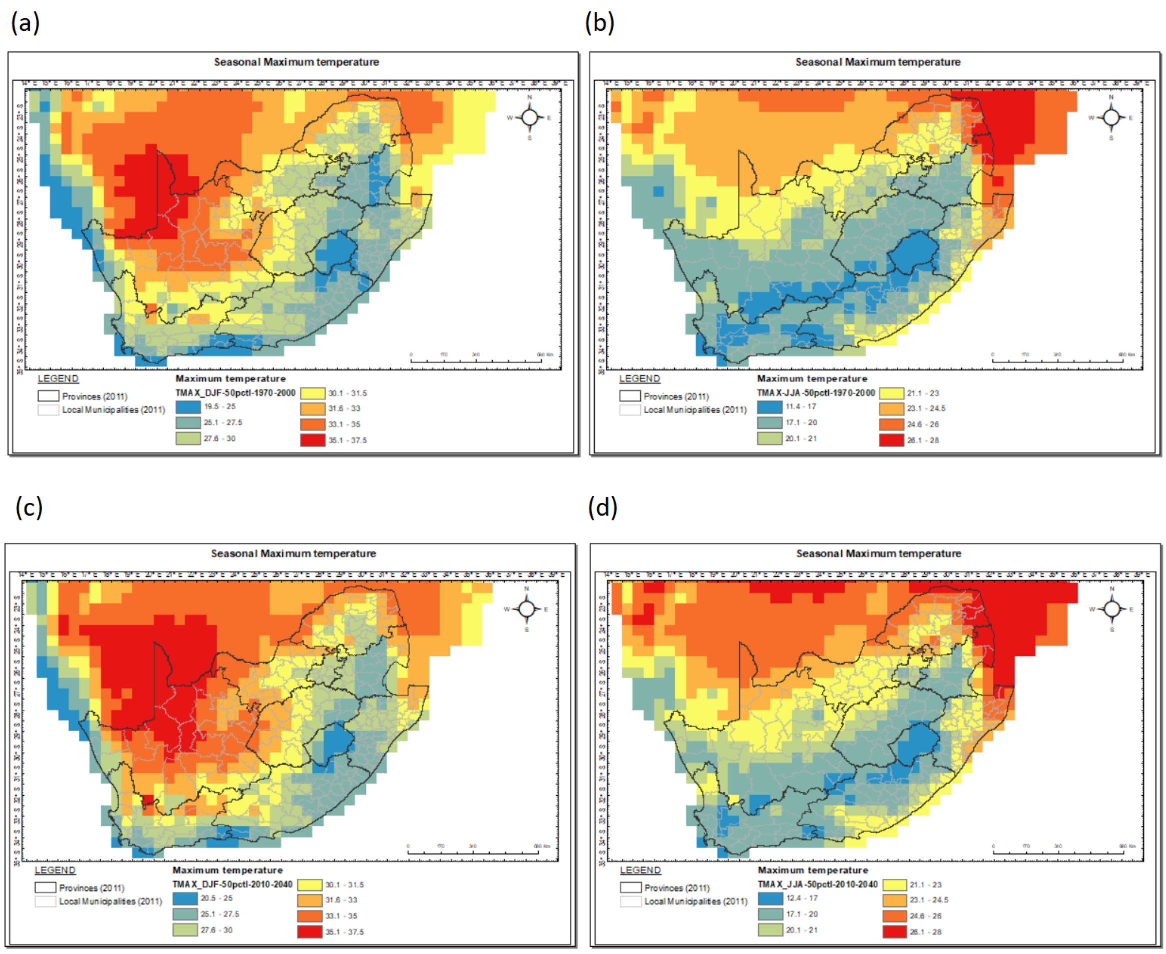


Figure 2.1-2: Same as in Figure 2.1.1 but for maximum temperatures

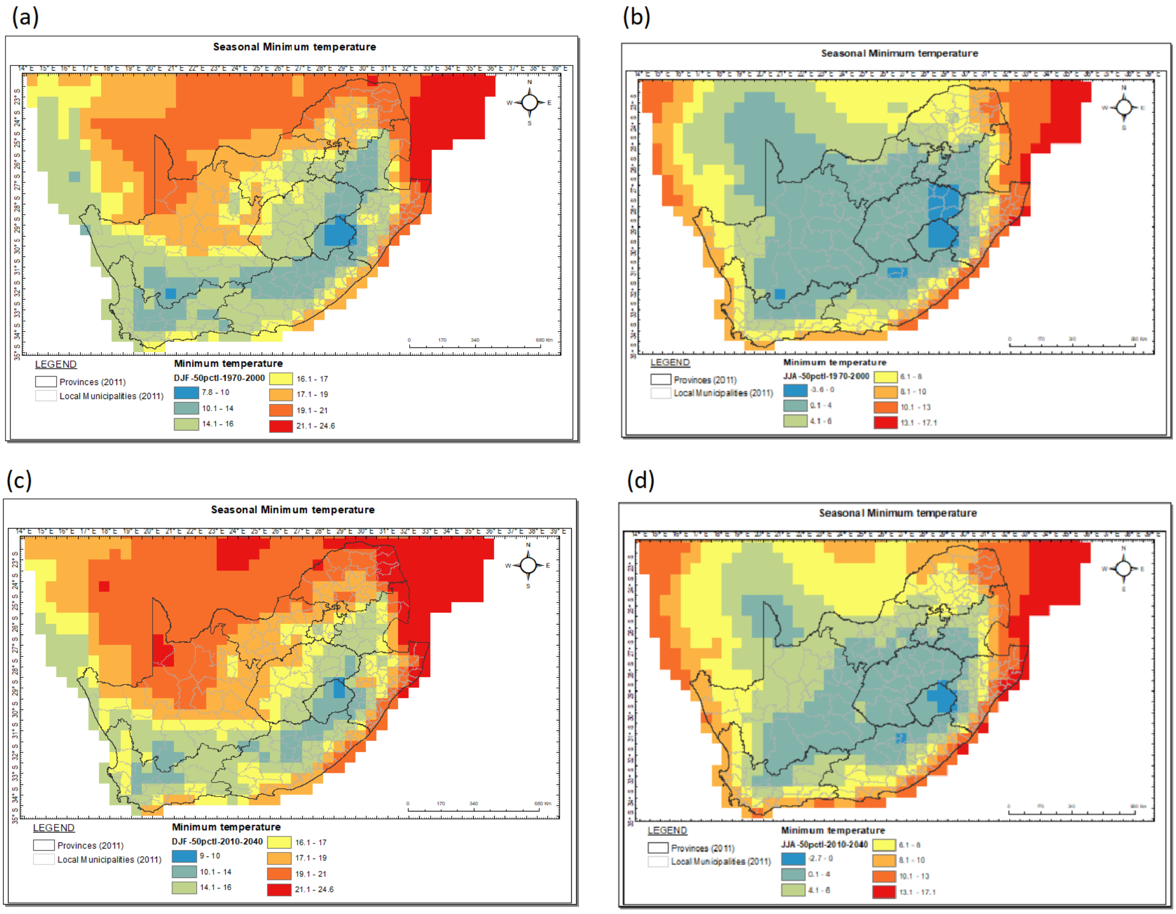


Figure 2.1-3: Same as in Figure 2.1.1 but for minimum temperatures

2.2 Sector-specific climate indices

The NDC considers climate change impacts and the accompanying risk and vulnerability assessments in the Agriculture, Forestry and Fisheries, Biodiversity, Energy, Health, Human Settlements and Water Resources sectors that are anticipated to be the key impacted sectors by climate change. This update technical document of the Intended Nationally Determined Contributions (INDC) provides a basis to understand other sectors not considered here and how South Africa respond to climate change in a sector-specific context. The remaining gaps policy and research gaps are highlighted to enable planning and implementation of necessary climate change adaptation interventions beyond the scope of the chosen sectors. The clear problem that needs to be addressed in the first instance is that temperatures and precipitation, as well as their GHG induced changes, impact climate-sensitive areas in sector-specific ways. As such, this iteration of the NDC undertook to develop sector-specific climate indices that are derived from the basic model output. These, together with the methods used to generate will now be described.

- Daily fire severity rating (DSR)

  The Daily Severity Rating (DSR) is a numeric rating of the difficulty of controlling fires and was described by van Wagner (1987). The index is based on the Fire Weather Index (FWI), but it more accurately reflects the expected effort required for fire suppression When averaged temporally over a season, it is a measure of fire climate from season to season or from region to region. DSR is a subcomponent of the Canadian Forest Fire Weather Index (FWR) system and is publicly available through the *cffdrs* package in R.
- Standard Precipitation-Evapotranspiration Index (SPEI)

  The Standardized Precipitation-Evapotranspiration Index (SPEI) is used to determine the onset, duration and magnitude of drought conditions relative to the normal conditions both in the natural vegetated system and in managed systems such as crops, ecosystems, water resources and water bodies such rivers. The advantage of SPEI over other precipitation-based drought indices is that it considers potential evapotranspiration (PET) in quantifying drought severity. In this study, it is used to identify drought tendencies in the context of climate change. This is achieved by a calculation of instances where SPEI values are below the normal range of (-0.5 < SPEI <0.5) weighted over the number of months during the period. The anomalies of the drought tendencies during the future period (2011-2040) are calculated relative to that of the reference historic period (1960-1971).
- Large scale flooding:

  Large-scale flooding was represented by heavy precipitation events, where these events were defined as having rainfall in excess of 20 mm per day, over an area of 50 x 50 km, for three successive days or more. This type of event is typically caused by tropical cyclones and cut-off lows (DEA, 2015).
- More localized flooding:

  More localized flooding was represented by the 10-year return period design rainfall. To give an example of the scale at which this variable has application, the 10-year return period flood peak is used as a factor in the design of local roads and associated drainage in urban and rural settings. Although the 10-year return period rainfall event does not necessarily result in the 10-year return period flood peak (due to actual catchment conditions prior to a storm), it is often assumed to do so for design purposes (SANRAL, 2013). The 10-year return period rainfall was determined by fitting the Log Pearson III distribution to the highest daily rainfall in each year (annual maximum series) of the baseline and future periods. This analysis was undertaken at the quaternary catchment level. Changes in the magnitude and frequency of the 10-year return period event were assessed.

- Vapour pressure:

  Using an assumed saturation vapour pressure value at a temperature of 273 K, the Clausius-Clapeyron equation was used to calculate the saturation vapour pressure at any other temperature. This was combined with the relative humidity to produce the vapour pressure.
- Very hot days:

  Very hot days were calculated in terms of the maximum temperatures. If the maximum temperature is larger than the 85^{th}, 90^{th} and 90^{th} percentile of historic period maximum temperature distribution, the day is considered as a very hot day. This figure is divided by the number of years to obtain the number of very hot days per year.
- Anomalies

  Some sectors required the anomalies of the variables (both basic and post-processed). Using daily CCAM data, the long-term averages for each time slab are first calculated, after which the monthly averages are also calculated. The anomalies are calculated by subtracting the monthly averages from the 1971 - 2000 long term climatologies of the variables.

3 Sectors

3.1 Agriculture, forestry and fisheries

3.1.1 Risk and vulnerability profile

The Agriculture, Forestry and Fisheries sector of South Africa plays a fundamental role in supporting national food security, stimulating economic development and reducing poverty. Commercial production of grain crops, horticulture, forestry and livestock takes place across South Africa under various climate conditions, ranging from arid to subtropical, while various fishery activities are found along the 3650 km long coastline of the country. The geographical distribution of the main agricultural branches across South Africa is depicted in Figure 3.1.1.

Around 40 000 commercial farmers in South Africa feed a population of roughly 55 million which means that one farming unit provides food for approximately 1375 persons (Van Zyl, 2018). The sector also provides around 700 000 jobs, making it one of the biggest employers in the country, accounting for just over 5% of the country's labour force (World Bank, 2019). While agriculture contributes only 2.2% to South Africa's gross domestic product (GDP), its contribution increases significantly when all backward and forward linkages in the South African economy is recognized (DAFF, 2018).

Additionally, there are around 2.5 million to 4 million subsistence farmers in rural areas where more than 70 per cent of the population depends on agriculture for their livelihoods (Aliber and Hart, 2009; Baiphethi and Jacobs, 2009). They are located on small farms and use labour-intensive, traditional production techniques to provide household sustenance. Of these subsistence farmers, some 200 000 are market-oriented to some extent. Small-scale and subsistence farmers make an important contribution to food security on a local level in rural areas. Subsistence farmers are however also among the people most vulnerable to current climate variability. They encounter several constraints such as a lack of access to finance and insurance, challenges regarding land governance in the communal areas, access to water, the need for effective extension services and poor physical infrastructures such as roads, electricity and access to markets (Johnston, 2019). Apart from coping with these challenges, small-scale farmers will also be faced with new risks brought about by climate change.

The fishery sector comprises of a commercial section, subsistence line fishers as well as small scale gillnet and seine net fishers (Potts et al., 2015). The major fishing grounds are situated along the west and south coast and therefore the main fishing ports, processing factories and service industries are found in the Western Cape Province. Subsistence and small-scale fishing play an important role in the provision of employment and food security, particularly protein to poor coastal communities (Isaacs and Hara, 2015).

Commercial forestry production in South Africa is mostly restricted to Mpumalanga and Kwa-Zulu Natal, while smaller areas within the Eastern Cape, Western Cape and Limpopo also comprise some forestry activities. The most important species that are being cultivated are Pinus species, Eucalyptus species and *A. mearnsii*.

The forestry industry employs approximately 150 000 people, which amounts to 1.6% of South Africa's workforce (Forestry SA, 2019). Although forestry makes a modest contribution to the national GDP, it has a key role to play in the development of local economies, particularly in rural areas. The majority of forestry workforce is in rural areas, where unemployment levels are high and a single wage supports multiple dependants (Forestry SA, 2019).

Changing precipitation regimes and increases in temperature could make it more difficult to grow crops, raise animals and catch fish in the same ways and same places as we have done in the past. Climate change will have direct effects on crop quality and quantity as well as livestock viability with ultimate impacts on food security, employment, supply chains and livelihoods. The people most vulnerable to climate change impacts are communities and subsistence farmers in rural areas which have low or compromised resilience levels to climate change.

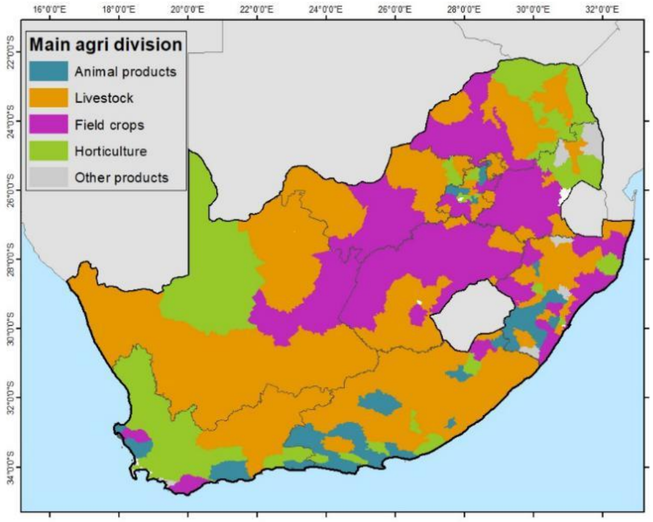


Figure 3.1-1: Main agricultural division per magisterial district in South Africa

3.1.2 Climate change impacts

Climate change, through modified precipitation regimes, increasing climate variability and the prevalence of more extreme events presents a significant threat to agriculture, forestry and fisheries across the country. Increased temperature and changing rainfall patterns can have fundamental impacts on agriculture if the natural thresholds of the commodities been farmed are breached. However, the nature and extent of these impacts depend on the type of commodity been farmed and the relative position of the farmer with regard to the industries he serves. The same climate impact can have different impacts on different commodities in different areas.

Predictions are that by 2050, the rainfall in the Western Cape will likely have decreased by about 30% from current levels. Other parts of the country are expected to see more erratic rainfall patterns and more frequent and intense extreme events, such as droughts and floods with significant impacts on crop yields. Certain areas on the east coast of South Africa could experience an increase in rainfall. However, across the country, the strain on water resources will be amplified by higher demand for irrigated water resulting from increased temperature and evaporation rates (Engelbrecht et al., 2009; McGregor, 2005).

Predictions are that average temperatures will increase by between 1.5° and 2° Celsius in the near future, with even more extreme increases over the north-western interior of the country (Engelbrecht et al., 2015a; Engelbrecht et al., 2009). Temperature controls the life cycle and development of all crop, livestock, forage, insects and pathogen species. Each species has a specific temperature range represented by a minimum, maximum and optimum. Significant general warming accompanied by heat waves that are projected to become more intense, more frequent and last longer will become a primary factor affecting crop and livestock viability. Above certain threshold temperatures, plant growth, pollination and reproductive processes decline significantly (Hatfield and Prueger, 2015). A range of weeds, pests and diseases are also projected to thrive under warmer conditions and climate change may increase the prevalence of parasites and diseases that affect livestock and crops.

3.1.3 Risk and vulnerability assessment

3.1.3.1 Agriculture

3.1.3.1.1 Grain crops

Maize and wheat are the country's most important field crops in terms of earners of gross income (Figure 3.1.2). Maize (*Zea mays L.*) is the staple food of the population as well as the main concentrate source of the livestock feed industry. The crop is produced in all the provinces of South Africa, but the most significant producing regions are the Free State, Gauteng, Mpumalanga and the North-West provinces, accounting for roughly 87% of overall production. Wheat is the second biggest staple food after maize (De Wet and Liebenberg, 2018) and mostly cultivated in the Western Cape, Free State and Northern Cape provinces. Around 80% of the total area planted to wheat is cultivated under dryland conditions while the remaining 20 is under irrigation (Schulze et al., 2016). Sorghum is, after maize and wheat, the most important grain crop produced in South and a basic staple food for many rural communities. The latter is especially true in the more drought-prone areas of South Africa where this hardy crop provides better household food security than maize (DEA, 2013).

Regardless of water availability, for both maize and wheat, yield potential is becoming increasingly limited by warming itself (Harrison et al., 2011). The prevalence of more very hot days will breach critical crop thresholds during reproductive stages resulting in a decline in crop yield and quality. Maximum temperatures (> 32°C) on a given day may lead to yield reductions (Schulze and Durand, 2016). Pollination is one of the most sensitive phenological stages to temperature extremes across all species, for example, different authors have reported that maize pollen viability and production decreases with exposure to temperatures above 33°C to 35 °C (Herrero and Johnson, 1980; Hatfield, 2015; Smith, 2019) and during these developmental stage temperature extremes would greatly affect production. This is especially important over areas of North West, the western Free State and Northern Cape, where temperature extremes are most pronounced (Figure 3.1.3). In these areas, maize yields may taper off markedly because of heat stress, even when water is not a limiting factor. However, in cooler, optimal growing areas of Mpumalanga certain areas may attain higher yields in the near future. Ideally for maize production, 450-600 mm rainfall is required during the growing season (Schulze and Durand, 2016).

Dryland wheat yields are expected to decrease in the most western wheat zone of the Western Cape province due to a projected decrease in rainfall and strong warming. Temperatures that exceed 22°C are generally too hot for wheat production (Figure 3.1-4). However, wheat yields along the southern Cape wheat zone are projected to remain relatively unchanged in the near future. Some decreases are also projected in parts of the Free State and the Northern Cape (Schulze et al., 2016). If the climate projections are correct, then a potentially major new dryland winter wheat area is emerging in the eastern Free State, the northern parts of the Eastern Cape and the western parts of KwaZulu-Natal.

Since sorghum is indigenous to Africa and therefore better adapted to dry and warm climate conditions, it can take advantage of the warmer conditions in the near future (Schulze et al., 2016).

Overall, field crops such as maize and wheat will be most vulnerable during its pollination phase to increasing temperatures, especially the increase in extremely hot days (and warm nights). Depending on planting date and cultivar type, temperature extremes would greatly affect production. Given the majority of the field-crops are produced under dryland conditions, any changes in shifting rainfall dates will greatly impact on planting dates and general crop management. Although average rainfall is not predicted to change in many areas, the increase in temperatures and change in the distribution of rainfall will reduce available water for crops.

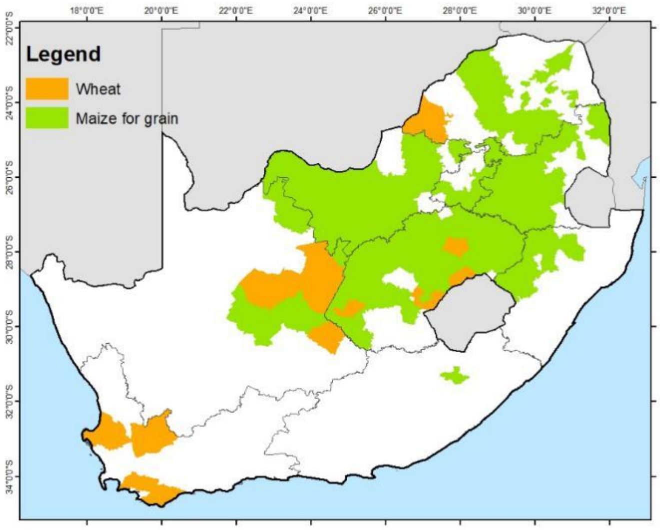
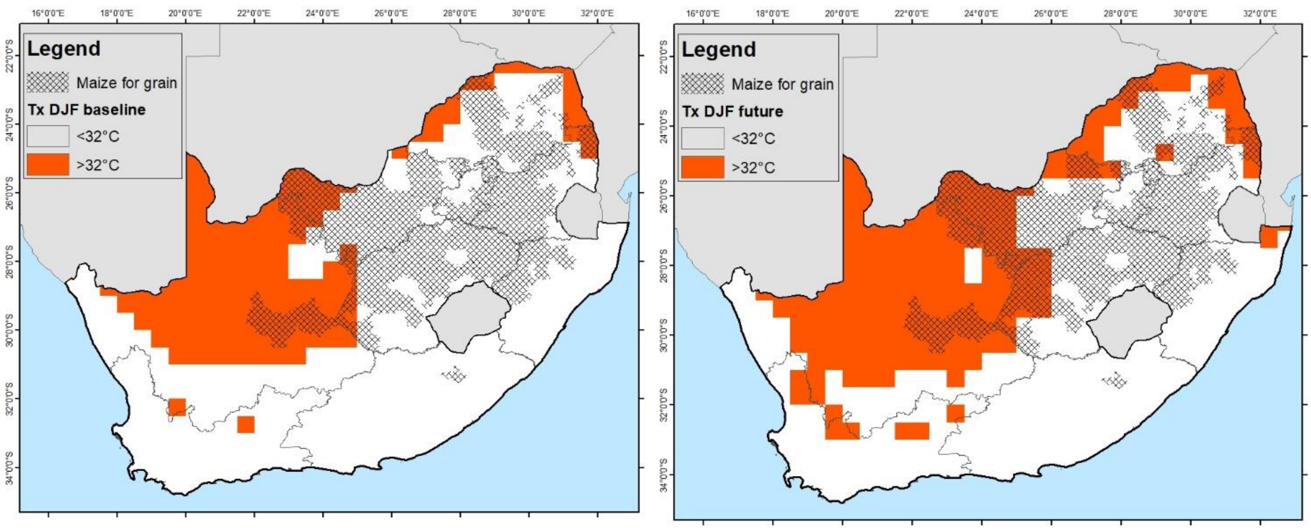


Figure 3.1-2: Important maize and wheat growing areas of South Africa

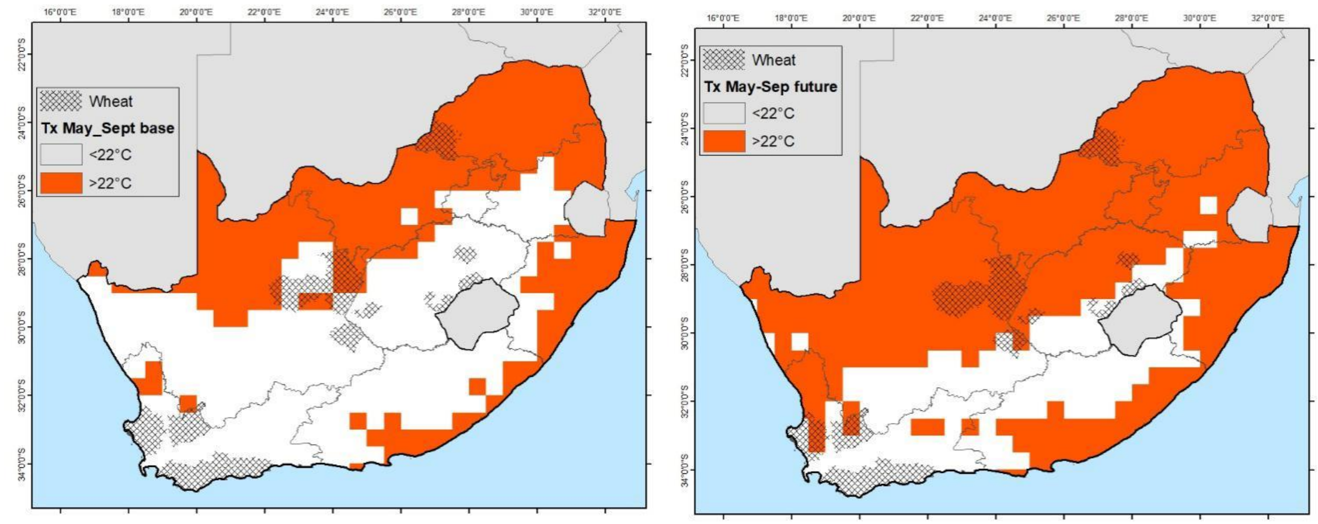


(a)

(b)

Figure 3.1-3: Critical maximum temperature thresholds during summer for maize growing areas under a baseline (a) and future (b) climate scenario.

(a)



(b)

Figure 3.1-4: Critical maximum temperature thresholds during winter for wheat-growing areas under a baseline (a) and future (b) climate scenario.

3.1.3.1.2 Livestock

Poultry industry

The poultry industry is the largest segment of the South African agricultural sector, contributing more than 16% to the gross domestic product. The chicken industry, specifically, represents the largest agricultural subsector in South Africa (BFAP, 2019). The Western Cape and North West are home to the largest number of birds. The poultry industry is vulnerable to climate change through heat stress and drought. An increase in temperature reduces feed intake and impact on body weight gain, reproduction efficiency and egg quality, while droughts impact on the availability of feed grain causing price increases which affect production costs to poultry farmers.

In the eastern parts of the country, where predictions are for an increase in rainfall and relative humidity, these conditions create a conducive environment for the breeding of parasites that causes the outbreak of diseases. For indoor broilers, increased production costs will be required for ventilation and cooling to maintain optimal seasonal temperatures and reduce the risk of heat stress.

Beef cattle

Livestock farming comprises nearly 70% of agricultural land in South Africa. Beef cattle production takes place almost across South Africa, with different breeds being suited to different climatic conditions and areas. There is also a large variety of farmers, ranging from subsistence to large commercial producers and breeders. In 2016/2017 Mpumalanga accounted for 21% of the beef produced followed by Free State, Gauteng, KwaZulu-Natal and North-West accounting for 18%, 16%, 11% and 8% respectively. (DAFF, 2018a). The beef industry is a major employer with some 2 125 000 people dependent on the livestock industry for their livelihood (DAFF, 2018a).

Climate change will impact directly on livestock through temperature and humidity changes and indirectly through changes in the nutritional status (quality and quantity) of pastures. This is especially true for extensive livestock production (cattle, sheep, goats and ostriches) due to expected rangeland vegetation changes.

Heat stress on livestock is dependent on temperature, humidity, species, genetic potential, life stage and nutritional status. Sheep and goats are less vulnerable to the effects of high temperature, whereas dairy and beef cattle are most sensitive. Heat stress can reduce foraging time, feed intake, growth performance, carcass quality and reproduction performance. Overall, the warmer temperatures and concurrent changes in heat exchanges are likely to cause heat stress in cattle raised on natural pastures and in feedlots. A range of pests and diseases are also projected to thrive under warmer conditions and climate change may increase the prevalence of parasites and diseases that affect the livestock. The most severe temperature increases are predicted for parts of Limpopo, North West province and parts of the Northern Cape. Heat stress coupled with a reduction in rainfall will render these areas especially vulnerable.

Dairy farming

Dairy farming occurs throughout South Africa with the highest concentration being in the Western Cape, Eastern Cape and KwaZulu-Natal (MPO, 2019) (Figure 3.5). The contribution of milk production in South Africa contributed approximately 0.8% to the world milk production in 2018 (MPO, 2019). The coastal areas with their more moderate climate contribute about 83% to the total milk production in the country. KwaZulu–Natal contributed 29.3% of the total milk produced in South Africa followed by Western Cape and Eastern Cape with 28.4% and 27.1% respectively (MPO, 2019).

Temperature also dictates weight gain, milk production, reproductive rates and feed conversion efficiencies in dairy cattle. It has been shown that future climate change is likely to have a negative impact on milk production for currently suitable milk-producing areas in South Africa (Williams, Scholtz and Neser, 2016). Temperature Humidity Index (THI) assess likely changes in heat stress levels for livestock over time. It accounts for the combined effects of environmental temperature and relative humidity and is a useful and easy way to assess the risk of heat stress (Figure 3.1.6). As temperatures increase above optimal thresholds for dairy production, certain areas in the interior of the country may be more vulnerable to heat stress, whereas dairy production on the south-eastern seaboard may be affected less frequently due to the lower expected temperature increase. The optimal milk-producing areas may shrink progressively, shifting towards the southern parts of the south-eastern coastal belt.

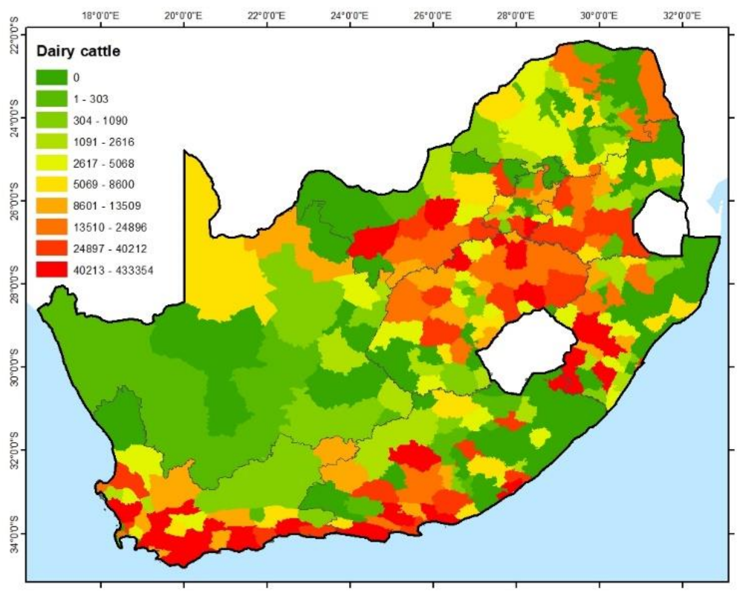
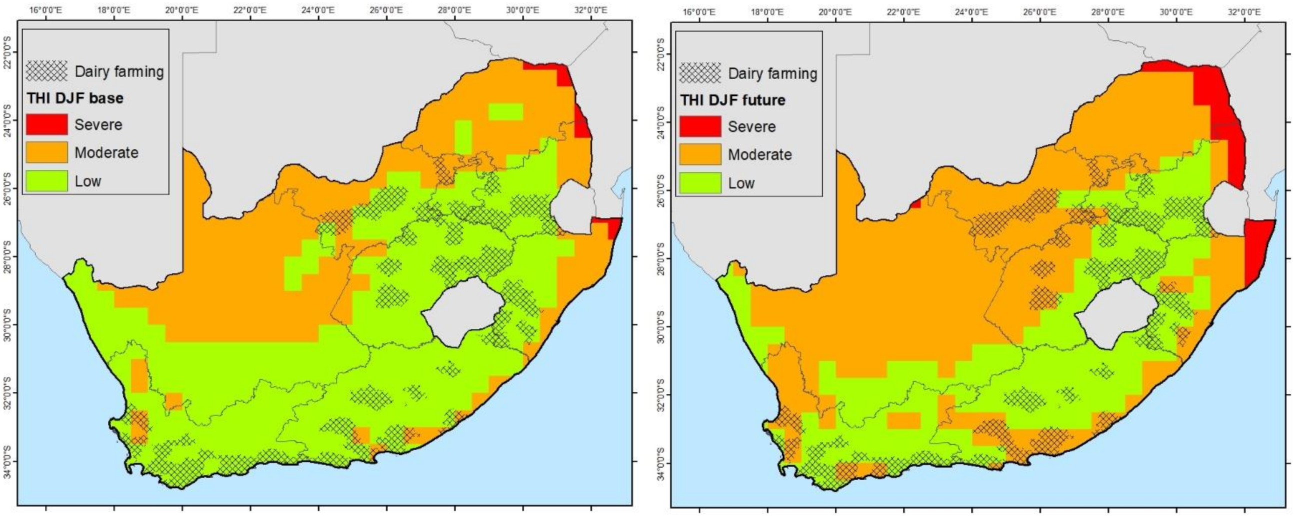


Figure 3.1-5: Important dairy farming areas depicted by the amount of milk (in litres) produced in South Africa.

(a)



(b)

Figure 3.1-6: The temperature-humidity index during summer for important dairy production areas under a baseline (a) and future (b) climate scenario.

Sheep and goats

The main production areas are in the semi-arid areas of the Eastern Cape, Western Cape and Northern Cape, while the Free State, Mpumalanga and KwaZulu-Natal also contribute. Climate change is likely to have implications for sheep and goats, principally through its effects on forage and water resources and animal health. The increase in droughts projected for the western parts of South Africa makes areas of the northern cape and interior of the western cape especially vulnerable. In certain areas, the warmer winters could lower cold weather associated livestock mortality but are also conducive to the survival of pests and parasites that threaten livestock.

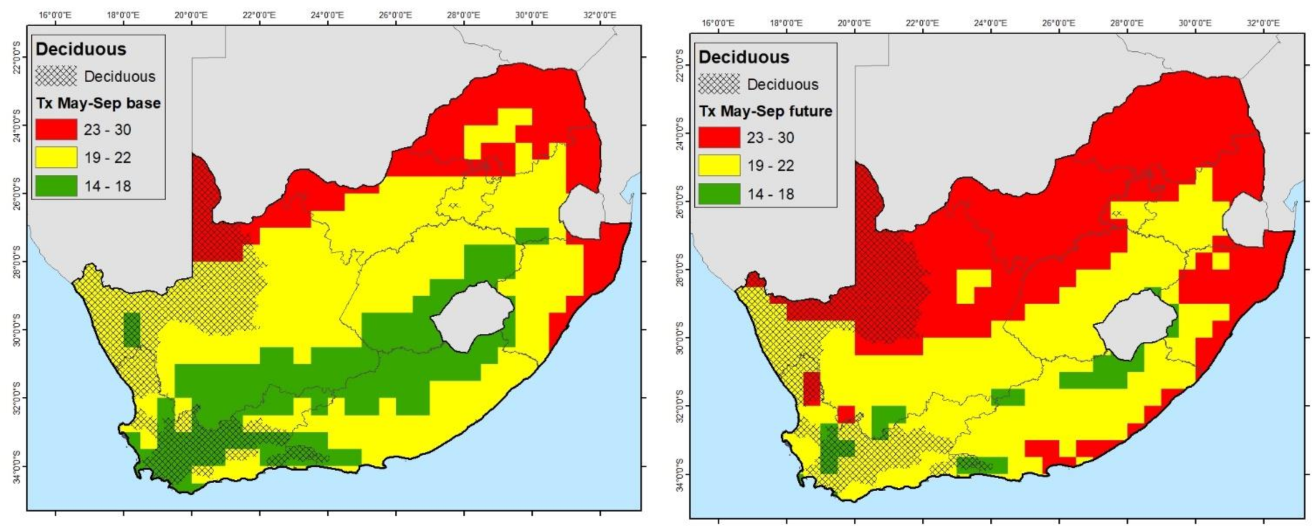
Across South Africa, increases in the occurrence of extreme temperatures will directly impact livestock productivity (e.g. reduced growth and reproduction performance) during the summer season. Indirectly, livestock will be impacted through changes in nutritional status as a result of changes in the quality and quantity of pastures as well as animal health. This is especially true for extensive livestock production (cattle, sheep, goats and ostriches) due to expected rangeland vegetation changes. Changes in temperature and rainfall may also result in altered patterns of diseases in animals. This relates to the emergence of new diseases as well as a change in the prevalence of existing diseases, particularly those spread by biting insects (Scholtz et al., 2013).

3.1.3.2 Horticulture

A range of vegetable and fruit production is taking place across South Africa. For the purposes of this report, the focus will be on the deciduous fruit industry. Deciduous fruit is grown mainly in the Western Cape and in the Langkloof Valley of the Eastern Cape with smaller production areas found in the Northern Cape along the Orange River and in the Free State, Mpumalanga and Gauteng. South Africa is the 2nd largest exporter of both apples and pears in the Southern Hemisphere. Risks and vulnerabilities of concern for deciduous fruit are the accumulation of cold units for completion of plants' seasonal dormancy as well as water availability. A potential problem facing apple producers is the risk of insufficient chilling hours required to break dormancy. Some growing regions are already too mild during winter to satisfy the requirements of some commercial apple varieties. The increase in temperatures is especially worrying for areas of Elgin-Grabouw-Vyeboom-Villiersdorp region where the accumulation of chill units may reach a critical threshold at a faster rate than the Ceres production areas (Figure 3.1-7). The increase in temperature will raise evapotranspiration and irrigation requirements which will impact on water availability affecting fruit quality and quantity.

The Western Cape region, which is the main producer of deciduous fruit may be most vulnerable to changing climate conditions. Depending on the production region, an increase in hot days, fewer cold days, reduced rainfall and more intense rainfall events are important risk factors for sustainable production.

(a)



(b)

Figure 3.1-7: Maximum temperatures during winter for deciduous fruit production areas under a baseline (a) and future (b) climate scenario. This figure indicates that maximum temperature during May-Sep increasing to such an extent that some areas do not accumulate sufficient chill units in future.

3.1.3.3 Forestry

Compared to field crops such as maize and wheat, forestry species are more resilient to drought. Nevertheless, forestry production is sensitive to decreasing rainfall and the geographic location of a plantation will determine the extent of the impact. Climatically optimal areas for plantation forestry are located in parts of Mpumalanga and Kwa-Zulu Natal where rainfall exceeds 750 mm per annum. In these areas, the effect of climate change on timber production will be least severe, although any decline in rainfall will still reduce tree growth. The most noticeable impact on timber production will be in forestry areas which receive less than 750 mm of rainfall. In these areas, the viability of plantation forestry may be greatly reduced (DEA, 2013).

With rising temperatures, the extent of land that is currently climatically suitable for specific species are likely to decrease in KwaZulu-Natal while certain areas within the Eastern Cape and Mpumalanga may become more favourable for forestry, given that rainfall is still optimal.

Warmer and drier conditions also increase the susceptibility of trees to existing and new pests and pathogens. Insects are very sensitive to even small changes in temperature and moisture and so they move, adapt and flourish where they couldn’t survive before. Another threat to plantations is fire, which is likely to burn hotter and cause more damage under hotter, drier conditions.

Overall, the most important forestry areas in South Africa will still remain viable under climate change in the near future. Rising temperatures may even open up new production areas in parts of the Eastern Cape and Mpumalanga.

3.1.3.4 Fisheries

Climate change associated impacts of concern for the fishing industry includes changing sea surface temperatures, changes in wind strength and direction that influence water circulation, elevated CO_2 and ocean acidification, current speed and strength as well as sea-level rise. Depending on the species in question and geographic location, these changes can affect species distribution, species growth rate and reproduction and ultimately the catchability of resource species. This could result in significant adverse impacts on subsistence fishing livelihoods as well as commercial and recreational industries (DEA, 2013a).

3.1.3.5 Key messages

Agriculture, forestry and fisheries is an important earner of foreign exchange, provide job opportunities, create a market for produce and services and is an important supplier of raw materials to a large number of sectors in the economy of South Africa. Moreover, the sector is critical in ensuring food security and sustaining the social and economic welfare of rural communities. However, the sector faces several challenges associated with anticipated climate change. Across South Africa, the increase in temperatures and changing rainfall patterns will bring about distinct risks for different crops and commodities in different growing areas. The most important impacts in the near future will be on crops, tree species and livestock produced in marginal growing areas where growing conditions are already close to temperature and water availability thresholds. Production systems in optimal growing or grazing areas will still be viable although extreme climate events may become more prevalent and occur with higher frequency.

In the near future, rainfall is expected to remain within historical ranges over most of South Africa, except for a decline over the Western Cape and some increases over the far eastern parts of Kwa-Zulu Natal. More significant changes are expected in maximum and minimum temperatures, as well as extreme temperatures, heat waves. This will have major implications for crops, tree species, livestock, game and fisheries as well as the prevalence of pests and diseases.

The National Climate Risk & Vulnerability (CRV) Assessment Framework provides guidelines, practical steps and standardized concepts to perform risk and vulnerability assessments in any sector of South Africa. This chapter incorporates important aspects and principles related to risk and vulnerability assessment as highlighted in the CRV Assessment Framework for South Africa. Risk and vulnerability for this chapter was mainly framed in terms of physical climate risk to the specific agricultural sub-sector or industry and generally did not include or consider exposure or sensitivity indicator such as socio-economic circumstances. An example of such a condition is where an area has significant exposure to drought and heat stress, but low vulnerability due to the greater capacity of farmers to adapt to adverse conditions. This chapter could therefore expand to include economic, social and environmental indicators to assess vulnerability. This involves trade-offs between ecosystem services to agriculture and the extent to which the sector impacts biodiversity. In a changing climate, these trade-offs and synergies will become even more important and subject to external pressures.

3.2 Biodiversity sector

3.2.1 Risk and vulnerability profile

Biodiversity provides a variety of ecosystem services that are crucial to human well-being. South Africa is one of the biologically diverse countries in the world due to its species diversity, high levels of endemism, particularly in plants and diversity of ecosystems. South Africans depend on healthy ecosystems for economic and livelihood activities which include agriculture, tourism and numerous income-generating and subsistence-level activities. According to the latest National Biodiversity Assessment (SANBI, 2019), the biodiversity sector contributes more than 418 000 jobs and contributes significantly to the Gross Domestic Product (GDP).

Global environmental change including climate and land cover or use change is attributed to rapid biodiversity loss at a species and habitat level, consequently reducing the intended ecosystem services. This change is responsible for the transformation of approximately 50% of earth's land surface, thus having significant effects on biodiversity and ecological processes (Vitousek et al., 1997). The IPCC Special Report (IPCC, 2019) focusing on climate change, desertification, land degradation, sustainable land management, food security and greenhouse gas fluxes in the terrestrial ecosystems, recognizes that land provides the principal basis for human livelihoods and well-being including the supply of food, freshwater and multiple other ecosystem services, as well as biodiversity. Unregulated land cover change has been cited as one of the main determinants of biodiversity loss in the world and Africa at large (IPBES, 2018). The latter unregulated land cover change coupled with human population growth entails the extensive conversion of natural ecosystems to non-natural classes such as agriculture, settlements and other infrastructure developments. Agricultural intensification is driven by the need to produce more food for the ever-increasing human population (WWF, 2020). Similarly, urban expansion and infrastructure development are key pillars of socioeconomic development, while often leading to habitat loss.

In this study, we are only going to focus on habitat loss or habitat transformation (conversions), not bush encroachments, as an indicator of biodiversity loss. Habitat conversion is one of the direct drivers of biodiversity loss, among others such as overgrazing, overharvesting, invasive species, pollution, poor land management and sustainable land management (IPBES, 2018). The habitat loss is defined within the context of land cover change as a conversion from natural vegetation classes such as forests, woodlands, grasslands, shrubs, wetlands to non-natural classes such as forestry, agriculture, urban areas (settlements, mining, etc).

3.2.2 Climate change impacts on biodiversity

According to the recent global convention reports related to biodiversity, land degradation and climate change, the world has not achieved targets between 2010 and 2020 for reversing biodiversity loss (IPCC, 2019; IPBES, 2018, CBD, 2020; WWF, 2020). Also, climate change is expected to make it difficult to reverse such loss and there is a need to adopt a holistic approach towards reducing food consumption and developments while allowing recovery of biodiversity. Climate change has a direct effect on biodiversity loss particularly on the continent that is experiencing high human population's growth and the need for other land uses such as Africa. This suggests that the impacts of habitat loss on biodiversity have to be taken into context with how they will be enhanced by climate change (Meadows and Hoffman, 2003). Canadell et al. (2009) reported that between the year 2000 and 2005, Africa's contribution to the global emissions from the land-use change was as high as the combustion of fossil fuels (e.g. CO_2). These large-scale habitat conversions occur in some of the most threatened biodiverse regions of the world such as the biodiversity hotspots (Myers et al., 2000). In the context of South Africa, this includes the Succulent Karoo and the Fynbos biomes (DEA, 2013b). Biomes and specifically vegetation types have played an important role in guiding conservation efforts in the country (Reyers et al., 2001; Lombard et al., 2003) and future conservation actions (e.g. DEA, 2016a).

At the biome scale, early correlative models predicted that the extent of the Succulent Karoo will move southwards in tracking suitable climate space (Hannah et al., 2002; Midgley et al., 2002). Moreover, both the Fynbos and the Succulent Karoo biomes are expected to lose suitable climate space and to be more fragmented. However, the implementation of more advanced process-based models such as the Dynamic Global Vegetation Models (Moncrieff et al., 2015) suggests a more complex relationship (Midgley and Bond, 2015), such that changes at the biome level will largely be driven by an increased CO_2 input in the system rather than changes in temperature and precipitation. This will also lead to an increase in the woody vegetation and the alteration of savannah (Moncrieff et al., 2016) and the grassland biomes (Moncrieff et al., 2015). The current models are also not well parametrised for disturbance driven systems such as the Fynbos and the Succulent Karoo, making predictions in these systems very difficult (Moncrieff et al., 2015). Field observations also indicated that the Nama Karoo biome exhibit a shift in grass versus shrub dynamics due to land-use change and a shift in rainfall season as well as increased temperatures. This will affect biodiversity and livestock farming in the transition areas of the two biomes (Masubelele et al., 2014). This supports Midgley and Bond (2015) that grassland will shrink in the near future.

While looking at the impacts of climate change on other taxa in South Africa, Erasmus et al. (2002) found that while some species were expected to gain in distribution ranges, the majority (78%) were expected to experience range contractions. Since then, many more studies have also predicted suitable climate space loss for plants (Midgley et al., 2002), birds (Coetzee et al., 2009) and frogs (Mokhatla et al., 2015) to name a few. What is even more challenging is the dual impacts of both climate change and land-use change of the biodiversity of the region as a transformed landscape will make colonisation of suitable climates difficult. It is suggested that these two factors (climate and land use or cover change) acting in synergy will impact hydrological cycles (Schulze, 2000) and lead to significant loss of biodiversity in terms of habitat (Mantyka-Pringle et al., 2015) and Red-Listed plants (Bomhard et al., 2005), amphibians (Hof et al., 2011), mammals and birds (Mantyka-Pringle et al., 2015) across the sub-Saharan region (Mantyka-Pringle et al., 2012). There is high confidence that sustainable land management can contribute to reducing the negative impacts of multiple stressors, including climate change, on ecosystems and societies.

3.2.3 Risk and vulnerability assessment

Changes in land-use are largely driven by human actions at a broader landscape. This explains why human population-related variables also correlate with factors such as invasive species richness (Chown et al., 2003; Van Rensburg et al., 2002). Also, evidence suggests that both biodiversity and human population respond to similarly to environmental energy availability, albeit at coarse spatial scales (Chown et al., 2003; Luck, 2007). This means that where they co-occur, human-mediated land-use changes are indeed the single most factor driving species extinctions as outlines in the biodiversity hotspots in the early 2000’s (Brooks et al., 2002) and the Biodiversity Hotspots ideas. Thus, in addition to modelling land-use change as a function of known human factors, we wanted to determine if the non-human variables such as of bioclimatic variables used primarily to model species distribution as a function of climate (e.g., Elith et al., 2010), could be used to model current land-use patterns and eventually used to predict future of land-use in the region.

3.2.3.1 Data used and pre-processing / preparation

South African National Landcover Products

Remote sensing has been used for undertaking land cover and land use mapping and change detection for over decades. The maturity of land cover mapping is directly related to progress made on the development of image classification techniques and the launching of medium to high-resolution satellite sensors. Today, image classification techniques are not only restricted to parametric classifiers but also to the non-parametric ones, including the machine learning techniques which improve the land cover classification. In South Africa, the national land cover products (SANLC) for 1990 and 2018 were derived from multi-seasonal Landsat data at 30m and Sentinel-2 images at 20m spatial resolution, respectively. The SANLC products for respective dates and the land cover change data were acquired from the Department of Forestry, Fisheries and the Environment (DFFE) (https://egis.environment.gov.za/). The habitat loss was derived from all land cover classes that were converted from natural to non-natural classes such as agriculture, built-up and forestry plantations. According to Thompson (2019), the conversion or transformation change (i.e. from natural to non-natural classes) from these data products are of a higher quality than those changes from natural to natural classes (e.g. grassland to woodlands or woodlands to grasslands).

Data preparation for modelling

For the modelling purposes, the conversion classes were denoted as ones and other changes as zero, these were created to derive the presence (habitat loss) and absence (no-loss) (see Figure 3.2.1). The first step was to create a systematic point grid at 1km and 5km to select the grid that is easier to use but deriving acceptable modelling results. Secondly, point grids were used to extract climate variables to be used for modelling. For the generalized linear model (logistic regression), climate and hazard data derived from this project were used. Climate data derived from this project included (1) anomalies, coefficient of variations (CV) for various seasons, fire index, flood days and water vapour pressure from 1971 – 2000 (baseline), 2000-2020 (current), 2020-2025, 2025-2030 (future) (see Section 2.2). For MaxEnt modelling, the World Climate (worldclim) data was used, see maxent section for details 3.2.3.4). According to NCCAS 2018 and 2019, terrestrial ecosystems' sensitivity (i.e. current stressor) include habitat fragmentation, land-use change and invasive alien plants, whilst the exposure (climate drivers) are; 1) increase in temperatures and extremes, 2) changes in rainfall and distribution and 3) changes in fire. The latter informed the choice of the climate drivers selected in this study.

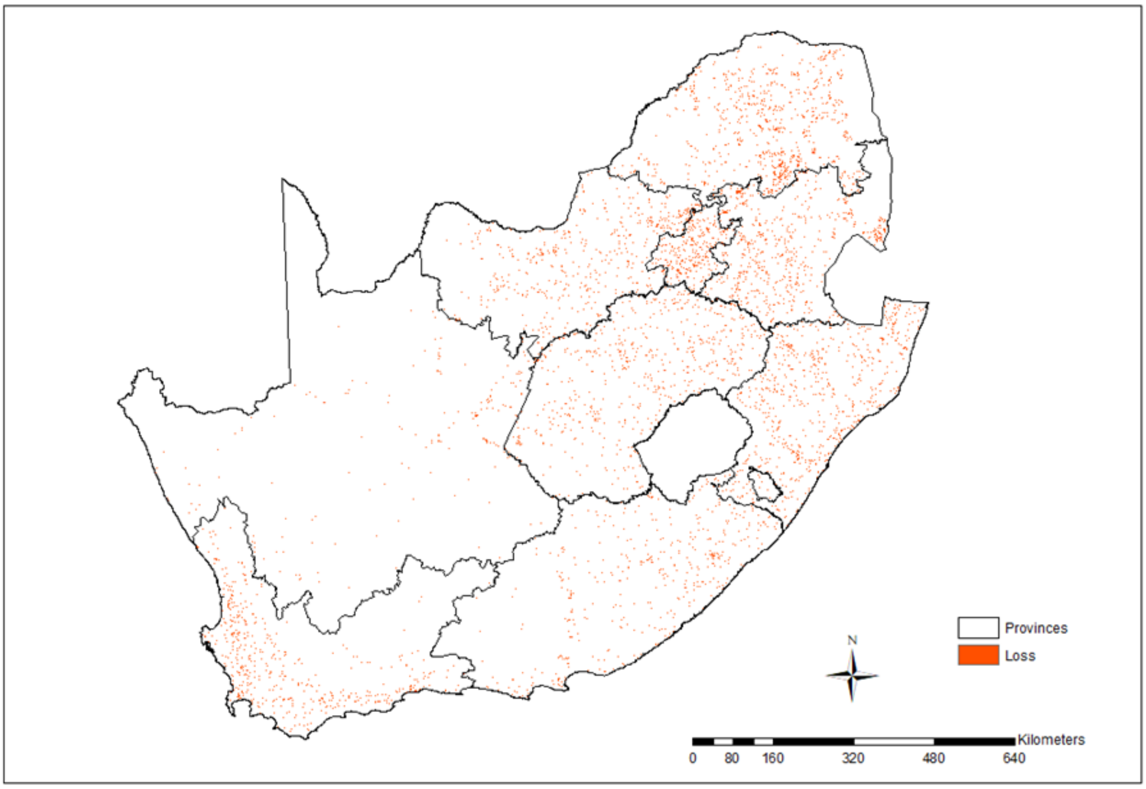


Figure 3.2-1: Habitat loss based on the land cover change data between 1990 and 2018.

3.2.3.2 Modelling probability of the habitat loss risk

Two model frameworks were used for modelling habitat loss: (1) the generalized linear model (logistic regression) and (2) the maximum entropy model (MaxEnt) (Aguilar et al., 2018). Although MaxEnt has been used to model land-use changes (Aguilar et al., 2018), it has mostly been used in this platform using remote-sensing layers (e.g., Amici et al., 2017). This is despite the understanding that factors such as stable climate and their associated derivatives drive, not only the occupation of habitats across space and time (Xu et al., 2020), but also the evolution of hominids (De Menocal, 2011).

3.2.3.3 Logistic regression

A grid of 1 km was created to extract the habitat loss and corresponding climate variables for modelling (Figure 3.2.2). Stepwise logistic regression was applied to minimize model overfitting and multi-collinearity. The best model with the lowest Akaike Information Criteria (AIC) and significant variables was selected for mapping the probability of habitat loss based on historical and current data.

Therefore, the future prediction of habitat loss for 2020-2025 and 2025-2030 was based on the current model (2000-2020) (See Figure 3.2.2).

The initial model for mapping the probability of the historical, current and future habitat loss risk included over 50 climatic variables, including long-term changes in temperature and rainfall, flood days based on the seasonal or three-monthly coefficients of variation (CV) and relative anomalies, drought (SPEI) and fire danger index. The optimal variables finally selected through stepwise logistic regression, included the long-term changes in rainfall and temperature (seasonally) and flood days based on the coefficient of variation metric, relative anomalies (minimum temperature and water vapour pressure) and fire danger index. Specifically, the optimal model for mapping habitat loss risk or probability using 1971-2000 climate data had about 15 predictors, while about 13 optimal predictors were used from the 2000 – 2020 climate data. The future habitat loss risk (2020 -2025 and 2025 -2030) was based on the 2000-2020 model. About 70% of the sampling points were used for calibration and 30% was equally used for testing and validation. The area under the receiver operating characteristic curve was 0.73 and 0.72 for the 1971-2000 and 2000-2020 models, respectively. Since the empirical models are often data-dependent and not easy to transfer to new data sets, we used the 2000-2020 current model to predict both the 2025 and 2030 habitat loss risk.

3.2.3.4 MaxEnt – entropy modelling – for comparative analysis

To evaluate the reliability of the logistic regression results, we used MaxEnt modelling software to predict the risk of habitat loss. MaxEnt is commonly used for species distribution modelling to look at the past and future impacts of climate change on species, as well as modelling invasive species in novel environments. We used 19 bioclimatic variables downloaded from the WordClim dataset (Fick and Hijmans, 2017) at 30 arc seconds (≈ 1 km resolution) and 2.5 arc minutes (≈ 5 km resolution). The climate data was cropped for the study extent (Republic of South Africa). We wanted to use the dataset that closely matched the land-use transformation data (≈ 30m resolution). Although there is current climate data at 30 arc seconds data (≈ 1km) resolution for the bioclimatic variables, we could not use the dataset to project land-use changes into the future as it lacked future projections datasets. We took the 19 bioclimatic variables and ran a multicollinearity test across the study extent using the VIF package (see above) implemented in R (R Core Team, 2020) to test for the relationship between our variables. These variables included: Mean diurnal range (BIO2), Isothermality (BIO3), Mean temperature of the wettest quarter (BIO8), Mean temperature of the driest quarter (BIO9), Precipitation of warmest month (BIO13), Precipitation seasonality (BIO15) and Precipitation of coldest quarter (BIO19). These variables were thought to provide a mix of a mean as well as limiting factors that may play a role in human land-use categories such as agriculture. We modelled land-use change for the current (at both 1 km and 5 km resolutions) and projected the results into future up to the year 2050 using the MRI-ESM 2-0 General Circulation Model dataset at 5 km resolution only. To account for climate change variability, data was projected on the four-shared socio-economic pathways (ssp126, ssp245, ssp370 and ssp585), with an increase in global mean temperature between 1.2 and 5.5°C respectively, across different socio-economic pathways.

Grid squares were grouped according to whether they have undergone habitat loss or not (as described in Section 3.2.3.1). We then used this land-use/habitat loss presence-absence dichotomy as an input to model land-use change projections at a 30 arc seconds and 2.5 arc minute resolution, using the machine learning algorithm MaxEnt v3.3.3k (Phillips and Dudík, 2008), based on the Bioclimatic variables explained above. For model evaluation, we divided the species records into 70% used to train the models and 30% for model evaluation using the area under the receiver operating characteristic curve: AUC (Swets, 1988). MaxEnt uses presence-only data and automatically set 10 000 randomly selected points for pseudo-absences to model relative occurrence rates of land-use (in our case). In the quest to keep our models simple, we only allowed linear, quadratic and hinge features. The final model was averaged over 100 replicates, using the bootstrap sampling technique. We then projected model outputs for the year 2050. Non-analogous climatic conditions that exceeded the training range of the models were quantified wherein the numbers of these predictors are highlighted using Multivariate Environmental Similarity Surfaces: MESS (Elith et al., 2010).

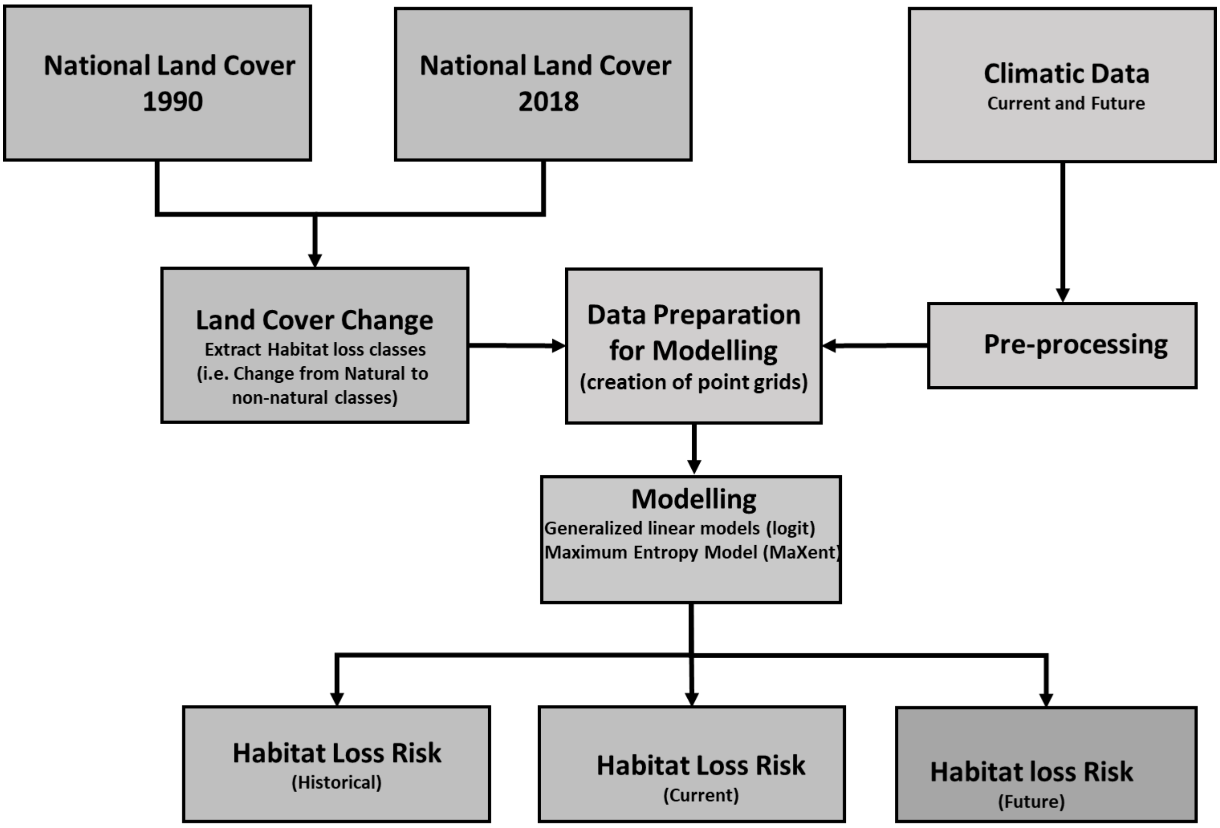


Figure 3.2-2: Schematic representation of the method for mapping risk biodiversity loss.

3.2.3.5 Results – the risk of habitat loss modelling

This section will present the results from the current land cover change and current and future habitat loss risk, based on climate data.

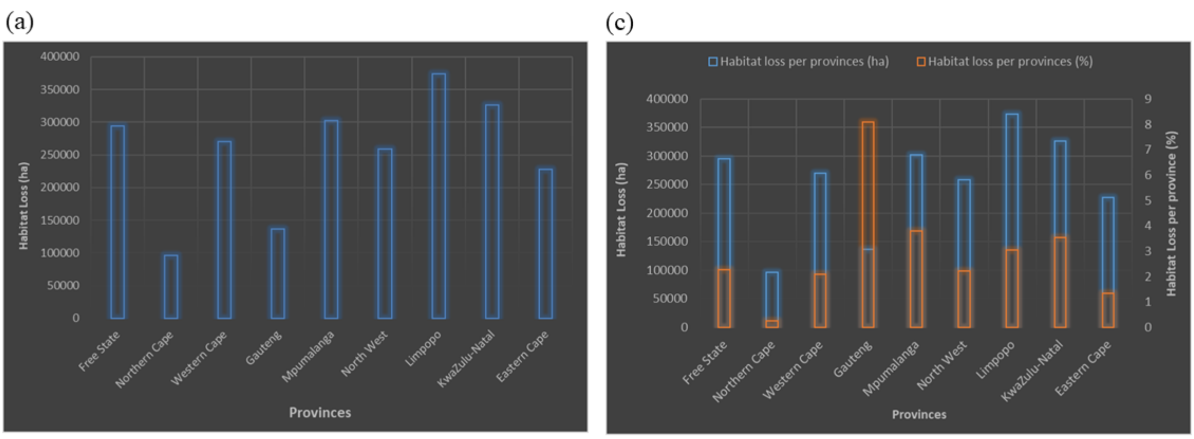


Figure 3.2-3: (a) habitat loss in the area (ha) summarized per province (between 1990 and 2018) and (b) habitat loss in terms of the percentage.

At the provincial level, habitat loss between 1990 and 2018 was highest in Limpopo, followed by KwaZulu Natal, Mpumalanga, Free State and the Western Cape. The Northern Cape province experienced the least habitat loss, followed by the North-West and Eastern Cape during this time period. The graphs below highlight areas or municipalities in the provinces where the most change has occurred between 1990 and 2018.

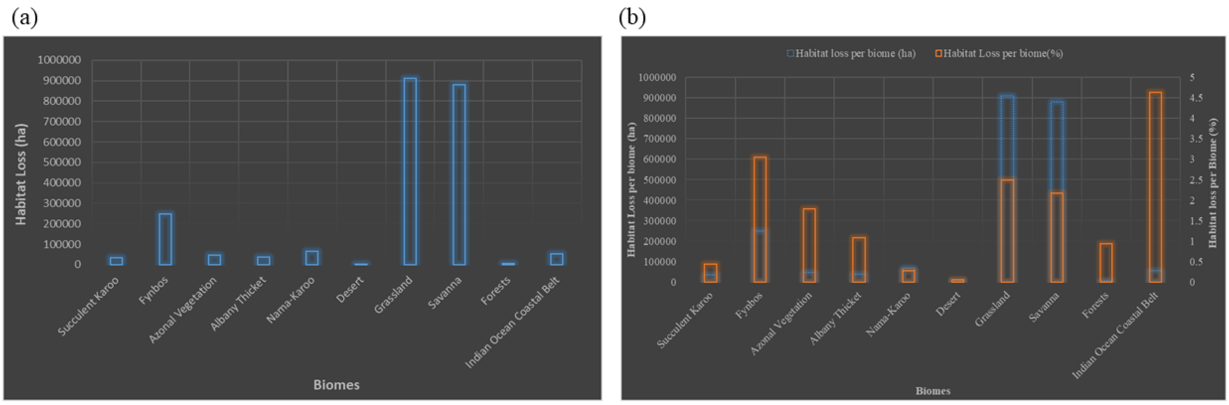


Figure 3.2-4: (a) habitat loss area (ha) summarized by biomes (between 1990 and 2018) and (b) percentage habitat loss per biome (%).

Savannah, and especially grassland and fynbos, experienced the most loss in habitat in terms of the total areas (ha). The habitat loss in fynbos, grassland, azonal and Indian coastal belt are of most concern because these are the biomes that are the most biodiverse in the country and are of international significance as biodiversity hotspots. Also, perhaps of concern to some degree, is the Pondoland Maputaland hotspot in KZN.

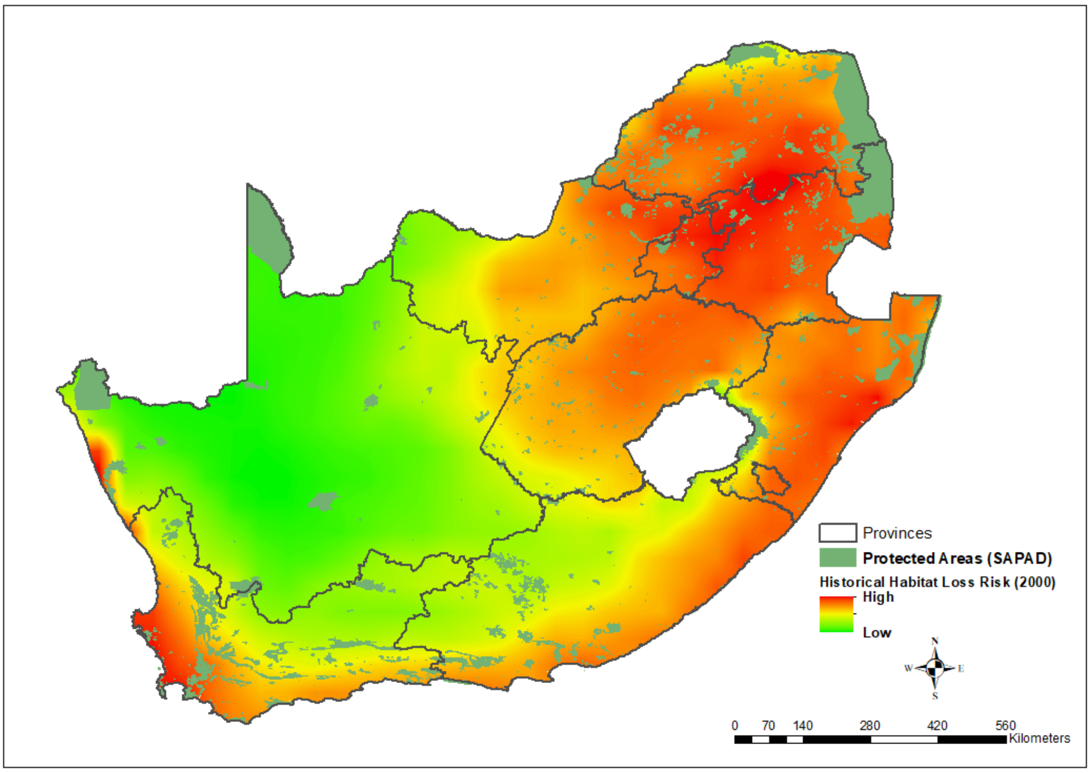


Figure 3.2-5: probability or risk of biodiversity loss (habitat) – 1971 – 2000, based on a generalized linear model and climate data from this project.

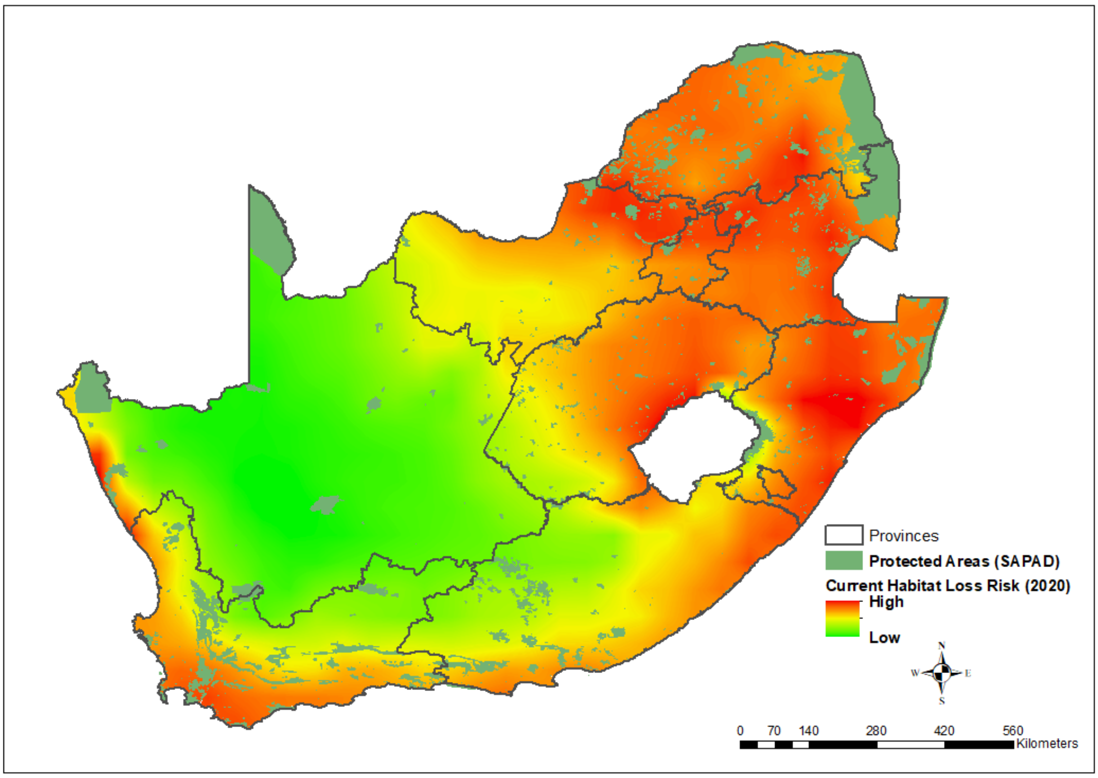


Figure 3.2.6: probability or risk of biodiversity loss (habitat) – 2000 – 2020, based on a generalized linear model and climate data from this project.

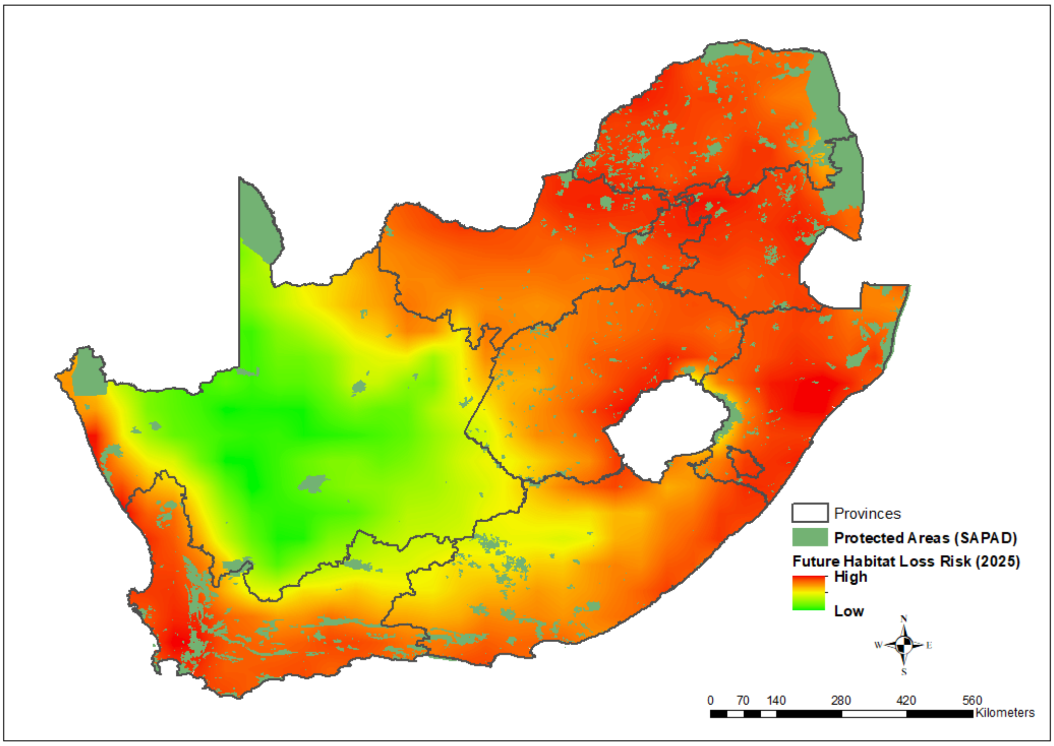


Figure 3.2-6: probability or risk of biodiversity loss (habitat) – 2020 – 2025, based on a generalized linear model and climate data from this project.

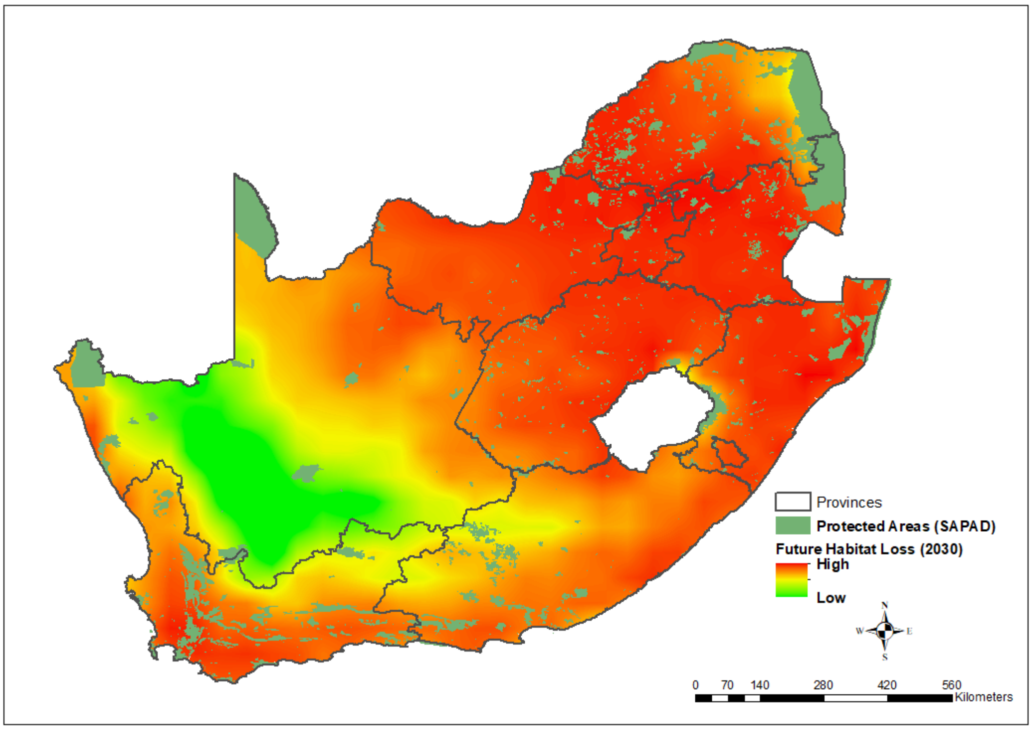


Figure 3.2-7: probability or risk of biodiversity loss (habitat) – 2025 – 2030, based on a generalized linear model and climate data from this project.

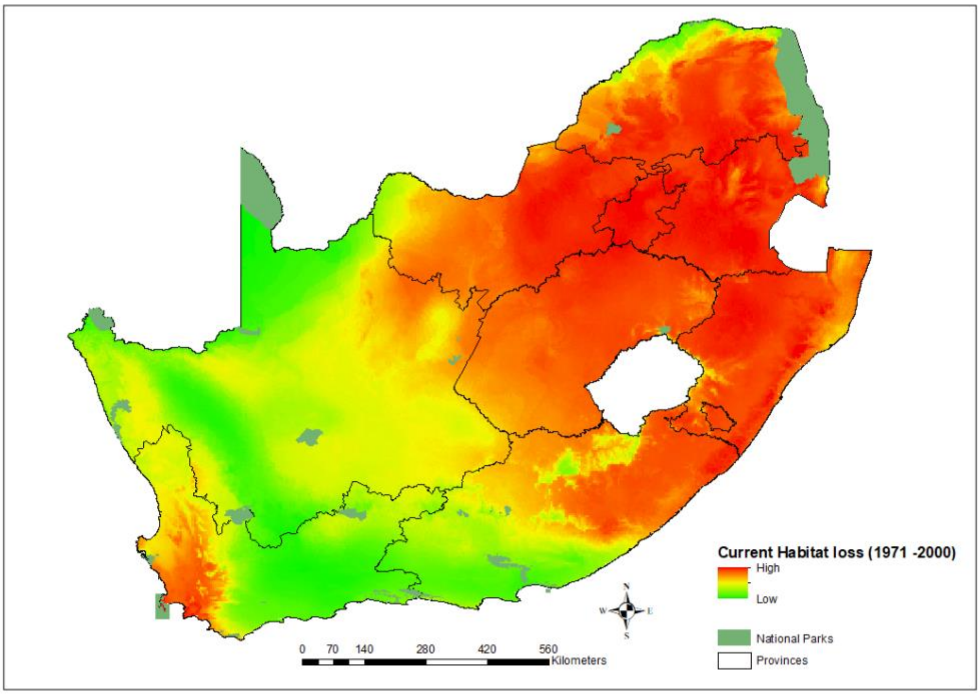


Figure 3.2-8: probability or risk of biodiversity loss (habitat) – historical to current (1971-2000), based on a MaxEnt model and Worldclim climate data (independent data, not simulated in this project).

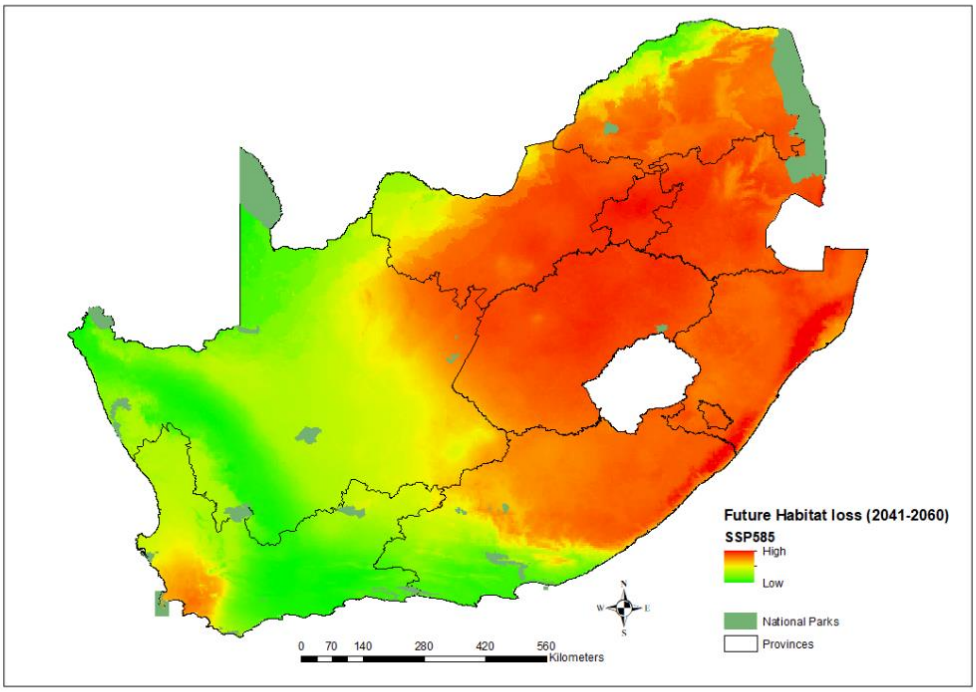


Figure 3.2-9: Probability or risk of biodiversity loss (habitat) – future (2050), based on the MaxEnt model and Worldclim climate data (independent data, not simulated in this project).

3.2.3.6 Key Highlights

- Savannah and the grassland biome experienced the most biodiversity loss currently and the future risk is also significant in those two biomes (see Figure 3.2.5, 3.2.6, 3.2.7, 3.2.8, 3.2.9). The loss of biodiversity in the fynbos and Indian coastal belt is also high relative to their sizes. About 3 and 4.5 per cent of habitat was lost between 1990 and 2018 in the fynbos and the Indian coastal belt biomes respectively. The risk of loss based on climatic variability is also significant in the latter biomes, including the savanna and grasslands.

- Limpopo, Western Cape, Mpumalanga, Free State and KwaZulu Natal provinces experienced the highest biodiversity loss. The highest probability or risk of biodiversity loss has been evident both currently and in future in these provinces (See Figure 3.2.3, 3.2.5, 3.3.6, 3.2.7, 3.2.8, 3.2.9, 3.2.10).

- In terms of municipalities in Limpopo, Thabazimbi, Lephalale, Blouberg and Musina have experienced the most habitat loss due to agricultural intensification and settlement expansion and will continue to do so until 2030. KZN coastal municipalities that have experienced the most habitat loss include uMhlabuyalingana LM near Mozambique, down to Port St Johns in the Eastern Cape province. The same is true for all of the Western Cape coastal municipalities, with the most habitat loss experienced by Saldanha Bay LM and the City of Cape Town. For the North West, Mafikeng, Ramotshere Moiloa, Ditsobotla, Moses Kotane and Ratlou LM are hot spots. According to the map, Dihlabeng, Maluti-A-Phofung and Phumelela LM in Free State have experienced the most habitat loss. For Mpumalanga, Emalahleni, Emakhazeni and Steve Tshwete LM have experienced the most habitat loss. These changes in the Mpumalanga and Free State LM are associated with the loss in grassland habitat. In the Eastern Cape, King Sabata Dalinyebo and Nyandeni LMs show the most habitat loss. In the Northern Cape, Kamiesberg LM has experienced the most habitat loss. The Namaqua National Park is situated within this LM.

- Protected areas, including the National Parks, that are surrounded by the most habitat loss risk in all periods until 2030, include Golden Gate Highlands in the Free State; potentially iSimangaliso in KZN, Marakele in Limpopo, the West Coast, Table Mountain and Agulhas in the Western Cape and, finally, Namaqua National Park in the Northern province. Large areas outside of Kruger experienced moderate habitat loss. Most of the coastal areas experienced a moderate change in habitat loss. This will certainly have implications for the implementation of the National Protected Area Expansion strategies.

- Generally, the generalized linear models based on logistic regression results are comparable to those derived from the MaxEnt model. The accuracy of the models was both acceptable with the area under the curve (AUC) up to 0.73 and 0.69 for the generalized linear model and MaxEnt, respectively.

3.3 Health sector

3.3.1 Climate change impacts on health

The impact of climate change on health and the health sector is highly complex. Figure 1 below highlights these complex interactions between climate change and health, including the multiple pathways through which health can be impacted. This relationship between climate and health can be impacted by external factors, that are called “modifying factors” in Figure 1. These factors can either mitigate or exacerbate the impacts that climate will have on health and form the basis for many adaptation actions in the sector. A changing climate will put additional strain on the health system, including the increasing burden of disease, as well as affecting aspects such as infrastructure, services, availability of medicines and medical supplies and emergency services (NDoH, 2019; Dos Santos et al., 2019; Garland et al, 2016), The implementation of the National Health Insurance (NHI) scheme can provide an opportunity to improve the equity and the climate-resilience of the sector (Wright et al., 2019).

In a recent literature review on climate change and health in South Africa, it was found that, while the sector is at risk from a changing climate, there is a lack of research on the impacts on health and the health sector, though the field is growing (NDoH, 2019). Much of the information available focuses on qualitatively discussing the potential impacts on health, with less research focusing on quantifying the linkages between climate and health; this is the key first step towards quantifying the impact of climate change on health in South Africa (Myers et al., 2011). In addition, there is a lack of research on the impacts of climate change on the health system.

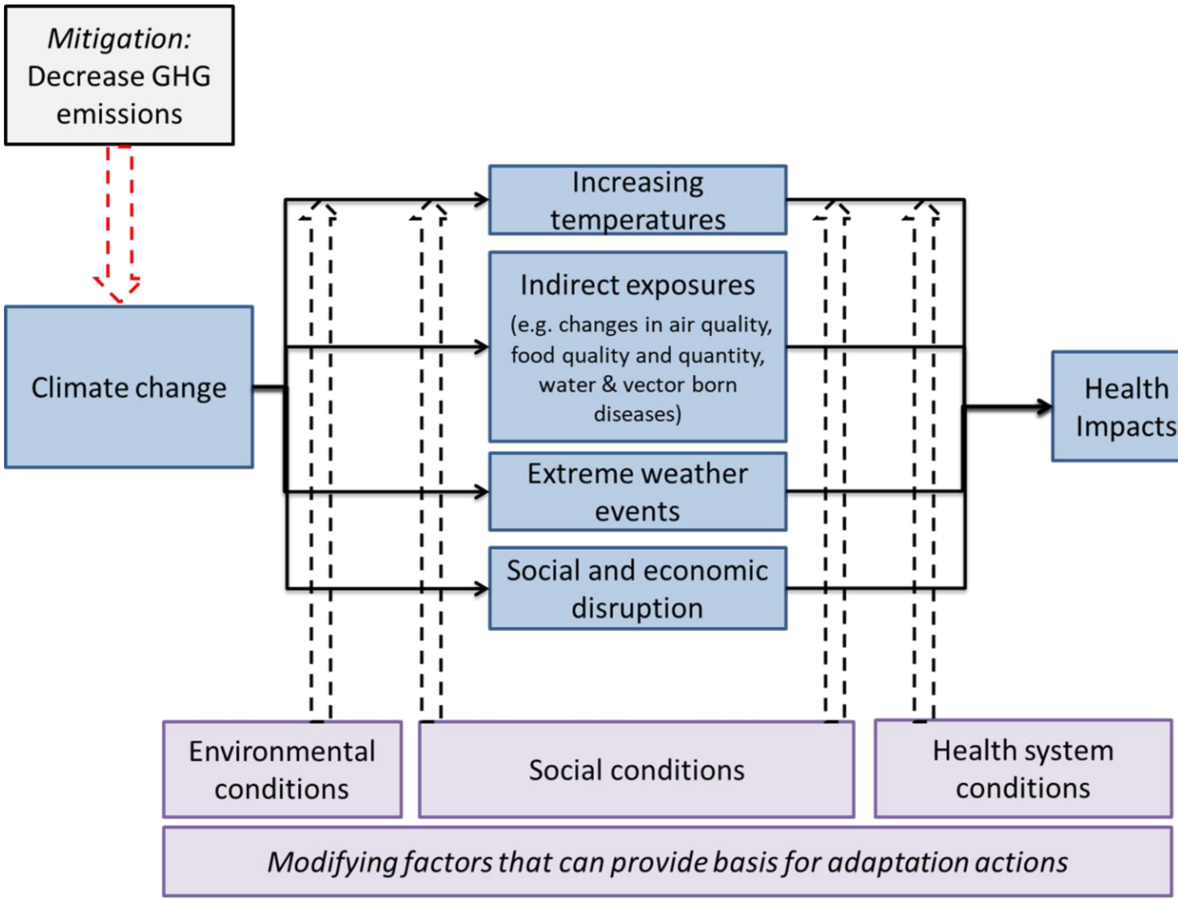


Figure 3.3.1. Schematic summarizing linkages between climate change and health. (adapted from Garland and Rother, 2017, adapted from Confalonieri et al., 2007; Ahdoot and Pacheco, 2015).

3.3.2 Risk and vulnerability profile

3.3.2.1 What are the most pressing issues facing the health sector?

Climate-related hazards impacting on health include extreme events and gradual trends involving changes in temperature and precipitation. Key risks from climate change on the health sector is the exacerbation of the current burden of disease from climate-related diseases and the ability of the health system to cope with this changing burden (McMichael, 2009; Smith et al., 2014). It is expected that climate change will affect public and occupational health in many ways in South Africa (NDoH, 2019; NDoH, 2019a. The potential indirect effects are numerous and include communicable and non-communicable diseases, chronic illnesses, air pollution-related illnesses, malnutrition, violent injuries and mental health concerns. Climate change and this increase in health impacts will put an additional burden on the health system, which is already under strain (NDoH, 2019; Dos Santos et al., 2019; Garland et al, 2016).

The definitions of risk and vulnerability were informed by the IPCC framework that has been adopted by the National Climate Risk and Vulnerability Framework (CRVF). This framework was used to define and identify indicators that describe the health sector's state of exposure and vulnerability to climate hazards. A Climate Risk and Vulnerability Assessment has not been conducted for the health sector yet, but the Department of Health is in the process of finalising a list of priority indicators for climate change. For this assessment, indicators were thus based on the literature on vulnerability to heat exposure determined internationally. Identified indicators for which data were readily available, were used to assess the exposure and vulnerability of the health sector. These factors provide an indication of the pressing issues in different areas and should inform the identification of adaptation needs. The underlying reason for doing this assessment was to fulfil the requirements for the NDC but also to collect baseline data/information for monitoring and evaluation, specifically to inform adaptation options. Standardisation of the methodology should assist in the comparison of indicators across different sectors and between and across different studies. It is hoped that the assessment will be used by a variety of stakeholders including implementers, academics and strategic audiences. The willingness of stakeholders to engage with the CRV has not been determined yet. A potential engagement platform may include the Green Book.

3.3.2.2 Exposure to climate hazards or signals

There are numerous potential health impacts from exposure to climate hazards (Figure 3.3.1). However, quantitative assessments linking health outcomes and exposure to climate hazards in current and future climate in South Africa do not exist for all hazards.

There is local research linking temperature (i.e., hot days) and mortality that can be used to assess the risk on account of high temperatures. This is a critical risk to highlight as southern Africa has been identified as a global climate change "hotspot" for heat extremes (Engelbrecht et al., 2015b; Hoegh-Guldberg, et al., 2019).

3.3.2.2.1 Hot temperature

Exposure to high or low temperatures can lead to increases in morbidity and mortality (e.g., Gasparini et al., 2015; Baccini et al, 2008; Basu et al., 2009; Ballester et al., 2011; McMichael et al., 2004; Hajat and Kosatky, 2010). In addition to the direct health impacts from exposure to hot temperatures, there is growing evidence that higher temperatures are related to an increase in violent crimes (Chersich et al., 2019; Schutte and Breetzke, 2018; Bruederle et al., 2017; Breetzke and Cohn, 2012; Gates et al., 2019). In a national study, it was found that 1ºC increase in maximum temperature was associated with a 1.5% increase in definite homicides (Gates et al., 2019). The main drivers behind these associations are not yet untangled but may be due to the impacts of temperature on physiological,

physiological and behavioural factors (Chersich et al., 2019). Health is negatively impacted by both individual "hot days" and consecutive hot days (e.g. heat waves) (e.g. Guo et al., 2017). In addition to increases in temperatures, it is projected that the frequency and duration of heatwaves in South Africa will increase in the future under climate change (Mbokodo et al., 2020).

A national assessment found that currently there are more deaths in South Africa from exposure to cold temperatures than from high temperatures (Scovronick et al., 2018). However, the risk to health from exposure to high temperatures is expected to increase in the future under climate change (e.g. Smith et al., 2014; Hoegh-Guldberg, 2018; Garland et al., 2015). In addition, the impact that a warming climate will have on deaths from cold temperatures is not clear, as there are other important contributing factors and drivers in cold-weather deaths (e.g. seasonal factors such as influenza) (Staddon et al., 2014; Kinney et al., 2015).

3.3.2.2.2 Hot days

The relationship between temperature and mortality is generally a U or J-shaped curve, with the risk of mortality increasing above or below an optimal temperature (Ballester et al., 2011; McMichael et al., 2004; Hajat et al., 2010). This "optimal temperature" is referred to as the Minimum Mortality Temperature (MMT). In a national study, it was found that the MMT for all-cause mortality in South Africa is at the 84^{th} percentile of daily maximum temperature (the 95^{th} confidence interval was 56-87^{th} percentiles (Scovronick et al., 2018). The risk of mortality increased by 6% at the 99^{th} percentile of daily maximum temperature (the 95^{th} confidence interval was 3-9% increase) compared to the risk at the MMT. These percentiles are used in this assessment, with the thresholds set in the current climate and applied to the future projections to understand the change in the number of "hot days" and "extremely hot days". By using percentiles as the definition, the threshold will be spatially heterogeneous.

In this assessment,

- "hot days" refer to the days when the daily maximum temperature is above this MMT of 84^{th} percentile of the reference period daily temperature distribution.
- "Extremely hot days" are days when the daily maximum temperature is above the 99^{th} percentile of the reference period daily temperature distribution.

Drivers of the vulnerability of health to climate change in South Africa are explained below.

3.3.2.3 Vulnerability to climate signals and hazards

The vulnerability of the health sector to climate hazards are the factors that determine the sensitivity and/or coping capacity of receptors associated with this sector. In this context, sensitivity factors are internal characteristics of a system. Intrinsic (biological) or extrinsic (exposure-related) characteristics of receptors may increase the risk of health impacts to the receptor following exposure. Factors may include age, nutritional status, level of education. Coping capacity factors relate to those that assess the ability of the receptor to cope if there is exposure. These indicators have been based on the literature on vulnerability to heat exposure determined internationally (e.g., Inostroza et al., 2016; Reid et al., 2012; Wolf and McGregor, 2013; Bao et al., 2015; Rinner et al., 2010; Paterson and Godsmark, 2020). Suitable factors may either increase the sensitivity of individuals for adverse health impacts when they are exposed to climate hazards such as elevated temperatures or extreme rainfall or may affect their ability to cope or adapt when they are of have been exposed.

Factors that impact on the sensitivity and coping or adaptive capacity of communities exposed to climate hazards that were considered for inclusion into the Vulnerability Assessment are shown in **Error! Reference source not found.**.

Table 3.3-1: Indicators for sensitivity and coping capacity associated with climate hazards

Vulnerability aspect	Indicator name	Potential Indicators	Source of information
Sensitivity (intrinsic)			
Age dependency	The elderly population (physiological) and young population	The total population that is not working age (below 15 and above 65)	Census
Family structure (gender/age)	Women and children	Women and child-headed households	Census
Nutrition	Nutritional status, e.g. malnutrition, obesity	Severe acute malnutrition inpatient under 5 years; Adults overweight or obese	DHB
Underlying health conditions	Mental health	Mental health separation[1] rate	DHB
	Physical disability		Census, DHB

Vulnerability aspect	Indicator name	Potential Indicators	Source of information
	Nutritional diseases, e.g. diabetes	Diabetes new client 40 years and older detection rate	DHB
	Water-and food-borne diseases Cholera, diarrhoea	Diarrhoea separation[1] under 5 years	DHB
	HIV infection	Total number of the population that is HIV positive HIV test positive 19 months to 14 years rate	DHB
	Chronic/lifestyle diseases	The population on chronic medication	Census
	Immunity	Immunisation under 1 year Vitamin A dose 12-59 months coverage	DHB
Sensitivity (exposure-related)			
Geographic location	Low-lying areas, inner-city	The proportion of the population living below the flood line	
Air pollution	Access to electricity – no access can increase air pollution	Total number of the population that does not have access to electricity	Census
Housing quality	Informal structures	Total number of informal residential structures	Census
Earnings and income	Unemployment	The total population that is not working age (below 15 and above 65)	Census
Overcrowding	Household and population density	Total number of people per square metre; the number of people/room	Census
Vector-borne diseases	Malaria		DHB, NICD
Coping capacity			
Education	Education level Literacy rate	Total number of the population without secondary education /who are illiterate (Based on population older than 20)	Census

Vulnerability aspect	Indicator name	Potential Indicators	Source of information
Services	Access to water - hydration	Total number of the population that does not have access to water	Census
Infrastructure	Health infrastructure	Health worker density Hospital beds / 10000 target population	DHB
Information	Access to information/ communication methods	Cell phone access in house	Census
Open spaces	Access to open spaces/vegetation	Vegetation fraction	National Land Cover

3.3.3 Risk and vulnerability assessment

3.3.3.1 Exposure to hot days and extremely hot days

3.3.3.1.1 Hot days

The threshold that was used for "hot days" is shown in Figure 3.3-1.3.2. This threshold is the Minimum Mortality Temperature; above this temperature, the risk of death increases, though slowly at first. Figure 3.3-1 shows the spatial trend that the threshold temperature is the greatest in the north, north-west and north-east. In the current climate, there are ~58 days per year that have maximum temperatures above these MMT.

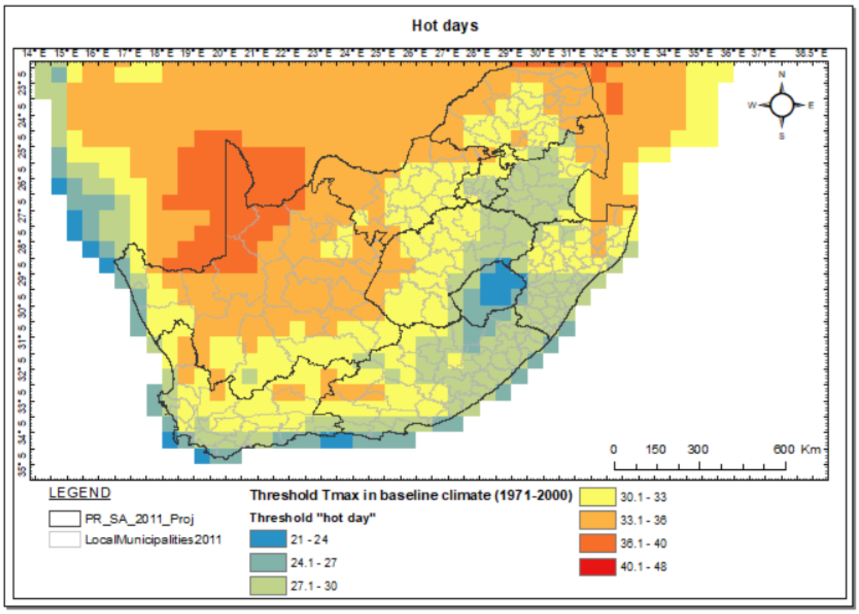


Figure 3.3-1: Value of "hot day" threshold.

Figure 3.3-2 displays the simulated increase in the number of "hot days" in the future climate for the ensemble median. It is noted that nowhere is projected to have a decrease in the number of "hot days" in the ensemble median. The largest increases are seen in the north, north-east and in the north-east interior.

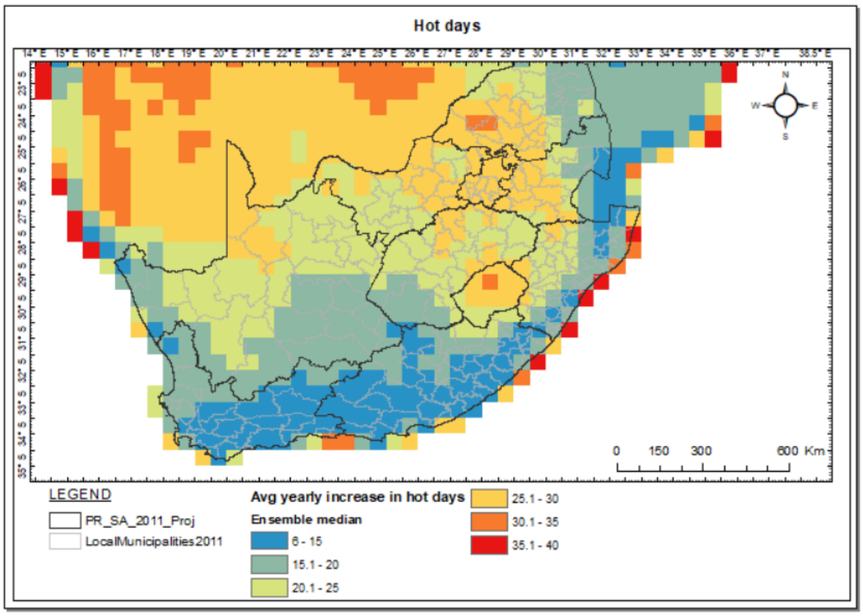


Figure 3.3-2: Simulated increased number of "hot days" in future climate (2011-2040) under RCP8.5 from the baseline climate (1974-2000) of the ensemble median.

3.3.3.1.2 Extremely hot days

The threshold for "extremely hot days" is shown in Figure 3.3-3. This is on the same scale as Figure 3.3-1 and the spatial trends for the higher thresholds in similar. In the current climate, there are ~3-4 days per year that have maximum temperatures above this threshold. With days at this threshold, the risk to mortality was 6% higher (the 95th confidence interval was 3-9% increase) compared to the risk at the MMT (defined here as "hot day" (Scovronick et al., 2018)).

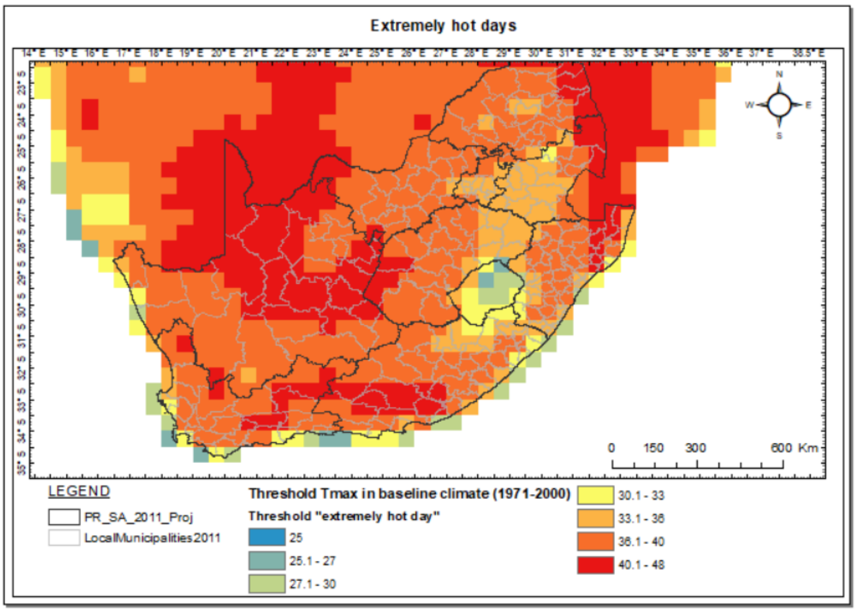


Figure 3.3-3: Value of "extremely hot day" threshold

Figure 3.3-4**Error! Reference source not found.** displays the simulated increase in the number of "extremely hot days" in the future climate compared to the current climate across the ensemble. There are no places where a decrease in days is seen. The largest increases in these "extremely hot days" are seen in the north, north-east and north-east interior of the country. This spatial distribution differs slightly from when a static threshold is used (e.g. 35°C) (CSIR, 2019).

This threshold is based on health impacts and thus this increase in "extremely hot days" does indicate an increase in days where health will be at risk from exposure to high temperatures.

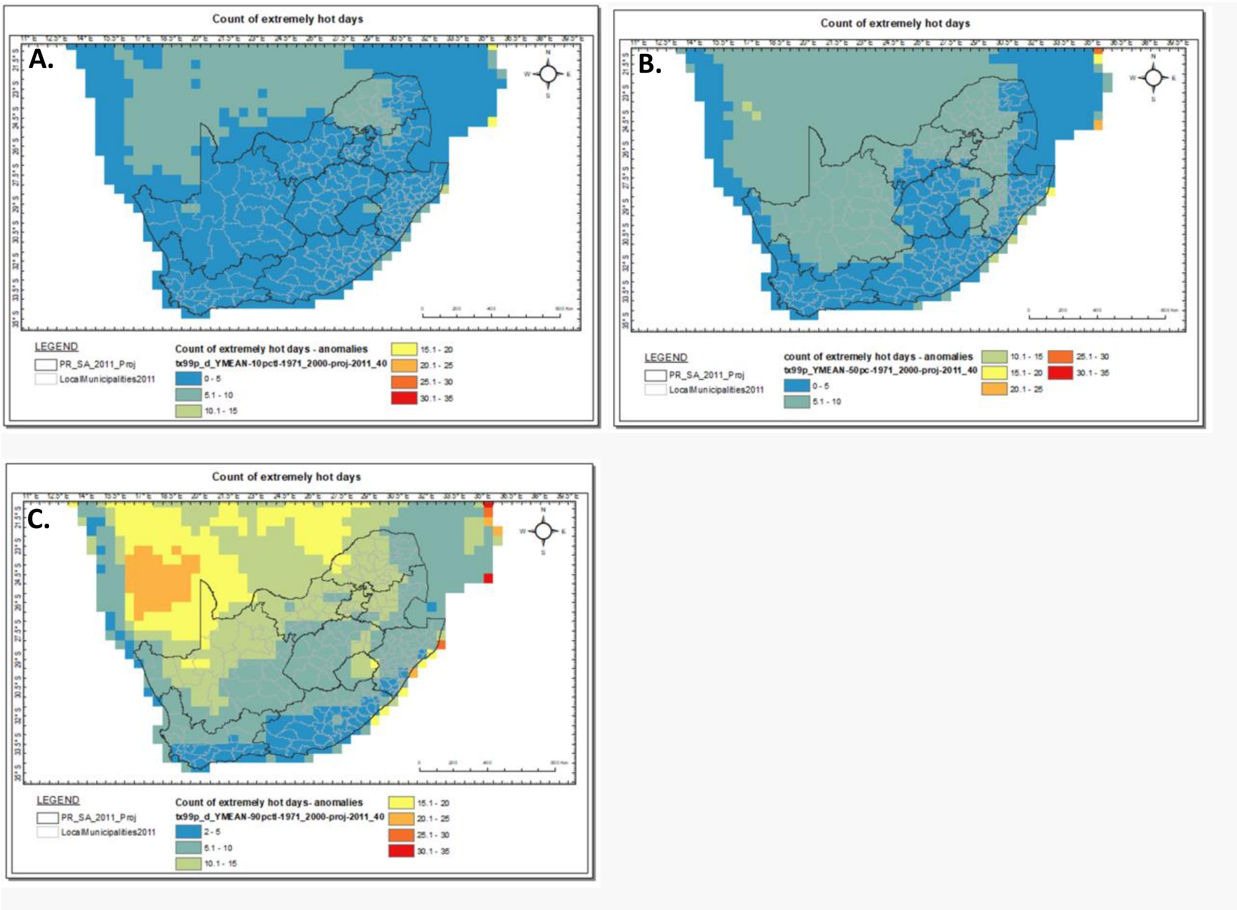


Figure 3.3-4: Simulated increased number of "extremely hot days" in future climate (2011-2040) under RCP8.5 from the baseline climate (1974-2000) of the ensemble a) 10th percentile, b) median and c) 90th percentile.

3.3.3.2 Risk and vulnerability assessment

3.3.3.2.1 Sensitivity: Health status and pre-existing disease

South Africa experiences a quadruple burden of disease with the following health impacts contributing to this:

- HIV and tuberculosis,
- Trauma and violence,
- Non-communicable disease, and
- Maternal and child health (Young et al., 2010).

HIV/AIDS reduces the ability of the human body to recover from shock due to its rapid transmission and effect on the immune system. People living with AIDS are thus more at risk when exposed to climate-related hazards such as rising temperatures (Abayomi and Cowan, 2014).

Risk factors for HIV transmission in southern Africa which may be aggravated by climate change include population displacement, poverty and dislocated communities (Myers et al., 2011; Drimie and Casale, 2009).

Impacts such as displacement and lost livelihood (e.g. long-term drying in rural regions) may aggravate mental health conditions such as anxiety, depression, post-traumatic stress disorder and suicide (Myers et al., 2011). People with pre-existing mental health conditions may also be more vulnerable to changes in climate. A relationship between changing temperatures and increasing aggression has been shown which may indicate that, if temperatures deviate significantly from local averages, this may be associated with increased mental health problems (Berry et al., 2010).

Lifestyle issues such as obesity represent the other end of the spectrum related to nutrition. The ranked distribution of overweight or obese adults during 2019 are indicated in Figure 3.3-5 (HST, 2018/19). Districts that are the worst-off are shown in red.

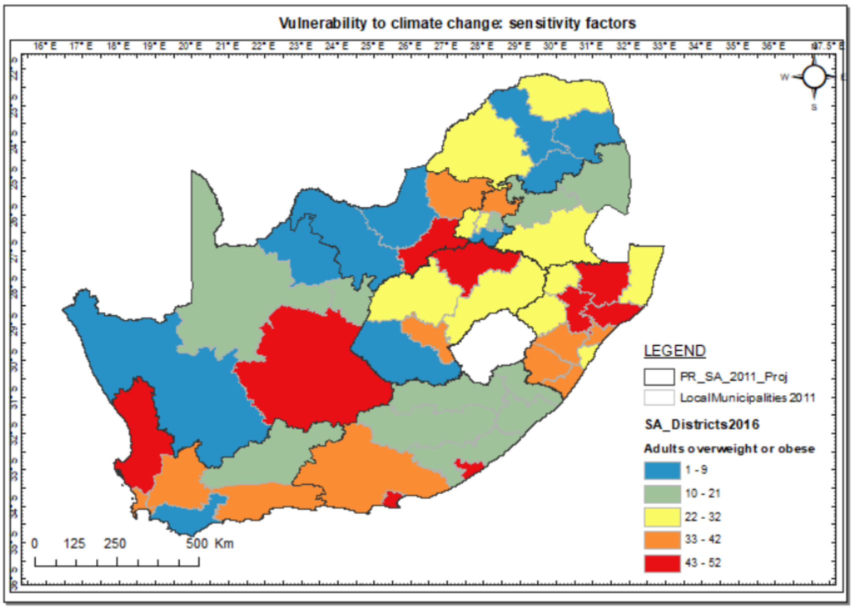


Figure 3.3-5: Ranked distribution of overweight or obese adults for 2019 (HST, 2018/19)

3.3.3.2.2 Sensitivity: Nutrition-related factors

High temperature and changes in rainfall caused by climate change will negatively impact on food production (Mugambiwa and Tirivangasi, 2017; Stanke et al., 2013; Dinkelman, 2013). Food security is of great concern, especially for poor households and those in rural areas that rely heavily on agriculture for survival. (Mugambiwa and Tirivangasi, 2017).

The prevalence of undernourishment in South Africa between 2006 and 2017 (Table 3.3-2) has been showing an increase. The ranked severe acute malnutrition case fatality rates under 5-years for 2019 are indicated in Figure 3.3-6 (HST, 2018/19). Worst-performing districts are indicated in red.

Table 3.3-2: South African prevalence of undernourishment

YEAR	PREVALENCE (%)	CHANGE, %
2017	6.2	1.64%
2016	6.1	7.02%
2015	5.7	9.62%
2014	5.2	8.33%
2013	4.8	6.67%
2012	4.5	2.27%
2011	4.4	0.00%
2010	4.4	-2.22%
2009	4.5	-2.17%
2008	4.6	0.00%
2007	4.6	2.22%
2006	4.5	

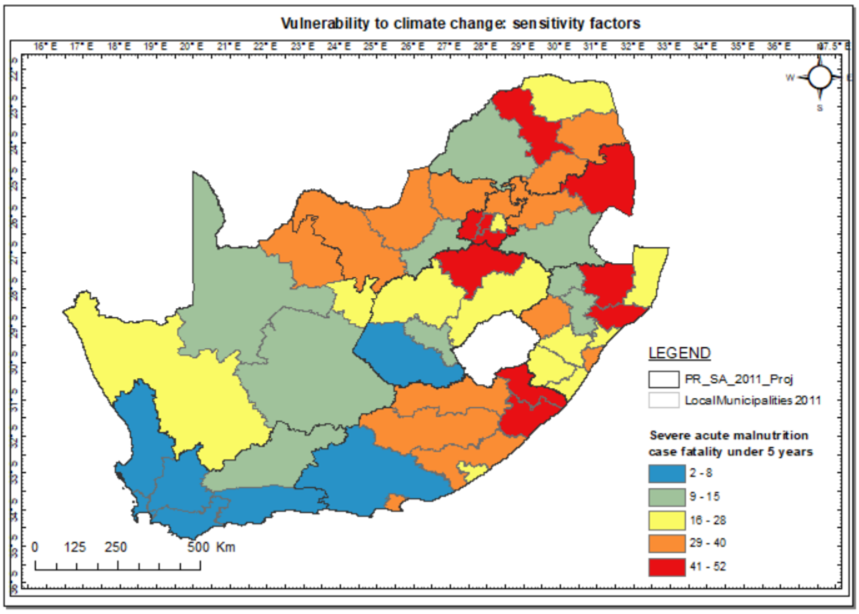


Figure 3.3-6: Ranked distribution of severe acute malnutrition case fatality under 5-years for 2019 (HST, 2018/19).

3.3.3.2.3 Climate hazard-related health impacts

3.3.3.2.3.1 Food and water-borne diseases

Boeckmann et al. (2019) described an association between hot days and food-borne diseases (FBD) due to more people being outdoors, eating raw or cold food (Boeckmann et al., 2019). Power outages, especially on hot days, can also result in increased food spoilage. Salmonella, Cholera and Escherichia coli multiply more easily in higher temperatures (Boeckmann *et al.*, 2019). A 40% increase in diarrhoea in children (< 5 years old) have also been found during the hot, dry months of the year, one week after a 5 °C peak in temperature (Musengimana et al., 2016). Children under 5 years with diarrhoea are also more sensitive to dehydration in the presence of heat.

High sea surface temperatures can increase the risk of heavy rainfall which may cause flooding, Should water and sanitation services be disrupted subsequently, this will increase the risk of cholera outbreaks (Boeckmann et al., 2019).

3.3.3.2.3.2 Vector-borne diseases such as malaria

Malaria morbidity and mortality dropped significantly between 2000 and 2010, after which it has been fluctuating between different areas (Fig 3.3.7) (MRC, 2019). A malaria endemic district such as KwaZulu-Natal province has made steady progress towards elimination, whereas Limpopo province has shown an overall upward trend. Between 2014 and 2016, malaria cases decreased from approximately 14,000 to 5,800. However, an epidemic in 2017 in Limpopo and Mpumalanga provinces, saw an increased to 30,000 cases.

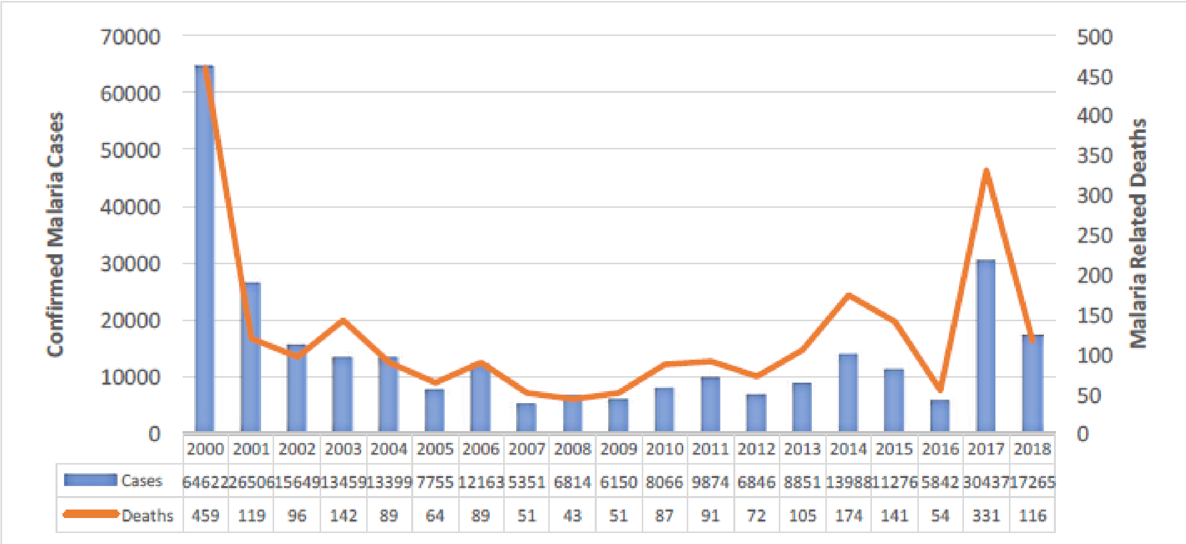


Figure 3.3-7: Total malaria cases and deaths from 2000 to 2018 in South Africa, by calendar year (NDoH, 2018).

Local transmission is prevalent in approximately 40 sub-districts in South Africa with imported malaria cases currently constituting 63% of the total cases reported in the country. Some provinces such as KwaZulu-Natal have reported importation rates of more than 80% (MRC, 2019).

Notified cases of malaria for South Africa between 2007 and 2018 are shown in Table 3.3-3

Table 3.3-3. Notified cases of malaria for South Africa between 2007 and 2018 (WDI, 2020)

YEAR	VALUE	CHANGE, %
2018	1.7	-58.21%
2017	3.9	413.54%
2016	0.8	268.18%
2015	0.2	-90.27%
2014	2.1	33.27%
2013	1.6	28.49%
2012	1.3	-33.94%
2011	1.9	20.55%
2010	1.6	30.82%

YEAR	VALUE	CHANGE, %
2009	1.2	-23.19%
2008	1.6	21.58%
2007	1.3	

3.3.3.2.3.3 Ability to cope: Health workforce

The ability to cope with the health impacts associated with heat depends on a number of factors. Some of these factors have been listed in Table 3.3-4.

The ranked distribution of the health worker density and hospital beds/10000 target population for 2019 are shown in Figure 3.3-8 and Figure 3.3-9 respectively. Districts with the worst performance are indicated in red.

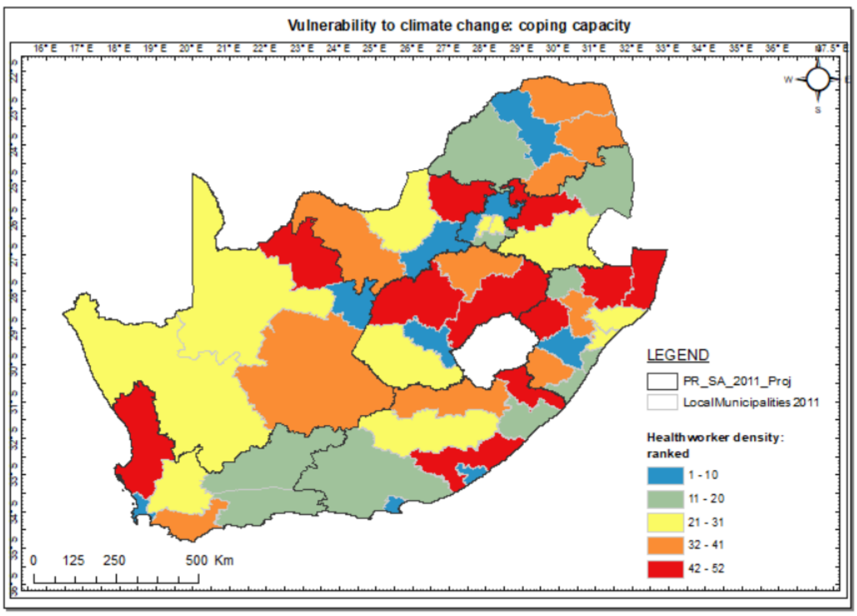


Figure 3.3-8: Ranked distribution of health worker density for 2019 (HST, 2018/19)

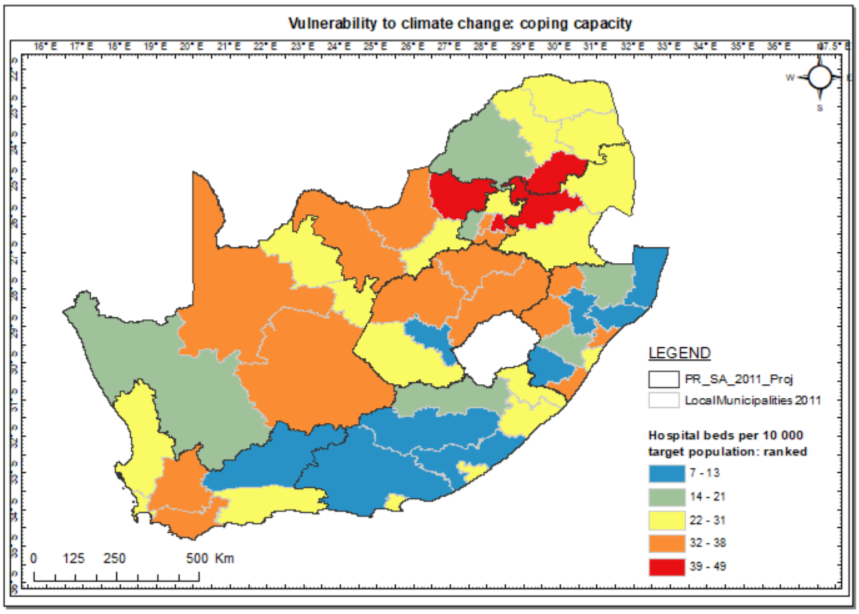


Figure 3.3-9: Ranked distribution of hospital beds/10000 target population for 2019 (HST, 2018/19)

3.3.3.2.3.4 Ability to cope: access to clean drinking water

Easy access to clean water is also a crucial service, especially in the event of hot days and heatwaves. The districts that performed the worst in terms of having piped water inside houses are indicated in Figure 3.3-10.

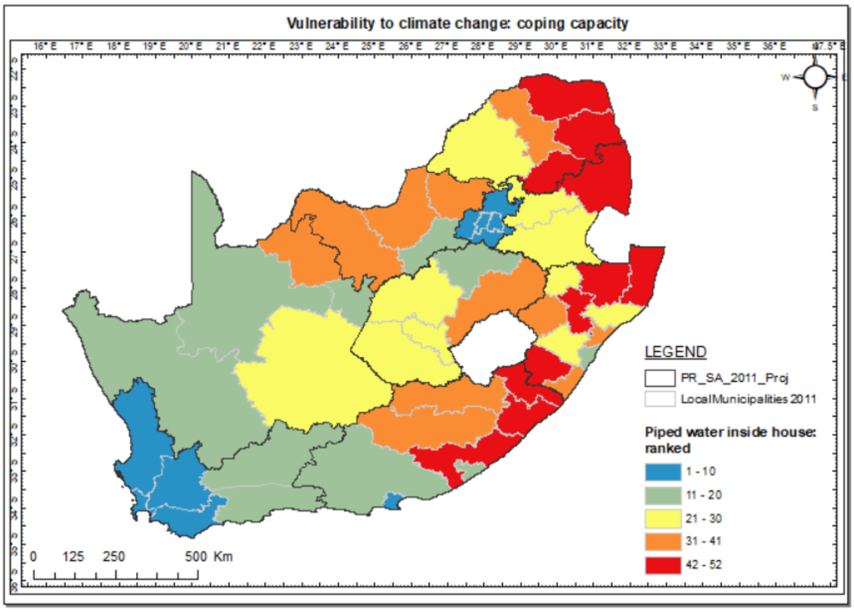


Figure 3.3-10: Ranked distribution of districts with piped water inside the house for 2019 (HST, 2018/19).

Vulnerability factors related to heat exposure have been summarised by province (HST, 2018/19). The dark green cells indicate the lowest vulnerability and the dark red, the province that has the highest vulnerability relative to the other provinces.

Table 3.3-4. Vulnerability factors that may modify the risk of health effects due to heat exposure, by province (HST, 2018/19)

Vulnerability aspect	Indicator	Gender	Data sources	Year(s)	ZA	EC	FS	GP	KZN	LP	MP	NC	NW	WC
Health workers and facilities, clinic - coping	Number of health facilities		DHIS	2019	3140.0	728.0	212.0	328.0	597.0	454.0	238.0	127.0	264.0	192.0
Health workers and facilities, district hospital - coping	Hospital beds /10 000 target population,	both sexes	DHIS	2019	6.1	9.2	6.7	2.4	7.9	7.6	6.7	5.8	4.0	5.6
Health workers and facilities, public sector – coping	Hospital beds/ 10 000 target population	both sexes	DHIS	2019	17.9	20.6	19.8	17.1	20.9	14.2	12.4	17.7	13.8	20.0
Health workers and facilities, district hospital - coping	Inpatient bed utilisation rate		DHIS	2018/19	65.2	54.9	60.3	68.1	59.5	73.1	69.9	54.2	60.3	91.4
Health workers and facilities, public sector – coping	Medical practitioners/ 100 000 population	both sexes	DHIS	2019	32.0	30.8	27.7	33.7	35.8	24.5	26.1	42.2	26.0	38.9
Health workers and facilities - coping ability	Number of Community Health Workers (CHWs)		CHW Register	2018	54180	4438.0	2009.0	8589.0	9780.0	10570.0	6640.0	2553.0	6059.0	3542.0
Health workers and facilities, public sector – coping	Health worker density (index)	both sexes	CHW Register	2019	15.3	16.6	13.2	15.0	15.1	14.3	12.6	19.2	12.7	17.2
Health workers and	The proportion of health facilities with essential		DHIS	2018/19	62.6	73.7	1.0	81.8	79.7	34.5	55.0	70.3	55.0	90.3

Vulnerability aspect	Indicator	Gender	Data sources	Year(s)	ZA	EC	FS	GP	KZN	LP	MP	NC	NW	WC
facilities - coping	medicines													
Health workers and facilities - coping	Inpatient bed utilisation rate – total		DHIS	2018/19	72.5	64.8	73.9	80.7	65.4	74.9	64.5	60.4	72.1	86.6
Services – coping	Environmental health services compliance rate		NDoH	2018/19	62.3	66.9	59.4	68.8	56.4	64.2	58.0	75.2	40.5	68.3
Demographics – sensitivity	Formal dwellings		StatsSA CS	2016	79.2	65.1	83.6	81.4	72.7	88.9	84.7	83.5	78.3	82.4
Demographics – sensitivity	% of female-headed households		StatsSA CS	2016	41.3	49.1	41.7	35.9	47.4	48.8	39.7	38.9	35.2	38.0
Demographics – sensitivity	% of households using electricity for lighting		StatsSA CS	2016	90.3	85.4	93.8	89.7	88.5	93.0	90.3	88.8	89.0	96.6
Demographics – sensitivity	% of households with piped water inside dwellings		StatsSA CS	2016	44.4	33.4	37.8	60.0	37.4	13.1	29.0	43.7	24.0	76.9
Demographics - coping	% of population 20 years and older with no schooling	both sexes 20+ years	StatsSA CS	2016	7.1	8.1	5.9	3.9	8.6	13.9	11.3	7.9	8.7	2.4
Demographics - coping	Unemployment rate		Census	2011	29.8	37.4	43.0	26.3	33.0	38.9	31.6	31.5	27.4	21.6
Burden of disease - YLL	% of YLLs due to communicable, maternal, perinatal, nutrition causes	both sexes	Vital registration	2014	21.2	15.8	23.6	22.3	19.9	30.4	24.1	19.2	26.1	10.7
Burden of disease - YLL	% of YLLs due to HIV and	both sexes	Vital	2014	27.0	31.2	27.1	22.7	32.3	25.1	32.1	28.4	28.2	19.6

Vulnerability aspect	Indicator	Gender	Data sources	Year(s)	ZA	EC	FS	GP	KZN	LP	MP	NC	NW	WC
	TB		registration											
Burden of disease - YLL	% of YLLs due to non-communicable diseases	both sexes	Vital registration	2014	38.2	38.5	37.2	42.0	34.7	34.0	31.0	38.3	35.5	50.7
Health financing	Expenditure per patient day equivalent (district hospitals)		BAS real 2018/19 prices	2018/19	2959.0	3055.7	2666.3	3465.4	2991.8	3186.5	2657.5	2863.8	3315.4	2502.0
Health financing	+-+ & LG District Health Services expenditure per capita (uninsured)		BAS real 2018/19 prices	2018/19	1942.4	1972.4	1760.3	1620.4	2077.8	2343.9	2077.7	2155.1	1728.6	1956.6
Health financing	Provincial & LG PHC expenditure per capita (uninsured)		BAS real 2018/19 prices	2018/19	1206.1	1032.5	1130.6	1269.0	1367.3	1065.3	1124.8	1383.4	1189.6	1204.5
Health financing	Provincial & LG PHC expenditure per PHC headcount		BAS real 2018/19 prices	2018/19	494.6	406.3	536.2	639.4	486.2	412.1	474.3	523.6	551.6	445.2
Nutrition - sensitivity	% of adults overweight or obese	both sexes 15+ years	NiDS age-standardised	2017	48.2	48.1	50.6	47.8	50.6	44.7	44.6	45.6	47.2	51.4
Nutrition - sensitivity	Vitamin A dose 12-59 months coverage	both sexes	DHIS	2018/19	56.6	55.4	51.3	55.1	71.0	42.2	66.0	48.5	42.5	52.2
Health outcome – sensitivity	Diabetes prevalence	both sexes 15+ years	NiDS modelled	2017	10.6	12.2	11.2	8.3	12.8	8.3	6.9	10.4	7.0	17.8

Vulnerability aspect	Indicator	Gender	Data sources	Year(s)	ZA	EC	FS	GP	KZN	LP	MP	NC	NW	WC
Health outcome - coping	Diabetes treatment coverage	both sexes 15+ years	NiDS modelled	2017	35.8	34.6	31.7	37.0	33.1	33.0	39.7	46.1	43.4	29.6
Sensitivity	Immunisation under 1-year coverage	both sexes	DHIS	2018/19	81.9	71.9	74.8	84.4	90.8	71.0	96.8	87.5	68.4	82.7
Health impacts – sensitivity	HIV test positive 19 months to 14 years rate	both sexes 19 months - 14 years	DHIS	2018/19	1.6	1.2	4.2	2.7	1.1	1.6	3.5	1.3	2.3	0.7
Health impacts – sensitivity	HIV test positive client 15 years and older rate (incl ANC)	both sexes	DHIS	2018/19	6.1	5.3	9.7	8.1	6.8	3.7	7.4	4.3	5.9	2.9
Mental health - coping	Mental disorders treatment rate new		DHIS	2018/19	0.4	0.2	1.2	0.4	0.0	1.1	0.5	0.4	0.2	0.0
Mental health - sensitivity	Mental health separation rate		DHIS	2018/19	2.5	2.3	8.8	1.1	2.1	2.0	1.3	1.9	1.5	3.3
Lifestyle - sensitivity	Tobacco non-smoking prevalence	both sexes 15+ years	NiDS	2017	80.7	83.4	80.3	78.6	87.2	87.9	82.0	66.8	80.2	69.4

Key highlights of linkages between climate hazards and health are shown in Table 3.3-5.

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Table 3.3-5: Linkages of climate hazards and health

	Environmental health risk	Climate Change Hazard: Climate signal → physical impact	Example of impacts	Overview of people and areas at risk	Possible Adaptation Measures
Climate-sensitive events					
	Heat stress	Increase in temperature → heat waves	Increased temperature can have a direct impact on public and occupational health	Elderly, Small children People with nutritional deficiency Pre-existing health conditions, including mental and physical health Sportspeople Outdoor workers People who are displaced, homeless Inmates in prisons Municipalities with poor service delivery (water, electricity, health) Informal settlements Inner-city, high-rise buildings Overcrowded areas Areas with sparse vegetation	Early warning systems Information portal for information about climate change, its health implications and appropriate actions Strengthen provincial epidemic preparedness and response teams. Educational material on climate-related diseases increases community awareness. (community health care workers)
	Respiratory diseases	Changes in climate (i.e. temperature, precipitation) → Air pollution → Fungi, pollen	Ambient air pollution levels are climate-sensitive; changes in climate factors (e.g. temperature, relative humidity, rainfall) can impact on pollutant emissions, transport and deposition.	People with compromised immune systems, pre-existing diseases, elderly children, People living in informal structures, industrial areas	Air Quality Index Early warning systems Educational material and community awareness (community health care workers) Improve air quality Air quality management plans include climate change considerations
	Health impacts due to natural disasters,	Increase in extreme rainfall → Flooding Increase in extreme temperature →Fires Decrease in rainfall→drought	Natural disasters (e.g. floods, drought, fires) can have immediate and long-term impacts on health and well-being, e.g. food security, injuries and death, respiratory impacts,	Displaced people, people in informal structures Elderly and children Small municipalities responsible for their own infrastructure are likely to be more vulnerable.	Flood early warning systems Fire early warning system Education and community awareness (community health care workers)
	Vector-and rodent-	Increase in extreme rainfall →	Changes in rainfall and temperature may	Areas with inadequate waste removal	Improve service delivery

	Environmental health risk	Climate Change Hazard: Climate signal → physical impact	Example of impacts	Overview of people and areas at risk	Possible Adaptation Measures
	borne diseases	Flooding Decrease in rainfall → drought Changing temperatures	impact the geographical range of vectors	Low-lying areas Areas on fringes of where vector-borne diseases are currently present	Education and community awareness (community health care workers) Strengthen programmes and activities related to improved industrial and household waste management
	Water-borne diseases	Increase in extreme rainfall →flooding Decrease in rainfall → drought Extreme events	Some communicable diseases (e.g. cholera) are climate sensitive and can cause displacement of people with associated health impacts	Areas with inadequate water services Areas with inconsistent supply of potable water	Improve service delivery Education and community awareness (community health care workers)
	Food insecurity, hunger and malnutrition	Decrease in rainfall → drought, fires Increase in extreme rainfall →flooding	Agricultural and fisheries sectors are climate-sensitive, which can have an impact on malnutrition.	Subsistence farmers Subsistence fishermen Rural, farming areas	Flood early warning systems Fire early warning system Education and community awareness (community health care workers) Diversification
Modifying factors and potentially climate sensitive					
	Pre-existing, non-communicable diseases	Extreme temperatures → heat waves	Pre-existing cardiovascular diseases have been found to make people more vulnerable to heat stress	People with compromised immunity, pre-existing diseases Elderly Informal structures	Health screening, education and community awareness (community health care workers)s
	Mental illness and physical disability	Extreme temperatures →heat waves Extreme rainfall → flooding	Adverse situations, such as natural disasters create a conducive environment for the occurrence of mental health problems	People with mental health conditions or physical disabilities, especially the elderly, those who live alone, in informal settings	Health screening, education and community awareness (community health care workers)
Modifying factors, i.e. factors that may affect the health outcomes directly related to climate variability					
	Housing and settlement conditions (Housing, infrastructure and service delivery)	Extreme temperatures →heat waves Extreme rainfall → flooding	Improve service delivery Can be a modifying factor for many health risks, e.g. clean water supply can mitigate water-borne diseases, improved thermal comfort in houses can mitigate heat stress	People in informal settings, especially with poor service delivery Low-lying areas	Improve service delivery
	Pre-existing communicable diseases	Changes in temperatures → heat waves, air pollution	Can be pre-existing conditions e.g. HIV/AIDS that may make people more vulnerable to climate-sensitive diseases	People with compromised immunity, pre-existing communicable diseases Elderly	Health screening Education and community awareness (community health care workers)

	Environmental health risk	Climate Change Hazard: Climate signal → physical impact	Example of impacts	Overview of people and areas at risk	Possible Adaptation Measures
			such as heat stress	People in informal settings	

3.4 Human settlements

3.4.1 Risk and vulnerability profile

In order to create and strive for the development of climate-resilient human settlements, we need to plan for and adapt South African settlements to be more resilient to the anticipated effects of climate change and climate variability. This calls for a thorough understanding of climate risk and the various components that contribute to this risk within settlements. This chapter unpacks the components of climate risk and vulnerabilities and maps the location of those settlements expected to be affected within the next three decades. The results contained in this chapter are a extraction and synthesis of the research findings presented in the Green Book (CSIR, 2019).

Weather-related (hydrological, climatological and meteorological) hazards are a sub-set of natural hazards and are globally responsible for 80% of all recorded natural hazards (EM-DAT, 2020). These hazards cause widespread devastation, triggers hardship for the most vulnerable in our societies and can be felt across all sectors and aspects of human settlements.

South African settlements tend to be particularly vulnerable to the effects of climate variability and since 1980 have recorded 86 noticeable weather-related disasters that have affected more than 22 million South Africans and have cost the economy in excess of R113 billion (US$6.81 billion) in economic losses. Flooding and storms are the most frequent of these disasters (Figure 3.4-1), contributing up to 88% of lives lost and tend to be particularly damaging to settlement infrastructure, accounting for almost 30% of the losses recorded in the past four decades. Droughts are responsible for affecting the largest number of people (94%) and are the costliest (contributing 38% to economic losses recorded) (EM-DAT, 2020).

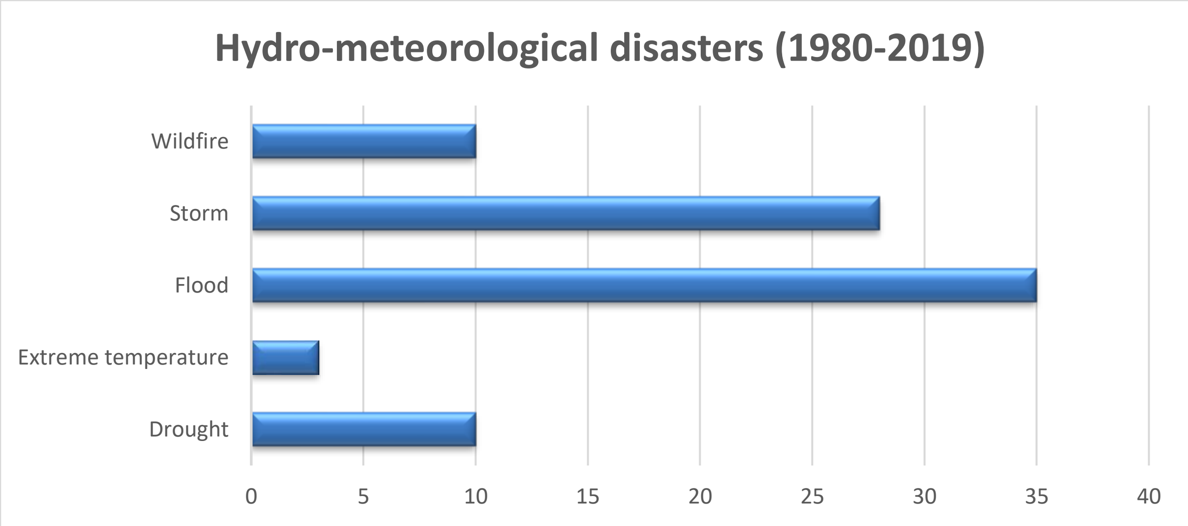


Figure 3.4-1: South Africa's recorded hydro-meteorological hazards (extracted from EM-DAT, 2020)

Recent events such as the nationwide droughts in 2015/16, the Western Cape drought in 2017/18, the Knysna Fires of 2017 and the KwaZulu Natal, Eastern Cape and Free State floods of 2019 had devastating economic and social consequences and showed just how susceptible and vulnerable our cities and towns are to these hazards.

It is estimated that, in the coming decades, a growing number of cities and towns will be exposed to the impacts of weather-induced hazards such as flooding, heatwaves, droughts, wildfires and storms. This growing exposure can be attributed in part to the high socioeconomic vulnerability already present within settlements, land-use practices associated with accommodating a growing urbanising population and changes projected in the frequency and intensity of weather-related natural hazards (Engelbrecht et al., 2015a; Le Roux et al., 2017).

Since the socio-economic landscape and the risks that settlements are faced with are geographically unique, it is imperative that our response and offerings are unique. There is a thus a great need for investment in adaptation in South African settlements that is not just the responsibility of one sector or department but that of multiple actors and role players from all spheres and domains, spanning across municipal planning functions. In the pursuit of building climate resilient settlements, South African cities need transformative and holistic adaptation approaches that are customised for their individual hazards (geographically unique) and embedded in effective planning and policy interventions (Pieterse et al., 2019).

3.4.2 Risk and vulnerability assessment

3.4.2.1 The framework for defining the risk and vulnerability of human settlements

Targeting high-risk settlements with appropriate adaptation actions, policies and plans require an unpacking of the factors contributing to the risk posed to human settlements. The risk assessment of human settlements is therefore grounded in the conceptual framework and definitions as presented in the Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change, Working Group 2 (IPCC, 2014). This framework and approach place the concept of risk at its centre Figure 3.4-2 and is an attempt to streamline the definitions of disaster risk from a climate change adaptation and disaster risk reduction perspective. High-risk settlements are therefore a function of understanding the exposure of settlements (geographic locations) to current and projected natural hazards and the vulnerabilities present within these exposed settlements.

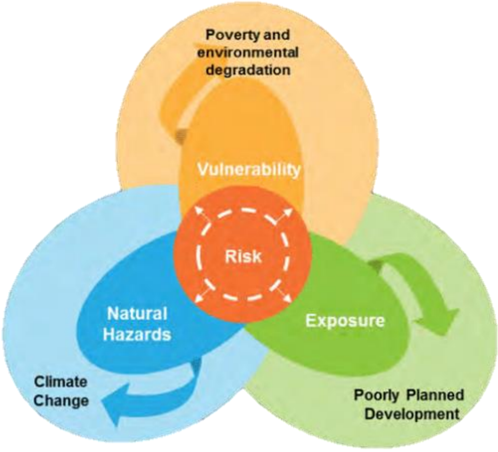


Figure 3.4-2: Green Book research design and terminologies (adapted from World Bank, 2013 and IPCC, 2014).

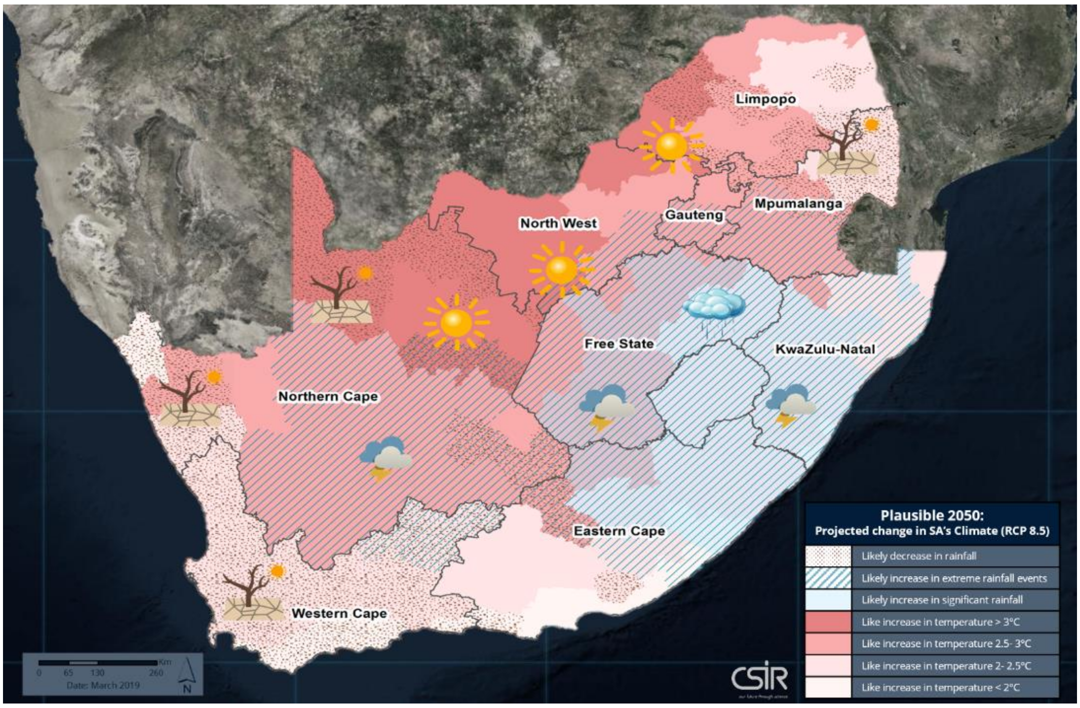
The following section will unpack the risk components through: 1) providing an interpretation of the key climate change findings emanating from an RCP8.5 scenario; 2) mapping settlements impacted by these plausible climate changes and natural hazards as they relate to a) heat-stress, b) wildfires, c) drought and d) flooding; 3) highlighting the vulnerability of settlements across South Africa and their projected growth pressures; and 4) mapping South Africa's high-risk settlements taking into account a changing climate and growing urbanising population.

Plausible climate shifts by 2050: RCP8.5 scenario considered for risk assessment

2050 Projected climate changes under the RCP 8.5 scenario

Background

The risk assessment utilises the Green Book’s climate projections and focusses on the findings of the representative concentration pathway (RCP) 8.5 scenario, a scenario of low mitigation in terms of combating greenhouse gas emissions, low economic growth and high population growth.



Source: Lotter et al., 2019.

Summarised findings

Under a low-mitigation scenario (RCP 8.5) it is plausible that South Africa will experience several noticeable climatic shifts for the period 2021 to 2050 (relative to the period 1961-1990), these include (Engelbrecht, 2019);

- Temperature increases to rise at about twice the rate of global temperature increases.
- Noticeable temperature increases across South Africa ranging from 1 to 2.5°C over the southern coastal regions, 2-3°C in the interior regions and increases in excess of 3°C over the northern parts of the country.
- Increases in the frequency of occurrences of very hot days and heatwave days with as many

as 40-60 more days per year in the Limpopo River Valley and 70 days more per year for the northern parts of the Northern Cape and North West, including the Orange River Valley. More modest increases are projected for the southern interior regions.

- Increased rainfall over the central interior and east coast and a minority of ensemble members projecting a general increase in rainfall over eastern South Africa.
- Increase in extreme rainfall events over most of the central interior and east coast, with a minority of ensemble members projecting an extreme rainfall increases over most of eastern South Africa.
- Decreased rainfall over the western interior and south-western regions of the Cape as well as decreased rainfall in the north-eastern regions of the Cape.
- These climate changes might plausibly increase extreme weather events particularly flooding, drought, wildfires and storms.

Key message for consideration

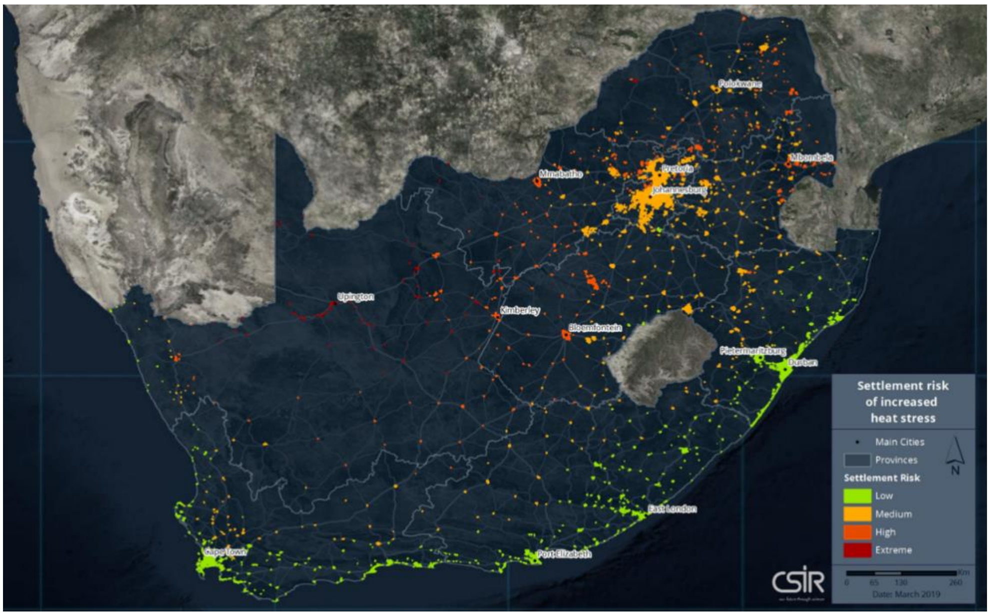
The projected temperature increases in the RCP8.5 scenario will have significant impacts on human settlements and their various contributing economic sectors. The first order findings of the Green Book suggest that the direct losses emanating from temperature increases to the national GDP could be approximately R38 billion by 2050 (Ngepah and Djemo, 2019).

HAZARDS: Settlements projected to be exposed to increases in weather-related hazards

Heat stress: Settlements projected to experience an increase very hot days combined with heatwave days

Background

The RCP8.5 scenario presented above signals that significant temperature increases are projected for southern Africa. A heat-stress matrix was created to determine which of South Africa's settlements might be most at risk. This is based on a projected increase in very hot days, in combination with an increase in heat-wave days. The heat-absorbing qualities of the built-up urban areas in our settlements will exacerbate these temperatures and will undoubtedly impact on human and animal health and comfort levels (Engelbrecht et al., 2019). Heat stress and loss of lives have received lots of attention after the devastating heatwaves in Europe in 2003 and India in 2019 and although few deaths have been recorded in South Africa it should be noted that this is an emerging hazard for our cities and poses a significant risk to our infrastructure and people living in these spaces.



Settlements exposed to increases in heat-stress (Engelbrecht.et al., 2019)

Summarised findings

The map depicts the settlements that will likely experience increased heat stress. It is projected that almost 70% of all settlements in South Africa (depicted as red, orange and yellow) will be subjected to increased heat stress by 2050. The temperature moderating effect of the ocean will protect our coastal settlements from heat stress and make this less of a concern for the other 30% of South Africa's cities. The settlements in the Northern Cape province will face the greatest risk as a result of significant increases in heatwaves and very hot days. The majority of settlements in the North West and Limpopo provinces are at high risk of increased heat stress, while settlements in Gauteng, Mpumalanga and Free-Sate will have a moderate risk of increasing heat stress (Engelbrecht et al., 2019). This highlights the urgent need for adaptation interventions in these settlements.

Key messages for consideration

Some of the expected impacts that settlements will face emanating as a result of heat stress include (Van Niekerk & Le Roux, 2017; Engelbrecht et al., 2019):

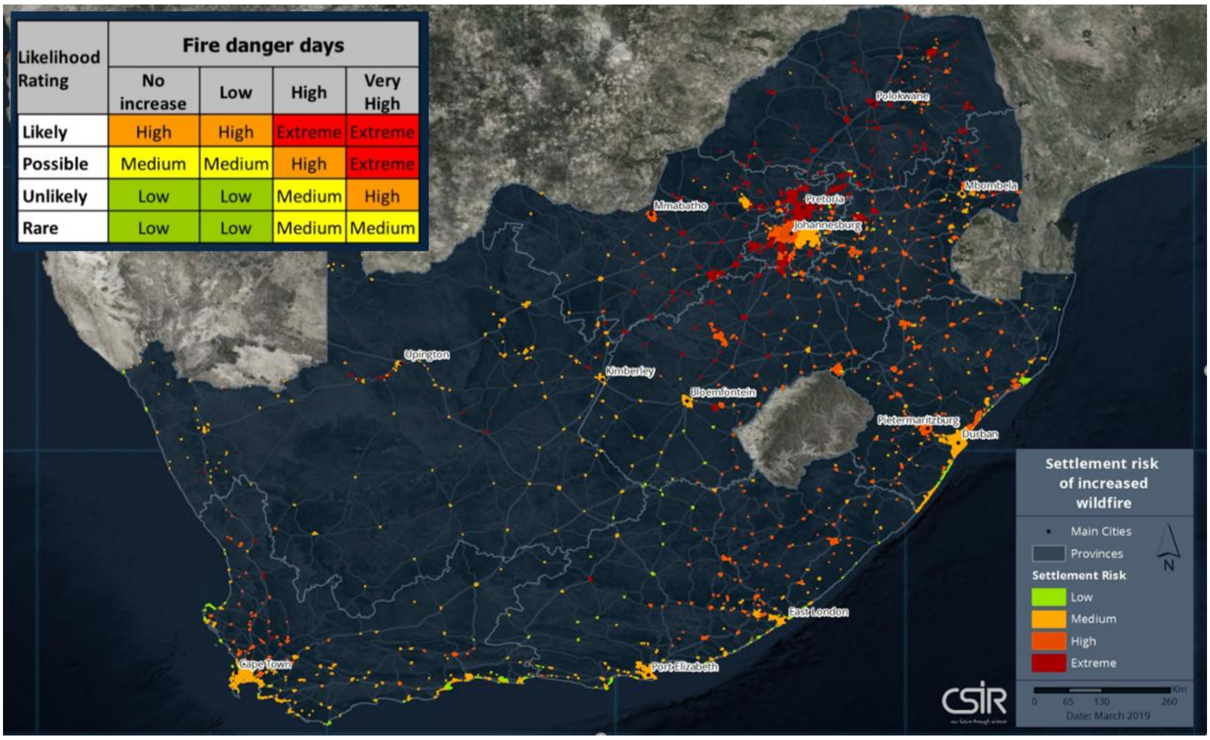
- Intensified heat island effect
- Increase in energy consumption due to the increased need for cooling
- Increased exposure to UVR

- Increase in vector-borne diseases
- The threat of heat strokes for occupants in informal settlements and poorly isolated buildings
- Increase in emergency department visits and responses
- Excessive mortalities and hospital admissions, especially for the elderly, chronically sick, very young and poor.
- The decline in air quality
- Declining water quality, water stress and pressure on supply systems

Wildfires: Settlements projected to experience an increase in wildfire events

Background

Wildfires are a regular occurrence in South Africa and essential in the maintenance of fire-prone ecosystems. However, wildfires can cause significant damage to settlements, properties and livelihoods (Forsyth, et al., 2019). Under an RCP 8.5 scenario, the likelihood of wildfires will increase significantly exposing more settlements to the devastating impacts of this hazard. The Knysna Fires in 2017 is a recent example of such devastating fires resulting in direct losses and damages in excess of R5 billion (EM-DAT, 2020).



Settlements exposed to increases in wildfires (Forsyth et al., 2019)

Summarised findings

Determining the impact climate change will have on the exposure of settlements to wildfires used a risk matrix in which the likelihood of wildfires was combined with the increase in high fire dangers days projected for the near? future (2050). The findings suggest that:

- Many settlements in South Africa are already exposed to high fire risks and experience considerable losses every year.
- 95% of South Africa's settlements will be subjected to some degree of exposure to wildfires in the next three decades.
- 60% of SA's settlements will be under a high and extremely high risk of exposures to wildfires.
- The risk of wildfires increases significantly by 2050 as climate shifts are likely to bring longer, warmer and, dryer periods that increase fire hazards.
- Urban encroachment into the wildland-urban interface also contributes to increased risk of loss of economic activity and livelihoods (Forsyth et al., 2019).

Key message for consideration

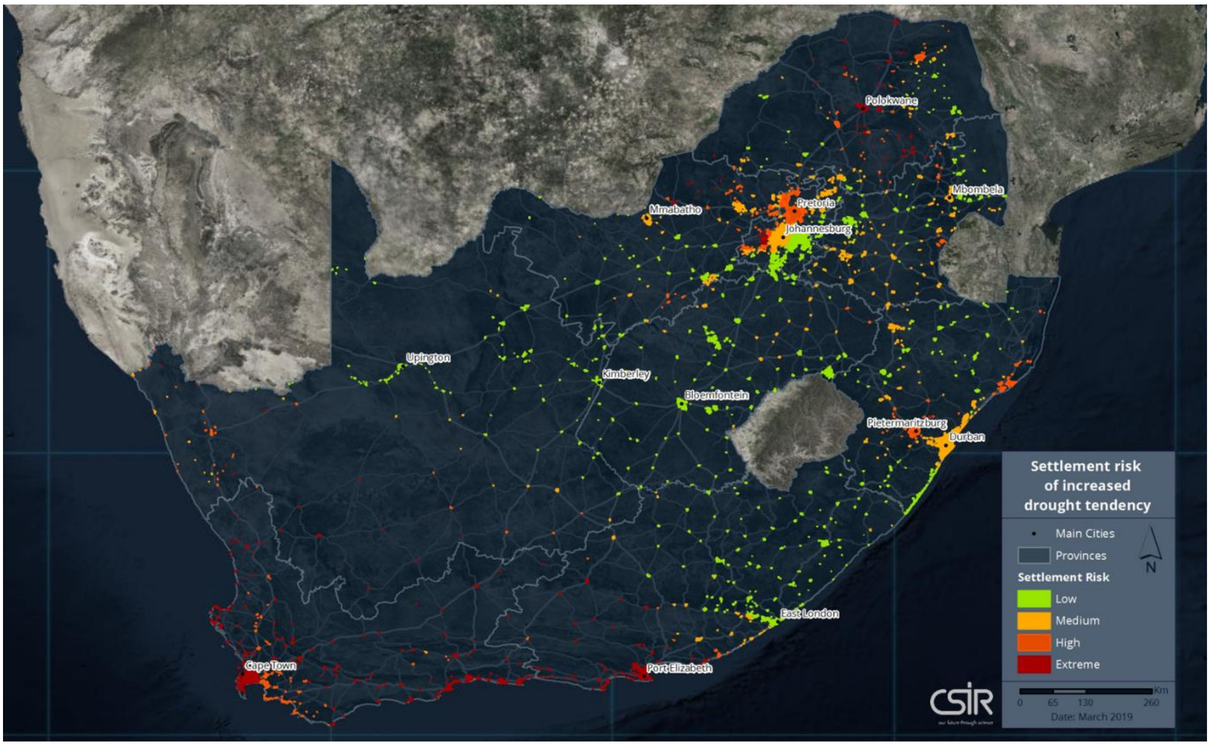
Wildfires are part of the South African landscape and it is very likely to continue and increase in the future. The majority of South African settlements are located in fire ecology types that naturally require fires and that burn regularly. Active fire adaptation measures in human settlements on the wildland-urban interface is therefore urgently required for the majority of settlements across South Africa (Forsyth et al., 2019).

Drought: Settlements projected to experience an increase in drought tendencies

Background

Droughts are particularly devastating slow-onset disasters causing widespread economic devastation with severe social consequences. These hazards also have the potential to impede economic growth and disrupt critical resource distribution. South African cities and towns are extremely susceptible and vulnerable to these hazards. It is estimated that the 2015/16 droughts cost the economy close to R3.5

billion and the 2017/18 droughts cost a staggering R17 billion in economic losses (EM-DAT, 2020).



Settlements exposed to increases in drought tendencies (Beraki et al., 2019)

Summarised findings

Sixty per cent of all settlements in South Africa will be subjected to some degree of exposure to increases in drought tendencies while 36% of SA's settlements will be under a high and extremely high risk of experiencing increased drought tendencies. Many of the high-risk settlements are located in the Western Cape, south western areas of the Eastern Cape, southern areas of the Northern Cape and northern areas of South Africa. Settlements in the Western Cape are likely to be severely affected, forcing these settlements to adapt to water sensitive urban practices.

Key messages for consideration

Some of the expected impacts settlements will face as a result of an increase in drought tendencies include:

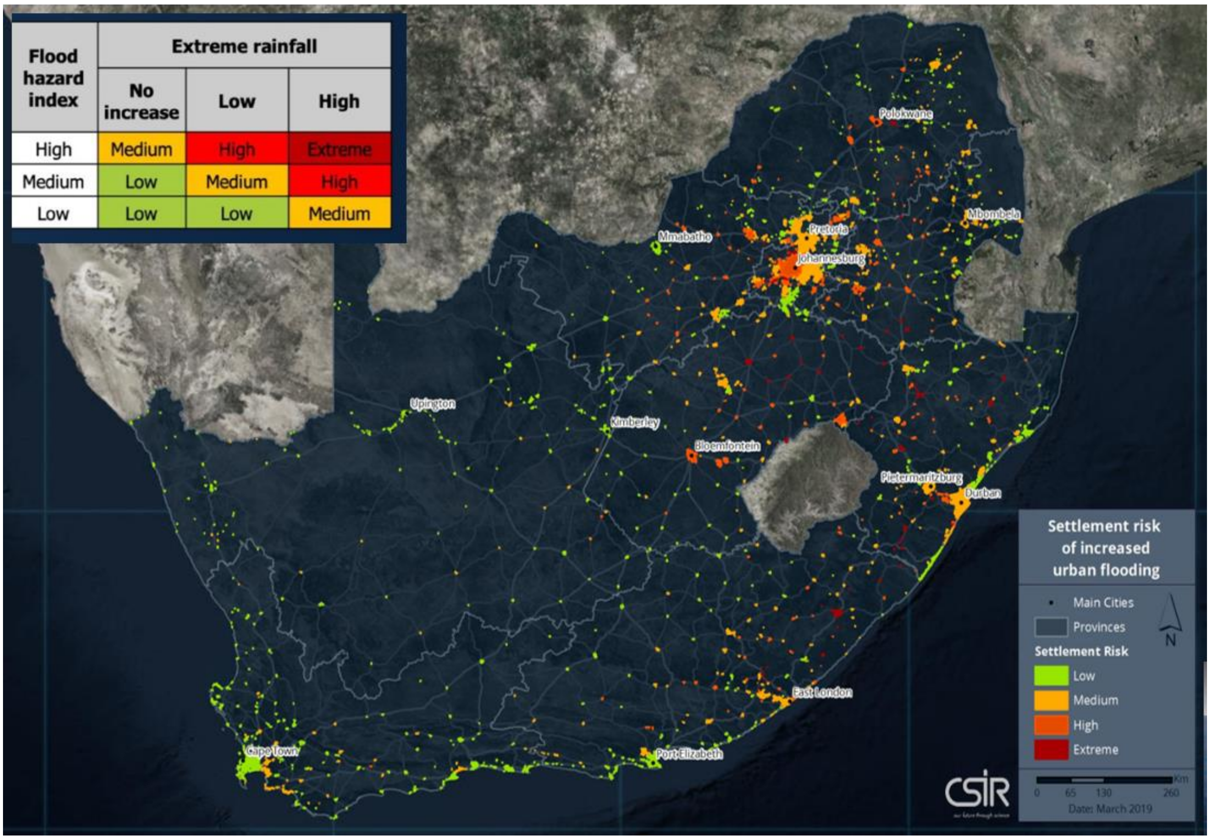
- Severe economic losses
- Disrupted supply chains
- Reduction in hygiene and increased transmission of diseases

- Water supply stress and shortages
- Water rationing and interrupted supply
- Affected urban food networks and food insecurity
- Declining quality of life
- Declining water quality
- Resource conflicts
- Outbreaks in fires

Inland flooding: Settlements projected to experience an increase in flooding events

Background

Floods are the most frequent natural disaster in South Africa and in the past four decades, 35 recorded flooding events have been responsible for the death of 1266 people and have inflicted damages to the value of R30 billion (EM-DAT, 2020). Under the RCP 8.5 scenario, increases in extreme rainfall events are projected over most of the central interior and east coast, with a minority of ensemble members projecting extreme rainfall increases over most of eastern South Africa. Determining South Africa's settlements that will be exposed to an increased risk of flooding considers these changes in extreme rainfall and combines it with the current flood hazard index calculated for South Africa (Le Maitre et al., 2019).



Settlements exposed to increases in flooding events (Le Maitre et al., 2019)

Summarised findings

54% of all settlements in South Africa will have an increased risk of experiencing flooding events in the next 3 decades. 21% of settlements will experience a high and extremely high risk of increases in flooding events and these high-risk settlements are located mostly towards the eastern side of South Africa. It should also be noted that six of the 8 metropolitan cities will experience an increase in flood risk within the next three decades. Most of the low-risk settlements are located on the western and southern side of South Africa.

Key message for consideration

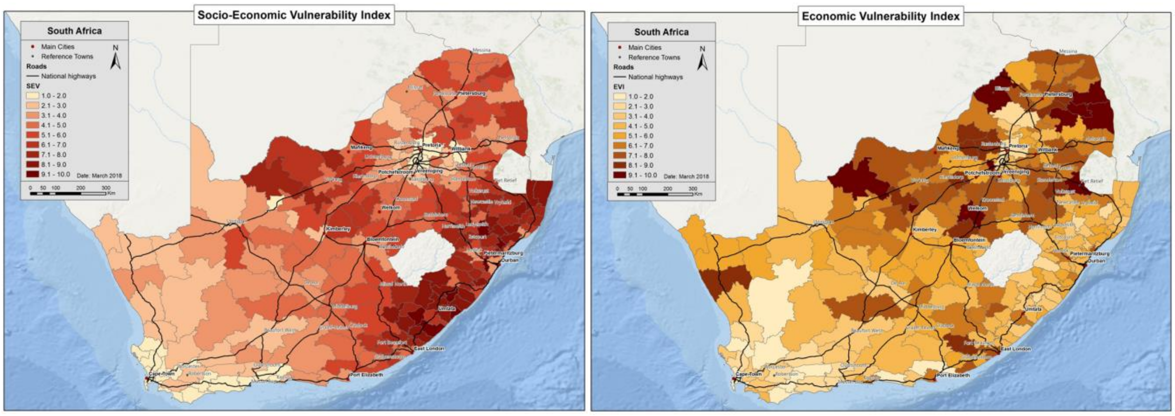
It is clear that flooding is part of the South African landscape and that the severity of floods is likely to increase in the future specifically towards the eastern parts of the country (Le Maitre et al., 2019). Climate is not the only driver of flood risk increases: changes in land cover, the management of stormwater systems, land-use practices upstream and the expansion of urban areas can also have significant impacts.

Vulnerable settlements and their projected population growth by 2050

Vulnerabilities: South Africa's most vulnerable municipalities

Background

Vulnerability is present before a disaster strike contributes to the severity of losses experienced and persists long after a disaster occurred (Van Niekerk & Le Roux, 2017). There are many factors that influence the vulnerability of our cities and neighbourhoods: rapid population growth combined with the slow delivery response from the housing sector, the slow GDP growth rate, the lack of land use management, inability to enforce planning policies and failure to maintain and retrofit infrastructure have contributed to the vulnerabilities and exposures of cities.



The socio-economic and economic vulnerability indexes of South African settlements (Le Roux et al., 2019b)

Summarised findings

Socio-economic vulnerability: The vulnerability present in households

The Eastern Cape and KwaZulu-Natal have the largest number of vulnerable communities in the country. There are also a number of vulnerable municipalities in traditional settlements located in the north of the country, in the area around the North West and Northern Cape (Le Roux et al., 2019b). These municipalities house a large number of vulnerable households that would struggle to withstand the adverse effects of disasters.

Economic vulnerability: The vulnerability present local municipalities economies

The North West province has the largest number of economically vulnerable municipalities in the country, followed closely by Limpopo and then Mpumalanga. The economies in these municipalities are extremely vulnerable and it's unlikely that these municipalities will have the funds available to implement large scale adaptation investment projects or withstand any adverse shocks (Le Roux et al., 2019b).

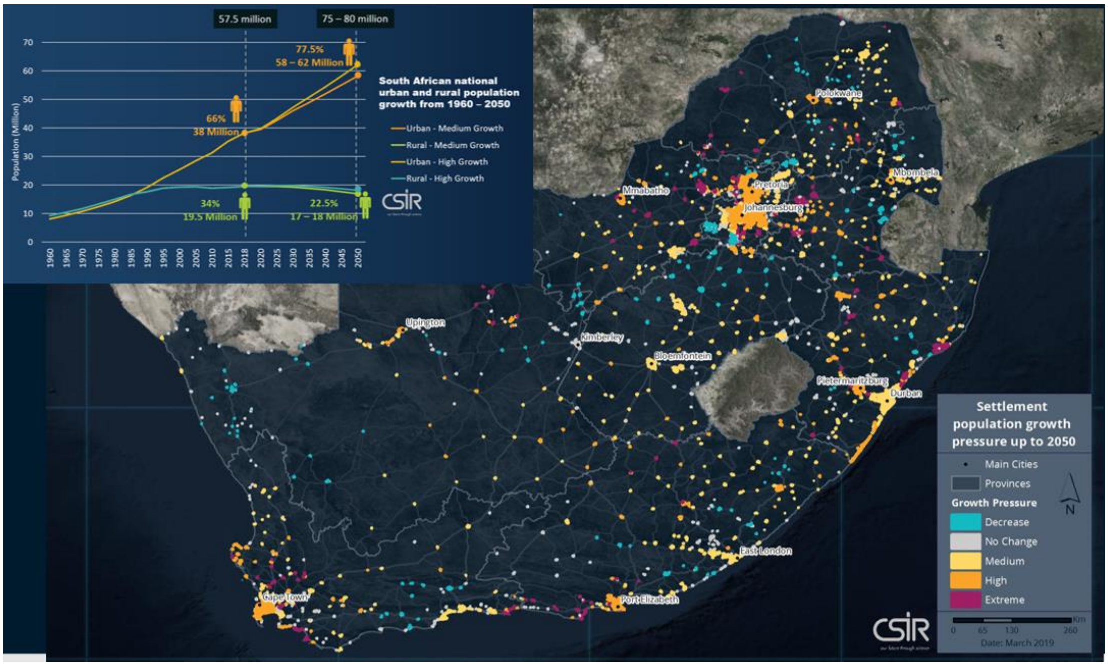
Key message for consideration

Unemployment and inequality in South African settlements are among the highest in the world and municipalities are already under tremendous stress to address the many complex and persistent urban challenges present. The compounding impact of climate change on the human settlement will push cities far beyond their capacity to adapt and respond. Settlements will respond and be impacted to a varying degree and it is undeniably the poor and vulnerable communities that will experience the most severe setbacks from the impacts of climate change, eroding their adaptive capacity and threatening their resilience (Van Niekerk and Le Roux, 2017).

Urban growth: Projected urban growth in South Africa

Background

Normal development trajectories can either increase or decrease the vulnerabilities of settlements and communities. Municipalities in South Africa are already under tremendous pressure to address many complex urban challenges, in many cases with limited resources. It is therefore imperative that our efforts to do disaster reduction and climate change adaptation address current pressing matters while strongly considering the unfolding and projected climate and urban growth challenges (Pieterse, 2019). The projected growth of settlements should thus be considered when looking at unfolding future risks to human settlements. To this accord, the projected population growth under a high growth scenario was considered to look at settlements that will experience increases in population growth pressures (Le Roux et al., 2019).



Population growth pressure in South Africa's settlements by 2050 (Le Roux et al., 2019a)

Summarised findings

It is estimated that the South African population will grow with approximately 21 million people, increasing the population from around 59 million people in 2019 to 80 million in 2050. The vast majority of this growth is projected to be in cities, towns and settlements across South Africa (Le Roux et al., 2019). Population pressure is based on both the relative and actual population changes between 2011 and 2050. The following findings should be noted;

- The South African urban population is expected to increase from 40 million to 60 million in the next three decades.
- 58% of all settlements in South Africa will be subjected to various degrees of population growth pressure.
- Metropolitan cities will absorb an enormous amount of people in absolute numbers.
- 10% of cities and towns will experience extreme growth pressure (purple areas on the map) and in some cases even doubling or tripling in size.
- 12% of all settlements are expected to decline (blue areas on the map).

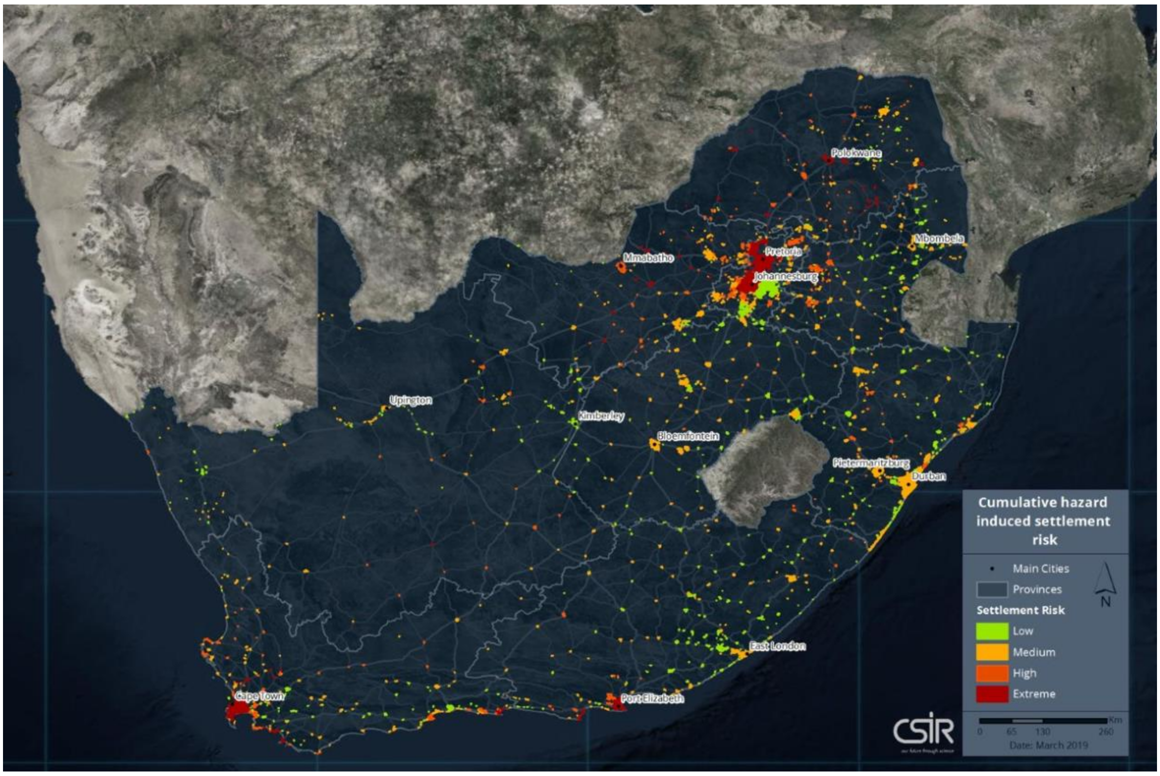
Key message for consideration

Much of the infrastructure needed to accommodate the additional 20 million people, has not been built yet, allowing a unique opportunity for building the principles of resilience into our cities and towns. The infrastructure and settlements we built today will exist for decades to come and it is therefore imperative that, in addition to proactive maintenance and retrofitting, we increase the resilience and sustainability of our settlements by making them climate-proof, energy-efficient, water-sensitive and resistant to hazards. If we accommodate and plan for the expected urban growth in a sustainable manner, we can safeguard our cities and protect them from the devastating losses associated with weather-related hazards, however, if the growth is not managed and planned for effectively it will place an enormous amount of pressure on bulk infrastructure delivery, translate to informality, contribute to future disaster losses and have serious implications for critical resources such as water, electricity and food provision.

South-Africa’s high-risk settlements in need of adaptation interventions

Background

Considering a low-mitigation future (RCP 8.5) combined with a growing and urbanising population (high growth scenario) it is projected that an increasing number of settlements will be subjected to the devastating effects of weather-related disasters by 2050.



South Africa's settlements at risk to the cumulative impacts of climate change (Le Roux et al., 2018)

Summarised findings

The map displays the high growth settlements that are likely to experience an increase in hydro-meteorological events. Many of the settlements at extreme risk will be subjected to a range of complex issues such as high population growth rates, high socio-economic pressures, low economic growth combined with exposure to multiple hazards that is projected to increase in frequency. Within these settlements, the vulnerable and marginalised groups and communities will disproportionately feel the impacts. The following is concluded from the map:

- 4 out of the 8 metropolitan cities will experience an extreme increase in the risk associated with weather-related disasters.

- Nine out of the top 10 most at-risk settlements are located in the Limpopo province.
- While most settlements will be impacted to some degree by climate change, it is projected that 66% of settlements will experience losses associated with weather-related disasters if no adaptation actions are taken.
- 22% of settlements (those highlighted in red and dark orange) are urged to mainstream climate adaptation as a matter of urgency to avoid significant economic losses from weather-related events.

Key message for consideration

The rise in the frequency and intensity of hydro-meteorological hazards combined with a growing and urbanising population, poor land-use practices, growing informal settlements and failure to rapidly deploy resilient infrastructure is likely to exacerbate the vulnerabilities of communities and place even more people at risk of climate-induced disasters.

3.4.2.2 Responding to SA's high-risk settlements

The ultimate aim of adapting South Africa's settlements is to become more resilient to the devastating impacts and threats posed by climate change through creating cities that are capable of sustaining themselves by coping with or adapting to climate change threats (Van Niekerk and Le Roux, 2017). Adaptation is thus a vital mechanism to reduce the exposure of settlements and infrastructure to natural hazards and how we respond to these challenges will define different futures for different cities.

South Africa already has a number of national policies on disaster risk reduction (DRR) and climate change adaptation (CCA) that promote the role of human settlement planning. These include;

- **The amended National Disaster Management Act, 57/ 2002 and the amended Act (Act no. 16 of 2015*):*** The Act requires that local disaster management plans must consider climate change impacts and risks for each municipality, as well as provide measures and indicate how it will invest in adaptation responses.
- **The National Disaster Management Framework of 2005:** The Framework specifically speaks to elements of settlement planning. According to the Framework, disaster management centres must in association with spatial planners ensure that hazard and vulnerability factors, as reflected in the spatial development framework, inform disaster risk planning, while

verified risk information is incorporated into spatial development plans and maps. For example, urban planners need to get involved in the disaster risk assessment of potential fire risk in large informal settlements. Furthermore, effective and adaptive local disaster risk reduction interventions (and by implication climate change adaptation) are best planned for and implemented through IDP mechanisms as development initiatives. The Framework stipulates that municipalities and provinces must introduce measures to ensure effective disaster risk reduction, discourage risk-promotive behaviour and minimise the potential for loss. This may involve:

  - "Amendment of urban planning standards;
  - Amendment of land-use regulations and zoning;
  - Amendment of minimum standards for environmental impact assessments;
  - Introduction of standards for 'risk-proofing' lifeline services and critical facilities from known priority disaster risks; and
  - Introduction of by-laws to implement extraordinary measures to prevent an escalation of a disaster or to minimise its effects" (South Africa, 2005).

- **The Draft Climate Change Bill of 2018*:*** The Bill aims to facilitate a more coordinated and integrated response to climate change and its impacts by all spheres of government. The Bill requires the development of climate change response assessments and implementation plans on either district or municipal level (DEA, 2018).
- **The National Climate Change Adaptation Strategy (NCCAS) of 2018:** The NCCAS recognises the role of local government in responding and adapting to climate change, as well as a general need for guidance and capacity building within local government to be able to fulfil this role. One of the nine strategic interventions of the NCCAS is to facilitate the mainstreaming of adaptation responses into sectoral planning and implementation and particularly into municipal development and infrastructure planning (Pieterse, 2019).
- **The National Climate Change Response Policy (NCCRP) of 2011*:*** The NCCRP provides a policy framework for South Africa's response to climate change adaptation and mitigation. It also aims to ensure that the country is able to manage the impending climate change impacts through adaptation interventions that build and sustain the social, economic and environmental resilience and emergency response capacity. The NCCRP highlights human settlements, among others, as a priority sector for adaptation (DEA, 2011).

Urban planning is seen as a key component of climate change adaptation by the IPCC and many others because of the role it plays in addressing the root causes of risk and vulnerability. Climate change adaptation is not loose standing from urban planning, but an integral part of good planning practice that generate multiple benefits. The mainstreaming of climate change adaptation measures in planning instruments is crucial to ensure successful implementation of adaptation interventions, for planning instruments influence the form, structure and function of settlements. South Africa has well-established planning policies, instruments and plans. Many of these have already integrated climate change adaptation to protect human settlements to the likely impacts from climate change (Pieterse, et al., 2020). The list below mentions some of these important sectoral policies, plans, instruments and decision support tools that promote the mainstreaming of climate change adaptation into settlement planning (Pieterse, et al., 2019):

- The Spatial Planning and Land Use Management Act (Act No. 16 of 2013) (RSA, 2013)
- The Medium-Term Strategic Framework (MTSF)
- The National Spatial Development Framework (NSDF)
- Climate Change Adaptation Sector Strategy for Rural Human Settlements
- The Integrated Urban Development Framework (IUDF)
- The Let's Respond Toolkit
- The 3rd South African Risk and Vulnerability Atlas
- The District development model , COGTA
- Include the district model
- Include National Climate Change Information System
- The draft Framework on Climate services

It is therefore vital that we utilise these policies, instruments and plans to our disposal to ensure we adapt, retrofit and built climate-resilient cities and towns.

3.5 Water sector

3.5.1 Introduction to South Africa's water resources

South Africa is known to be a water-scarce country. This is evidenced in its low mean annual rainfall (450 mm) and the high variability in this rainfall in space and time. Spatial variability manifests in a general east-west gradient of declining rainfall (especially in non-mountainous interior regions), while strong temporal variability exists at seasonal and inter-annual scales. Furthermore, the rate at which rainfall is converted into the runoff is low, with mean annual runoff being only 40 mm, which is in contrast to the global mean of 260 mm per year (DWA, 2013).

This low and variable rainfall has necessitated the development of infrastructure to store and transfer water between different locations, as needed. These integrated bulk water supply schemes involve transferring water between catchments via pipelines and tunnels. These schemes have been developed in various parts of the country, with the largest being the Integrated Vaal River System, where water is moved to and from the Vaal catchment via transfers with catchments in Lesotho and neighbouring provinces. This system supplies water to the economic hub of Gauteng, as well as to other large users including power stations, irrigation schemes, industry and mining. The city of Johannesburg is the only major city in the world that is located on a continental divide, far away from major water resources and has been a major driver in the development of this system (Cullis and Phillips, 2019). Figure 3.5-1 shows water transfers made between the previously defined 19 Water Management Areas (WMAs) of the country (Stats SA, 2010).

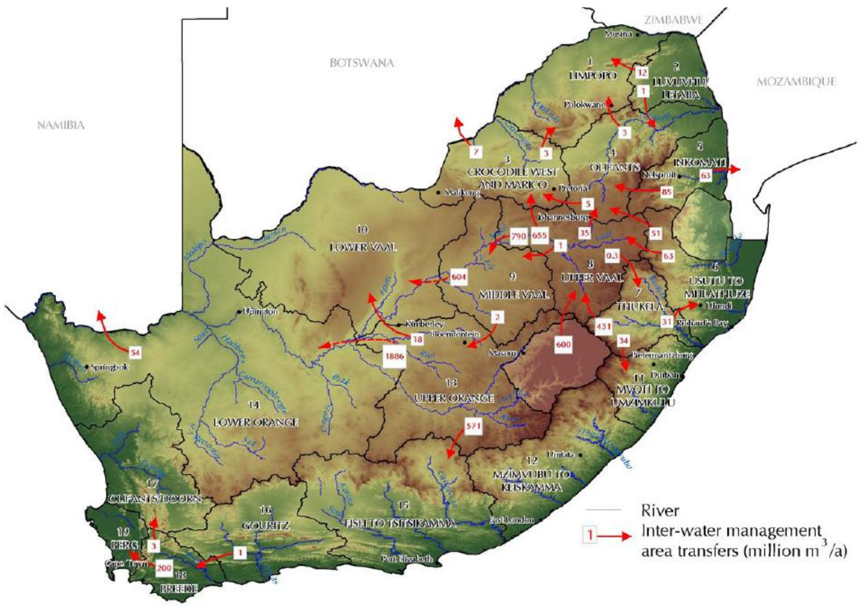


Figure 3.5-1: Water transfers made between Water Management Areas (Stats SA, 2010)

The sector water requirements in each of the above WMAs are presented in Table 3.5-1 to give an indication of the users of water in each of the regions. These water requirements are for the year 2000 and represent the local demand for water in each area (excluding transfer demands to other catchments) and are standardized to a 98% assurance of supply.

Table 3.5-1: Sector water requirements for the year 2000/Water Management Area (DWAF, 2004)

Water management area	Irrigation	Urban (1)	Rural (1)	Mining and bulk industrial (2)	Power generation (3)	Afforestation (4)	Total local requirements
Limpopo	238	34	28	14	7	1	322
Luvuvhu/Letaba	248	10	31	1	0	43	333
Crocodile West and Marico	445	547	37	127	28	0	1 184
Olifants	557	88	44	94	181	3	967
Inkomati	593	63	26	24	0	138	844
Usuthu to Mhlathuze	432	50	40	91	0	104	717
Thukela	204	52	31	46	1	0	334
Upper Vaal	114	635	43	173	80	0	1 045
Middle Vaal	159	93	32	85	0	0	369
Lower Vaal	525	68	44	6	0	0	643
Mvoti to Umzimkulu	207	408	44	74	0	65	798
Mzimvubu to Keiskamma	190	99	39	0	0	46	374
Upper Orange							
Lower Orange	780	126	60	2	0	0	968
Fish to Tsitsikamma	977	25	17	9	0	0	1 028
Gouritz	763	112	16	0	0	7	898
Olifants/Doring	254	52	11	6	0	14	337
Breede	356	7	6	3	0	1	373
Berg	577	39	11	0	0	6	633
	301	389	14	0	0	0	704
Total for country	7 920 62%	2 897 23%	574 4%	755 6%	297 2%	428 3%	12 871

1) Includes the component of the Reserve for basic human needs at 25 litres/person/day.
2) Mining and bulk industrial that are not part of urban systems.
3) Includes water for thermal power generation only, since water for hydropower, which represents a small portion of power generation in South Africa, is generally also available for other uses. (For ease of direct comparison with Eskom these numbers have not been adjusted for assurance of supply; the quantitative impact of which is not large).
4) Quantities given refer to impact on yield only. The incremental water use in excess of that of natural vegetation is estimated at 1 460 million m^3/a.

Critical to many bulk water supply schemes are the country's Strategic Water Source Areas (Figure 3.5.2). These high rainfall areas (also located in Lesotho and eSwatini) are often in mountainous areas and supply 50% of the region's mean annual runoff from only 8% of its land area. As such, these water towers are indicative of the high spatial variability in water resources in the region and are essential to preserving for future water security. The source areas are vital for water supply to the major urban areas of Johannesburg, Pretoria, Cape Town, Port Elizabeth and Durban-Pietermaritzburg.

Figure 3.5-2: Strategic water source areas of South Africa, Lesotho and eSwatini (Nel et al., 2013)

Groundwater is also an important water source in South Africa, with the total utilizable volume of the resource being estimated to be almost equivalent to that of surface water resources (Middleton and Bailey, 2009). However, unlike surface water resources, groundwater is largely under-utilized (DWA, 2010). The availability of utilizable groundwater follows a similar east-west gradient to surface water resources, with a greater abundance in the east and along the southern coast (DWA, 2010). The spatial distribution of large-scale groundwater extraction in the country is shown in Figure 3.5.3, while the breakdown of sector usage is given in Figure 3.5.4 for the previous 19 WMAs.

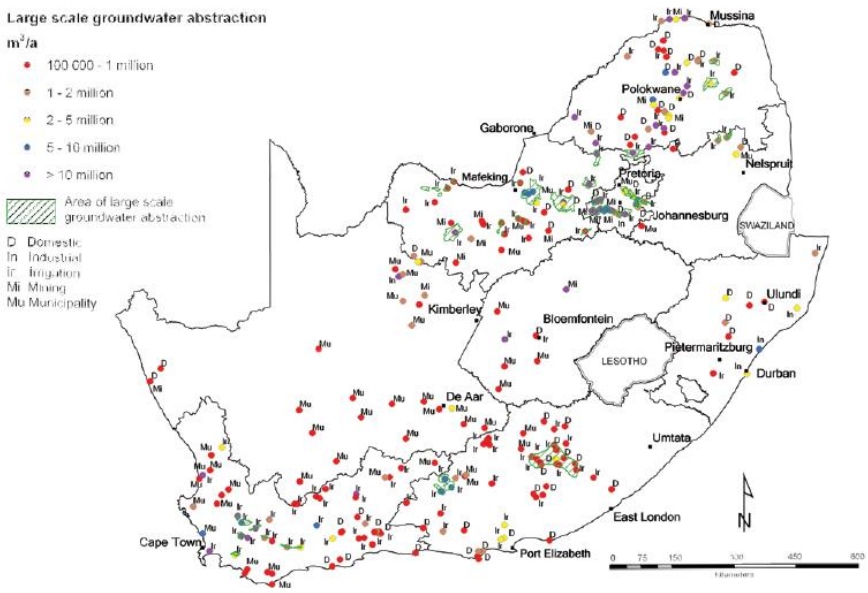


Figure 3.5-3: Spatial distribution of large-scale groundwater extraction (DWA, 2010)

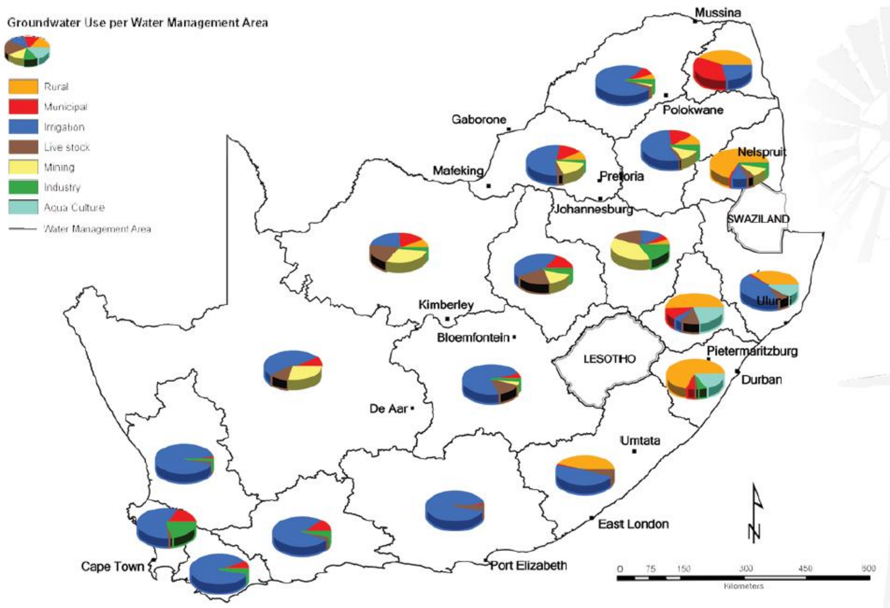


Figure 3.5-4: Total groundwater use per sector in the 19 Water Management Areas (DWA, 2010)

Small cities and towns that do not source water from bulk water supply systems generally have less flexibility to respond to droughts, particularly if they rely on a single source of water (Cullis and Phillips, 2019). Some settlements rely on a combination of surface water and groundwater and others rely entirely on groundwater. An estimated 41% of all settlements in South Africa have a water supply that is comprised of more than 50% groundwater. However, since these are mostly in rural areas, these settlements account for only about 12% of the country's population (Le Maitre et al., 2018).

Groundwater is subject to lower evaporative losses than surface water, buffering it from the impacts of a warming climate. However, groundwater is influenced by changes in rainfall which impact on groundwater recharge. The relative under-utilization of groundwater makes it an important additional source of water for adapting to climate change in areas experiencing a decline in surface water resources or increasing variability in supply. It is important that groundwater be used sustainably in order to maintain the quantity and quality of supply and to ensure sustained baseflows in rivers (in connected systems). Land use should also be managed in a manner that promotes the recharge of groundwater resources (DWA, 2010).

The impacts of warming temperatures on surface water include enhanced evapotranspiration and evaporation, which act to reduce catchment runoff and increase evaporation from dams. Warming temperatures will also contribute to deteriorating water quality, as the risk of algal blooms increases. Rainfall is also projected to become more intense, leading to more flooding, while the impact on overall rainfall amounts is less certain. The exception to this is the southwestern Cape where a robust signal of declining rainfall is evident (Maúre et al., 2018). The increase in intense rainfall may further contribute to deteriorating water quality as more sediment, nutrients and other pollutants will potentially runoff into rivers.

The risk and vulnerability analysis of the water sector will view the above climate change impacts through the lens of increasing climate extremes, as manifested in the form of floods and droughts. These extreme climate events represent the periods when water infrastructure and supply systems (both surface- and groundwater-based) are most at risk. During floods, the risks are in terms of damage to the physical infrastructure, or reductions in the efficiency of the structures and related consequences. This could relate to, for example, stormwater infrastructure, dams, pipelines, canals, treatment works etc. Flooding is also a risk to human life, non-water related infrastructure, livestock etc. These risks are considered in other sectors in this report. The risks posed by drought relate to the ability of water supply systems to meet demands given reduced rainfall, higher evaporation and increased water demands.

The projected patterns of changing climate extremes (floods and droughts) are assessed in the next section, after which the risk and vulnerability analysis is presented.

3.5.2 Projected climate change impacts

Projections of the potential impact of climate extremes on the water sector were made by selecting appropriate climatic indicators and assessing changes in these between baseline (1971-2000) and future (2011-2040) periods. These changes were determined under a low mitigation scenario for six climate models, with the median of these models then being assessed in analyses. The selected indicators are described below for different climate extremes:

- Large-scale flooding: Large-scale flooding was represented by heavy precipitation events, where these events were defined as having rainfall in excess of 20 mm per day, over an area of 50 x 50 km, for three successive days or more. This type of event is typically caused by tropical cyclones and cut-off lows (DEA, 2015).
- More localized flooding: More localized flooding was represented by the 10-year return period design rainfall. To give an example of the scale at which this variable has application, the 10-year return period flood peak is used as a factor in the design of local roads and associated drainage in urban and rural settings. Although the 10-year return period rainfall event does not necessarily result in the 10-year return period flood peak (due to actual catchment conditions prior to a storm), it is often assumed to do so for design purposes (SANRAL, 2013). The 10-year return period rainfall was determined by fitting the Log Pearson III distribution to the highest daily rainfall in each year (annual maximum series) of the baseline and future periods. This analysis was undertaken at the quaternary catchment level. Changes in the magnitude and frequency of the 10-year return period event were assessed.
- Drought: Drought was firstly represented by the Standardized Precipitation Evapotranspiration Index (SPEI). This index reflects the difference between precipitation and evapotranspiration and can be summed over varying lengths of time to reflect lags in different hydrological processes. At longer time scales the index is associated with storage variations in large dams and groundwater resources. The SPEI was calculated over 12-month periods for the purpose of this assessment to reflect these features (Papadopoulou et al., 2020; Vicente-Serrano et al., 2010; Beguería et al., 2014). The index oscillates between positive and negative values corresponding to wet and dry conditions, respectively. It is usually in the range +3 to -3 but can stray outside of this in exceptional conditions. The index was calculated at the level of quaternary catchments. Separate to the SPEI, drought was also represented by a threshold of rainfall in the form of the 10th percentile of annual rainfall. This threshold can be considered to reflect severe drought conditions if annual rainfall falls below this level (Schulze et al., 2011). Changes in the magnitude of this threshold and the frequency with which rainfall falls below

the baseline threshold, were assessed at the quaternary catchment scale. It is recognized that droughts vary in spatial and temporal scale and their severity and that the above drought indicators only reflect a sample of possible drought conditions. Furthermore, the indicators do not directly quantify hydrological drought (reflecting the levels of rivers, dams and groundwater supplies), which can only be achieved through a hydrological modelling analysis (beyond the scope of this assessment).

The analysis of the calculated indices is discussed in the following paragraphs:

Large-scale flooding

The pattern of projected changes in large-scale flooding (as represented by heavy precipitation events) is presented in Figure 3.5.5.

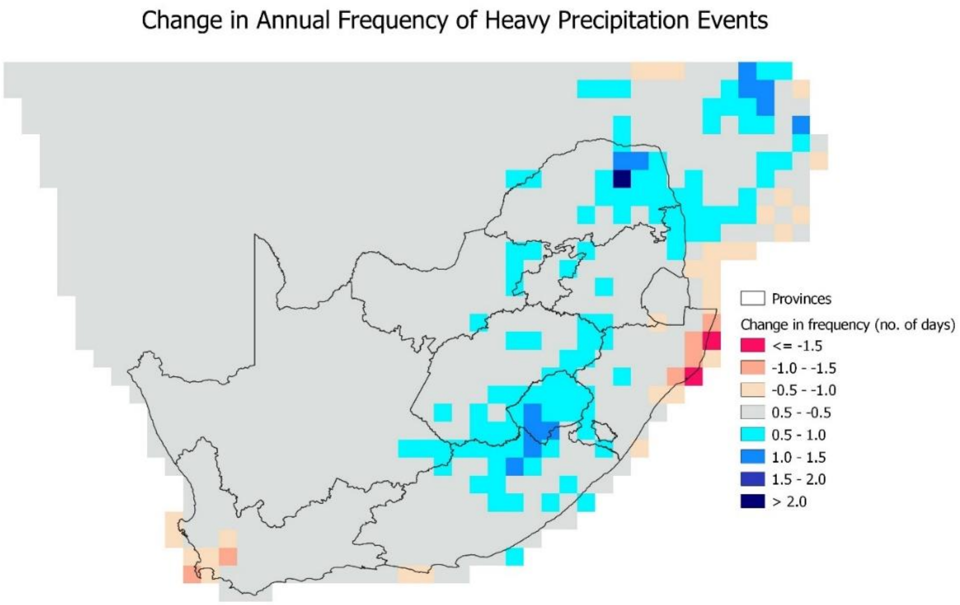


Figure 3.5-5: Change in Mean Annual Frequency of Heavy Precipitation Events

The following patterns are evident in Figure 3.5-5:

- Reductions in large-scale flooding over northern KwaZulu-Natal and increases over Limpopo and Mozambique. This finding is consistent with Malherbe et al. (2012) who showed that the location at which tropical cyclones are projected to make landfall is shifting northward.
- Reductions in large-scale flooding over the south-western Cape. This may be due to the general decline in rainfall projected over the region. These reductions are less intense than those over northern KwaZulu-Natal.

- The pattern of increases in heavy precipitation over the mountainous areas of Lesotho and surrounds is associated with a lower level of confidence, given the challenges associated with modelling rainfall in these environments.

Although the identified changes are only in the order of 1 to 2 days per year, they are noteworthy given that the events concerned are large and impactful.

More localized flooding

The projected changes in more localized flooding (as represented by the 10-year return period design rainfall) are mapped in Figure 3.5.6.

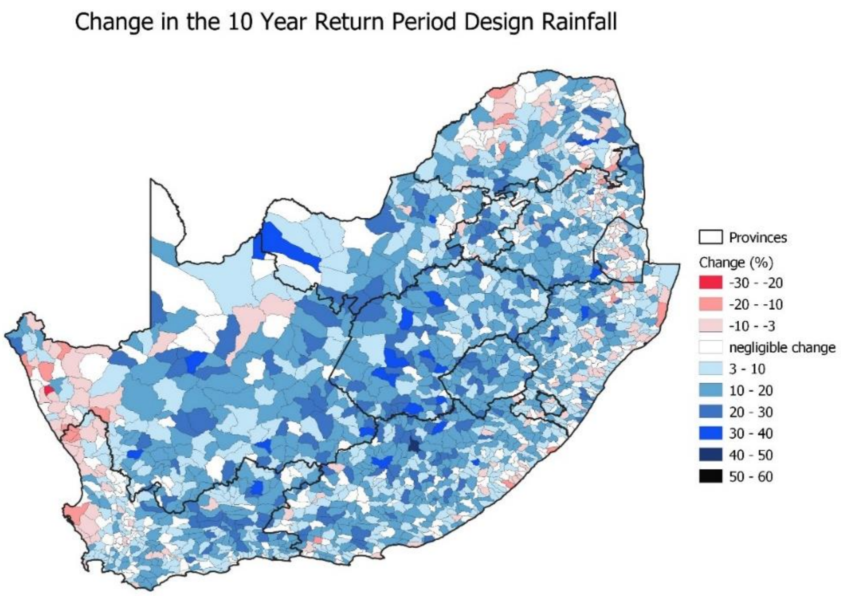


Figure 3.5-6: Change in the 10-Year Return Period Design Rainfall

Figure 3.5.6 shows a general increase in the magnitude of flood events, with the exception of the West Coast and parts of northern Limpopo and KwaZulu-Natal, where there are weak reductions. Many quaternary catchments show increases in the magnitude of over 20%.

To assess changes in the frequency of flooding, the number of cases in the baseline and future time series' where the baseline event magnitudes used in producing Figure 3.5.6 were exceeded, were determined. Changes in the frequency with which the events were exceeded were then mapped in Figure 3.5.7 as the ratio of future occurrences to baseline occurrences. In this context, values greater than one indicate an increasing trend.

Figure 3.5.7 shows a general increase in the frequency with which flood events are projected to occur. In many quaternary catchments, there are increases in the frequency of more than double the baseline value, suggesting that increases in the frequency of flooding are greater than increases in the magnitudes. There are scattered areas where flood frequencies are projected to reduce, notably on the West Coast.

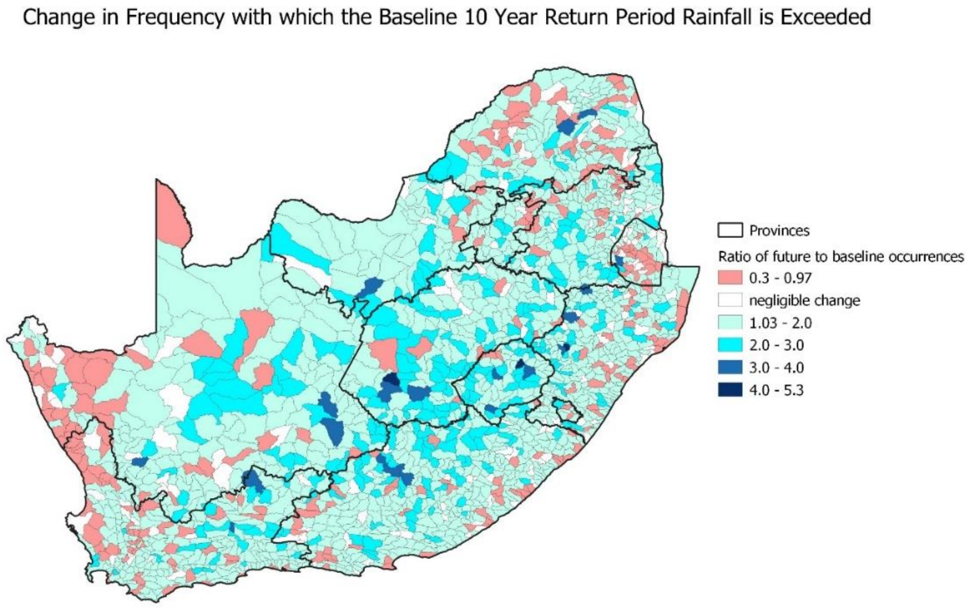


Figure 3.5-7: Change in Frequency with which the Baseline 10 Year Return Period Rainfall Event will be Exceeded in Future Relative to the Baseline Period. The change in frequency is expressed in terms of the ratio (future: baseline) of the total number of occurrences in each 30-year period.

Drought

Changes in the long-term mean value of the monthly SPEI values (each representing conditions over the past 12 months) for the 30-year baseline period relative to the 30-year future period were determined and mapped in Figure 3.5.8.

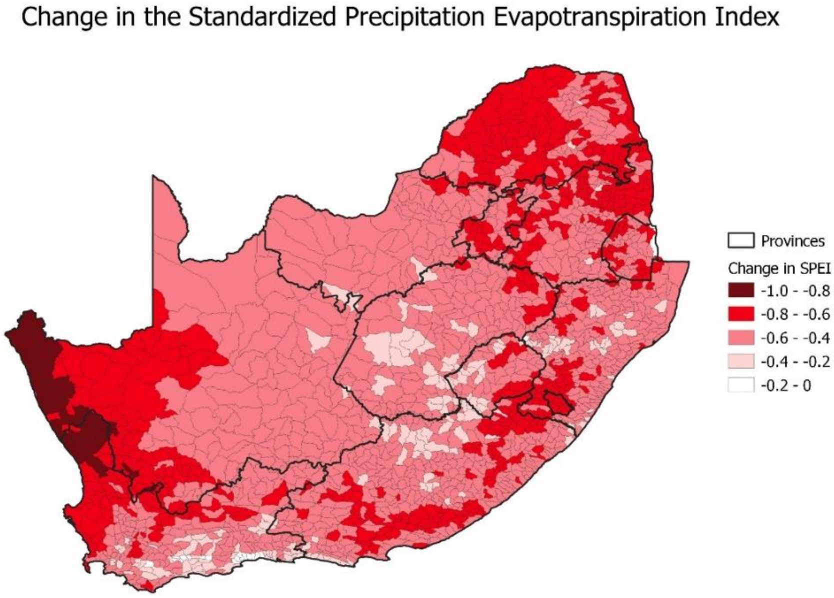


Figure 3.5-8: Change in the 30-year mean of the Standardized Precipitation Evapotranspiration Index

All changes in the 30-year mean index value across the country were negative, indicating a reduction in the index value and a shift toward drier conditions. It is assumed that in an unchanging climate, a long-term average of the SPEI would be close to zero (reflecting both wet and dry phases). Therefore, a reduction of up to -1 in the 30-year mean index value for the West Coast and the adjacent interior is considered significant, given that a value of -1 in an individual month (representing conditions over the past 12 months) can be considered a threshold for drought (Lee et al., 2017). Large parts of Limpopo, also show strong shifts towards drier conditions, as do scattered parts of the eastern coastal provinces and Mpumalanga. The central interior shows a weaker shift to drier conditions.

Changes in the magnitude of severe drought, as defined by the 10^{th} percentile of annual rainfall, are mapped in Figure 3.5.9. These changes are shown as a difference in mm and as a percentage change. In this context, a negative change (in shades of red) indicates that the 10th percentile is associated with a lower rainfall value in future i.e. the driest year in ten becomes drier, signalling more extreme drought. Figure 3.5.9 indicates that for much of the country, the intensity of drought increases by up to 10%. Notable exceptions to this include the west coast where the intensity of drought increases by up to 30% and the central interior where the intensity of drought weakens by up to 10%. These patterns bear some resemblance to those reflected in the SPEI in Figure 3.5.8, although the impact of warming temperatures on evapotranspiration in the SPEI suggest that there will drier conditions across the entire country (this is not reflected in an analysis focused only on rainfall).

Changes in the frequency of severe drought, as reflected in the frequency with which annual rainfall falls below the 10th percentile value (for baseline conditions), is presented in Figure 3.5.10. Changes are shown as a difference in the number of occurrences of severe drought (over 30 years) and as a percentage change in the number of severe droughts. Figure 3.5.10 suggests that with the exception of the central interior, there will be more frequent severe droughts across the country. These increases will be up to 150 % for much of the country and up to 300% along the west coast. In the central interior, some reductions in drought frequency are projected. It should be noted that the percentage of changes in occurrences is calculated relative to a small number of occurrences in the baseline period, resulting in some high values when viewing changes as a percentage. For example, the number of occurrences in the baseline period is always 3 (corresponding to the 10th percentile over 30 years), so an increase of 6 occurrences in the future will equate to a 200% increase in the number of occurrences.

From Figures 3.5.9 and 3.5.10, it is apparent that the frequency of droughts will increase more than the magnitude of droughts, according to the manner in which these are defined in this assessment. It is again emphasized that the definitions of drought used here only reflect a sample of drought conditions that may occur. For example, the occurrence of multi-year droughts is not reflected in this assessment. This form of drought is particularly debilitating and places much greater stress on water supply systems. However, their relatively infrequent occurrence makes them more difficult to assess over short time periods such as that considered in this assessment (30 years for each of the baseline and future periods).

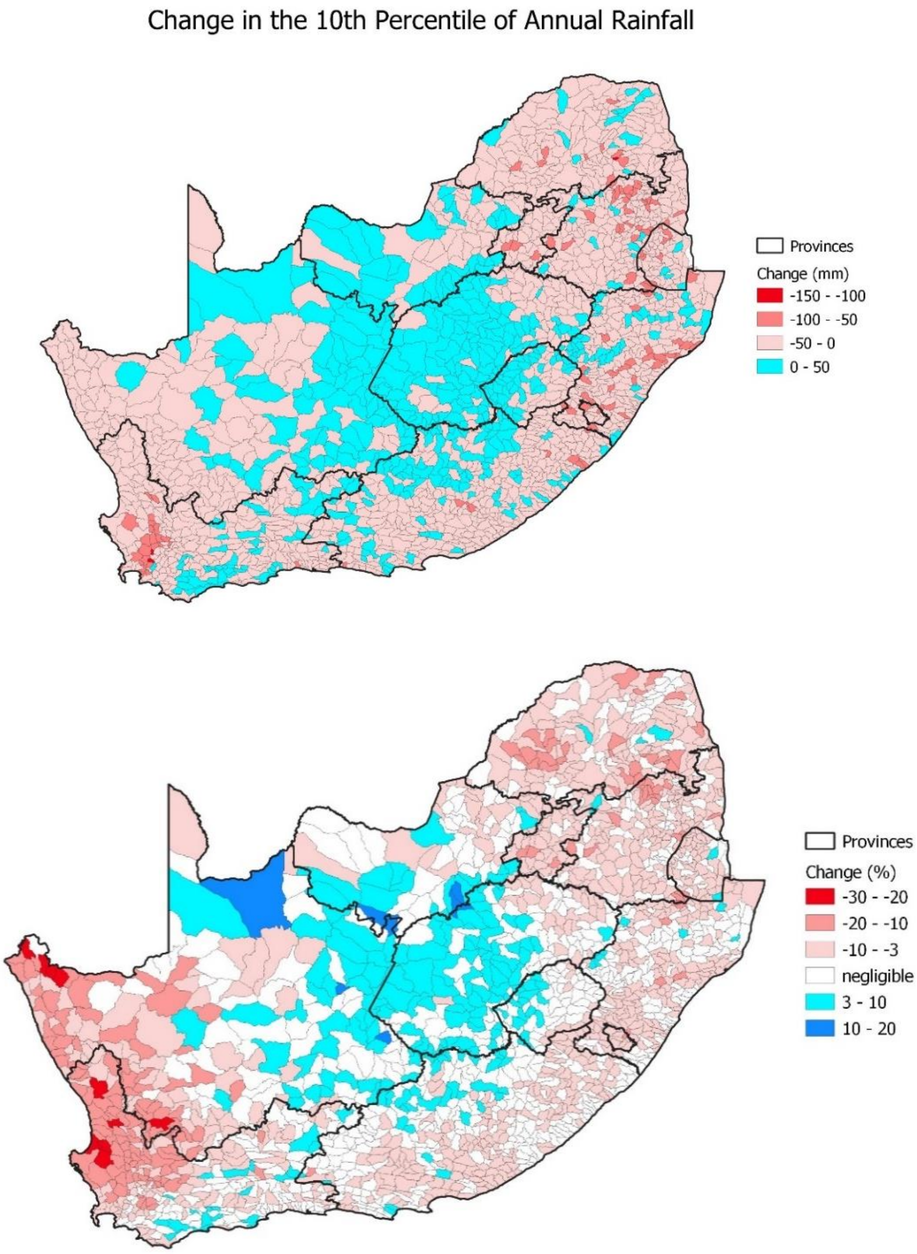


Figure 3.5-9: Change in the magnitude of severe drought, as represented by the 10th percentile of annual rainfall. Negative changes indicate that the 10th percentile is associated with a lower rainfall value in future i.e. the driest year in ten becomes drier. Changes are mapped as differences in mm (top) and as a percentage change (bottom).

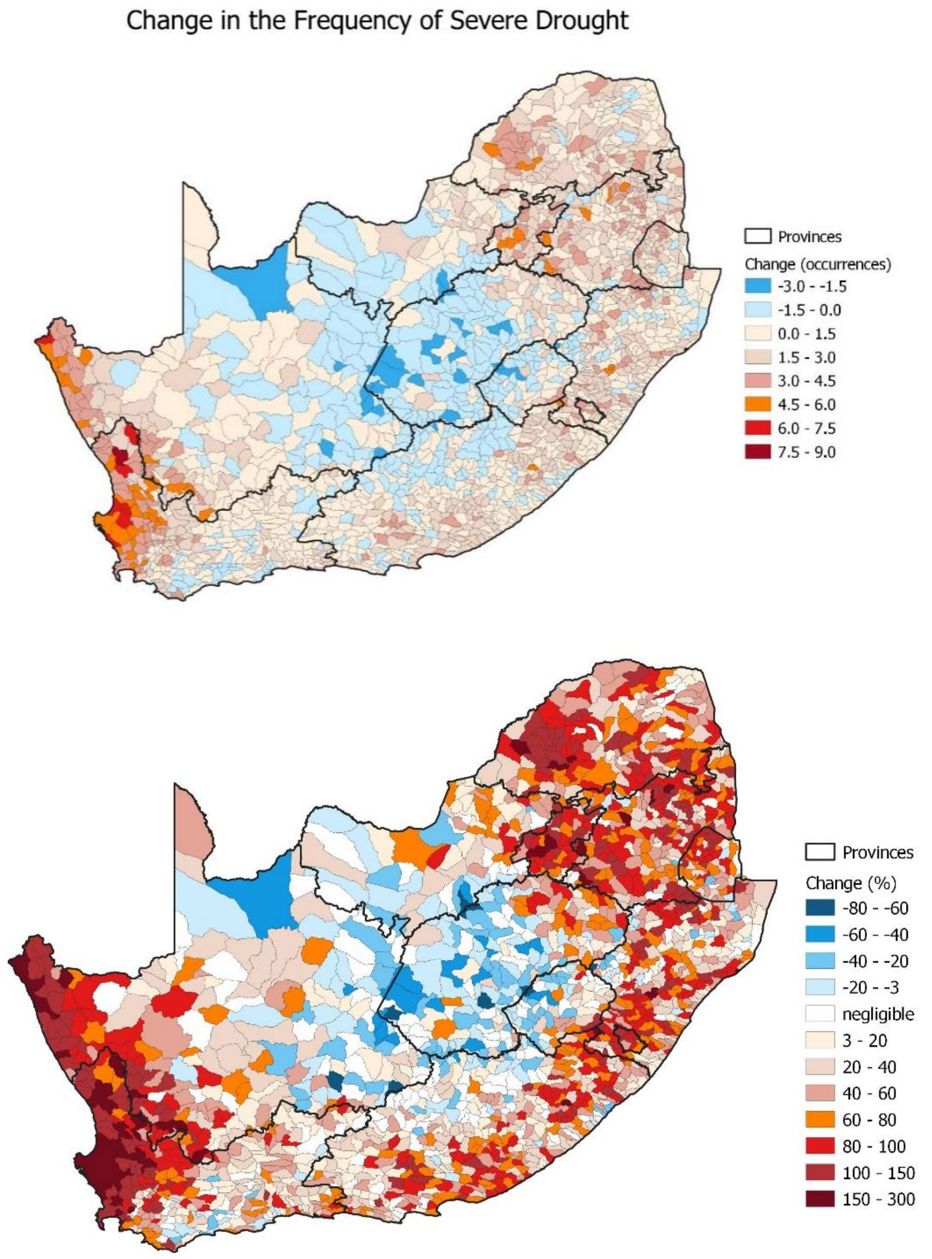


Figure 3.5-10: Change in the frequency of severe drought as represented by the change in the number of years in which annual rainfall falls below the baseline period 10th percentile value. Changes are mapped as differences in the number of occurrences (top) and as a percentage change (bottom).

3.5.3 Risk and vulnerability assessment

As alluded to previously, the risk and vulnerability assessment focuses on the hazards of flooding and drought. The assessment follows the definitions adopted in the IPCC Fifth Assessment Report (2014), which describes climate risk as a function of hazards, exposure and vulnerability and where vulnerability is comprised of sensitivity and adaptive capacity. The assessment was informed by the projected climate impacts described above, the South African water sector context and insights obtained from the literature. The draft National Climate Risk and Vulnerability (CRV) Assessment Framework also guided the process, with the assessment being carried out at the level of an Initial CRV screening (DEFF, 2020). The level of assessment was largely dictated by the time available for the work, as the assessment was required to cover an entire sector at the national level. Owing to time constraints, it was largely conducted as a desktop study with minimal stakeholder consultation. Initial CRV screening does not normally have a quantitative aspect (DEFF, 2020), however, the assessment presented here was partly quantitative in that the climatic indicators analysed in the previous section were employed.

3.5.3.1 Flooding

The systems exposed to flooding are categorized into water resources infrastructure (used to store, convey and treat water for consumption) and stormwater infrastructure (used to drain stormwater in built-up areas and around roads and other structures, into natural watercourses). While there are many similarities in terms of the vulnerability of these two categories of structures to floods, they are considered separately due to their different purpose and scale.

Water resources infrastructure

Water resources infrastructure for storage, conveyance and treatment includes, for example, dams, weirs, canals, pipelines, pump stations and treatment plants. The patterns in projected large-scale flooding suggested a trend towards increasing frequency in these events in eastern Limpopo. This area already experiences the impacts of tropical cyclones and according to the projection, this may increase in future. Large dams in the region (> 100 Mm^3) include Nandoni, Middel Letaba, Tzaneen, Inyaka and Driekoppies Dams. However, it is possibly smaller dams that are designed around a lower return period that may be more vulnerable to damages. Certain types of dams may also be more vulnerable, such as erodible (earthfill) embankment dams (Atkins, 2013). Dam monitoring, management and maintenance are important to ensure the continued integrity of these structures. Relatively few transfers of water are made in the region (Figure 3.5.1), suggesting that there is less of this type of infrastructure at risk. The region is dominated by the Kruger National Park.

The projected changes in more localized flooding showed that increases in the magnitude and frequency of flooding at this scale are likely for most of the country (with the exception of the West Coast and possibly western Limpopo). This suggests that storage, conveyance and treatment structures close to rivers are at greater risk of damages. It is recognized that larger structures (with a longer design life) are unlikely to be affected by localised flooding as it was defined in this assessment (10-year return period). However, when considering that there is likely to be an increase in flooding at a range of scales, this implies that all structures are potentially at greater risk.

Possible measures that can be implemented to adapt to the increased risk of flooding include the construction of flood barriers, the preservation of natural wetlands or the construction of artificial wetlands (to attenuate flood waters), development of flood early warning systems and the revision of engineering design criteria for future infrastructure development. In general, small municipalities and groups responsible for water infrastructure (e.g. small irrigation schemes) will be more vulnerable due to a lack of capacity to implement adaptation measures.

As alluded to previously, an increase in flood events may result in reduced water quality due to wash off of sediments, nutrients and other pollutants. This has the potential to impact water treatment costs and efficiency and the usability of water for some applications. Again, it is small municipalities and groups responsible for water infrastructure that are likely to be most vulnerable.

The National Water Resources Strategy 2 calls for more research into the impact of climate change on flooding and the consequences for water resources infrastructure in terms of safety and resilience of structures (including dams, treatment works, wastewater treatment works and industrial tailings dams). The Strategy also calls for water institutions managing such infrastructure to incorporate climate change considerations into their asset management plans (DWA, 2013).

Stormwater infrastructure

Stormwater infrastructure includes, for example, drains, culverts and pipes that are used to convey water for discharge into natural water sources or larger constructed channels. The patterns of flood risk are similar to those described above for storage infrastructure. Adaptation measures to counter the increased risks include improved maintenance of structures (particularly keeping them free of blockages), development of sustainable urban drainage systems (SUDS), implementation of flood early warning systems and the revision of engineering design criteria for future structures.

While improved maintenance of structures and revision of design criteria are more achievable adaptation measures, the other measures require fairly significant investment to achieve. Therefore, it is again small municipalities that are more likely to be vulnerable to the increased risk of flooding, unless they are able to access the required resources. The large scale of stormwater systems in cities may prove to be equally challenging in terms of implementing adaptation. The built-up area and the number of vehicles is much greater in this context, thus increasing the potential risk of damages.

3.5.3.2 Drought

To augment the analysis of drought impacts presented previously, reference is made to Cullis and Phillips (2019), who conducted a vulnerability analysis of water supplies at the local municipality level. This analysis had the advantage of incorporating hydrological modelling, thus giving a more direct estimate of the impact of climate change on the availability of water resources. The study also incorporated changes in the demand for water (driven by increasing population and economic development), thus further improving estimates of water availability. Limitations of the study were that it was not possible to model the unique water supply characteristics of individual municipalities and that the assessment only considered changes in mean annual runoff and the impact on annual average supply i.e. drought conditions were not specifically tested. Access to groundwater was accounted for through a rainfall factor (reflecting recharge potential), while surface water access was related to local mean annual runoff or regional water supply (regional water supply was derived from a different study). The vulnerability of water supply was expressed as the ratio of water demand to a water supply i.e. values of greater than one represents water insecurity. The future (2050) water vulnerability for a median (long term) wetness climate projection, medium population projection and a scenario that assumes that municipalities have access to regional water supply systems (if they exist in the WMA where they are located), is presented in Figure 3.5.11.

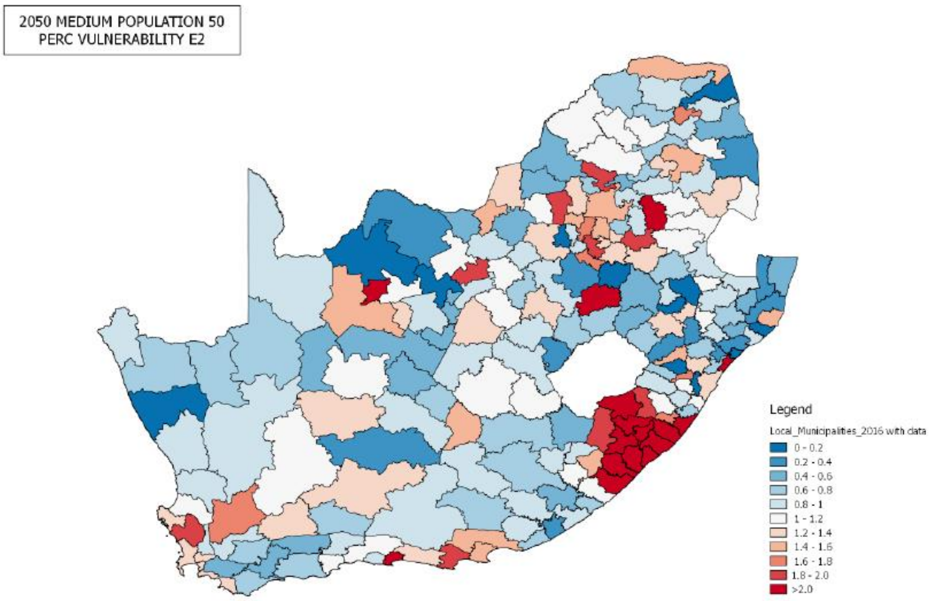


Figure 3.5-11: Future (2050) water vulnerability (ratio of water demand to supply) at local municipality level for a median wetness climate, medium population projection and the assumption of access to regional water supply (Cullis and Phillips, 2019)

Figure 3.5.11 shows that the highest vulnerability is in the Eastern Cape in an area that does not have well-developed water supply systems (DWA, 2013) and is located in the only WMA that does not have inter-basin transfers (Figure 3.5.1). This area was not highlighted in the previously presented assessment of climate impacts (Figures 3.5.8 – 3.5.10) and demonstrates the value of a more detailed modelling-based analysis. Under a worst-case scenario comprising of a dry (long term) climate projection and high population growth, nearly half of all municipalities in the country showed severe water deficiencies (Cullis and Phillips, 2019). These scenarios did not assume any adaptation in the form of supply augmentation or Water Conservation and Water Demand Management (WCWDM). When these were included for the Eastern and Western Cape (where information on potential adaptation was readily available), only a handful of municipalities still showed water deficiencies.

The water systems exposed to drought stress are categorized into bulk water supply systems, local water supply systems and groundwater supply systems for the vulnerability assessment. These systems are considered separately due to differences in their response and vulnerability.

Bulk water supply systems

The climate impact analysis presented previously (Figures 3.5.8 – 3.5.10) showed a pattern of droughts increasing in magnitude and frequency (especially the latter) throughout most of the country (the central interior excepted) and particularly for the south-western Cape and West Coast. While Figure 3.5.11 showed significant vulnerability in only one region of the country, the study concerned only considered changes in mean annual runoff and the impact on annual average supply (Cullis and Phillips, 2019). Therefore, since water supply under drought conditions was not specifically tested, it follows that vulnerability levels may be higher in this region (and elsewhere) during drought periods. This will particularly be the case during multi-year droughts (not assessed in this study), where water resource systems are especially impacted and take longer to recover from. Vulnerability levels were found by Cullis and Phillips (2019) to be significantly higher across the country for drier climate projections and high population growth scenarios. This implies that adaptation will be vital in the water sector to secure future supplies. All users of water are implicated in terms of higher vulnerability, but particularly irrigation which is generally associated with the lower priority of use. Irrigation is a major user of water in every WMA, while urban areas are major users of water in the Upper Vaal, Crocodile West and Marico, Mvoti to Umzimkulu and Berg WMA's (Table 3.5-1). The possible reduction in droughts over Lesotho bodes well for the Johannesburg and Port Elizabeth areas that both receive part of their water requirements from this strategic water source area (Figure 3.5.2). Most other strategic water sources areas, however, lie within regions that are projected to experience increased droughts (Figure 3.5.9 – 3.5.10). Increase in drought risk is not only indicated by changes in rainfall, but also by warming temperatures which drive up evaporative demand. Temperatures are increasing generally under climate change but are also often higher during drought periods. Warmer temperatures result in increases in evapotranspiration losses, evaporation losses from dams and water demand by a variety of users (notably irrigation and urban users). These processes all result in reduced water availability.

The vulnerability of two key bulk water supply systems are reviewed in more detail below:

Integrated Vaal River System

There is no further potential to develop local surface water resources within the Vaal catchment system, as all tributaries have been developed. Water quality in the catchment is compromised by mining and untreated effluent. Options for improving water security include eliminating unlawful use, applying WCWDM measures, treatment and re-use of mine water and untreated effluents (which will also save water as required for dilution of pollutants), additional inter-basin transfers and the use of groundwater. The Polihali Dam in Lesotho is currently under construction and when completed will allow for additional transfers to the Vaal system, thus ensuring water security until 2035 (DWA, 2013). Additional transfers of water are also possible from the Thukela and Orange river systems but will be considerably more expensive. Groundwater use will be explored, particularly for towns in the Northern Cape. The Lower Vaal WMA relies on return flows from the Middle and Upper Vaal, which would diminish under reuse and improved efficiency. As the Vaal system supports 60% of South Africa’s economy (DWA, 2013), it will always be a top priority in terms of ensuring water security. Delays in the construction of the Polihali Dam will likely result in water shortages until it is completed.

Western Cape Water Supply System

The effects of declining rainfall under climate change have already been felt in the Western Cape, with severe multi-year drought leading to the recent Day Zero scenario in Cape Town. The Berg and Breede rivers are now almost fully developed and do not offer long term solutions to increasing water supply in the region. The Western Cape Water Supply System serves more than 3.2 million people, providing water to the City of Cape Town, Overberg, Boland, West Coast and Swartland towns, as well as to irrigators along with the Berg, Eerste and other local rivers (DWA, 2013). Options to increase water supplies in this system include limited surface water development, large-scale groundwater development (from the Table Mountain Group Aquifer and coastal aquifers), re-use of water and desalination of seawater (DWA, 2013). Some of these options are already being implemented as a result of the current drought. WCWDM is also being practised rigorously to realize savings and improve water security. The considerable water use of high-value crops in the region raises the question of whether this is sustainable in the long term, however, agriculture is a large employer and economic driver in the region, making this issue very complex. The region is characterized by a large inward migration of people, which places an increasing demand on water resources. The drought in the Western Cape has highlighted uncertainty around some of the roles and responsibilities for drought planning and response across the different tiers of government and should be clarified to avoid being a source of vulnerability in future or elsewhere. Until new projects to increase water supplies are implemented on a large scale, the region will remain vulnerable to climate change.

Local water supply systems

In general, local water supply systems supply water to smaller-scale settlements, irrigators, industry and other users. They are distinct from large bulk water supply systems, in that they only supply water to a local area and do not involve large scale transfers of water between catchments. The region in the Eastern Cape identified as highly vulnerable in Figure 3.5.11, is an example of an area that is dependent on local water sources. By nature, these systems are more vulnerable during drought periods, as surface water cannot be imported from elsewhere if the main source/s dry up (Cullis and Phillips, 2019). While emergency transfer pipelines are sometimes possible, these are usually very expensive to implement. Supplementation with groundwater offers a possible solution to increasing water supplies. Other potential options to improve water security include desalination (of seawater or saline groundwater - cost permitting), rainwater harvesting and WCWDM. As local water supply systems are located throughout the country and increasing drought is projected for most parts of the country, these systems are likely to become vulnerable in future if adaptation measures are not implemented.

Groundwater supply systems

As alluded to previously, groundwater resources are less affected by increases in temperature and accompanying evaporative losses. However, the impact of changes in rainfall on groundwater recharge is less well understood. In general, groundwater resources are impacted slower than surface water during drought periods and often only experience impacts after prolonged drought (DWA, 2010). Ideally, the analyses of drought in this assessment (Figures 3.5.8 – 3.5.10) should also have been repeated at longer time scales (e.g. 24 - 48 months) to more comprehensively assess potential impacts on groundwater, although the relatively short periods of assessment (30 years) would likely make it difficult to detect robust trends. However, the strong drought patterns over 12-month time periods combined with a robust signal of declining rainfall over the south-western Cape and West Coast, suggest that groundwater will be impacted in this region. Consumers of groundwater in this region include agriculture, industry and municipal users (Figure 3.5.4). More research into the impacts of climate change on groundwater is required (DWA, 2010).

Findings of the risk and vulnerability analysis are summarized in Table 3.5-2.

3.5.4 Cost Considerations Regarding Adaptation

In terms of preventing flood damage to water resources infrastructure, constructing flood control structures is not necessarily the first adaptation that should be pursued. Options such as preserving natural wetlands, which serve to attenuate floodwaters, are possibly less costly and result in other environmental benefits (e.g. water filtration). Flood early warning systems can benefit a range of sectors and can be centralized, thus saving costs. In terms of building new infrastructure, it is recommended that engineering design criteria be reviewed to minimize increased flood risks in future.

Recommendations for adaptation of stormwater infrastructure are similar to those for water resources (storage) infrastructure. Basic maintenance of these structures to keep them free of blockages become more critical and helps to minimize flood damages to other assets (properties, vehicles, roads etc.). While sustainable urban drainage systems require time and resources to develop, they deliver other environmental benefits apart from flood protection.

In terms of adapting to droughts, WCWDM can produce rapid results (regardless of the scale or nature of supply systems) and is much cheaper than developing new infrastructure, thus delaying the need to build this infrastructure (DWA, 2013a). WCWDM can be implemented across all sectors to yield savings. In particular, reducing urban leaks is a priority, as an average of 37% of the water from reticulation systems is lost to leaks or illegal connections i.e. non-revenue water (Mckenzie et al., 2012). Groundwater is underutilized and where feasible is likely to be cheaper and more environmentally friendly (considering energy requirements) than large scale desalination (DWA, 2010). Clearing alien invasive plants is an ongoing strategy to counter drought and has important benefits for employment creation. Rainwater harvesting offers a more decentralized form of water supply and is ideal for areas that are far from other water sources where water transfer costs would be high. While it is inevitable that more water storage and transfer infrastructure schemes will to need to be constructed in South Africa, the opportunities to do so are limited and the associated costs are rising sharply (DWA, 2013a).

Table 3.5-2: Summary of risk and vulnerability analysis for the water sector

Climate Change Hazard	Impact of Climate Hazard	Exposed System	Possible Adaptation Measures	Sensitivity and Adaptive Capacity	Vulnerable Areas / Groups
	Flooding (poses risks to infrastructure and water quality)	Water resources infrastructure (dams, weirs, canals, pipelines, pump stations, treatment plants etc.)	Construct flood-barriers Preserve natural wetlands or construct artificial wetlands Flood early warning systems Adapt future engineering designs	Small municipalities and user groups often lack resources to adapt	Most areas projected to experience increased flooding (SW Cape and West Coast region is a possible exception) Small municipalities responsible for their own infrastructure are likely to be more vulnerable.
		Stormwater infrastructure (culverts, drains, pipes etc.)	Sustainable urban drainage systems Good maintenance of structures (keeping free of blockages) Flood early warning systems Adapt future engineering designs	Small municipalities and user groups often lack resources to adapt	Most areas to experience increased flooding (SW Cape and West Coast region is a possible exception) Small municipalities are likely to be more vulnerable.
Increases in	Drought	Bulk water supply	Augmentation (develop new sources)	Integrated bulk water	With the exception of

Climate Change Hazard	Impact of Climate Hazard	Exposed System	Possible Adaptation Measures	Sensitivity and Adaptive Capacity	Vulnerable Areas / Groups
Extremes of Climate	(poses risks to water supply and water quality)	(supplies larger cities and users e.g. power generation, mining, irrigation)	Alternative sources (e.g. desalination) Conjunctive surface/GW use WCWDM Re-use of water Clearing of invasive alien plants	supply systems with the ability to move water to critical areas are inherently more resilient	the central interior most areas projected to experience increased severity and frequency of drought. SW Cape and West Coast will be particularly impacted. Lower priority users (e.g. irrigation) more vulnerable
		Local water supply (mostly supply towns and other users)	Augmentation (develop new sources) Alternative sources (e.g. desalination, rainwater harvesting) Conjunctive surface/GW use WCWDM Re-use of water Clearing of alien invasive plants	Areas with few/no alternative water sources have lower adaptive capacity	With the exception of the central interior most areas projected to experience increased severity and frequency of drought. SW Cape and West Coast will be particularly impacted. Lower priority users (e.g. irrigation) more vulnerable.
		Groundwater supply	New extraction sites	Areas with few/no alternative water sources	Impacts on groundwater are less certain, but a

Climate Change Hazard	Impact of Climate Hazard	Exposed System	Possible Adaptation Measures	Sensitivity and Adaptive Capacity	Vulnerable Areas / Groups
		(mostly supply smaller towns, agriculture, mining)	Artificial recharge Alternative sources (e.g. desalination, rainwater harvesting) Conjunctive surface/GW use WCWDM Re-use of water Clearing of alien invasive plants	have lower adaptive capacity	strong drought signal and a general decline in rainfall suggest SW Cape and West Coast will be impacted and become more vulnerable

4 Adaptation cost[1] functions development

4.1 Introduction

South Africa has ratified the Climate Change Paris Agreement that aims to ensure that atmospheric gases such as greenhouse gases (GHG) are reduced. Moreover, there is a need to ensure that adaptation measures are put in place. In this section of the report, we focus on costing the adaptation needs as well as the recognition of effort (i.e. previous and projected adaptation needs expenditure). In this report, we model the cost for adaptation measure that will be required to manage projected hazard incidents that are highlighted in the risk and vulnerability profile. The adaptation costing uses historic costs to project future adaptation needs costs that are identified under the risk and vulnerability profile for all sectors under consideration in chapter 3:

- Agriculture
- Water
- Biodiversity
- Health
- Human Settlements

The methodology that is adopted to develop adaptation cost functions that use the historical cost of climate incidents to determine the cost of climate change for all the sectors under consideration. The cost of climate change incidents on the economy (for not adapting) is determined to inform adaptation measures that could lessen the impacts of climate change shocks as well as the associated costs. The determined adaptation measures will inform the adaptation cost function and proxies.

The **agricultural** sector risk identified is drought which is likely to affect crops like wheat, maize, sugarcane and sorghum. Based on the risk matrices for the sector, the approach taken determine climate change historic costs of adaptation on the selected crops and estimate what could be spent in the absence of adaptation measures. Moreover, the adaptation measures are costed the over report period (2020 – 2030). **Wate**r – The adaptation cost measures will be developed for the period (2020 **-** 2030) targeting water sector infrastructure such as dams. This will entail infrastructure resilience techniques and measures to climate change associated risks such as low water levels, water leaks in the face of droughts. Infrastructure like substation can get damaged by extreme hot temperature especially those that use natural air cooling.

[1] All costs will be converted to USD at ZAR 1 = USD 13.31 (2018 average exchange rate)

Increased heat exposure as a result of climate change results in negative impacts on human **health.** In chapter 3, the identified risks associated with heat exposure relates to physiological effects, such as heat stroke and chronic diseases. Also, psychological effects that relate to diminished human performance (lack of productivity). Adaptive measures for the associated risks will be investigated.

Settlements in the coastal regions and low-lying areas are vulnerable to the risks that are associated with climate change, such as flooding, rising sea levels and strong winds. Adaptation measures for human settlements will be assessed as a measure to reduce such risks. The proposed adaptation measure will be indicated together with the associated cost that is developed from historic incidents. Literature also shows that there is a strong link between climate change and **wildfires**, which have an impact on human settlement as a result of the damages that are caused thereon. The adaptation measures for all the sectors discussed in Chapter 3 will be assessed and associated costs will be calculated using the input-output model that is discussed in section

4.2 The adaptation cost functions development methodology

The proposed adaptation measures options were mainly motivated by data availability, the socio-economic impact of projected hazards, as well as the GDP impact of historic climate hazards that South Africa recently encountered. Some sectors are in the early stages in terms of developing adaptation measures responses. Moreover, the magnitude of climate change disasters differs for each sector and regions, for example, drought impacts are likely to have diverse impacts in different provinces. As such, a selection of priority sectors was motivated by risk and vulnerability information indicated in Chapter 3 and the national priorities that are discussed in Chapter 5.

This section is aimed at presenting a summary of steps followed to estimate the adaptation needs costing. This is achieved by highlighting the assumptions introduced, limitations as well as considerations per sector towards the determination of climate exposure and hence adaptation activities. For each of the sectors, the economic costs of adaptation during the baseline period are calculated and change during the period 2021-2030 is projected by considering how climate change could make the current situation better or worse during the projection period. The method includes establishing, using climate models, the nature of hazards that are relevant for the country identifies where the impacts occurred during the baseline period and where the spatially linked changes are projected to occur during the period 2021-2030; The development of a portfolio detailing who or what should be prioritized for adaptation is based on the expert judgement of physical climate hazards and exposure information. capacity of the impacted people or area. Steps leading to the adaptation costing include:

Establishment of the **baseline information** about the physical and social context which covers, among others, spatial distribution of the population, location of infrastructure, location and type of economic activity.

Projection of information detailing how **climate change** is likely to affect the area and livelihoods of its inhabitants. This is often referred to as climate risk and vulnerability. Such a projection may include quantification of frequency, magnitude, probability, and extent of the hazards using indices derivable from modelled present and future meteoroidal variables outputs.

Projection of exposure to climate hazards by combining changes in climate and the local area or social context to determine what and/or who would be affected.

Estimation of financial expenditure required to implement adaptation options. The estimates target major adaptation activities; thus sourced support based on the costing will be informed by key interventions.

Before providing general information about the four steps and how they are undertaken in the project, it is worth presenting the key assumptions behind the chosen adaptation costing methodology.

Step 1: Baseline/current economic and climate context

The current economic context in the face of climate variability and change is quantified by looking at a baseline period projection of climate hazards. The baseline adaptation activities could be uncovered by looking at how Government addresses extreme weather events challenges. The associated data is accessible from disaster risk response to climate impacts databases? as well as the Department of Forestry, Fisheries and Environment (DFFE) through the National Climate change Information portal. The Department expenditure data cover climate-related costs, some of which have prevailed even before climate change became an issue. In South Africa, like many developing countries, there is a significant gap between how current climate variability is being addressed and how it might optimally be addressed, primarily because adaptation activities are constrained by other development challenges such as poverty and underdevelopment. On account of this, records of historic expenditure on climate variability are likely to underestimate the economic needs of adaptation.

Estimates based on scenario-based model outputs are instrumental in understanding change in risk and vulnerability, and hence adaptation needs, relative to a reference historic period. There is considerable uncertainty in understanding the probability of climate hazards from model outputs. The uncertainty is reflected by reporting change through a range of models and scenarios. In particular, the uncertainty in projecting impacts of climate change is reflected by looking at 10, 50 and 90th multi-model percentiles of the risk and vulnerability matrices. The reported risk and vulnerability analysis do not factor in social factors such as a) population growth between the baseline and projection period and b) economic growth or decline associated with drivers such as improvements in technology and political circumstances for the country.

Step 2: Change in climate risk and vulnerability

The activities towards the establishment of change in climate risk and vulnerability in the projection period are built on the assumptions that: Climate change and its associated extremes will likely have an impact on lives, physical infrastructure, and livelihoods. Proposed adaptation activities stand a chance to alleviate the undesirable impacts of climate change. Based on the first assumption, evidence of present and likely future climate hazards is developed from representative concentration pathways (RCP) scenarios which form the basis for the projected change in Global Circulation Models (GCMs). Meteorological variables are downscaled for a total of six GCMs to uncover the present and future climate physical hazards through extreme climate indices, derived from the data. The resultant extreme climate indices reflect the spatial extent, frequency, probability or even intensity of the physical hazards analysed in unison with existing geo-spatial information to come up with risk and vulnerability profiles, per priority sector, of the economy. The process is a data-intensive activity and involves the use of a high-performance computing facility at modelling stages.

The adaptation activities are proposed by sector experts and are based on the assumption that such activities will lessen the impact of climate change. To this effect, a portfolio of adaptation activities is suggested. In principle, adaptation activities include autonomous individual responses as well as government or donor-funded initiatives in response to climate impacts. The chosen approach does not consider autonomous adaptation activities.

Step 3: Projection of exposure

To quantify exposure to climate change at a local or regional context, the climate signal in a form of change relative to the baseline is combined with the baseline context or information. The future needs projection factors in climate change with the assumption that the social and economic growth will not be fundamentally different from the baseline context during the period 2021-2030. This is done for the considered sectors of the economy. The approach used to estimate exposure differs by sector.

Table 1: Summary of steps required to determine who, or what, will be exposed to climate change.

	Agriculture	**Water**	**Health**	**Biodiversity**	**Human Settlements**
Step 1: **Current Situation**	The main agricultural divisions are determined nationwide looking at grain crops livestock during the baseline period.	Flooding hazard is considered in terms of impacts on infrastructure. Drought impacts are considered in terms of the effect on water supply systems. Maps of water use, water source areas, water transfers, groundwater extraction and settlements were used to characterize the current water sect or landscape.	The regions where hazadous exposure to extreme heat a mapped to assess the spatial extend of the lives and livelihoods potentially exposed to climate hazards during the baseline period. The baseline analysis of exposure of communities asuggest that nd individuals may be more vulnerable due to factors such as their health status, location and socio-economic status, etc.	Habitat Conversion classes are created to represent loss based on the land cover change data between 1990 and 2018.	Green book quantification of vulnerability and exposure during the baseline period is used to dirive matrices for human settlement throught the country. The spatial overlays of risk are used to determine stettlement that are at risk of climate hazards nationwide.
Step 2: **Climate Change Hazards**	Baseline period as well as projection period extreme climate threshold indices based on temperature and humidity (e.g., chill, temperature-humidity index, etc.) relevant for horticulture, crop and livestock farming seasons are computed.	Changes in the frequency of large-scale rainfall events is used as an indicator of the change in flood hazards. Changes in the frequency of severe drought are used as an indicator of the change in drought hazards. Other climatic indicators of floods and droughts were also assessed. Climatic indicators were calculated over the whole country.	Increased temperatures have direct impact on human health. Increased rainfall may cause flooding which may directly affect human health through injury or death, or indirectly, through an increase in water-borne diseases. A prolonged decrease in rainfall causes drought which may adversely impact on food security.	National Land Cover Change (for 1990 and 2018), Historic (1971-2000) and projected (2020-2025, 2025-2030) meteorological viable and their derived indices, such as fire danger and drought indices are used to develop a data-driven model in the frameworks of generalized linear model and maximum entropy model.	
Step 3: Projection of Exposure and risk to Climate Change in 2021-	Geo-spatial overlays of climate extremes threshold indices in combination with baseline agriculture divisions are used	Projected changes in flood risk (according to the relevant indicators) are combined with knowledge of the location of	Geospatial overlays of projected temperature extremes with communities that are vulnerable to high temperatures can be used to demarcate areas	The probability of biodiversity loss (Habitat) during the historic and projection period is predicted based on land use and climatic drivers. The	

	Agriculture	Water	Health	Biodiversity	Human Settlements
2030	to demarcate priority types of trees, crops and livestock at risk during projection period.	infrastructure and settlements (maps in Step 1) to assess exposure. Projected changes in drought risk (according to the relevant indicators) are combined with knowledge of the location of water source areas, water use, supply systems and settlements (maps in Step 1) to assess exposure.	and populations that are at risk during the projection period. Projected changes in population size can give an indication of potential changes in exposure.	habitat loss probability is used as a matric for quantifying exposure, risk and vulnerability profiles for the whole country.	

Adaptation Costing

The costing of adaptation activities follows an assumption that adaptation activities will be implemented at a cost and therefore need to be estimated. The costing approach makes use of risk and vulnerability profiles, derived from the geospatial information of the hazards, as well as its probability and exposure information to cost implementation of adaptation options at a national level, in some cases starting at the provincial level.

The first category of adaptation activities is classified as **soft adaptation (**e.g, climate change infrastructure resilience requirements**).** These are adaptation activities that do not qualify as hard adaptation. In particular, these may not involve physical construction or object design to counter the undesirable impacts of climate change. Components of soft adaptation are difficult to categorise as they strongly overlap, but include strengthening of the following: 1) information creation and improvement through research and data collection; 2) adaptive capacity through education and awareness campaigns for communities; 3) policy development at the national and sub-national level of planning and implementation; 4) implementation of adaptation financial incentives to encourage those who are at the lower end of the adaptive capacity scale or, those who may lead to bigger impact; and 5) institutional arrangements that entail an array of activities designed to promote and support adaptation. This can range from agencies helping communities identify and implement adaption at a provincial scale, to collaborative support to national ministries in adaptation projects. While insurance efforts toward distributing the risk pool contribute to the adaptive response, the associated activities are not included in the estimation but qualify as soft adaptation.
Briefly, soft adaptation is likely to include more expenditure on labour, maintenance, and extreme climate variability response measures and little to none on capital expenditure. The associated expenditures are made by institutions for which the functional accounting system are well established and operational. In the case, that the expenditures on activities involve small funds at community scale or district level, such costs are not included in the calculation. Much focus is placed on aggregating provincials cost to a national level. The soft adaption cost function for a projection year (y) includes a correction to a baseline effective estimate for a particular activity, as well as additive corrections, accounting for climate change and inflation. See equation (1) below.

$$C_{y,r} = \quad F_{bsln} \sum_{k=1}^{N} P_{bsln}(x_h) W_{bsln}\left(x_h\right) + \ F_{proj} \sum_{k=1}^{N} Delta\ (x)\ P_{proj}(x_h) W_{proj}(x_h)$$

The first term of equation (1) estimates soft adaptation during the baseline period, where for each activity F_{bsln} represents the effective cost per region (r). In this case, r runs over provinces in the country. The effective cost is weighted by the probability of occurrence $\mathbf{P(x_h)}$ of a considered hazard $\mathbf{x_h}$ and a binary factor $\mathbf{W_{bsln}(x_h)}$ which take the value 1 if the event happens in a particular province or 0 if it does not occur during the baseline period. The baseline cost of an adaptive activity $\mathbf{F_{bsln}}$ can be found in the literature, treasury records or departmental budgets.

To account for climate change, a second correction term is added. It considers climate change through anomalies in the spatial extent of the hazard represented by the term:

$$\text{Delta}\ (x_h) = (A_{proj}(x_h) - A_{bsln}(x_h))/A_{bsln}(x_h)$$

with the probability of occurrence of the considered hazard (x_h), denoted by $P_{proj}(x_h)$, which also captures frequency of change in the hazard during the projection period, and the binary weighting factor $W_{proj}(x_h)$, capturing whether the hazard happens or not during the projection period in the considered region. The probability of occurrence and change in area extent of a particular hazard during the projection period 2021-2030, as well as the baseline period are estimated from the climate model outputs. The projections are an average over a 30-year period. To estimate the costs for a particular year, activity F_n is calculated by correcting the baseline amount for the inflation in year y. Since an activity can be in response to multiple independent hazards to which lives or livelihoods, depending on the sector, are sensitive to, we sum over all probabilities of the N independent hazards that induce an adaptation activity. The number of hazards N varies from adaptation activity to activity. The total adaptation cost per activity for the country for the projection period is given by:

$$C_{adaptation} = \sum_{r=1}^{Total\ provinces\ in\ SA} \sum_{y=1}^{Length\ of\ projection\ period(Years)} C_{r,y}$$

The cost is split into two categories. The second category can be referred to as **hard adaptation** activities (e.g., adaptation infrastructure requirements). These involve physical structures whose purpose is to prevent impacts of climate change or whose design incorporates elements that prevent these impacts. This could include capital investment. Typical examples include flood barriers or drainage systems and air conditioning systems in areas where they were not needed before. The direct costing approach of hard adaptation is fairly simple and is an estimate as per the engineering approach that proceeds their construction. This includes consideration of the envisaged social impact or environmental impact to be avoided as well as national regulatory frameworks.

$$C_{y,r} = F_{proj} \sum_{k=1}^{N} P_{proj}(x_h) W_{proj}(x_h)|$$

4.3 Adaption cost measures for agriculture, forestry and fisheries

The risk and vulnerability identified for the agriculture, forestry and fisheries are discussed in Chapter 3. In this section, we formulated adaptation needs cost for extreme heat, floods and droughts that are identified as major risks for the water sector hazards. As such, the agricultural sector plays an important role in addressing the triple challenges that the South Africa face (i.e. poverty, unemployment and inequality). Moreover, the agricultural sector has a role to play in stimulating the country's economic development. Figure 4.3-1 shows that the South African agricultural sector contributed to about 89 120.92 million ZAR towards the Gross Domestic Product (GDP) in 2018 and this contracted to 68 767.48 million ZAR in 2019 (Trading Economics, 2020a). As a result, the implications of climate change hazards on adaptation needs costs for agriculture, forestry and fisheries need to be understood. The climate change hazards such as extreme heat, droughts, wildfires and rainfall shift and drought have affected the country's agricultural sector over the years. According to the African Development Bank (AfDB, 2011), South Africa will continue to experience reduced rainfall thus reduced water availability, the African Development Bank (AfDB) projected that water reduction will decline by 20% in 2011.

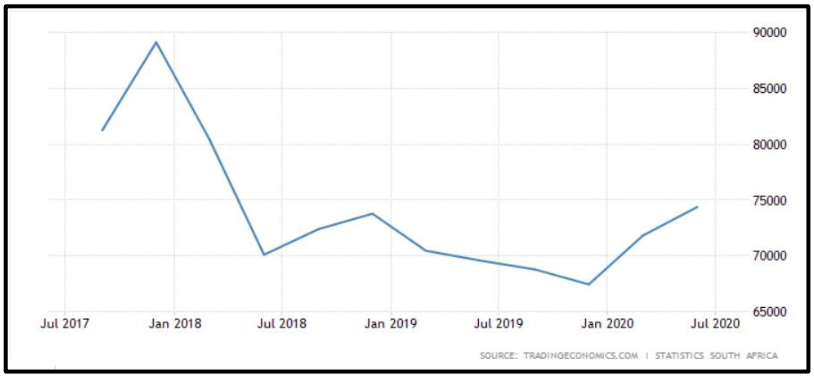


Figure 4.3-1: South African Agricultural contribution to the SA GDP

4.3.1 Adaptation cost measures development for livestock

The drought impacts not only lead to a drop in the number of animals retained by farmers but also lead to an elevated need for supplementary feeding at increased costs. The shortage and high costs of animal feed during drought are highlighted by (Mare et al., 2018). According to (Mare et al., 2018), livestock farmers indicated that drought imposes the use of any type of animal feedstuff available, regardless of price and quality. The feedstuff cost varies from very expensive and scarce sources such as lucerne hay and maize to very low-quality hay such as crop residue and even poultry manure (although it is unlawful to use manure as animal feed in South Africa). The average cost of the additional purchased feed per producer in as indicated by (Mare et al., 2018) increased from approximately R121,732/annum in 2013 to R337,020/annum in 2016, an increase of nearly 177%. The weekly cost of class A2 beef remains between 2013 and 2017 is shown in Figure 4.3-2. According to (Walker, 2018), South Africa has a population of cattle approximately 14 million head, this includes 33 types of beef breeds. Most of the operational farms own at least 100 head which yields an annual harvest of nearly 2.5 million heads. As such, the annual beef animal feed cost is inflated with 5% (South Africa – Consumer Price Index) per annum to determine the adaption needs cost between 2020 – 2040.

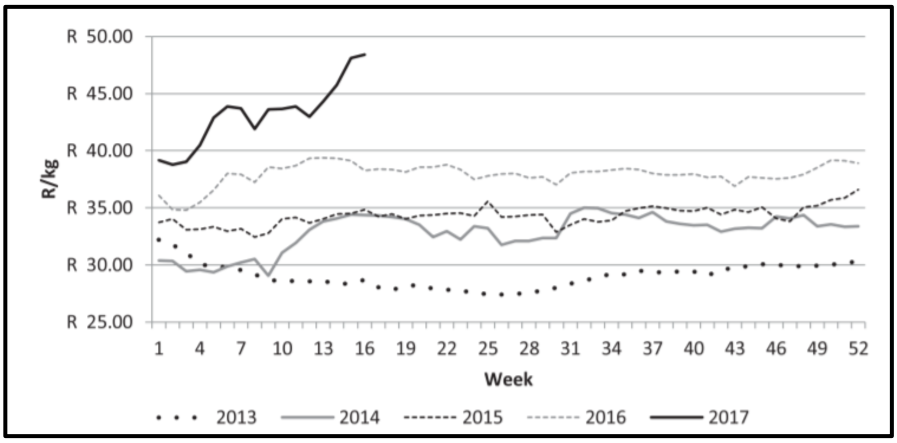


Figure 4.3-2: Weekly cost of class A2 beef escalation (Mare et al., 2018)

Although climate change hazards pose increasing challenges towards animal production, most of the research focus of climate incident has been in food crops. According to (Liverpool-tasie et al., 2019) few research studies have been conducted for livestock adaptation measures and small animal farming such as for such as poultry has not been largely considered. Heat stress linked to climate change is a serious challenge to poultry farmers, this is due to the negative effects it has on chicken growth and production outputs (Liverpool-tasie et al., 2019). Understanding how farmers manage climate change impact in poultry production is important. Contributing to the understanding, in 2018, the South African Poultry Association (SAPA) highlighted the main challenges facing the poultry industry. It reported that the epidemic of avian flu that is associated to climate change, in connection with bird migration patterns, caused a loss of revenue assessed to be R954 million and this contributed to 1 300 jobs that were lost (PMG, 2018).

4.3.2 Adaptation cost measures development for agricultural irrigation

According to Richmond et al. (2019), the intensity and frequency of extreme weather incidents and have increased for many years. These climatic changes have strengthened the case for adaptation investments. In developing countries alone, climate change adaptation measures are expected to cost between USD 280 billion to USD 500 billion per year by 2050 (Richmond et al., 2019). Approximately 46 countries that built-in adaptation cost estimates in their 2015 Nationally Determined Contribution (NDC) projected a total adaptation investment cost of USD 783 billion by 2030 (Worldbank, 2019). In 2015-16, national and multilateral Development Finance Institutions (DFIs) were the main source of adaptation investment, with an average USD 15 billion deals facilitated annually (Richmond et al., 2019). According to the Trading Economics (2020b), arable land (hectares) in South Africa was reported at 12.5 million ha in 2016. Furthermore, (Reynolds et al., 2020) shows that the adoption of new irrigation technology such as the Mobile Drip Irrigation (MDI) aims to conserve groundwater, extend the economic life of agricultural production and improve profitability. As such the adaptation cost for irrigation is adopted from (Reynolds et al., 2020) where low elevation spray application irrigation investment is estimated to be $371 per hectare. However, the cost to install irrigation infrastructure in existing facilities declines to $185 per hectare (Reynolds et al., 2020). Therefore, to irrigate the 12 500 000 arable land, however, only 1 334 562 hecters of land are irrigated in South Africa (WRC, 2015). This means that available in South Africa would cost approximately $2 312 500 000 billion (2.3 billion USD) in 2020. As a result, agricultural production can be able to grow water-intensive crops and recover the adaptation costs of converting to MDI while water use efficiency faster than producers growing standard and lower water use crops.

4.3.3 Adaptation cost development for fisheries

Figure 4.3-3 shows that South Africa exported above 90 000 tons of fish and aquatic invertebrates and generated an export value above R3.0 billion per year during the period 2008-2017. The increasing GHG have contributed to global warming, this has an impact on the oceans including changes to oceanographic characteristics. According to Food and Agriculture Organisation of the UN (FAO, 2014), adaptation costs for fisheries vary and they also depend on the local context and type of adaptation action required. The Marine Stewardship Council (2020) proposes three-step adaptation measures to ensure that the fishery industry is sustainable, namely,

- Sustainable fish stocks
- Minimising environmental impact
- Effective fisheries management

Public investment in infrastructure is needed for adaptation in the fisheries industry. The case study by the Food and Agriculture Organisation of the UN (FAO, 2014) shows that to maintain the current market trends sales growth projections until 2050 a total adaptation cost of USD 191 million is required for the aquaculture sector. As a result, adaptation funds are required to protect this industry (DAFF, 2018). For South Africa R66.3 billion rand would be needed by 2030.

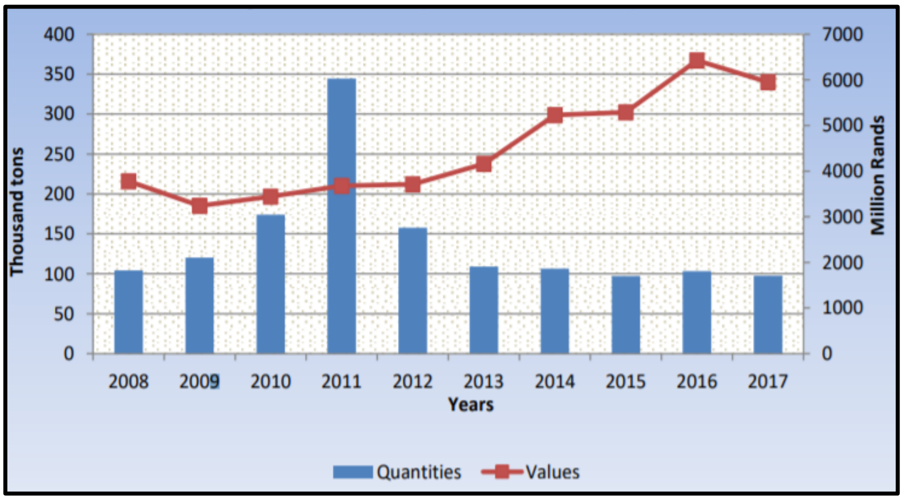


Figure 4.3-3: Fish and aquatic invertebrates exports (DAFF, 2018)

4.3.4 Adaptation cost development for forestry

South Africa has about 122 million hectares land area and only 1% (1 220 000 million h.a) of this land is used for forestry (Godsmark, 2017). According to (Afr100, 2017) South Africa has commited to restore 3.6 million hectares for water retention, landscape stability, clearing sparse, re-vegetation, soil and donga rehabilitation. Therefore the investment cost required for forestry restoration is estimated to range between USD 28 -305.9 billion (infrastructure resilience requirements and climate extremes response actions, 10^{th}, 50^{th} and 90^{th} percentile).

As such the agricultural risk matrices identified in Chapter 3, show that forestry production is sensitive to decreasing rainfall and the geographic location of a plantation will determine the extent of the impact, therefore not all provinces will be suitable for forestry plantation but these with sufficient rainfalls. The total adaptation needs cost for the agriculture, forestry and fisheries are shown in **Error! Not a valid bookmark self-reference.**, Table 4.3-2 and **Error! Reference source not found.**.

Table 4.3-1: Adaptation needs for the agricultural sector for the 10th percentile scenario

Sectoral adaptation measure	Agricultural irrigation cost	Animal feed (Beef)	Poultry farming	Fisheries	Forestry restoration
Cost description formulation	1334562 arable irrigated land X ($185*16.47)= 3046.95	14miillion cows X annual feedlot cost inflated for 7 years then by CPI	R954 million loss	191 million USD required to adapt inflated by CPI 5% ($191 m X16.47)	3600000 million h.aX ($2390X16.47) =39363.30
2021	R 225 889 614.24	R 3 064.28	R 154 443 363.56	R 68 854 613.76	R 20 405 934 720.00
2022	R 248 478 575.67	R 3 217.50	R 162 165 531.74		
2023	R 273 326 433.23	R 3 378.37	R 170 273 808.32		
2024	R 300 659 076.56	R 3 547.29	R 178 787 498.74		
2025	R 330 724 984.21	R 3 724.65	R 187 726 873.68		
2026	R 363 797 482.63	R 3 910.89	R 197 113 217.36		
2027	R 400 177 230.90	R 4 106.43	R 206 968 878.23		
2028	R 440 194 953.99	R 4 311.75	R 217 317 322.14		
2029	R 484 214 449.39	R 4 527.34	R 228 183 188.25		
2030	R 532 635 894.33	R 4 753.71	R 239 592 347.66		
Adaptation cost in real tearm (2025)	R 1 379 078 683.92	R 16 932.09	R 853 397 076.03	R 68 854 613.76	R 20 405 934 720.00
Adaptation cost in real tearm (2030)	R 3 600 098 695.15	R 38 542.21	R 1 942 572 029.67	R 68 854 613.76	R 20 405 934 720.00

Table 4.3-2: Adaptation needs for the agricultural sector for the 50th percentile scenario

Sectoral adaptation measure	Agricultural irrigation cost	Animal feed (Beef)	Poultry farming	Fisheries	Forestry restoration
Cost description formulation	1334562 arable irrigated land X ($185*16.47)= 3046.95	14miillion cows X annual feedlot cost inflated for 7 years then by CPI	R954 million loss	191 million USD required to adapt inflated by CPI 5% ($191 m X16.47)	3600000 million h.aX ($2390X16.47) =39363.30
2021	R 1 568 677 876.69	R 21 279.73	R 1 072 523 358.05	R3 145 770 000.00	R 141 707 880 000.00
2022	R 1 725 545 664.36	R 22 343.72	R 1 126 149 525.95		
2023	R 1 898 100 230.79	R 23 460.91	R 1 182 457 002.24		
2024	R 2 087 910 253.87	R 24 633.95	R 1 241 579 852.36		
2025	R 2 296 701 279.26	R 25 865.65	R 1 303 658 844.97		
2026	R 2 526 371 407.18	R 27 158.93	R 1 368 841 787.22		
2027	R 2 779 008 547.90	R 28 516.88	R 1 437 283 876.58		
2028	R 3 056 909 402.69	R 29 942.72	R 1 509 148 070.41		
2029	R 3 362 600 342.96	R 31 439.86	R 1 584 605 473.93		
2030	R 3 698 860 377.26	R 33 011.85	R 1 663 835 747.63		
Adaptation cost in real tearm (2025)	R 9 576 935 304.97	R 117 583.96	R 5 926 368 583.57	R 3 145 770 000.00	R 141 707 880 000.00
Adaptation cost in real tearm (2030)	R 25 000 685 382.97	R 267 654.21	R 13 490 083 539.36	R 3 145 770 000.00	R 141 707 880 000.00

Table 4.3-3: Adaptation needs for the agricultural sector for the 90th percentile scenario

Sectoral adaptation measure	Agricultural irrigation cost	Animal feed (Beef)	Poultry farming	Fisheries	Forestry restoration
Cost description formulation	1334562 arable irrigated land X ($185*16.47)= 3046.95	14miillion cows X annual feedlot cost inflated for 7 years then by CPI	R954 million loss	191 million USD required to adapt inflated by CPI 5% ($191 m X16.47)	3600000 million h.aX ($2390X16.47) =39363.30
2021	R 2 996 174 744.47	R 40 644.29	R 2 048 519 613.87	R 6 008 420 700.00	R 270 662 050 800.00
2022	R 3 295 792 218.92	R 42 676.51	R 2 150 945 594.56		
2023	R 3 625 371 440.81	R 44 810.33	R 2 258 492 874.29		
2024	R 3 987 908 584.89	R 47 050.85	R 2 371 417 518.00		
2025	R 4 386 699 443.38	R 49 403.39	R 2 489 988 393.90		
2026	R 4 825 369 387.72	R 51 873.56	R 2 614 487 813.60		
2027	R 5 307 906 326.49	R 54 467.24	R 2 745 212 204.28		
2028	R 5 838 696 959.14	R 57 190.60	R 2 882 472 814.49		
2029	R 6 422 566 655.06	R 60 050.13	R 3 026 596 455.22		
2030	R 7 064 823 320.56	R 63 052.64	R 3 177 926 277.98		
Adaptation cost in real tearm (2025)	R 18 291 946 432.49	R 224 585.37	R 11 319 363 994.62	R 6 008 420 700.00	R 270 662 050 800.00
Adaptation cost in real tearm (2030)	R 47 751 309 081.47	R 511 219.54	R 25 766 059 560.17	R 6 008 420 700.00	R 270 662 050 800.00

4.4 Adaption cost measures for water infrastructure

The risk and vulnerability identified for the water sector are discussed in chapter 3. In this section, we formulated adaptation needs cost for floods and droughts that are identified as a major risk for the water sector hazards. South Africa has been affected by the increase of droughts in recent years. Since 1990 - 2020, 12 years have been identified as dry years. However, in the past two decades (2000 – 2020) seven years have been defined as dry years, signalling an increase in dry years (Kalaba, 2019). The latest droughts were experienced in three consecutive years of drier conditions (2014 to 2016). Some provinces, such as the Western Cape that is the second-largest contributor to the South African GDP were affected by drought significantly. As such, the Western Cape province was forced to established strict water restrictions regulations, this included discontinuation of irrigation in some instances. At the time dams' levels dropped below 20% and this has a direct impact on the agricultural sector as well as the broader economy. More than R5 billion was lost to the economy, mainly as a result of droughts. This is significant because the Western Cape contributes about 22% of the country's national agriculture GDP (Kalaba, 2019). About 25% of the country's farmworkers are employed in the Western Cape, as such, job losses and the socio-economic impact associated with drought impacts resulted in approximately 25,000 jobs being lost in 2017 (Kalaba, 2019). Moreover, most farmworkers are not likely to get employment opportunities elsewhere in a country that stands with 30.1% unemployment rate. The drought modelling work conducted in this study shows that drought is likely to increase by 10%, therefore, the economic and socio-economic implications can be expected to follow suit. For the west coast region droughts, projection signals a 30% increase thus worsening the consequences. If drought patterns continue as projected, it's expected to negatively affect the country's financial position. This means that the country finance department will need to available financial resources to manage the impact. This cannot be sustainable in the long-term hence there is a need to invest in adaptation measures. In 2019, R3 billion was sought by farmers that were affected by droughts (Kalaba, 2019). Future assistance should focus on adaptation infrastructure development for both droughts and floods that are estimated to increase in the coming years. The adaption measures cost requirements are built based on historical spent of 2017/2018 from the shown in Figure 4.4-1. The Western Cape is a disaster-prone province that experienced climate change incidents that resulted in significant losses. For the period 2017 to 2019, a total amount of R 1.251 billion national disaster grant funding was allocated for disaster recovery and rehabilitation projects towards recent disasters such as drought, storms and fires. To build resilience in line with projected climate hazards the allocated budget spent will need to increase by 30% at minimum. The other eight provinces are assumed to need 50% of the recent historical spent in the Western Cape.

TOTAL CONDITIONAL DISASTER GRANTS March 2017 to February 2019			
Total Allocation	Amount Spent	Balance	Percentage Spent
R1 251 742 942	**R409 526 093**	**R832 216 555**	**33%**

Figure 4.4-1: Aggregate historical adaptation spent per province (National Disaster Management Centre, 2019)**.**

South African has 278 municipalities in 9 provinces that are responsible for proving basic services such as electricity, water supply, drainage and Stormwater need among others. The provision of these services come along with infrastructure maintenance responsibilities. This means that any climate change hazards incident will need to be catered and budgeted for by respective municipalities.

According to (Fisher-Jeffes and Armitage, 2013), globally, an increasing number of cities have adopted direct charges for Stormwater management to secure the funding required to manage Stormwater as well as the related water contamination, this serves as a disincentive to polluting practices on the part of the end-users. To raise adequate financial resources for Stormwater management, South Africa suggests that municipalities need to plan to charge either based on an Equivalent Residential Unit (ERU) or Residential Equivalent Factor (REF) (Fisher-Jeffes and Armitage, 2013). This report proposes that that additional funds to be raised for adaptation measures needed for climate change impacts. The stormwater Damage Avoidance Cost (DAC) was recommended to cost between ZAR 30 (2010) to ZAR110 (2010) per household monthly depending on climatic precinct and level of treatment required (Fisher-Jeffes and Armitage, 2013). As such the ZAR 30 is inflated with 10% from 2010 – 2040 to determine stormwater management cost required. This means that in 2040, the management will cost ZAR 523, 48 per household. According to (SAHRC, 2014), 60.1% of South African had access to water and sanitation services in 2013, as such, in this report we determine the stormwater adaptation cost for 60.1% of household[2] in South Africa.

According to Fuller Housing Centre (2014) the South African National Housing Code of 2000 aims to increase the housing roll-out peak to 350 000 houses per annum until the housing backlog is overcome. As such, it is assumed that 3 500 000 RDP house would be built between 2020 and 2030 which will require drainage infrastructure. Drainage costs shown in Figure 4.4-2 are inflated by 10% annually from 2010 – 2020 to determine drainage capital costs in real terms. The recent Clanwilliam

[2] In 2018, South African had 16.7 million households
https://www.statista.com/statistics/1112732/number-of-households-of-south-africa/

dam that was constructed in South Africa in 2014 cost R2.5 billion (News24, 2014). The proposed adaptation measures as well as the total adaptation needs costs are shown in Table 4.4-1.

Asset	Unit	Average cost R's (Gauteng)
Unlined channel	m	230
Lined channel	m	770
Pipe culverts (600 mm diameter; Class 100D)	m	3,600
Box culverts (1500 mm x 1500 mm)	m	17,000
Low level stream crossings	m	59,000
Dewatering (subsoil)	m	5,100
Gabions	m^3	1,300
Reno mattresses	m^3	1,600

Figure 4.4-2: Estimates of capital costs for conventional drainage design in 2010 (Armitage et al., 2013)

Table 4.4-1: Water sector adaptation needs costs for proposed measures for the 10th percentile

Sectoral adaptation measure	Sustainable urban drainage system (Stormwater maintenance charges)	Future drainage infrastructure requirements	Dam Construction	Historical Disaster Management Expenditure	Early Warning System for floods management centre
Cost description formulation	16.7 million household X R77.81 (R30 inflate by 10% from 2010)	As described by Armitage et al., 2013) (R88 614* 3500 000 RDP houses that will be developed from 2021 -2030)	R2.5 billion Clan william Dam	National Disaster Spent in the WC 2019	(100 000 million X16.47) FEWS Cost
2021	R 20 765 151 292.01	R 887 135 700.00	R396 000 000.00	R 193 949 071.19	R 2 099 728.83
2022	R 22 841 666 421.21			R 203 646 524.75	
2023	R 25 125 833 063.33			R 213 828 850.99	
2024	R 27 638 416 369.67			R 224 520 293.54	
2025	R 30 402 258 006.63			R 235 746 308.21	
2026	R 33 442 483 807.30			R 247 533 623.62	
2027	R 36 786 732 188.03			R 259 910 304.81	
2028	R 40 465 405 406.83		R 396 000 000.00	R 272 905 820.05	
2029	R 44 511 945 947.51			R 286 551 111.05	
2030	R 48 963 140 542.26			R 300 878 666.60	
Adaptation cost in real tearm (2025)	R126 773 325 152.86	R 887 135 700.00	R 396 000 000.00	R 1 071 691 048.68	R 2 099 728.83
Adaptation cost in real tearm (2030)	R330 943 033 044.79	R 887 135 700.00	R 792 000 000.00	R 2 439 470 574.81	R 2 099 728.83

Table 4.4-2: Water sector adaptation needs costs for proposed measures for the 50th percentile

Sectoral adaptation measure	Sustainable urban drainage system (Stormwater maintenance charges)	Future drainage infrastructure requirements	Dam Construction	Historical Disaster Management Expenditure	Early Warning System for floods management centre
Cost description formulation	16.7 million household X R77.81 (R30 inflate by 10% from 2010)	As described by Armitage et al., 2013) (R88 614* 3500 000 RDP houses that will be developed from 2021 -2030)	R2.5 billion Clanwilliam Dam	National Disaster Spent in the WC 2019	(100 000 million X16.47) FEWS Cost
2021	R144 202 439 527.86	R 6 160 095 700.00	R 2 750 000 000.00	R 1 346 868 549.94	R 14 581 450.22
2022	R158 622 683 480.64			R 1 414 211 977.43	
2023	R174 484 951 828.71			R 1 484 922 576.30	
2024	R191 933 447 011.58			R 1 559 168 705.12	
2025	R211 126 791 712.74			R 1 637 127 140.38	
2026	R232 239 470 884.01			R 1 718 983 497.39	
2027	R255 463 417 972.41			R 1 804 932 672.26	
2028	R281 009 759 769.65		R 2 750 000 000.00	R 1 895 179 305.88	
2029	R309 110 735 746.62			R 1 989 938 271.17	
2030	R340 021 809 321.28			R 2 089 435 184.73	
Adaptation cost in real tearm (2025)	R 880 370 313 561.52	R 6 160 095 700.00	R 2 750 000 000.00	R 7 442 298 949.17	R 14 581 450.22
Adaptation cost in real tearm (2030)	R 2 298 215 507 255.49	R 6 160 095 700.00	R 5 500 000 000.00	R 16 940 767 880.61	R 14 581 450.22

Table 4.4-3: Water sector adaptation needs costs for proposed measures for the 90th percentile

Sectoral adaptation measure	Sustainable urban drainage system (Stormwater maintenance charges)	Future drainage infrastructure requirements	Dam Construction	Historical Disaster Management Expenditure	Early Warning System for floods management centre
Cost description formulation	16.7 million household X R77.81 (R30 inflate by 10% from 2010)	As described by Armitage et al., 2013) (R88 614* 3500 000 RDP houses that will be developed from 2021 -2030)	R2.5 billion Clanwilliam Dam	National Disaster Spent in the WC 2019	(100 000 million X16.47) FEWS Cost
2021	R 275 426 659 498.21	R 11 765 695 700.00	R 5 252 500 000.00	R2 572 518 930.38	R 27 850 569.92
2022	R 302 969 325 448.03			R2 701 144 876.90	
2023	R 333 266 257 992.83			R2 836 202 120.74	
2024	R 366 592 883 792.11			R2 978 012 226.78	
2025	R 403 252 172 171.33			R3 126 912 838.12	
2026	R 443 577 389 388.46			R3 283 258 480.02	
2027	R 487 935 128 327.30			R3 447 421 404.02	
2028	R 536 728 641 160.03		R 5 252 500 000.00	R3 619 792 474.23	
2029	R 590 401 505 276.04			R3 800 782 097.94	
2030	R 649 441 655 803.64			R3 990 821 202.83	
Adaptation cost in real tearm (2025)	R 1 681 507 298 902.51	R 11 765 695 700.00	R 5 252 500 000.00	R 14 214 790 992.91	R 27 850 569.92
Adaptation cost in real tearm (2030)	R 4 389 591 618 857.98	R 11 765 695 700.00	R10 505 000 000.00	R 32 356 866 651.96	R 27 850 569.92

4.5 Human Settlements

The size of rural communities is reducing, due to urbanization where it currently sits at 39% of the population residing in the rural and estimates by the Department of Rural Development and Land Affairs (DRDLA, 2013) that the population will further decrease to 20% by 2050. This is due to urbanisation to cities that generally offer better economic opportunities.

4.5.1 Flooding (inland and coastal)

Adapting to the risks identified for human settlement are discussed in chapter 3. As such, in this section, we focus on developing adaptation needs cost for the proposed adaptation measures. An example of the cost of the rising sea level that leads to storm surges and erosion in South Africa is the Cape Town area, where the Milnerton municipality has embarked on removing its residents (and other regions affected too). According to Alves (2019), the city spent R13.5 million for recovering and restoration of the infrastructure that was damaged, in the year 2018.

Research findings show that adaptation to reduce the impact of the rising sea levels in the coastline can be achieved through the addition of sand to the beaches to prevent erosion and also for flooding; this can be prevented by building dikes (The Conversation, 2018). However, such an exercise requires a heavy investment, which is estimated in billions of Rands. As such, we project the adaptation costs for flooding associated sea-level rise.

Table 4.5-1: Estimated adaptation cost measures for human settlement (10th Percentile projection)

Sectoral adaptation measure	Rehabilitation of coastal dunes and forestry vegetation	Development of fire breaks
Cost description formulation	The cost is estimated by Chamberlain et al., for implementation of the coastal dunes and vegetation plantation	The case is built on the rural area, based on a 1% of the area dedicated for firebreaks. The cost calculated on a 8341 ha.
2021	R 184 526 419.01	R 205 702 865.63
2022		R 215 988 008.91
2023		R 226 787 409.35
2024		R 238 126 779.82
2025		R 250 033 118.81
2026		R 262 534 774.75
2027		R 275 661 513.49
2028		R 289 444 589.17
2029		R 303 916 818.62
2030		R 319 112 659.56
Adaptation cost in real tearm (2025)	R 184 526 419.01	R 1 136 638 182.53
Adaptation cost in real tearm (2030)	R 184 526 419.01	R 2 587 308 538.12

Table 4.5-2: Estimated adaptation cost measures for human settlement (50th Percentile projection)

Sectoral adaptation measure	Rehabilitation of coastal dunes and forestry vegetation	Development of fire breaks
Cost description formulation	The cost is estimated by Chamberlain et al., for implementation of the coastal dunes and vegetation plantation	The case is built on the rural area, based on a 1% of the area dedicated for firebreaks. The cost calculated on a 8341 ha.
2021	R 1 281 433 465.33	R 1 428 492 122.42
2022		R 1 499 916 728.54
2023		R 1 574 912 564.96
2025		R 1 736 341 102.87
2026		R 1 823 158 158.02
2027		R 1 914 316 065.92
2028		R 2 010 031 869.21
2029		R 2 110 533 462.67
2030		R 2 216 060 135.81
Adaptation cost in real tearm (2025)	R 1 281 433 465.33	R 7 893 320 712.00
Adaptation cost in real tearm (2030)	R 1 281 433 465.33	R 17 967 420 403.62

Table 4.5-3: Estimated adaptation cost measures for human settlement (90th Percentile projection)

Sectoral adaptation measure	Rehabilitation of coastal dunes and forestry vegetation	Development of fire breaks
Cost description formulation	The cost is estimated by Chamberlain et al., for implementation of the coastal dunes and vegetation plantation	The case is built on the rural area, based on a 1% of the area dedicated for firebreaks. The cost calculated on a 8341
2021	R 2 447 537 918.78	R 2 728 419 953.81
2022		R 2 864 840 951.50
2023		R 3 008 082 999.08
2024		R 3 158 487 149.03
2025		R 3 316 411 506.48
2026		R 3 482 232 081.81
2027		R 3 656 343 685.90
2028		R 3 839 160 870.19
2029		R 4 031 118 913.70
2030		R 4 232 674 859.39
Adaptation cost in real tearm (2025)	R 2 447 537 918.78	R 15 076 242 559.91
Adaptation cost in real tearm (2030)	R 2 447 537 918.78	R 34 317 772 970.91

4.5.2 Wildfires

Rural communities are most vulnerable, and they are negatively impacted by the climate change in many ways, which can be referred to as climate extremes. These are presented in the rain that is below the average or normal and temperatures that are higher than average and this resulting to veld or wildfire risks (DRDLA, 2013).

Efforts taken to compensate for loses due to wildfires and the reduction of the frequency and severity of the wildfires. Land management activities help with the reduction of the frequency and severity of such fires. Also measures such as early warning and detection systems of fire that will alert of fire within 5 minutes and thus reduce the expenses on suppressing the fire (The Monitor Climate, 2012). Fire serves as an essential component of the health of the ecosystem, for several habitats. However, catastrophic fires lead to mortality of vegetation, thus affecting the ecosystem.

4.5.3 Adaptation cost measures – coastal and inland flooding

There are adaptation measures that have been identified for human settlements, to deal with flooding (CSIR, 2019). Figure 4.5-1 shows the list of some of the measures that were identified that can be considered in dealing with the problems of flooding.

Flooding Adaptation measures

- Defining the urban expansion/urban edge. The spatial plan
- Protection of critical infrastructure (bridges, sewer systems, portable water, transportation, energy systems, sanitation, IT), leads to significant investment
- Identification of vulnerable infrastructure to climate change and added to the Spatial Development Framework. The infrastructure that is important to the functioning of the settlement
- Identification of the appropriate areas where vegetation coverage can be increased, to be noted in the Spatial Development Framework. These spaces can be used for planting more trees, shrubs and other vegetation.
- Connection of the key transit nodes to support climate resilience. Creation of settlements that are connected
- Identification of vulnerable communities that are located in high risk areas and include in the Spatial Development Framework, for protection and possible relocation.
- Identify open spaces that can be used, for recreation, stormwater management, and mitigation of heat waves by cooling air.

Figure 4.5-1: Adaptation measures identified for flooding

An adaptation measure for flooding includes the restoration and building of natural or artificial dunes, which includes building fences and planting of vegetation to stabilize the dunes (CSIR, 2019). Costs accounting for the building and restoration of dunes was discovered to be R1.147 billion (price inflation accounted for from the year 2003, from R508 million) (Chamberlain et al., 2005). The estimated cost of rehabilitation of coastal dunes and vegetation plantation is at a current value of

R1.148 billion. The projection of the rehabilitation, over the years (within 10 years) is shown in Figure 4.5-2.

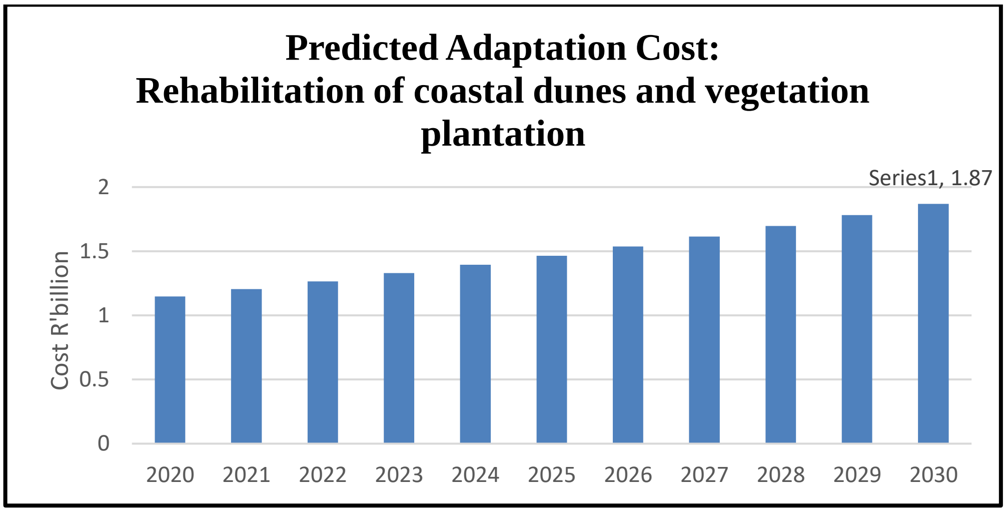


Figure 4.5-2: Projected cost of rehabilitation of coastal dunes and vegetation plantation

The cost for the rehabilitation and maintenance of the coastal dunes and the plantation of vegetation is estimated to cost R1.870 billion in 2030, over 10 years at an escalation rate of 5%. The adaptation cost shows a 62% increase from 2020 to 2030. The adaptation costs needs are shown in

.

4.6 Wildfires

On a global perspective, the regions that are adversely affected, by the climate change is expected to increase the area that is burned and may result to more sever more damaging fires. In this case, the suppression costs per hectare could overwhelm the capabilities of firefighting. A case study shows that for fires associated with climate change, the resources will be required to be doubled, with an increase of 15% fire load (Yeo and Bailey, 2019). An example is a fire that broke out in Knysna area in 2017, where the total economic cost was estimated at R3.3 billion to deal with the incident, according to Stellenbosch University (Booysen, 2019).

Adaptation measure, such as wildfire management which work towards accommodation of fire, are likely to be better than the suppression approach.

indicates some of the adaptation measures of dealing with the fires.

Table 4.6-1: Adaptation strategies for wildfires

Adaptation strategy or action	Type of strategy
Creation of firebreaks for prevention of wildfire from spreading and protection of infrastructure and vegetation.	Win-win
Limit the development of settlements on slopes, in which such areas are at high fire risk	Win-win

The win-win strategy is an adaptation measure that contributes to the adaptation and also has other benefits such as social, environmental and economic. Both the fire break development and the limitation of settlements on slopes are deemed win-win strategies (CSIR, 2019).

4.6.1 Creation of fire breaks

A gap created between vegetation to prevent the spread of fire. The size of the firebreak could be between 2.5-3m wide for crop residue, agricultural land or road verge. However, farm infrastructure and homesteads, the firebreak can be 10m wide.

The estimated cost for developing firebreaks was based on the rural communities, based on the land that was awarded by the government estimated at 834134ha (DRDLR, 2017). The estimated cost for the machinery that will be required for the development of the firebreaks, was based on the Guide to Machinery Cost report (USDA-Natural Resources Conservation Service, 2013), where the inflation over the years was taken into consideration from 2012 to determine the current price (DAFF, 2013). Further predictions were made taking an estimate of 3% inflation until 2030.

Figure 4.6-1 shows the cost estimate for the next decade that will have to be considered as an adaptation measure for veld fires, in the protection of the people in the rural communities.

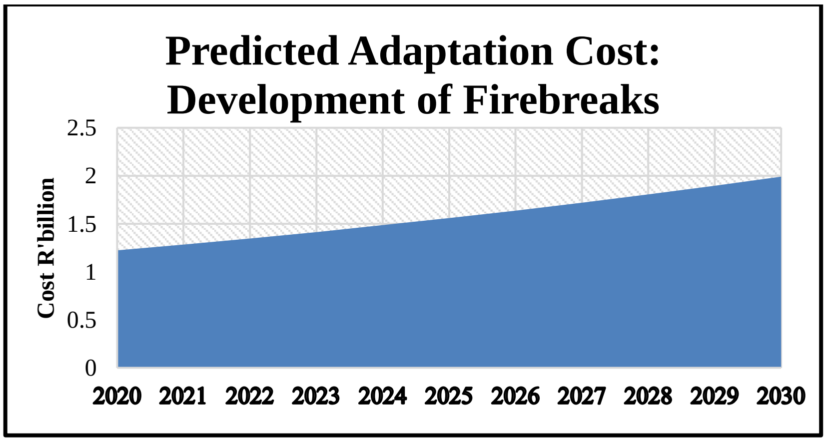


Figure 4.6-1: Projected adaptation costs for the development and maintenance of firebreaks

The cost is predicted to increase steadily year-on-year, for establishing and maintenance of fire breaks, predominantly in the rural areas, at R1.222 billion in 2020. By 2030, the cost will be at R1.991 billion. The accumulated spend for maintaining the firebreaks amounts to just over R17 billion, in 2030. The risk and vulnerability identified for the human settlement sector included flood and wildfires as the illustration above. Therefore, the adaptation needs costs and proposed measured are illustrated in **Error! Reference source not found.**.

4.7 Biodiversity

South Africa is estimated to spend R127.4 million between 2021 and 2030 for the servicing and maintaining the ecosystem that accounts for terrestrial, freshwater and estuarine habitats (Turpie et al., 2017; WRC, 2011). The balance between development and conservation of the ecosystem is a difficult exercise given other priorities for the country which are more pressing, such as poverty, whilst the ecosystem faces threats to climate change, alien invasive species, pollution, overexploitation of land and many others. The grassland biome, which relates to fodder demand for livestock, as the result of the soil, landscape and climate, it is also the preferred location for expansion of crop production. Replacement value of fodder for South Africa, which is more than the livestock production at R39.75 billion worth of products that will be lost if services are lost and completely degraded (Turpie et al., 2017). According to Department of Environmental Affairs (DEA, 2015a), some of the threats for this biomes include the conversion of cropland into human settlements and mining activities.

4.7.1 Adaptation cost measures for biodiversity

Figure 4.7-1 shows options for some of the adaptation measures that can be considered in dealing with the loss of biomes nationwide (DEA, 2015).

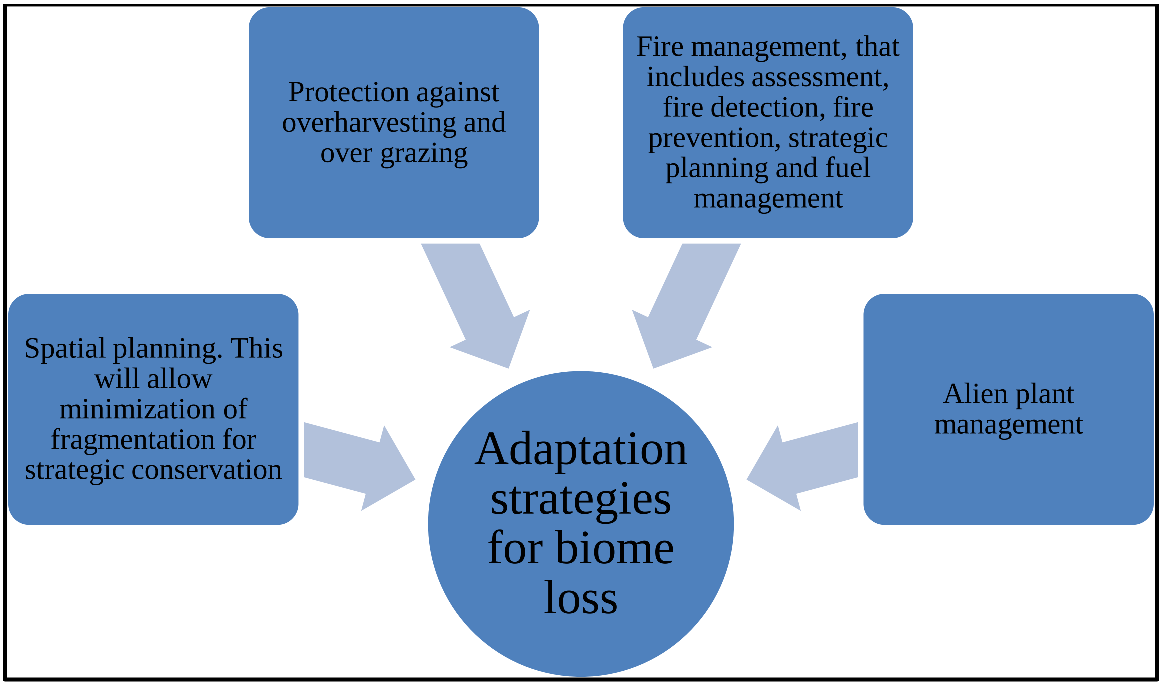


Figure 4.7-1: Adaptation measures for biome loss

4.7.2 Adaptation costs measures for invasive species

Clearing of the invasive species in the period 2002/2003 was reported by to be as high as R2 259/ha (as in 2020, whilst it was quoted to be R1000/ha in 2003).

Table 4.7-1 is the cost for clearing the invasive alien species, estimated in the study (Van Wilgen et al., 2004) and further calculated to the current values, taking into consideration the inflation.

Table 4.7-1: Cost of clearing the invasive alien species

Cost of clearing invasive alien species	Total cost (R' million) in 2002/2003	Total cost (R' million) in 2020
Eastern Cape	63.072	142.46
Free State	21.688	48.99
Gauteng	25.204	56.92
KwaZulu Natal	46.288	104.56
Limpopo	43.296	97.80
Mpumalanga	47.730	107.81
Northern Cape	21.688	48.99
North West	19.321	43.32
Western Cape	62.850	141.96
Total	**351.137**	**792.81**

Therefore R792.81 million is the total annual cost for clearing the alien invasive species, in the current rand value. However, for the prediction for the next decade is outlined in Figure 4.7-2.

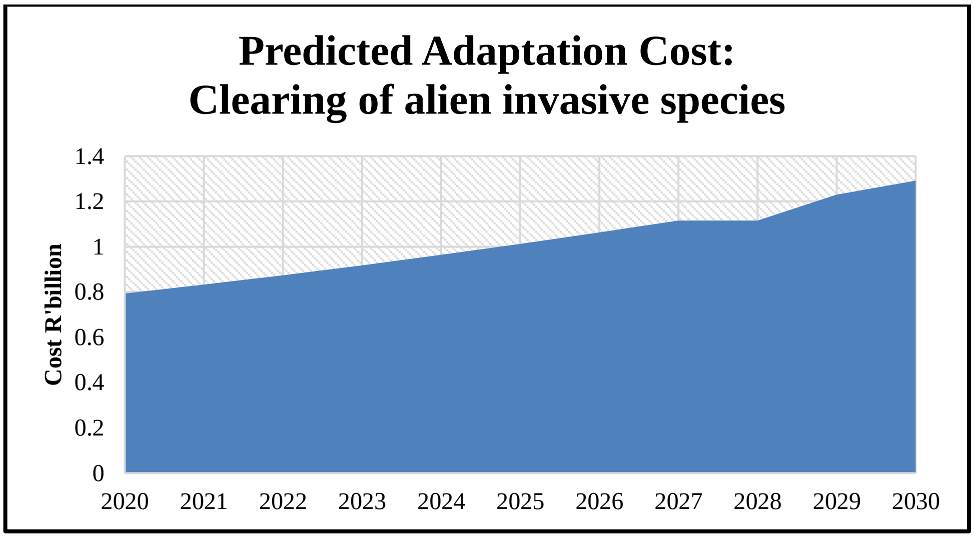


Figure 4.7-2: Adaptation cost predicted for clearing invasive alien species

The cost of removal and maintenance of the alien invasive species is estimated to gradually increase over the years, taking into consideration an estimate of 5% inflation rate and will reach R1.292 billion in 2030. The accumulated spend over the 10 years, results to R11 billion, which will ensure availability of the grassland biome that is vital for the livestock.

4.8 Health

Health is one sector that is vulnerable to climate change. The risk and vulnerability are discussed in chapter 3. Identified health risks are extreme temperatures, poor air quality, extreme weather events that required adaptation measures. The proposed adaptation measures are discussed from section 4.7.1 to 4.7.5.

4.8.1 Psychological effects adaptation measures

Some of the adaptation measures include consideration of building technology and building material-thermal properties that will lead to buildings that are naturally comfortable concerning climate (Magadza, 2000). Whilst other adaptation measures for loss of productivity due to the heat from climate change includes applying cooling systems at the workplace, the provision of sufficient cool, drinking water to the staff and also shifting the work to the times that are much cooler in the day (Kjellstrom, et al., 2016).

For minimizing the effects of heat stress during work, which however have an impact on labour productivity, is taking frequent rest breaks. These provide an opportunity for cooling off and for recovery. Another adaptation measure identified includes installation of external solar blinds, for blocking the sun which reduces the incoming solar radiation (Costa et al., 2016).

4.8.2 Other physiological impact adaptation measures

The impact of climate change on the mortality rate is affected by factors including the changes in medical treatment, medical infrastructure and lifestyle, which may have a greater effect on mortality than climate change. Some of the diseases that are increased by climate change effects. They include following asthma and respiratory diseases, diarrhoea, malaria, gastrointestinal tract and cancer (Deschênes and Greenstone, 2017). The Department of Health (NDoH, 2018a) recognizes that the successful interventions to improve the health outcomes comes from strengthening the effectiveness of the health system which serve as the foundation. Therefore, a National Health Insurance (NHI) system could be a measure that can deal with the related requests.

4.8.3 Proposed adaptation costs measures

The cost estimate for the adaptation actions identified is outlined in the Table 4.8-1 for the health care infrastructure, cooling system and solar blinds.

Table 4.8-1: Basic cost estimates for the adaptation measures

Adaptation strategy or action	Affected areas	Estimated cost	Total cost	Source
Cooling system	Manufacturing facilities – measurements, per square meter of the building	0.12Kw and 0.15kW per square meter of the room that needs cooling. The average cost of electricity according to City Power is R1.76	R0.211 – R0.264 per m^2 of the building that needs cooling Plus, the installation cost of R608.17. The total cost is R608.43 per m^2	(Costa et al., 2016; City Power Johannesburg, 2020)
Solar blinds	Manufacturing facilities - measurements based on per square meter of the building	Average cost as per the study findings R317.76 per m^2	R317.76 per m^2	(Costa et al., 2016)

Adaptation strategy or action	Affected areas	Estimated cost	Total cost	Source
Health care infrastructure that is more prepared and accessible	Disadvantaged communities, in the informal sector	It is estimated that R222 billion for the implementation of the National Health Insurance (NHI)	R222 billion	(Econex, 2010)
Early Warning System: Vector-Borne Diseases	At the national level	R17 811 annual cost	R455 837 accumulated cost for license and software	(Wilcox et al., 2019)
Initial implementation phase and the ongoing intervention costs are projected to be approximately €7.47 million	Infrastructure requirements	R97 601 158 504	R97 601 158 504	(Murphy et al., 2018)

4.8.4 Cooling system

Costing a factory, a car manufacturing factory was used as a case study, as it is a contributor to the GDP- manufacturing sector. This industry contributes about 6.8% on GDP and accounts for 4.3% of the manufacturing sector. The average size of such a factory is typically 520 963m^2 (factory in Uitenhage). The cost of implementation on a cooling system, for the car manufacturers in South Africa, considering the eight sites nationwide, amounts to R185 million upfront cost as per the pricing cost by AC Direct (2020), with an estimate of R20 million for maintenance of the system on an annual basis (Mikar-Air, 2020).

Figure 4.8-1 illustrates the costs associated with the implementation of the cooling system in the car manufacturing factories which requires a capital investment of R185 million for 8 sites in the first year. The costs thereafter are accounted only for maintenance at R20million per year. The total cost within the decade amounts to R438 million, for the system will help alleviate productivity loss due to heat exposure as a result of climate change.

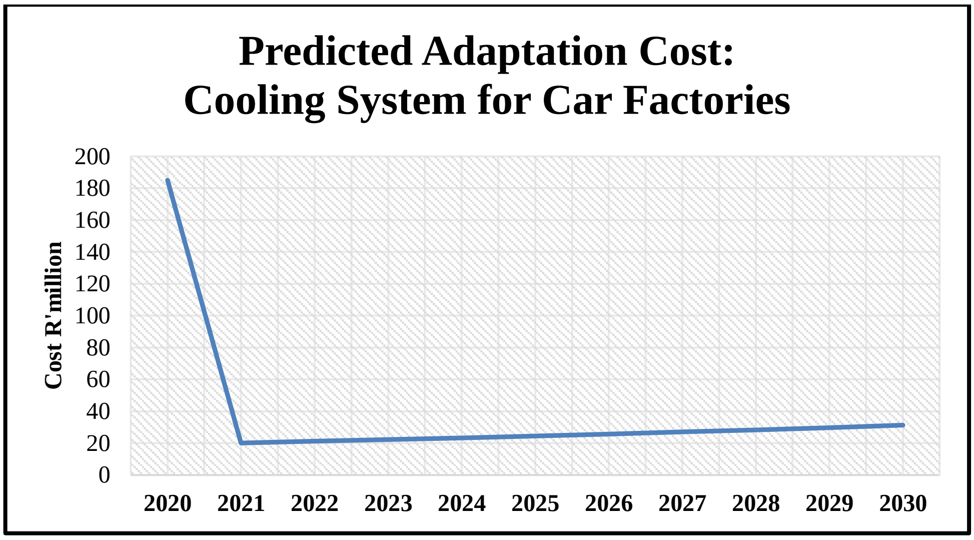


Figure 4.8-1: Predicted adaptation cost for the cooling system for the car manufacturing industry

4.8.5 Vector-borne diseases

The economic cost of malaria, according to (Tren, 1998) which includes direct costs such as treatment/care and control and also indirect costs that covers the cost due to productivity losses and future earning from death, was estimated to be R361 million in current value (initial estimate of R124 million as in 1998). The identified adaptation measure for vector-borne diseases is the implementation of meteorological forecasting platforms. An Early Detection System or Early Warning System which are based on the capability of use of the existing monitoring datasets from earth observation satellite (which are free), however, this need to be coupled with the GIS software (WHO, 2004). The model forecast is based on the prediction of disease in the areas surveyed and the ones that are not surveyed. The Geographic Information System (GIS) according to Caliper (2020), the South African license costs R11 356 for a 10-year license, plus the annual upgrades that cost R6 454. However, the cost of understanding these impacts as well as developing the necessary adaptation measures is more expensive. For example, the investment in the early warning system might have an affordable initial cost and low operational cost, however, the cost of setting up the hydrological weather monitoring is a major adaptation cost.

Table 4.8-2: Health sector adaptation needs costs for proposed measures (10th Percentile)

Sectoral adaptation measure	Clearing of invasive species	
Cost description formulation	Gis Software cost R11 356 + R6454 Subscription fee (7.47 million pounds) Murphy et al.) 7.47 million/ 1.28 (averg USD/GBP) = USD 58359375 *16.47 =96 117 890 625	Cooling system case built on car manufacturing factories, 8 located in SA. Factory area of 520 000 sqm, to use 2800 units. Cost covered: units and annual service fee. service fee at R20 million
2021	R 19 591.00	R 29 756 206.76
2022		R 31 244 017.10
2023		R 32 806 217.95
2024		R 34 446 528.85
2025		R 36 168 855.29
2026		R 37 977 298.06
2027		R 39 876 162.96
2028		R 41 869 971.11
2029		R 43 963 469.67
2030		R 46 161 643.15
Adaptation cost in real tearm (2025)	R 19 591.00	R 164 421 825.96
Adaptation cost in real tearm (2030)	R 19 591.00	R 374 270 370.91

Table 4.8-3: Health sector adaptation needs costs for proposed measures (50th Percentile)

Sectoral adaptation measure	Clearing of invasive species	
Cost description formulation	Gis Software cost R11 356 + R6454 Subscription fee (7.47 million pounds) Murphy et al.) 7.47 million/ 1.28 (averg USD/GBP) = USD 58359375 *16.47 =96 117 890 625	Cooling system case built on car manufacturing factories, 8 located in SA. Factory area of 520 000 sqm, to use 2800 units. Cost covered: units and annual service fee. service fee at R20 million
2021	R19 591.00	R 206 640 324.73
2022		R 216 972 340.97
2023		R 227 820 958.02
2024		R 239 212 005.92
2025		R 251 172 606.21
2026		R 263 731 236.52
2027		R 276 917 798.35
2028		R 290 763 688.27
2029		R 305 301 872.68
2030		R 320 566 966.32
Adaptation cost in real tearm (2025)	R19 591.00	R1 141 818 235.85
Adaptation cost in real tearm (2030)	R19 591.00	R2 599 099 797.99

Table 4.8-4: Health sector adaptation needs costs for proposed measures (90th Percentile)

Sectoral adaptation measure	Clearing of invasive species	
Cost description formulation	Gis Software cost R11 356 + R6454 Subscription fee (7.47 million pounds) Murphy et al.) 7.47 million/ 1.28 (averg USD/GBP) = USD 58359375 *16.47 =96 117 890 625	Cooling system case built on car manufacturing factories, 8 located in SA. Factory area of 520 000 sqm, to use 2800 units. Cost covered: units and annual service fee. service fee at R20 million
2021	R 19 591.00	R 394 683 020.24
2022		R 414 417 171.25
2023		R 435 138 029.81
2024		R 456 894 931.30
2025		R 479 739 677.87
2026		R 503 726 661.76
2027		R 528 912 994.85
2028		R 555 358 644.59
2029		R 583 126 576.82
2030		R 612 282 905.66
Adaptation cost in real tearm (2025)	R 19 591.00	R 2 180 872 830.47
Adaptation cost in real tearm (2030)	R 19 591.00	R 4 964 280 614.16

4.9 Adaptation spent recognition of effort by the South Africa government

Error! Reference source not found. shows the total adaptation needs costs for South Africa are estimated to amount to USD 122.8 billion in 2025 and USD 374.5 billion by 2030 for all the proposed adaptation measured discussed in this section. The adaptation cost has been adjusted by 4% to reflect the impact of climate change on the South African GDP, however, (Kings, 2019), shows that the research published by Stanford University confirms that South Africa is 10 – 20% poorer than it would have been without climate change impacts. As such, investments that will ensure that South Africa continues to grow while its climate change adaptation measures are put in place is crucial. The total adaptation needs costs are estimated to be approximately USD 374.5 billion. This cost represents all the adaptation measured required in all the sectors considered in this sector.

4.9.1 South African national government adaptation expenditure between 2013 and 2020

Figure 4.9-1 shows the South African government adaptation spending since 2013. The adaptation spending has grown from R5 billion annual spent in 2013 to nearly R 9 billion annual spent in 2020, this is a significant milestone in a country that is confronted by socio-economic challenges, high unemployment rate and inequality. A department's programmes are the activities that it spends money on during the financial year. Different programmes have different budgets, depending on their objectives and available budgets. More detail on the programmes is available in the department's Estimates of National Expenditure documents.

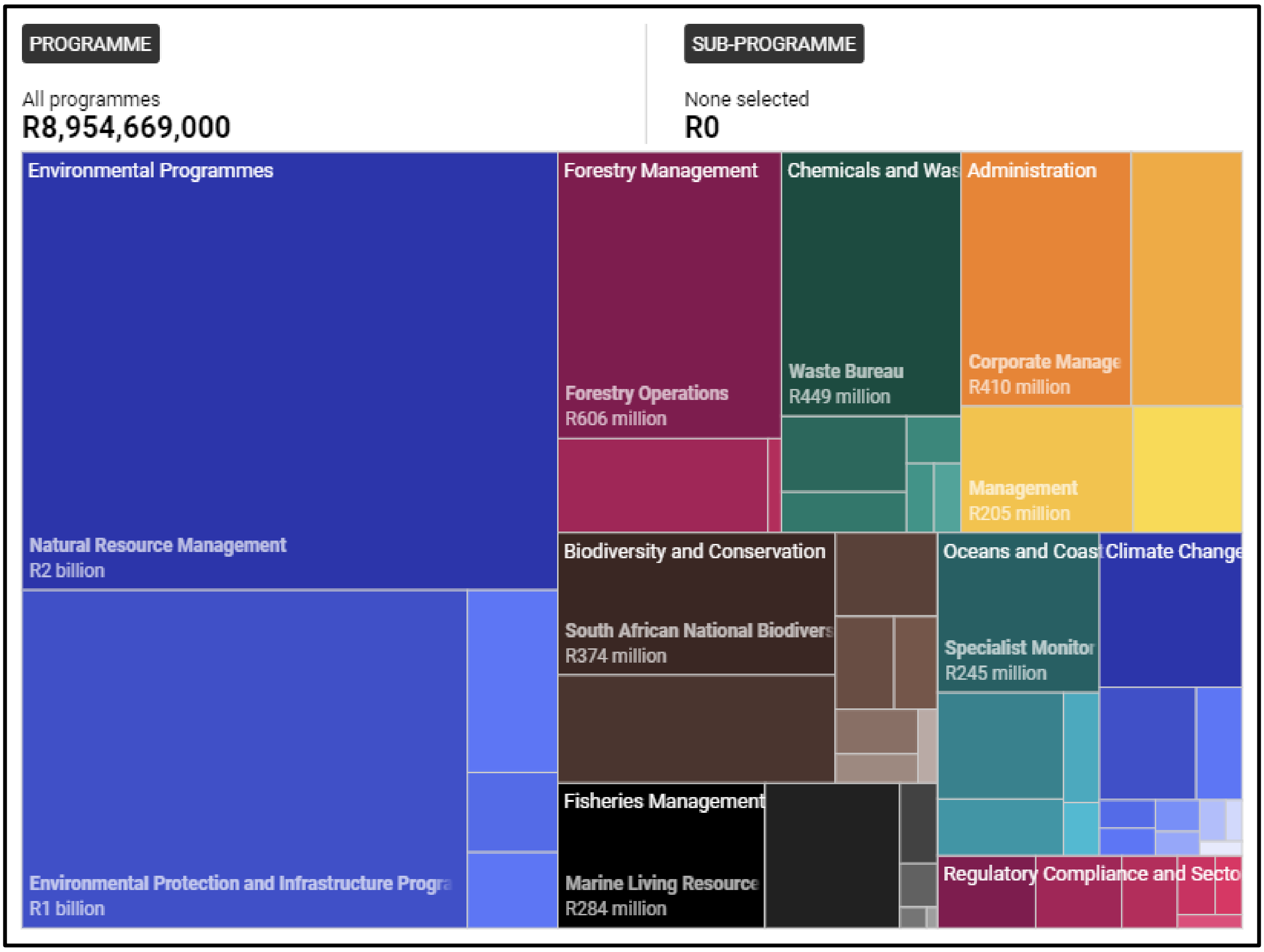


Figure 4.9-1: South African government adaptation spent between 2013 – 2020 (DFFE, 2020).

Figure 4.9-2 shows that budget has been also allocated for new initiatives such as legal, authorisation, compliance and enforcement as well as the climate change, air quality and sustainable development programmes. These are efforts that have been put in place to manage the South African adaptation measures.

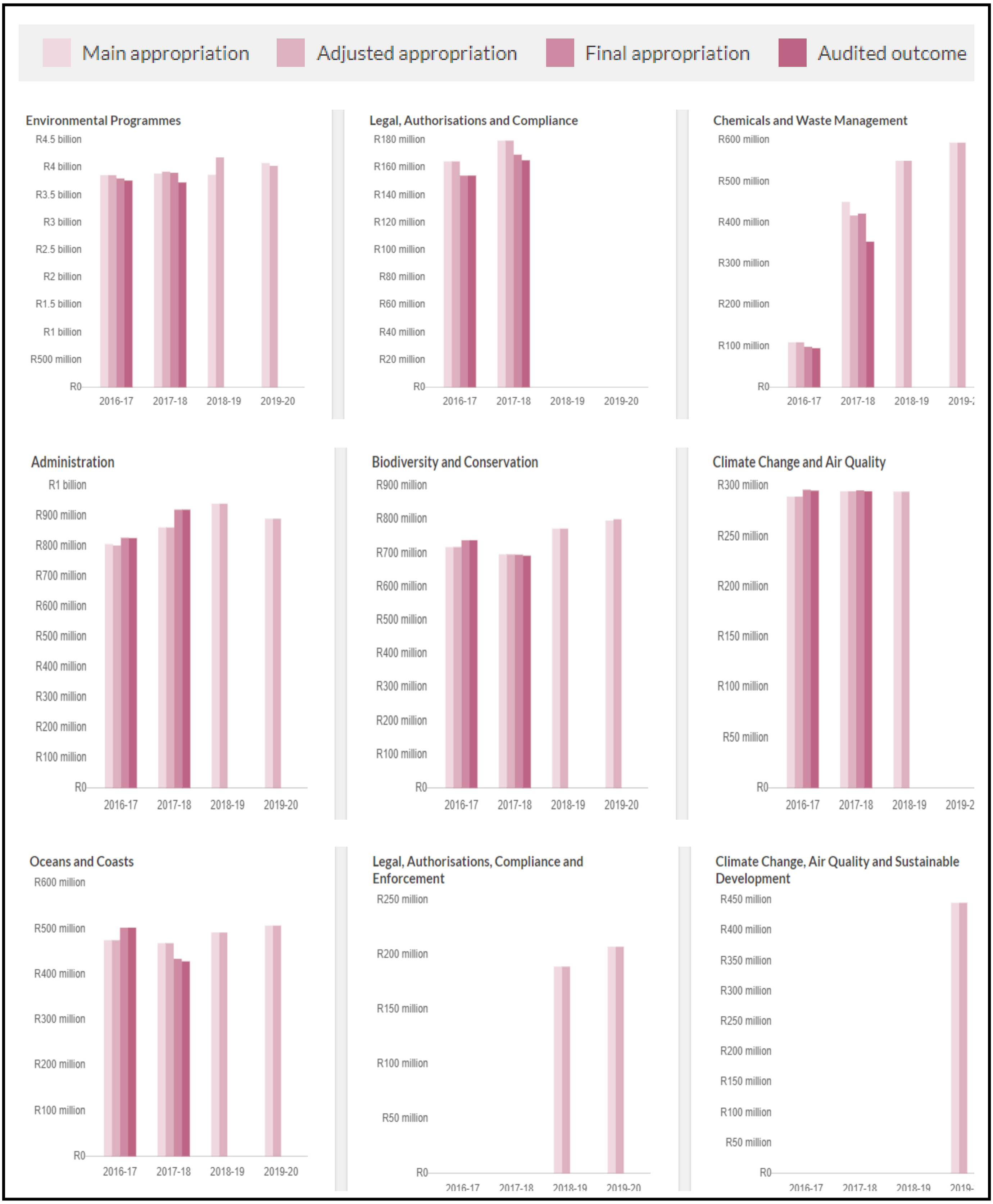


Figure 4.9-2: Audited African adaptation spent (DFFE, 2020).

The total national recognition of effort spent from the South African national government is R42 billion (USD 3.2 billion) from 2015 – 2020 (see Figure 4.9-3). This illustrated the efforts that the South African government has embarked on since 2015. Moreover, the recognition of effort should be perceived in light of the low economic growth trajectory that South Africa has experienced between 2015 -2020.

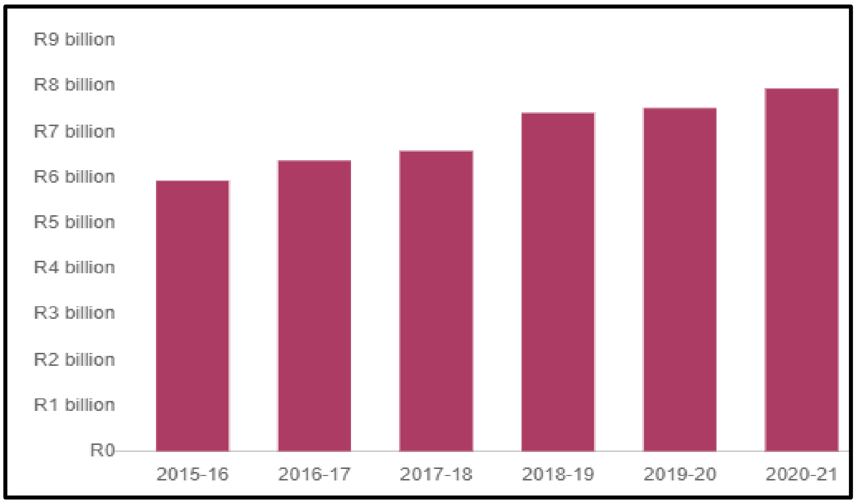


Figure 4.9-3: 2015 – 2020 South African government adaptation efforts (National Treasury, 2020).

4.9.2 Provincial adaptation expenditure (Eastern Cape province)

Error! Reference source not found. shows the total adaptation spent from 2017 – 2019 financial years, for example, the Eastern Cape Province government adaptation spending spent grew from nearly R300 million to almost to nearly R350 million in 2019. This is the general trend for all the Provinces in South African, the adaptation spent has increased consistently with global warming increased impacts and associated hazards. The recognition of effort for the South African Provinces for the 2017 – 2019 period is in the region of USD 2.2 billion (see **Error! Reference source not found.**). This means that the country has spent a total of at least USD 5.4 billion on adaptation measures when the national and provincial efforts are combined

Error! Reference source not found. shows Provincial adaptation efforts projection scenarios, **Error! Reference source not found.** shows the national adaptation efforts projection scenarios.

Table 4.9-1: Total provincial recognition effort scenarios until 2015 - 2020

Provincial efforts	Adaptation spent in 2017	Adaptation spent in 2018	Adaptation spent in 2019	Adaptation spent forecast 2020
Eastern Cape	$ 1 259 000 000.00	$ 1 240 000 000.00	$ 1 329 000 000.00	$ 1 294 681 854.84
Free State	$ 910 800 000.00	$ 960 900 000.00	$ 1 063 000 000.00	$ 984 238 323.45
Gauteng	$ 596 700 000.00	$ 727 500 000.00	$ 737 600 000.00	$ 666 242 041.24
Kwazulu-Natal	$ 2 560 000 000.00	$ 2 660 000 000.00	$ 2 800 000 000.00	$ 2 677 368 421.05
Limpopo	$ 2 010 000 000.00	$ 1 180 000 000.00	$ 1 290 000 000.00	$ 1 688 686 440.68
Mpumalanga	$ 532 300 000.00	$ 713 400 000.00	$ 743 100 000.00	$ 633 930 256.52
North West	$ 750 000 000.00	$ 824 700 000.00	$ 865 400 000.00	$ 805 856 729.72
Northern Cape	$ 353 700 000.00	$ 480 400 000.00	$ 446 300 000.00	$ 404 496 742.30
Western Cape	$ 724 400 000.00	$ 868 300 000.00	$ 856 400 000.00	$ 791 386 070.48
Total adaptation spent in ZAR	$ 9 696 900 000.00	$ 9 655 200 000.00	$ 10 130 800 000.00	$ 9 946 886 880.27
Total adaptation spent in USD	$ 588 642 250.10	$ 586 110 886.28	$ 614 981 788.75	$ 603 817 495.77

Table 4.9-2: Total national recognition effort scenarios until 2030

National efforts	Adaptation spent in 2015	Adaptation spent in 2016	Adaptation spent in 2017	Adaptation spent in 2018		Adaptation spent in 2019	Adaptation spent in 2020
	R 5 900 000 000.00	R 6 400 000 000.00	R 6 600 000 000.00	R 7 400 000 000.00		R 7 500 000 000.00	R 8 000 000 000.00
	$ 443 275 732.53	$ 388 506 677.46	$ 400 647 511.13	$ 449 210 845.81		$ 455 281 262.65	$ 485 633 346.82

5 Adaptation priorities

The National Development Plan (NDP) provides a long-term perspective to guide the country's development trajectory such that poverty is eliminated, and inequalities are reduced by 2030 (NPC, 2011). The plan is strongly aligned to reducing poverty by 2030 with specific goals related to reducing unemployment and building the country's economy. Other core objectives of the plan are to ensure the provision of services to improve the lives of South African people and the economy. The Medium-Term Strategic Framework (MTSF) reflects the commitments made to the national priorities of the government, including the commitment to implement the NDP (DPME, 2014). The 2019-2024 MTSF provides the foundation for all stakeholders in the country to work with the government to create inclusive economies, reduce inequality and eliminate poverty (DPME, 2020).

The policy framework that drives the country's response to both climate change mitigation and adaptation is the National Climate Change Response Policy (NCCRP) White Paper (DEA, 2011a). Interventions proposed in the NCCRP aim to ensure that the country is able to manage impending climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity (DEA, 2011a).

The country developed its first Nationally Determined Contributions (NDC) in 2015, the adaptation goals were developed taking cognisance of the NDP sectoral goals and timelines and were further aligned to the objectives of the NCCRP. The overarching adaptation aspiration of South Africa's first NDC is to place the availability and vulnerability of natural resources and the vulnerability of the South African population to climate change at the centre of the NDP initiatives (CSIR, 2015). The country's draft Climate Change Bill builds on these initiatives, to provide for a coordinated and integrated response to climate change and impacts in the country. With respect to adaptation, the Bill seeks to provide for the effective management of climate change impacts through enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to building social, economic and environmental resilience and an adequate national adaptation response in the context of the global climate change response. The Bill further states that national adaptation objectives will be used to guide the country's adaptation response and that a national adaptation strategy must be developed and reviewed every 5 years.

The National Climate Change Adaptation Strategy (NCCAS) has been approved by Cabinet and will soon be gazetted and serves as the country's National Adaptation Plan. The strategic objectives of the NCCAS include:

- Build climate resilience and adaptive capacity to respond to climate change risk and vulnerability;
- Promote the integration of climate change adaptation response into development objectives, policy, planning and implementation;
- Improve understanding of climate change impacts and capacity to respond to these impacts;
- Ensure resources and systems are in place to enable implementation of climate change responses.

There are 9 key strategic interventions that are listed in the NCCAS (DEA, 2019). The country has also introduced the concept of Desired Adaptation Outcomes (DAOs), that describe nine DAOs and the development of a Monitoring and Evaluation (M&E) system to track progress on the implementation of adaptation actions.

5.1 Sectoral adaptation priorities (2020-2030)

Government sectoral plans are structured to ensure long-term alignment with the NDP as well as to support short-term policies which allow for quick and effective responses to ensure the natural environment is protected from climate change. It is further envisaged in the NDP that by 2020 that resilience planning would be integrated into all planning processes in the country. The NDP further proposes that by the period of 2025-2030 the investments in climate resilient infrastructure made in the previous decade would start to bear fruit and that South Africa would be well capacitated to comfortably manage its policy, regulatory and support functions and report to the national and international arenas as appropriate.

Climate change is already having an impact on South Africa with marked temperature and rainfall variations and rising sea levels and this is likely to affect the ability of the country to meet its developmental goals. To mainstream climate-resilient development, all government sectors have to ensure that all policies, strategies, legislation, regulations and plans are in alignment with the NCCRP (DEA, 2011). The draft Climate Change Bill further requires that all national sectoral departments develop and implement a climate change response implementation plan.

This sub-section of the report outlines the key adaptation priorities for the country, emphasizing the policies within each sector that support the attainment of these goals and the priorities in terms of gaps in policy. The sectors considered are water, agriculture, biodiversity; energy; human health and human settlements (urban, rural and coastal).

5.2.1 Water

Ensuring that all households have access to clean drinking water and adequate sanitation services is an important goal of the NDP (NPC, 2011). South Africa is considered water insecure due to an acknowledged backlog in water infrastructure, insufficient maintenance and investment, inequities in access to water and deteriorating water quality. South Africa is also experiencing severe capacity challenges that impede the successful implementation of its water policy, legislation and various strategies. The sector has also been criticised for inappropriate maintenance of water service infrastructure and poor implementation of water-related duties in some spheres of government, which places additional strain on the functioning of water institutions in the country (DEA, 2018a). These issues are all exacerbated by recurrent droughts driven by climatic variation.

The National Water Resource Strategy (NWRS2) (DWS, 2013) seeks to manage water resources efficiently and effectively so as to facilitate equitable growth, development and job creation and is aligned with the NDP. The strategy discusses in detail how the water demands of mining, industry, agriculture and municipal sectors will be addressed whilst supporting job creation and economic development.

The National Water and Sanitation Master (NWSM) Plan (DWS, 2018), recognises that South Africa is facing increasing water demands to meet the needs of a rapidly growing and urbanising population, changing lifestyles and economic growth. The Plan further acknowledges that climate change is driving the country towards a warmer and drier future, with predicted longer and more extreme droughts and more intense floods and thus will be a compounding factor in potentially limiting the water available to meet the demand. The implementation of this plan is seen as a means to enable South Africa to become more resilient to climate change and the increasing intensity of droughts and floods while meeting the water needs of a growing population and economy (DWS, 2018).

The NWSM Plan, (DWS, 2018) proposes a number of actions around water and sanitation management, that need to be implemented to build water security by 2030, these include:

- Reducing water demand and increasing supply
- Redistributing water for transformation
- Managing effective water and sanitation services
- Regulating the water and sanitation sector
- Improving raw water quality
- Protecting and restoring ecological infrastructure

It is acknowledged in the NWSM Plan, that the current legislative environment is overly complex, insufficiently streamlined and hampering effective service delivery, the attainment of transformation objectives and the leveraging of economic growth (DWS, 2018). In response, policy changes are required in order to align to current governance best practice, contemporary institutional arrangements and the PFMA. Measures include:

- Revise and promulgate the National Water Amendment Bill, Water Services Amendment Bill and the Water Research Amendment Act by 2023,
- Develop new policies and strategies on matters not previously addressed, in consultation with all stakeholders, to facilitate the sustainability of various water sector programmes by 2025.

The Climate Adaptation Strategy for Water and Sanitation (DWS, 2019) aligns with the NWRS2 and highlighted key issues pertaining to the impacts of climate change on water resources and services and identified strategic actions that are needed to enhance resilience to water-related climate impacts and to reduce vulnerability.

The strategy outlines a number of strategic adaptation actions for addressing climate change impacts, these strategic actions include (DWS, 2019):

- Water governance – building adaptive institutions, creating intergovernmental relations, awareness, communication a shared learning, research and development, stakeholder participation, Regional development and the Review of Strategy.
- Infrastructure development, operation and maintenance – multi-purpose water storage, water supply and sanitation, groundwater development and management, flood protection measures, infrastructure safety, hydro-geo-meteorological monitoring system
- Monitoring and Management – Data and information gathering, Scenarios and climate modelling, vulnerability assessments, planning, water allocation and authorisation, Optimisation of dam and groundwater operation, water conservation and water demand management, water quality management, Resource management and protection.

The strategy further outlines the need to implement national early warning systems for the water resources sector.

The importance of research and development is emphasized in the Water Research, Development and Innovation (RDI) Roadmap for 2015-2025 (WRC, 2015). The roadmap that identifies the RDI gaps and opportunities and provides guidance to the sector in terms of coordination and investments that are needed for skills development and research. This framework is to be used to guide RDI activity to support the implementation of the sectors policies, plans and strategies. Some of the key activities and timelines associated with these are shown below:

- Scan and sort the innovation sector for solutions that are ready for application and invest in their implementation by 2021.
- Develop technologies, guidelines and implementation support tools that enable South Africa to use alternative and appropriate sources as part of the water supply by 2023.
- Link the Global Environment Fund 6 project on Water Pricing and Ecosystems to Water Master Plan implementation and position DWS to be closely involved in this process by 2024
- Apply the concepts of water sensitive urban design to a robust city-wide case study to demonstrate and learn how a city can transition to a sustainable city by 2027.

A summary of the key priorities for the sector is shown in

Table 4.9-1.

Table 4.9-1: Key challenges, policies and adaptation priorities in the Water Sector

Risk/challenges	Key Policy	Adaptation Priorities
Backlog in water infrastructure, insufficient maintenance and investment, inequities in access to water;	National Water Resource Strategy (NWRS2) Climate Adaptation Strategy for Water and Sanitation	Water governance – building adaptive institutions, creating intergovernmental relations, awareness, communication a shared learning, research and development, stakeholder participation, Regional development and the Review of Strategy;
High water demand: current water usage already exceeds reliable yield;	National Water and Sanitation Master Plan	Infrastructure development, operation and maintenance – Multi-Purpose water storage, water supply and sanitation, groundwater development and management, flood protection measures, infrastructure Safety, Hydro-geo-meteorological monitoring system;
High levels of variability in rainfall, resulting in frequent floods and droughts;	National Water Research, Development and Innovation (RDI) Roadmap for 2015-2025	Monitoring and Management – Data and information gathering, Scenarios and climate modelling, Vulnerability assessments, Planning, Water Allocation and authorisation, Optimisation of dam and groundwater operation, Water Conservation and Water demand management, Water quality management, resource management and protection;
Deteriorating water quality in river systems, water storage reservoirs and groundwater.		Develop and implement sector specific M&E system; Conduct research to advance technology innovation and facilitate technology transfer; Position sector to benefit from global funds.

5.2.2 Agriculture

The NDP identifies the agriculture sector as being critical for employment and food security (NPC, 2011). The Department of Agriculture, Rural Development and Land Reform (DARDLR) is the leading authority for the development of the agriculture sector and plays a coordinating role for various stakeholders across the agriculture value chain. The key focus of the department, together with the Department of Trade, Industry and Commerce (DTIC), Department of Environment, Forestry and Fisheries (DEFF), Cooperative Governance and Traditional Affairs (COGTA) and local government authorizes is to achieve the NDP target of creating one million jobs in the agricultural, forestry and fisheries sectors by 2030. These sectors have been identified as key job drivers in the economy and will require the unlocking of growth potential among key industries as specified in the NDP and prioritised in the Agricultural Policy Action Plan (APAP) (DAFF, 2014).

The direct impacts of climate change for agriculture are due to changes in precipitation, temperature and evaporation (DEA, 2018a). Risks in the sector from natural disasters and environmental health problems further compound these impacts. A reduction in rainfall in the KwaZulu-Natal, Mpumalanga and Western Cape provinces will lead to a reduction in field crop yields. The changing distribution of precipitation across the country will likely lead to shifts in the optimal growing locations for various field crop species. Finally, increasing temperatures and more frequent heat waves will lead to increasing water demand in the irrigation and livestock feeding sector. Other sectors will also be affected, including food insecurity, water and energy. A growing population leading to an increased demand for food and greater competition for land for urban and mining development is likely to result in further stress for the sector.

The DAFF developed a Climate Change Sector Plan for Agriculture, Forestry and Fisheries (DAFF, 2013a) in 2013 in fulfilment of the requirements of the NCCRP and in line with the National Disaster Management Framework of 2005. This plan focused on addressing vulnerability assessments, mitigation, adaptation and institutional arrangements for the agriculture, forestry and fisheries sectors. The draft Climate Change Adaptation and Mitigation Plan for South African Agriculture, Forestry and Fisheries sectors (CCAMPAFF) (DAFF, 2018b) was developed to replace the original CCSPAFF. The broad aims of the CCAMPAFF are to reduce the harmful effects of climate change on agriculture, forestry and fisheries in South Africa through the specific objectives of a) promoting mitigation of the causes at source (i.e. reducing the carbon footprint of these sectors) and b) encouraging the introduction of adaptation measures to anticipate and lessen their harmful effect.

The CCAMPAFF highlighted the need for current research efforts to be expanded and become more holistic in nature, comprising of research institutions, government department, non-government organisations (NGOs), SAEON, etc. Long-term, committed funding was identified as a need to drive that process. The CCAMPAFF provide a number of mitigation and adaptation options to promote soil, water and nutrient conservation for agricultural production to ensure sustainable agriculture and soil productivity (DAFF, 2018b). The adaptation options recommended are further aimed at supporting and promoting conservation agriculture, climate-smart agriculture, developing water infrastructure and conservation measures and rangeland and livestock management.

The policy gaps and needs identified in terms of alignment of the CCAPMAFF with the NCCAS interventions include (DEFF, 2020b):

- There is a need for provisions to reduce the impacts of climate change in the agriculture and forestry sectors, other than those related to water.
- The importance of establishing early warning systems was identified, however, no means of establishing early warning systems have been identified.
- While it is recognized that technology transfer should take place, no system has been established in the policy to facilitate the transfer of technologies.
- A clear plan to roll out climate change awareness is needed.
- A clear outline of the governance structures and legislative processes to integrate climate change in development planning is needed.
- There is a need for a clear process for obtaining financing.
- An M&E system to track climate change progress is needed for the Agriculture and Forestry sectors.

The Draft Smart Agriculture Strategic Framework for Agriculture (DAFF, 2018c) is meant to span the period of 2018-2028 and will be subject to review in the medium term in 2023. The core objectives of the framework are to reduce vulnerability and increase adaptive capacity such that the risks associated with climate change and climate variability are addressed within the sector. The framework promotes existing measures and policies, such that these are built on and supported to be more effective. This would, for example, include the Draft Conservation Agriculture (CSA) Policy, 2017 (DAFF, 2017), which is meant to guide widespread adoption of conservation in agricultural production systems. The further objective of the Conservation Policy is to promote and establish ecologically and economically sustainable agricultural systems that will increase food security levels and address associated national security risks.

Further priority actions of the strategic framework (DAFF, 2018c) are to:

- Build Capacity of State Actors and Stakeholders to understand and plan for climate change impacts and Climate-Smart Agriculture

- Invest in CSA Policy focused research
- Integrate CSA into existing Agriculture, Forestry and Fisheries sector policies and identify design and implement CSA programmes
- Focus on the food, water and energy nexus
- Promulgate and implement policies
- Involve stakeholders in policy processes
- Integrate indigenous knowledge systems into CSA policymaking and programme design and push its place into the forefront of both public and academic discourses

Adaptation strategies identified will include the adoption of efficient environmental resources management practices such as the planting of early maturing crops, adoption of hardy varieties of crops and selective keeping of livestock in areas where rainfall has declined.

The APAP (2015-2019) (DAFF, 2014) begins to address the change agenda and identifies priority commodities, based on the NDP's framework. It identifies commodities based on their capacity and potential to create jobs, contribute to food security, growth potential and potential contribution to the trade balance. The following commodities were identified as having the potential for growth: red meat integrated value chain, poultry integrated value chain, fruit and vegetables, wine, wheat, forestry, aquaculture and small-scale fisheries schemes and biofuels.

Sector interventions to assist smallholder farmers with technical, infrastructure and financial support have been rolled out since 2002. These include the Comprehensive Agricultural Support Programme (CASP), Ilima/Letsema and LandCare programmes specifically aimed at increasing farm output, especially for the beneficiaries of land reform, contributing towards the Fetsa Tlala Food Production Initiative (DAFF, 2015; (DAFF, 2019). The main objective of the National Policy on Comprehensive Producer Development Support is to regulate and guide the provision of support measures to the various categories of producers, thereby contributing to a sustainable and competitive agricultural, forestry and fisheries sector (DAFF, 2018d). Through the Fetsa Tlala initiative, the objective is to utilize one million hectares of land in rural areas to produce crops. Support is provided to communities to engage in food production and subsistence farming to promote food security. The 2019-2020 Sector Skills Plan (SSP) indicates the current skills gaps lists in the sector match the needs of the Agricultural sector and how AgriSETA might facilitate relevant skills and educational opportunities to address the occupational shortages and skills gaps identified (AgriSETA, 2018).

The CASP and Land Care programs are both financed in the long term by conditional grants to provinces from the National Treasury. Interventions prioritized for the long term to 2030, target mainly small producers and commercial farmers specifically with a focus to build resilience within the grain value chain and livestock sector. This is associated with adopting climate-smart approaches in agriculture to improve the production of staple foods as per the Food and Nutrition Security Policy (DAFF, 2014a). The Operation Phakisa executive summary highlights the important role of government to increasing the area under cultivation in smallholder farms and commercial farms, improving crop yields and increasing economic opportunities in the sector for employment and trade in the context of climate change threats to food security (RSA, 2016). Included in the portfolio of trade promotion and optimization in the agriculture sector is to improve the trade potential of the horticultural industry. Interventions prioritized for the livestock sector include skills and knowledge upgrading, improving access to commercial and alternative livestock value chains, census of national livestock, animal identification and traceability program and fortified veld management for sustainable livestock production.

A summary of the key priorities for the sector is shown in Table 4.9-2.

Table 4.9-2: Key challenges, policies and adaptation priorities in the Agricultural Sector

Risk/challenges	Key Policy	Adaptation Priorities
Land use and change; Water stress; Invasive alien plants.	Draft Smart Agriculture Strategic Framework for Agriculture (2018-2028); Draft Climate Change Adaptation and Mitigation Plan for the South African Agricultural and Forestry; Draft Conservation Agriculture Policy, 2017.	Supporting and promoting conservation agriculture, climate-smart agriculture, developing water infrastructure and conservations measures and rangeland and livestock management; Support climate change mitigation; Developing/improving early warning systems; Need for M&E system Research and development for the agricultural sector; Skills development and training.

5.2.3. Health

The NDP aims to promote the health and well-being of all South Africans and to provide affordable access to quality health care by 2030. Furthermore, the plan seeks to ensure that citizens will have a decent standard of living, which in addition to income, include important elements such as the need for adequate nutrition, housing, water, sanitation, electricity and a clean environment. The NDP further recognises women as vulnerable members of society, especially in rural areas and as such proposes measures that are aimed at advancing women's equality in terms of health and nutrition.

The National Health Act of 2003 (Act No. 61 of 2003) and the related strategic plans (e.g. National Department of Health Strategic Plan (NDHSP) for 2015/16 – 2019/20) (NDoH, 2015) and for 2020/21-2024/25 seek to address issues related to illness and the promotion of healthy lifestyles. A climate change adaptation plan has been developed for the health sector for the period 2020-2024. The adaptation plan outlines short, medium and long-term actions for the sector:

- Short-term actions: Review the National Climate Change and Health Steering Committee; Capacity building interventions; Participate in International exchange and collaboration;
- Medium-term actions: Review Monitoring and surveillance systems; Create Intersectoral action Health system readiness; Indicator development;
- Long-term actions: Conduct National Vulnerability Assessments; Research and development on risks of climate change to health; Conducting Health Impact Assessments; Model and Pilot Climate Change and Health Adaptation Projects; Identify adaptation actions.

A Heat Health Guideline was drafted in 2019 (NDoH, 2019b), that aims to provide guidance to ensure that the health sector is prepared to effectively respond to impacts of heat on the health of the South African citizens. This guideline specifically outlines the need to identify vulnerable groups and the health risks affecting each group; developing effective strategies, agency coordination and response planning to shape a Heat Health Action Plan that addresses heat-health risks; implementing the National Heat Health Action Guidelines; and Evaluating the Health sector response to extreme heat. A key facet to being able to respond to climate-related heat impacts is the development of early warning systems.

In South Africa's Third National Communication (DEA, 2018a) it has been indicated that an important barrier to adaptation for the health sector in South Africa is the lack of data on climate-health linkages and vulnerability and risk of communities to climate change. It is suggested therein that without such data and linkages, it is not possible to begin to estimate the potential magnitude of climate change on human health in South Africa (DEA, 2018a). This highlighted the need for a quantitative vulnerability and risk assessment for the health sector to identify the most important health risks, as well as begin to identify the most vulnerable populations or communities and used as a basis for the development of tailored adaptation strategies (DEA, 2018a).

The country's updated Technology Needs Assessment (DEA, 2019a) further recognised the health sector to be cross-cutting, as the technologies taken within other sectors would create an enabling environment for improving health. This indicates a need to collaborate with different national sector departments and across all spheres of government and stakeholders to effectively respond to the potential impacts of climate change and health.

A summary of the key priorities for the sector is shown inTable 4.9-3.

Risk/challenges	Key Policy	Adaptation Priorities
The quadruple burden of disease; Poor housing, infrastructure and service delivery; Change in distribution of diseases; Catastrophic events may affect the health of the population; Climate change (temperature, extreme weather events).	National Department of Health Strategic Plan (NDHSP) for 2015/16 – 2019/20) National Climate Change and Health Adaptation Plan A Heat Health Guideline 2019	Short-term actions: Review the National Climate Change and Health Steering Committee; Capacity building interventions; Participate in International exchange and collaboration. Medium-term actions: Review Monitoring and surveillance systems; Create Intersectoral action Health system readiness; Indicator development. Long-term actions: Conduct National Vulnerability Assessments; Research and development on risks of climate change to health; Conducting Health Impact Assessments; Model and Pilot Climate Change and Health Adaptation Projects; Identify adaptation actions. Developing/improving early warning systems. Research and development for technology transfer (cross-cutting with other sectors).

Table 4.9-3: Key challenges, policies and adaptation priorities in the Health Sector

5.2.4 Energy Sector

The NDP for the country provides the vision of for the provision of universal access to clean energy by all citizens by 2030. South Africa has a need for safe, affordable and clean forms of energy to enable productive economic activities to generate much needed income. However, the provision of energy must also be cognisant of South Africa's primary needs of also delivering potable drinking water and sanitation.

In addition to the need to deliver electricity and support economic development, the energy sector is also a focus for climate change mitigation, with coal-powered electricity generation being the largest source of greenhouse gas (GHG) emissions in the country. The sector is also expected to be impacted by climate change, as power lines, for example, are exposed to weather and climate, these systems are more vulnerable to the effects of climate change. Further to this, variations in temperature (hotter and colder days) will increase the demand for energy for both cooling and heating within homes and buildings. Thus, both the electricity supply and demand needs for the country are likely to be impacted by climate change. Electricity generation is also likely to be affected by the availability of natural resources and extreme weather events. The South African Energy risk Report (SANEA, 2019) ranked the key risks to the sector, which included, the risk of water quality and availability, with potential for a water crisis to result in an inability to obtain water at the right volumes and quality needed for operations, leading to increased costs and negative operational constraints.

The Integrated Resource Plan 2010-2030 (IR, 2011) set out South Africa's long-term energy needs and discusses the generating capacity, technologies, timing and costs associated with meeting that need. The IRP (2011) was updated in 2019 (DMRE, 2019), through an extension of the period of analysis to 2050 and provides updated projections and technology costs. The IRP (DMRE, 2019) provides a policy framework for addressing the short-to long-term challenges with respect to energy security and affordability. The framework provides specific interventions around electricity infrastructure development that also considers the protection of the environment and identifies the preferred generation technologies required to meet expected growth in demand.

The Department of Minerals, Resources and Energy (DMRE) has developed a strategic plan for the period of 2020 to 2025 that reflects on impacts, outcomes and outputs that need to be achieved in response to the IRP (DMRE, 2019). The strategy indicates that there is a need to develop an energy sector climate change strategy and to develop mitigation and adaptation plans for the energy sector.

A summary of the key priorities for the sector is shown in Table 4.9-4.

Table 4.9-4: Key challenges, policies and adaptation priorities in the Energy Sector

Risk/challenges	Key Policy	Adaptation Priorities
Increased demand and need for provision for universal access;	Integrated Resource Plan 2010-2030 (2019)	Specific interventions to address energy infrastructure development and energy provision need to consider the impact of climate change;
Risks to infrastructure from extreme weather events;	DMRE Strategic Plan (2020-2025)	Develop an understanding of the impact of climate change on resource availability;
		Develop an understanding of the impact of climate change on energy needs;
Water quality and availability.		Development of a climate change adaptation plan for the sector.

5.2.5 Biodiversity

The NDP highlights the need to protect the country's natural environment. The terrestrial ecosystems are delineated into nine biomes: Grassland, Fynbos, Succulent Karoo, Albany Thicket, Savanna, Nama Karoo, Desert, Forest and the Indian Ocean Coastal Belt. These biomes provide crucial ecosystem services such as soil production, water flow regulation, pollination and natural fodder for dry-land livestock grazing (RSA, 2018). A key priority for the biodiversity sector in South Africa is sustaining ecosystems and using our natural resources efficiently.

The climate variability and change threats include rising average temperatures, more temperature extremes, changes in rainfall intensity and magnitude, a higher likelihood of extreme events (such as droughts, floods, heatwaves, etc.). throughout South Africa, shifting rainfall season, sea-level rise and rising atmospheric concentrations of carbon dioxide (CO_2). In addition, non-climatic conditions such as changes in the occurrence, seasonality and severity of the fire and land-use change resulting from climate variability and change can also further impact the sector. Changes across the biomes through climate and non-climatic drivers are most likely to occur through the alteration of habitats, species distribution and ecosystems functioning. Non-climatic drivers include habitat fragmentation, land-use change and invasive alien plant species.

The National Biodiversity Assessment (NBA) is the primary tool for monitoring and reporting on the state of biodiversity in South Africa and informs policies, strategic objectives and activities for managing and conserving biodiversity more effectively. The NBA is especially important for informing the National Biodiversity Strategy and Action Plan (NBSAP) (DEAT, 2005), the National Biodiversity Framework (NBF) and the National Protected Area Expansion Strategy (NPAES) and also informs other national strategies and frameworks across a range of sectors, such as the National Spatial Development Framework, the National Water and Sanitation Master Plan (DWS, 2018; DWS, 2018a) and the National Biodiversity Economy Strategy.

The goal of the National Protected Area Expansion Strategy (NPAES) (DEA, 2016a) is to achieve cost-effective protected area expansion for improved ecosystem representation, ecological sustainability and resilience to climate change. It sets protected area targets, maps priority areas for protected area expansion and makes recommendations on mechanisms to achieve this. The common set of targets and spatial priorities provided by the NPAES enable co-ordination between the many role role-players involved in protected area expansion.

The National Biodiversity Economy Strategy (NBES) (DEA, 2016) provides the opportunity to redistribute South Africa’s indigenous biological/ genetic resources in an equitable manner, across various income categories and settlement areas of the country. Development and growth of the biodiversity economy focus on markets and activities, which address national socio-economic imperatives, especially in the rural areas. Working collaboratively and cooperatively, NBES provides the opportunity to develop the rural economy of the country and address environmental and rural development imperatives of government.

The aim of the National Biodiversity Offset Policy is to ensure that significant residual impacts of developments are remedied as required by NEMA, thereby ensuring sustainable development as required by Section 24 of the Constitution. The policy must be read with the National Environmental Management Act, 107 of 1998 Environmental Impact Assessment (EIA) regulations (2014), the Guideline on Need and Desirability (2014), the Minimum Requirements for Biodiversity in EIAs (draft, 2016), the Wetland Offsets - A best-practice guideline for South Africa (SANBI and Department of Water Affairs, 2014), Mining and Biodiversity Guideline - Mainstreaming Biodiversity in the Mining Sector, 2013 and any applicable national and provincial policies or guidelines.

The draft report on Climate Change Adaptation Plans for South Africa’s Biomes (DEA, 2015a) presented potential adaptation responses to guide current and future decision-makers in protecting South Africa’s natural ecosystems and biodiversity in the face of climate change. Broad categories of adaptive actions at a biome level include:

- Spatial-planning approaches which change the mix of activities in given biomes, including the possibility of abandoning some uses completely and introducing new ones;

- Management approaches that focus on adjusting how the land uses are executed under a changing climate - for instance by changing the species used or the intensity of use;
- Ecosystem-based adaptation, which sets out to support the inherent ability of ecosystems, including their human inhabitants and organisms, to adapt to climate change, principally by reducing the other stresses which might impede that capacity and restoring damaged ecosystem functions where necessary;
- Biodiversity stewardship programmes focussing on promoting sustainable land management and expanding protected areas on private land to form natural corridors that will enhance the adaptive capacity outside of state-owned protected areas.

The country has developed a strategic framework for Ecosystem Based Adaptation (EbA) (DEA and SANBI, 2016) with four core priorities around:

- Effective coordination, learning and communication mobilizes capacity and resources for EbA
- Research, monitoring and evaluation provides evidence for EbA's contribution to a climate-resilient economy and society
- Integration of EbA into policies and plans supports an overall climate change adaptation strategy
- Implementation projects demonstrate the ability of EbA to deliver a wide range of co-benefits

The key priorities to ensure sustainable use of these resources is presented in the updated National Biodiversity Strategy and Action Plan (NBSAP) for the period 2015-2025 (RSA, 2015):

- Management of biodiversity assets and their contribution to the economy, rural development, job creation and social well-being is enhanced.
- Investments in ecological infrastructure enhance resilience and ensure benefits to society.
- Biodiversity considerations are mainstreamed into policies, strategies and practices of a range of sectors.
- People are mobilised to adopt practices that sustain the long-term benefits of biodiversity.
- Conservation and management of biodiversity are improved through the development of an equitable and suitably skilled workforce.
- Effective knowledge foundations, including indigenous knowledge and citizen science, support the management,
- Conservation and sustainable use of biodiversity.

The National Biodiversity Framework provides for an integrated, coordinated and consistent approach to biodiversity management. The framework further identifies priority areas for conservation action and the establishment of protected areas. It also identifies a set of interventions or "acceleration measures” that can unlock or fast-track the implementation of the NBSAP and indicates the relative roles of the many agencies involved in implementing these activities.

A summary of the key priorities for the sector is shown in Table 4.9-5.

Risk/challenges	Key Policy	Adaptation Priorities
Habitat fragmentation; Land-use change; Invasive alien plants; Pollution and waste; Climate-induced changes (changes in rainfall patterns, temperature, ocean acidification, wildfires).	Draft Climate Change Adaptation Plans for South Africa’s Biomes. Strategic framework for Ecosystem-Based Adaptation. National Biodiversity Strategy and Action Plan (NBSAP) for the period of 2015-2025	Spatial-planning approaches which change the mix of activities in given biomes, including the possibility of abandoning some uses completely and introducing new ones; Management approaches that focus on adjusting the way in which the land uses are executed under a changing climate - for instance by changing the species used or the intensity of use; Support and promote ecosystem-based adaptation; Biodiversity stewardship programmes to enhance adaptive capacity.

Table 4.9-5: Key challenges, policies and adaptation priorities in the Biodiversity Sector

5.2.6 Human Settlements

Human settlements in South Africa face immediate and critical challenges including urbanization, limited local government capacity, increased strain on ageing infrastructure and reduced capacity for critical operations and maintenance of key infrastructure (DEA, 2018a). Human settlements further face the weather and climate related risks including coastal flooding/inundation; erosion and under-scouring and other natural hazards. A further priority is the upgrading of informal settlements through the implementation of the Upgrading Informal Settlements Programme (UISP) (DHS, 2009).

The Spatial Planning and Land Use Management Act, No. 16 of 2013 (SPLUMA) provides a framework to guide spatial planning and land-use management in-country (RSA, 2013). The Integrated Urban Development Framework (IUDF) aims to develop cities and provide access to social and economic services, inclusive, sustainable economic growth and development and spatial transformation. The IUDF further seeks to create liveable, safe, resource-efficient cities and towns that are socially integrated, economically inclusive and globally competitive, where residents actively participate in urban life (DCOGTA, 2016).

The draft National Spatial Development Framework (DRDLR & DPME, 2019) provides for the broader 'family' of strategic and sector plans of government the following key objectives:

- Target and direct all infrastructure investment and development spending decisions by all national sector departments and State-Owned Enterprises (SOEs);
- Guide and align plan preparation, budgeting and implementation across spheres and between sectors of government; and
- Frame and coordinate provincial, regional and municipal spatial development frameworks;
- Plan and prepare for climate change, not only in the areas themselves but also for the knock-on effects of climate change in other parts of the country and in neighbouring countries.

Human settlement types and their locations will have varying vulnerabilities and capacities to climate change hazards. Higher vulnerability and lower coping capacity areas such as informal settlements will have increased risk exposure to climate-related hazards. Increased exposure to both temperature and precipitation induced hazards, water and heat related stresses under projected climate change will compound future risk to human settlements. Other barriers around adaptation include the lack of or even failure of infrastructure and poor service delivery and that these barriers may be compounded by issues such as lack of resources and poor development practices (DEA, 2018a).

The Climate Change Adaptation Sector Plan for Rural Human Settlements (DRDLA, 2013) was developed to support the creation of sustainable livelihoods that are resilient to climate change. The plan specifically calls for access to climate-resilient services and infrastructure in rural areas to be promoted through climate-resilient rural housing programmes that include rainwater harvesting, solar water heaters and off-grid/mini-grid electrification, environmentally-friendly and socially acceptable sanitation solutions (DRDLR, 2013).

From a coastal perspective, nine key priorities were identified in the coastal management programme that sets out a series of goals and associated management objectives, aimed at coastal management efforts that should be addressed at a national level (DEA, 2014). The priorities and national management objectives are seen as emphasising the commitment. This programme was for the period 2013-2017. The priorities include the need for effective planning for coastal vulnerability to global change (including climate change) to ensure that all planning within the coastal zone addresses the coastal vulnerability (DEA, 2014).

From an urban settlement perspective the Comprehensive Plan for the Development of Sustainable Human Settlements, also known as Breaking New Ground (BNG), promotes a move away from a commoditized focus of housing delivery toward more responsive mechanisms which addresses the multi-dimensional needs of sustainable human settlements. It advocates that, rather than focusing on the provision of basic shelter, more efficient and sustainable human settlements should be developed. It encourages higher densities, mixed land use, the integration of land use and public transport planning and a more compact urban form to support the creation of more diverse and responsive environments and reduced travelling distances. The Social Housing Policy provides principles for the development of social housing and the mechanisms for creating an enabling environment in the housing sector to ensure development, growth and delivery at scale. The policy further provides clear institutional and regulatory mechanisms under which the sector should operate; further sets clear funding mechanism for the social housing sector, promote mechanism for capacity building which encourages the growth of the sector. The Inclusionary Housing Bill aims to promote greater social inclusion/integration and to break with highly segregated processes of built environment creation in South Africa. Boosting the supply of affordable housing is a secondary objective. The Bill aims to mobilize private sector delivery capacity for the provision of affordable housing, leverage new housing opportunities off existing stock, promote densification and make better use of existing infrastructure.

It is further recognised that there is a need for technological innovation for the different types of settlements to adequately respond to the development priorities, service delivery and infrastructure requirements and to build resilience to disasters and climate change impacts. The Science Innovation and Transformative Technologies for Sustainable Human Settlements (SITT 4 SHS) Roadmap provides appropriate, innovative technologies and approaches that may be applied to help address housing backlogs more rapidly and develop more sustainable human settlements (DSI, 2020). In order to capture the full value and opportunities presented by the 4th Industrial Revolution for the sustainable human settlements sector for South Africa, the ten-year SITT 4 SHS Roadmap defines a long-term implementation, investment and transition plan. It sets out an initial framework to deliver significant socio-economic impact for South Africa via a coherent and targeted portfolio of SITT for Human Settlements interventions, niches and initiatives that should be implemented in order to attain transformative outcomes spelt out in national strategies.

The human settlements sector is furthermore cross-cutting with adaptation priorities closely related to those of disaster risk management, health, energy security, water supply, food security and ecosystem-based adaptation. As such, there is a need for collaborative planning of adaptation responses and technology transfer with these sectors.

A summary of the key priorities for the sector is shown in Table 4.9-6.

Table 4.9-6: Key challenges, policies and adaptation priorities in the Human Settlements Sector

Risk/challenges	Key Policy	Adaptation Priorities
A deficit in infrastructure and provision of services; Direct wave impacts; Coastal flooding / inundation; Erosion and under-scouring; Land-use change Natural hazards; Weather and climate change related.	The Spatial Planning and Land Use Management Act, No. 16 of 2013 (SPLUMA) The Integrated Urban Development Framework (IUDF) The Climate Change Adaptation Sector Plan for Rural Human Settlements (2013)	Environmentally sustainable land use development; Integrated Development Planning; Needs and priorities of people in informal settlements; Environmentally sound low-cost housing and planning for housing development; Nine key priorities for coastal management are identified in the coastal management programme (2013 - 2017); Cross-cutting actions with other sectors and linkages for climate change mitigation; Update of adaptation plans and related programmes; Developing/improving early warning systems; Implementation of transformative technologies.

5.2 Synthesis of the national level adaptation interventions that should be applied across each of the key sectors for the period 2020-2030

Since the development of South Africa's first NDC, the national sector departments have made progress in responding to the key aspirational goals articulated therein. The NDP states that by 2020 that resilience planning would be integrated into all planning processes in the country. The NDP further proposes that by the period of 2025-2030 the investments in climate-resilient infrastructure made in the previous decade would start to bear fruit and that South Africa would be well capacitated to comfortably manage its policy, regulatory and support functions and report to the national and international arenas as appropriate. The NCCAS further outlines the 9 key interventions to which the sectoral responses need to align to.

In developing and implementing an effective adaptation response for the next 10 years, the priorities for the key sectors described in section 5.2 revolve will thus need to evolve around ensuring the following key priorities from a climate change perspective:

- Develop a strong scientific basis for the development of sector specifically tailored adaptation plans. All sectors need to have completed a risk and vulnerability assessment. There is further a need to overcome data availability challenges to ensure that there is a robust analysis to support the prioritisation of adaptation actions.
- Sector specific methodologies to vulnerability assessments need to be developed aligned to the general approach that has been developed at a national level.
- Early warning systems need to be implemented across all sectors.
- Climate change policy development and mainstreaming of climate change considerations into sector plans, policies and strategies are needed. This needs to be supported by a review of existing policies and plans, with amendments that support more integrative and holistic responses across all sectors.
- The capacity and skills needed to implement and monitor progress on adaptation planning need to be developed through complementary skills development plans.
- The barriers to the adaption of transformative technologies need to be unlocked. All sectors should develop RDI and technology transfer plans to fast track technological innovation needed to give effect to the sectoral adaptation response.
- The financial investment needed for sectors to adequately respond to climate change needs to be mainstreamed into budgetary processes in all spheres of government. Strategies to tap into global funds need to be planned for.
- Each sector should develop indicators and monitoring, evaluation and reporting systems that support and feed into the national M&E system

These priorities are aligned to the 9 interventions that are outlined in the NCCAS as shown below in. Figure 5.2-1.

Intervention 1 Reduce human and economic vulnerability, ensure resilience of physical capital and ecological infrastructure and build adaptive capacity	All sectors need to have completed a risk and vulnerability assessment Improving the measures aimed at reducing the vulnerability
Intervention 2 Develop a risk, early warning, vulnerability and adaptation monitoring system for key climate vulnerable sectors and geographic areas.	Development and operationalisation early warning systems in each of the sectors.
Intervention 3 Develop a vulnerability and resilience methodology framework that integrates biophysical and socio-economic aspects of vulnerability and resilience.	Enhancement of sector-specific methodologies and assessment supported by the provision and use of improved data.
Intervention 4 Facilitate mainstreaming of adaptation responses into sectoral planning and implementation.	Review of existing policies, regulations and bylaws to identify specific issues and amend. Development of a framework to improve the practical implementation of the policies and the cooperation between sectors.
Intervention 5 Promote research application, technology development, transfer and adoption to support planning and implementation.	Development of sector specific Research, Innovation and Technology Transfer Plans in support of sectoral climate change adaptation plans
Intervention 6 Build the necessary capacity and awareness for climate change response.	Integrate technical training into all sector adaptation plans and strategies.
Intervention 7 Establish effective governance & legislative processes to integrate climate change in development planning.	Legislative frameworks in which a specific policy must operate need to be developed. This approach helps to establish the roles, responsibilities and mandates of the bodies and departments.
Intervention 8 Enable substantial flows of climate change adaptation finance from various sources.	Mainstreaming of climate change into budgetary processes in all sector plans and positioning of climate change plans to benefit from global funds.
Intervention 9 Develop and implement an M&E system that tracks implementation of adaptation actions and their effectiveness.	All sectors need to develop indicators and M&E systems in support of the national system.

Figure 5.2-1: Alignment of sectoral adaptation priorities with interventions outlines in the NCCAS.

6 Governmental sectoral policies

6.1 Introduction

Since the submission of South Africa's first NDC in 2015, the country's climate change policies and strategies that have been revised or compiled have taken the goals of the first NDC into account. This section presents an update of national climate change policies and strategies presented in the first NDC for the key adaptation sectors in terms of high-level policy objectives for primary and supporting sectoral climate change policies, alignment of these policies with interventions in the National Climate Change Adaptation Strategy (NCCAS), as well as policy needs (or gaps). Climate change strategies and vulnerability studies at a provincial (sub-national) level are outlined in terms of provincial adaptation priorities and gaps or needs linked to climate change initiatives in the country's nine provinces.

6.2 National sectoral climate change policies, strategies or plans

South Africa’s climate change response actions are guided by Section 24 of the Constitution of the Republic of South Africa, NDP (NPC, 2011) and the National Climate Change Response Policy (NCCRP) (DEA, 2011). The country’s development pathway, defined by the NDP, is closely aligned to the Sustainable Development Goals (UN 2015). South Africa’s NDP 2030 is committed to a low carbon, climate-resilient future, while the NCCRP (DEA, 2011) provides a strategic roadmap to achieve this. These policies present government’s vision and strategy for an effective response to climate change over the short, medium and long-term, while supporting the country’s development needs by working towards inclusive economic growth, poverty alleviation and increased employment. The NCCRP provides a framework for the mainstreaming of climate-resilient development planning and action between the different spheres of government and all government sectors have to ensure that all policies, strategies, legislation, regulations and plans are in alignment with the NCCRP (DEA 2011a). All national departments are thus further mandated to develop sector specific climate change adaptation plans. Many of the national departments have developed or are currently developing climate change plans for their sectors and in some cases, they are taking steps to integrate these into departmental operational plans.

One of the strategic interventions in South Africa’s National Climate Change Adaptation Strategy (DEA, 2019) (Strategic Intervention 4) is to “Facilitate mainstreaming of adaptation responses into sectoral planning and implementation”. In support of this intervention, Outcome 4.2 in the NAS is to achieve 100% coverage of climate change considerations in sectoral operational plans. The provision of support to private sector businesses to incorporate climate change adaptation into their strategic implementation is one of the proposed actions to achieve this intervention (Action 4.2.5). Developing a National Climate Risk and Vulnerability (CRV) Assessment Framework (DEFF, 2020a), Strategic Intervention 3 in the NCCAS, is intended to guide sectors and provinces when reviewing and revising existing assessments and response plans. This will allow for comparison of the results of the assessments or to support aggregation of the results to provide an overall picture of vulnerability and response across sectors and spheres of government in South Africa.

Key developments since the NCCRP has been the submission of the country’s first Nationally Determined Contributions (NDC) (DEA, 2015a) and the National Climate Change Adaptation Strategy (NCCAS) which has been drafted and revised (DEA, 2019). The Carbon Tax Bill, Greenhouse Gas Emissions reporting, draft Climate Change Bill and Pollution Prevention Plan regulations are substantial policy steps undertaken by the country to curb GHG emissions. South Africa’s commitment to promoting low carbon economy and climate-resilient society is evident in the many increasing efforts by all levels of government and private sector organizations in mainstreaming climate change in their development policies, plans, strategies and reporting on emissions. An overview of SA's climate change policy framework is shown in Figure 5.2-1 and includes sectoral climate change adaptation strategies. Policies, plans, strategies and frameworks that support climate change adaptation in the key adaptation sectors *viz*. water; agriculture, forestry and fisheries; human settlements; biodiversity; and health include:

Water

- The National Water Resources Strategy 2 (NWRS2) (DWS, 2013);
- The National Climate Change Response Strategy for the Water Sector (DWS, 2014) *(developed in 2014, revised in 2019)*;
- The National Water Research, Development and Innovation (RDI) Roadmap for 2015-2025 (WRC, 2015); and
- The draft National Water and Sanitation Master Plan (NW&SMP) (DWS, 2018; DWS, 2018a).

Agriculture

- The Integrated Growth and Development Plan (IGDP) (DAFF, 2012)
- Climate Change Sector Plan for Agriculture, Forestry and Fisheries (CCSPAFF, 2013) (DAFF, 2013a)
- The draft Climate Change Adaptation and Mitigation Plan for South African Agriculture, Forestry and Fisheries sectors (CCAMPAFF) (DAFF, 2018b) *(developed to replace the original CCSPAFF) (DAFF, 2015a)*
- The draft Climate-Smart Agriculture (CSA) Strategic Framework (DAFF, 2018b)
- The draft Conservation Agriculture Policy (DAFF, 2017)
- *Strategic Plan for the Department of Agriculture, Forestry and Fisheries (*DAFF, 2013b); DAFF, 2015b)
- *Strategy for the development of small and medium agro-processing enterprises in the Republic of South Africa* (DAFF, 2015).
- *Conservation of Agricultural Resources Act 43 of 1983* (RSA, 1983).

Urban Settlements

- The Spatial Planning and Land Use Management Act, No. 16 of 2013 (SPLUMA)
- The Integrated Urban Development Framework (IUDF) (DCOGTA, 2016)
- The Housing Act, 1997 (Act No. 107, 1997) (RSA, 1997)

- The White Paper on a New Housing Policy and Strategy for South Africa (Department of Housing, 1995)
- The Department of Human Settlements' Environmental Implementation Plan 2015-2020 (DHS, 2015)
- Neighbourhood Planning and Design Guide (DHS, 2019)
- The Green Book (CSIR, 2019)

Rural Settlements

- The Climate Change Adaptation Sector Plan for Rural Human Settlements (DRDLA, 2013)

Coastal Settlements

- National Environmental Management: Integrated Coastal Management Act (Act No. 24 of 2008) (RSA, 2008)
- National Environmental Management: Integrated Coastal Management Amendment Act of 2014 (RSA, 2014)
- National Water Act (RSA, 1998), Biodiversity Act (RSA, 2004b) and the Protected Areas Act (RSA, 2004)
- National Guideline towards the Establishment of Coastal Management Lines (DEA, 2017)

Biodiversity

- White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity (DEAT, 1997)
- Natural Environmental Management Act (Act 2017 of 1998)
- National Environmental Management: Protected Areas Act (Act 57 of 2003)
- National Environmental Management: Biodiversity Act (Act 10 of 2004) (RSA, 2004)
- National Biodiversity Strategy and Action Plan (NBSAP) (2005)
- Updated National Biodiversity Strategy and Action Plan (NBSAP) (DEA, 2015b)
- Climate Change Adaptation Plans for South Africa's Biomes (DEA, 2015b)
- Strategic Framework and Overarching Implementation Plan for Ecosystem-based Adaptation (South African EbA strategy) (DEA and SANBI, 2016)

- South Africa's Fifth National Report to the Convention on Biological Diversity. Convention on Biological Diversity (CBD, 2014).
- RSA (2008). *National Environmental Management: Integrated Coastal Management Act 24 of 2008*. The Presidency. Available at: https://www.gov.za/documents/national-environmental-management-integrated-coastal-management-act
- RSA (2014). *National Environmental Management: Integrated Coastal Management Amendment Act of 2014*. Available at: https://www.gov.za/sites/default/files/gcis_document/201501/3817131-10act36of2014integratedcoastalmanagema.pdf

Health

- The National Health Act of 2003 (Act No. 61 of 2003)
- National Department of Health Strategic Plan (NDHSP) for 2015 - 2020)
- The Presidential Health Compact (July 2019) (The Presidency, 2019)
- The National Environmental Health Policy (2013) (NDoH, 2013)
- The Climate Change and Health Adaptation Plan of 2014-2019 (NCCHAP 2014 – 2019)
- The National Climate Change and Health Adaptation Plan 2020-2024 (NCCHAP 2020 – 2024)
- The National Heat Health Action Guidelines (NDoH, 2019b)

Each sector has its own primary and supporting policies in place. Table 6.2-2 outlines the high-level objectives of selected primary adaptation policies and supporting policies related to the key socio-economic adaptation sectors which are vulnerable to the impacts of climate change.

The NCCAS outlines nine strategic interventions which are required to achieve South Africa's vision to transition to a climate-resilient economy and society and have linked them to various, desired adaptation outcomes. Table 6.2-3 outlines, per sector, how the strategic outcomes of the sectoral adaptation policies support the nine strategic interventions and related outcomes of the NCCAS.

The following assessment, adapted from DEFF (2020b), broadly outlines what is needed to realise the outcomes of the NCCAS:

Outcome 1.1: Increased resilience and adaptive capacity achieved in human, economic, environment, physical and ecological infrastructure vulnerability

Measures aimed at reducing the vulnerability of water infrastructure and agricultural and fishery resources need to be improved.

Outcome 2.1: Develop a risk, early warning, vulnerability and adaptation monitoring system for key climate-vulnerable sectors and geographic areas

The majority of sectoral policies only recognise the need for the development and implementation of an early-warning system within the specific sector. Processes and requirements involved in realising Outcome 2.1 are still at an early stage and progress towards the realisation of the outcome will only commence upon the successful implementation of early warning systems in the various adaptation sectors.

Outcome 3.1: An adaptation vulnerability and resilience framework be developed and implemented across 100% of key adaptation sectors

There is room for improvement in developing a methodology framework within the Coastal Zones sector

Outcome 4.2: Achieve a 100% coverage of climate change considerations in sectoral operational plans

This outcome is achievable since all sectors confirm that climate change adaptation is a cross-sectoral issue that needs to be addressed on a cross-sectoral basis. There is room to improve the practical implementation of the policies and the cooperation between sectors, through instruments such as memoranda of understanding between the different government departments.

Outcome 5.1: Increased research output and technology uptake to support planning and implementation

Each sector needs to develop a climate research roadmap for climate change adaptation. This could involve identifying areas where new and additional research is required in South Africa and recommending priorities for research and development funding.

Outcome 6.1: Capacity building and awareness for climate change response enhanced

Policies have made progress towards creating awareness and building capacity; however, provisions of the policies are generally still not practically implemented across the sectors and there is room to improve the actions taken towards creating awareness and building capacity in the sectors

Outcome 7.1: Adaptation governance defined and legislated through the Climate Change Act once approved by parliament; Outcome 7.2: Institutional support structures for climate change

adaptation strengthened; Outcome 7.3: Enhanced public-private- civil society collaboration and stewardship

The actions and provisions set out in the various sectoral policies generally aim to realise the Outcomes 7.1 to 7.3. However, all of the policies would have to be reviewed upon the promulgation of the Draft Climate Change Bill in order to align with the provisions of the Bill.

Outcome 8.1: Adequate financial resources of national adaptation priorities from national fiscus and international sources

There needs to be an increase of access to funding from both national as well as international resources.

Outcome 9.1: A national M&E system developed and implemented

Urgent work will need to be undertaken to develop M&E systems in all of the vulnerable socio-economic sectors mentioned in the NCCAS

Table 6.2-1: South Africa's climate change policy framework including national sectoral climate change policies

DEVELOPMENT PATHWAY

National Development Plan (NDP 2030) aligned with Sustainable Development Goals (SDG) and Constitution of the Republic of South Africa (1996), Section 24

POLICIES AND LEGISLATION/REGULATIONS

2011	2014	2016	2017	2018	2019
• National Change Response Policy • Energy Efficiency Building Regulations	• National Environmental Management: Air Quality Act 2004 (as amended)	• National Energy Efficiency Strategy • Draft Integrated Energy Plan • Draft Integrated Resource Plan	• Draft National Adaption Strategy • GHG Reporting and Pollution Prevention Plans • National Green Transport Policy	• Draft Carbon Tax Bill • Draft Climate Change Bill	• Draft National Climate Change Adaptation Strategy • Integrated Resource Plan • Carbon Tax Act No.15 of 2019 • Carbon Offsets Regulation

POLICY INFORMING STUDIES

2008	2013	2015-2016	2016-2020	2017	2018	2019
• Long-Term Mitigation Scenarios (LTMS)	• Long-Term Adaptation Scenarios (LTAS) **2014** • Mitigation Potential Analysis (MPA)	• National Terrestrial Carbon Sinks Assessment and Atlas • GHG emissions baseline for AFOLU • Near-Term Priority Climate Change Flagship Programmes	• Voluntary Sector Desired Emission Reduction Outcomes and Voluntary Carbon Budgets	• Reduction in emissions from REDD+ • Grid Emission Factor • (GEF) Review	• GHG Emissions pathway study • Policies and Measures • Low carbon Technology stock take	• Tracking the transition to a low carbon and climate resilient society and economy

NATIONAL SECTORAL CLIMATE ADAPTATION STRATEGIES

AGRICULTURE, FORESTRY AND FISHERIES	BIODIVERSITY	SETTLEMENTS	HEALTH	WATER
• Draft Climate Change Adaptation and Mitigation Plan for South African Agriculture, Forestry, and Fisheries Sectors (2018) • Draft Climate Smart Agriculture Strategic Framework (2018) • Draft Conservation Agriculture Policy (2017)	• Strategic Framework and Overarching Implementation Plan for Ecosystem-Based Adaptation (EbA) in South Africa (2016 – 2021) • Guidelines for ecosystem-based adaptation (EBA) in South Africa (2017) • Climate Change Adaptation plans for South African Biomes (2015) • Biodiversity Sector Climate Change Response Strategy (2014)	• Department of Human Settlements' Environmental Implementation Plan (2015-2020) • National Guideline Towards the Establishment of Coastal Management Lines (2017) • National Coastal Management Programme (NCMP) of South Africa (2014) • Climate Change Adaptation Sector Strategy for Rural Human Settlements (2013)	• National Climate Change and Health Adaptation plan (2020) • National Heat Health Action Guidelines (2019) • Department of Health Strategic Plan 2015-2020 (2015)	• Climate Change Response Strategy for the Water and Sanitation Sector (2019)

Table 6.2-2: High-level objectives of selected primary and supporting adaptation policies for South Africa's key vulnerable socio-economic sectors (adapted from DEFF, 2020b)

Sector	Primary policies/ strategy for Climate Change	High-level objective of primary policy/strategy	Supporting policies	High-level objective of supporting policy/strategy
Agriculture, Forestry and Fisheries	Draft Climate Change Adaptation and Mitigation Plan for South African Agriculture, Forestry and Fisheries Sectors, 2018	Reduce the harmful impacts of climate change on agriculture, forestry and fisheries in South Africa by encouraging the introduction of adaptation measures to anticipate and lessen harmful climate effects	Draft Climate Smart Agriculture Strategic Framework, 2018	Enhance resilience to climatic and weather shocks on the social, environmental and economic aspects of agriculture, forestry and fisheries production and food systems
			Draft Conservation Agriculture Policy, 2017 (DAFF, 2017)	Promote and establish ecologically and economically sustainable agricultural systems that will increase food security levels and address associated national security risks
Human Settlements (Urban and Rural)	Environmental Implementation Plan 2015-2020 (Department of Human Settlements)	Ensure that development and/or implementation of policies, plans and programmes comply with environmental management principles for sustainable development outlined in Section 2 of NEMA	Draft National Spatial Development Framework, 2018	Provide for spatial development planning as a key means and driver in the creation of development and growth, in an equal society.
	Climate Change Adaptation Sector Strategy for Rural Human Settlements, 2013	The primary objective of primary policy 2 is to create sustainable livelihoods that are resilient to the shocks and stresses caused by climate change and do not adversely affect the environment for present and future generations.	Department of Human Settlements Revised Strategic Plan, 2015-2020	To facilitate the creation of sustainable human settlements and improved quality of household life. The Plan has 4 programmes which include: 1. Programme 1: Administration 2. Programme 2: Human Settlements Policy, Strategy and Planning 3. Programme 3: Programme Monitoring and Delivery Support 4. Programme 4: Housing Development Support

Sector	Primary policies/ strategy for Climate Change	High-level objective of primary policy/strategy	Supporting policies	High-level objective of supporting policy/strategy
Human Settlements (Coastal)	National Guideline Towards the Establishment of Coastal Management Lines (2017)	Develop a setback line adopted by the Competent Authority in terms of the Environmental Impact Regulations	National Environmental Management Act: Integrated Coastal Management Act 24 of 2008	The objectives of the ICM Act are: 1. Determination of the coastal zone in South Africa 2. Provision for coordinated and integrated management of the coastal zone 3. Preservation, protection, extension and enhancement of coastal public property 4. Equitable access to coastal public property 5. Giving effect to South Africa's obligations under international coastal and marine law
	National Coastal Management Programme (NCMP) of South Africa (DEA, 2014a)	The Programme identifies nine key priorities for coastal management that sets out a series of goals and associated management objectives aimed at coastal management efforts that should be addressed at a national level		
Health	National Climate Change and Health Adaptation plan 2020	The plan was developed to characterize climate and health adaptation challenges in South Africa and to propose steps that may be taken by the health sector to facilitate adaptation to climate change, especially in respect of the most vulnerable settings and groups in the country. A further goal was to approaches to climate change and health adaptation in relation to key national and international agreements, conferences and legislation	National Heat Health Action Guidelines (NDoH, 2019b)	To support Provincial Departments of Health, District Health Services and Municipalities in designing, improving and implementing Heat Health Action Plans to prevent the negative effects on health caused by heat and heatwaves
			Department of Health Strategic Plan 2015-2020 (NDoH, 2015)	The Strategic Plan's vision is to improve health status through the prevention of illness, disease and the promotion of healthy lifestyles and to consistently improve the health care delivery system by focusing on access, equity, efficiency, quality and sustainability

Sector	Primary policies/ strategy for Climate Change	High-level objective of primary policy/strategy	Supporting policies	High-level objective of supporting policy/strategy
Biodiversity	Climate Change Adaptation plans for South African Biomes, 2015	To review and prioritise the most significant potential climate change risks and vulnerabilities for each of the 9 biomes in South Africa and to present potential adaptation responses measures that will guide current and future decision-makers in protecting South Africa's natural ecosystems and biodiversity in the face of climate change	Strategic Framework and Overarching Implementation Plan for Ecosystem-Based Adaptation (EbA) in South Africa: 2016 – 2021 (DEA and SANBI, 2016)	The policy has 4 major objectives (outcomes) which it aims to achieve through the introduction of Ecosystem based adaptation which includes: 1. Effective coordination, learning and communication mobilise capacity and resources for EbA, 2. Research, monitoring and evaluation provide evidence for EbA's contribution to a climate-resilient economy and society, 3. Integration of EbA into policies, plans and decision-making supports an overall climate change adaptation strategy, 4. Implementation projects demonstrate the ability of EbA to deliver a wide range of co-benefits.
Water	Climate Change Response Strategy for the Water and Sanitation Sector, 2019 (Revision of National Climate Change Response Strategy for the Water Sector (DWA, 2019)	Provides for provides an integrated framework for climate change response to minimize the overall detrimental impacts of climate change and to maximize beneficial impact. The strategy sets out the key strategic actions to be undertaken to address climate change in the water and sanitation sector to build resilience and reduce vulnerability to the water related impacts of climate change.	Department of Water and Sanitation Revised Strategic Plan, 2015/16 – 2019/20	The plan sets out 5 outcome orientated goals which includes: 1. Enhanced and protected water as a resource across the value chain; 2. Equitable access to reliable, sustainable and acceptable water resources and water and sanitation services; 3. An enhanced contribution to socio-economic development and transformation by the sector; 4. An efficient, effective and development-oriented water and sanitation sector; 5. Sound cooperative governance and an active and engaged citizenry.

Table 6.2-3: The degree to which sectoral policies are aligned with, or support, the NCCAS' nine interventions (adapted from DEFF, 2020b)

NCCAS INTERVENTION	Water	Agriculture, Forestry and Fisheries	Urban and Rural Settlements	Coastal Settlements	Biodiversity	Health
Intervention 1: Reduce vulnerability and ensure resilience	Provisions related to reducing vulnerability in the water sector are well integrated into primary policies.	Specific provisions to address vulnerability are needed. While certain provisions are aimed at reducing water vulnerability in this sector, there is room to improve provisions to reduce the vulnerability of water-related infrastructure in the sector	Provisions related to reducing vulnerability in the Urban and Rural Settlements sector are well integrated into primary policies	Reducing vulnerability in the sector is well integrated into the various policies and is seen as a priority for the sector	Provisions in the primary policy are aimed at addressing environmental vulnerabilities. There is room to improve the vulnerabilities that communities and physical infrastructure face in the biodiversity sphere	Vulnerability assessments are integrated into Health Sector policies; however, the vulnerability of health infrastructure needs to be included
Intervention 2: Develop an early warning system	Importance of early warning systems was acknowledged, however, no specific system linked to disaster management policy has been implemented to	No means of establishing early warning systems have been provided for in the sector policies	Importance of an early warning system acknowledged. Policies and legislation that should inform the development and implementation of	Importance of early warning systems was acknowledged, however, no specific system linked to disaster management policy has been implemented to	Importance of early warning systems was acknowledged, however, no specific system linked to disaster management policy has been implemented to	The primary policy provides for the need to develop an Early Warning Response System and budget has been allocated to the design of EWRS for all

NCCAS INTERVENTION	Water	Agriculture, Forestry and Fisheries	Urban and Rural Settlements	Coastal Settlements	Biodiversity	Health
	date		such systems are highlighted	date	date	health priority areas
Intervention 3: Develop a vulnerability and resilience methodology framework	The primary policy has a very specific framework which is aimed at addressing climate change adaption in the sector	Integrated vulnerability assessments as part of the climate change adaptation methodologies are described in the adaptation policy	Integrated vulnerability assessments as part of the climate change adaptation methodologies are described in the adaptation policy	No clear methodological framework exists in the primary policy to increase biophysical or socio-economic resilience	Integrated vulnerability assessments as part of the climate change adaptation methodologies are described in the adaptation policy	Integrated vulnerability assessments as part of the climate change adaptation methodologies are described in the adaptation policy
Intervention 4: Facilitate mainstreaming of adaptation responses into sectoral planning	The policy acknowledges that an intersectoral approach is necessary to adapt to climate change and identifies key entities to ensure alignment between the national programmes of these departments and issues of water availability under scenarios of climate change	The policy identifies enablers necessary to mainstream adaptation responses in the agriculture and forestry sectors	Recognises that rural development and the design and implementation of climate change adaptation responses require multi-sectoral coordination and cooperative governance across government departments and the different spheres of government	The primary policy recognises the importance of mainstreaming adaptation responses into sectoral planning but provides no clear method for mainstreaming of adaptation responses	The primary policy recognises that, in line with the Long-Term Adaptation Scenarios (2013) programme, a multi-sectoral approach to the development of adaptation plans is critical	Intersectoral cooperation is specifically outlined as a medium-term action and various sectoral departments are identified by the primary policy as key departments for implementing the primary policy

NCCAS INTERVENTION	Water	Agriculture, Forestry and Fisheries	Urban and Rural Settlements	Coastal Settlements	Biodiversity	Health
Intervention 5: Promote research, technology development and transfer	Does not identify technology transfer as a key means to create climate resilience within the sectors	Recognises that technology transfer should take place, but no system has been established in the policy to actually facilitate the transfer of technologies	Integrates technology transfer and research as one of its four priority programmes, related to supporting research to create climate-resilient rural settlements	Does not identify technology transfer as a key means to create climate resilience within the sectors	Does not identify technology transfer as a key means to create climate resilience within the sectors	Does not identify technology transfer as a key means to create climate resilience within the sectors
Intervention 6: Build the necessary capacity and awareness	As part of its water governance action plan, awareness, communication and shared learning, are identified as key components in climate change adaptation	Climate change awareness is highlighted in the policy but no clear roll-out plan for climate change awareness is present	The primary policy addresses the need to increase the adaptive capacity and awareness of communities. The secondary policy includes building capacity in the sense of human resources to address climate change adaptation	Strengthening awareness, education and training to build capacity is listed as one of the primary policy's nine priorities	Provision is made for awareness creation and capacity building to promote ecosystem-based adaption approaches in the biomes	Capacity building is listed as a short-term action needed in order to achieve the objectives of the primary policy

NCCAS INTERVENTION	Water	Agriculture, Forestry and Fisheries	Urban and Rural Settlements	Coastal Settlements	Biodiversity	Health
Intervention 7: Establish effective legislative and governance processes	Policies clearly outline the legislative frameworks in which the policies must operate	Lacks a clear outline of the governance structures and legislative processes to integrate climate change in development planning	Policies clearly outline the legislative frameworks in which the policies must operate	Policies clearly outline the legislative frameworks in which the policies must operate	Policies clearly outline the legislative frameworks in which the policies must operate	Policies clearly outline the legislative frameworks in which the policies must operate
Intervention 8: Establish a substantial flow of climate change adaptation finance	Recognise the need for climate funding but provide no means of obtaining such finance	Recognise the need for climate funding but provide no means of obtaining such finance	Key climate finance resources for the sector are identified in the primary policy	Recognise the need for climate funding but provide no means of obtaining such finance	Key climate finance resources for the sector are identified in the secondary policy	Access to climate finance is highlighted as a key factor in realising capacity building related to climate change
Intervention 9: Develop and implement an M&E system	All sectors stress the importance of developing an M&E system, but none of the sectors yet developed an M&E system in order to track the progress towards the NCCAS outcomes					

6.3 Provincial Climate Change Strategies

Provincial policies and strategies are aligned to national policies where the primary policy approach for provinces in respect of climate change response is framed within the NCCRP and guided by the NDP. Integrated planning is one of the national priorities highlighted in South Africa's NCCRP and involves mainstreaming climate change considerations and responses into all relevant sector, national, provincial and local planning regimes. Each province within South Africa is mandated to develop a climate change response strategy as stipulated in the NCCRP. These strategies are expected to evaluate provincial climate risks and impacts whilst integrating the principles of the NCCRP at a provincial level. The importance of provincial and local government planning is echoed in one of the aspirational goals of South Africa's first NDC (Goal 2) and the NCCAS (Strategic Intervention 4), where it is noted that climate considerations need to be integrated into sub-national policy frameworks.

At a provincial level, departments responsible for the environment are assigned to lead climate change response action in collaboration with their respective environmental departments and provincial entities. Provincial climate change structures have been established by most lead departments to provide a platform for provincial stakeholders to jointly learn about climate change and to co-ordinate their respective climate change responses (DEA, 2018a).

The NCCAS recognises that provincial and local governments would have different resources available to implement national priorities and recommends that the adaptation priorities should be interpreted within the spatial area of the relevant authority, with the minimum information as stipulated for sectors, being applied as appropriate. Strategic intervention 4 in the NCCAS is to 'Facilitate mainstreaming of adaptation responses into sectoral planning and implementation' with key outcomes for the intervention including:

4.1.2 Provincial strategies and associated implementation plans should be reviewed and updated every five years.

4.2.1 Integrate climate change adaptation into Provincial Growth and Development Strategies. This will involve each province ensuring that climate change projects and programmes are reflected in their strategic Provincial Growth and Development Strategies.

Since the development of the NCCRP, considerable progress has been made in developing vulnerability assessments and climate response policies, plans and strategies in various sectors and spheres of government, including the development of climate adaptation plans in the provincial government. The nine provinces in South Africa are taking actions to address climate change responses and have developed risk and vulnerability assessments and climate change response strategies that include climate adaptation interventions (DEA, 2017b) (Figure 6.3-1 and Figure 5.2-1). Provincial priorities related to climate change adaptation are shown in Figure 6.3-1.

PROVINCIAL CLIMATE CHANGE STRATEGIES

GAUTENG
- Gauteng climate change response strategy (2011)
- Report on the updated climate change projections and broad risk and vulnerability assessment of selected sectors (2017)
- Gauteng City Region Over-arching Climate Change Response Strategy and Action Plan (2020)

MPUMALANGA
- Adaptation Strategies for Mpumalanga Province (2015)
- Mpumalanga Provincial Climate Change Vulnerability Assessment Report (2015)

KWAZULU-NATAL
- Draft Climate Change Action Plan (2014)

NORTH WEST
- North West Provincial Climate Change Vulnerability Assessment Report (2015)
- North West Provincial Climate Change Vulnerability Assessment Report - Climate Change Adaptation Strategies (2015)

FREE STATE
- Free State Climate Change Status Quo Report (2015)
- Climate Change Model Projection for the Free State Province (2015)
- Vulnerability Assessment for the Free State Province (2015)

LIMPOPO
- Provincial climate change response strategy (2016-2020)
- Adaptation Strategies for Limpopo Province (2015)
- Adaptation Strategies for Limpopo Province. Green Economy Plan (2013)

NORTHERN CAPE
- Northern Cape Climate Change Projections (2015)
- Northern Cape Climate Change Vulnerability Assessment (2015)
- Northern Cape Climate Change Status Quo (2015)

EASTERN CAPE
- Eastern Cape climate change response strategy (2011)

WESTERN CAPE
- Western Cape climate change response strategy (2014)
- A climate change strategy and action plan for the Western Cape (2008)

Figure 6.3-1: Provincial climate change strategies

Table 6.3-1: Provincial priorities related to climate change adaptation (adapted from DEA, 2017b)

Province	Priorities related to climate change adaptation
Gauteng	Sustainable water practices such as Use of Alternative water sources (e.g. groundwater), Water conservation, Rainwater harvesting, Greywater harvesting and Sustainable urban drainage systems
	Urban development and infrastructure – no encroachment onto floodplains, protection and expansion of high-value open spaces
	Sustainable and climate-resilient agriculture and agro-processing
	Review and implementation of biodiversity management plans
Western Cape	Effective land use and land care
	Protection, maintenance and enhancement of natural resources
	Climate Resilient low carbon agricultural sector
	Effective climate disaster risk reduction and management for agriculture
	Strengthen monitoring, data and knowledge management and sharing and lead strategic research for climate change and agriculture
KwaZulu-Natal	Catchment management (e.g. removal of invasive alien species)
	Capacity building and awareness of the value of using biodiversity in assisting societal adaptation to the adverse impacts of climate change
	Expanded rainwater harvesting, water storage and conservation techniques, water reuse, desalination, water-use and irrigation efficiency
Eastern Cape	Resilience to the effects of sea-level rise, storm surges, flooding and sea temperatures rise (fisheries)
	Disaster management and improved response to the impacts of extreme coastal events
	Water resources management
	Early implementation of water restrictions during extended periods of drought
	Improved wildfire prevention and suppression
	Societal adaptation to human health impacts from temperature increases
	Food security programmes, through small-scale farming and homestead agricultural production
	Climate Change Acclimatization and Resilience in provincial food security programmes
	Conservation Cropping Practices
Limpopo	Disaster risk reduction and management
	Water management
	Resource conservation and management
	Climate Smart agricultural programmes and water efficiency in agriculture
	Raise performance and efficiency of water service delivery for domestic use
	The green economy plan focused on economic systems and the integrity of ecosystems
Mpumalanga	Enhanced use of ecological infrastructure to create buffers for climate resilience
	Enhanced Sustainable Livelihoods
	Natural Resource Management
	Integrated Rainwater harvesting to combat drought effects

Province	Priorities related to climate change adaptation
	Research related to global climate change, energy and climate science
North West Province	River Health Programmes
	Alien Invasion Programmes
	Agriculture master plan
	Dam Remediation programmes
	Rapid Road Transport Improvements (BRT systems) and public transport systems
	Disaster Risk Reduction
Northern Cape	Namaqualand Wilderness Initiative: Building resilience and adapting to climate change
	Rainwater harvesting initiatives
	Water conservation, demand management, recycling and artificial recharge
	Use of boreholes as a temporary measure since groundwater is impacted by the current drought
	Disaster Risk Reduction and Early Warning Systems
Free State	Rainwater harvesting initiatives
	Water quality monitoring
	Drought and flood relief programmes for farmers (e.g. encourage water conservation, demand management, recycling and artificial recharge and boreholes as a temporary measure)
	Eco-schools and promotion of environmental management

While considerable progress has been made by the provinces in terms of their efforts to respond to climate change, needs and gaps remain in terms of their plans for implementation of adaptation actions, as well as the capacity and funding needed to achieve these actions.

Table 6.3-2 outlines gaps or needs linked to climate change initiatives across the provinces. Needs which were common to many of the provinces include:

a) The need to translate adaptation strategies into action plans
b) The need for a clear strategy around securing and allocating climate finance to projects and programs
c) The need to integrate adaptation responses into departmental sector plans and integrated development plans
d) Limited capacity to secure funding for climate change response options
e) Limited institutional and financial capacity to implement the climate change strategy

Table 6.3-2: Gaps or needs linked to climate change initiatives in the province (adapted from http://www.letsrespondtoolkit.org/)

Province	Gaps or needs linked to climate change initiatives in the province
Western Cape	A key intervention is to ensure that climate change issues are mainstreamed into public, private and civil society processes
Eastern Cape	Need for further research on the impacts of climate change on human settlements and infrastructure
	Limited institutional and financial capacity to implement the climate change strategy
	Need for the capacity to apply for funding
Northern Cape	Need to translate the Vulnerability Assessment into response options and action plans
	Need for integration of responses into departmental sector plans
North West	Need for the establishment of a multi-sector stakeholder forum to respond to climate change
	Need to translate draft adaptation strategy into an action plan
	Need to integrate responses into departmental sector plans
	Need for a more clearly defined strategy to secure financing for climate change response options
Free State	Need to consolidate climate change policy environment for the Free State into clear adaptation responses outlined in a provincial climate change strategy
	Need for provincial sector-specific research, specifically regarding social aspects of climate change and potential impacts on biodiversity
	Need for a clear institutional structure to drive climate change response and access financing in the province
KwaZulu-Natal	Need to assess potential avenues of climate financing and how this financing can be used for various response options
Gauteng	Need for a more clearly defined strategy to secure financing for climate change response options
Limpopo	A key gap is a lack of institutional structures and capacity to drive climate change response
Mpumalanga	A key gap is a capacity and stakeholder structures to respond to climate change
	Need for a clear action plan for the response options outline in the province's adaptation strategy
	Need to integrate response options into departmental sector plans and municipal integrated development plans
	Need for a more clearly defined strategy to secure financing for climate change response options

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