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NM ENVIROTECH SOLUTIONS

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1. Introduction

The vulnerability assessment covered in this chapter is based on changes in temperatures, rainfall and extreme weather events as described in climate science modelling projections chapter. The sectors assessed are agriculture, biodiversity, water, human health including air quality, the built environment including infrastructure. Extreme weather events are also discussed in this report. In addition, an assessment of social vulnerability based on data from the Statistics South Africa highlighting the vulnerability of the population in the Northern Cape is also included. With the exception of the social vulnerability, all the other sectors are highlighted as important to the development of the country as outlined in the National Climate Change Response Policy published the Department of Environmental affairs (DEA, 2013).

2. Sector Vulnerability Assessment

2.1 Agriculture

According to the land cover of the Northern Cape (see Figure 2.1) there are five different types of agriculture highlighted and these are cultivated subsistence, cultivated orchards, cultivated commercial pivots, cultivated vines and cultivated commercial fields. An estimated 2% of the province land area is available for mainly irrigated farming along the Vaal and Orange Rivers while 96% of the province is utilised for livestock such as beef cattle, sheep goats and game farming (Northern Cape, 2011). Apart from the main crops and livestock listed the Northern Cape is also a wine producer, responsible for 25.6% of the Colombard Wine and 10% of the Chinin Blanc as well as being a producer of Rooibos tea. Another anticipated are of growth for agriculture is the production of essential oils such as rose geranium and other herbaceous plants used in the pharmaceutical industry (Northern Cape Province, 2011).

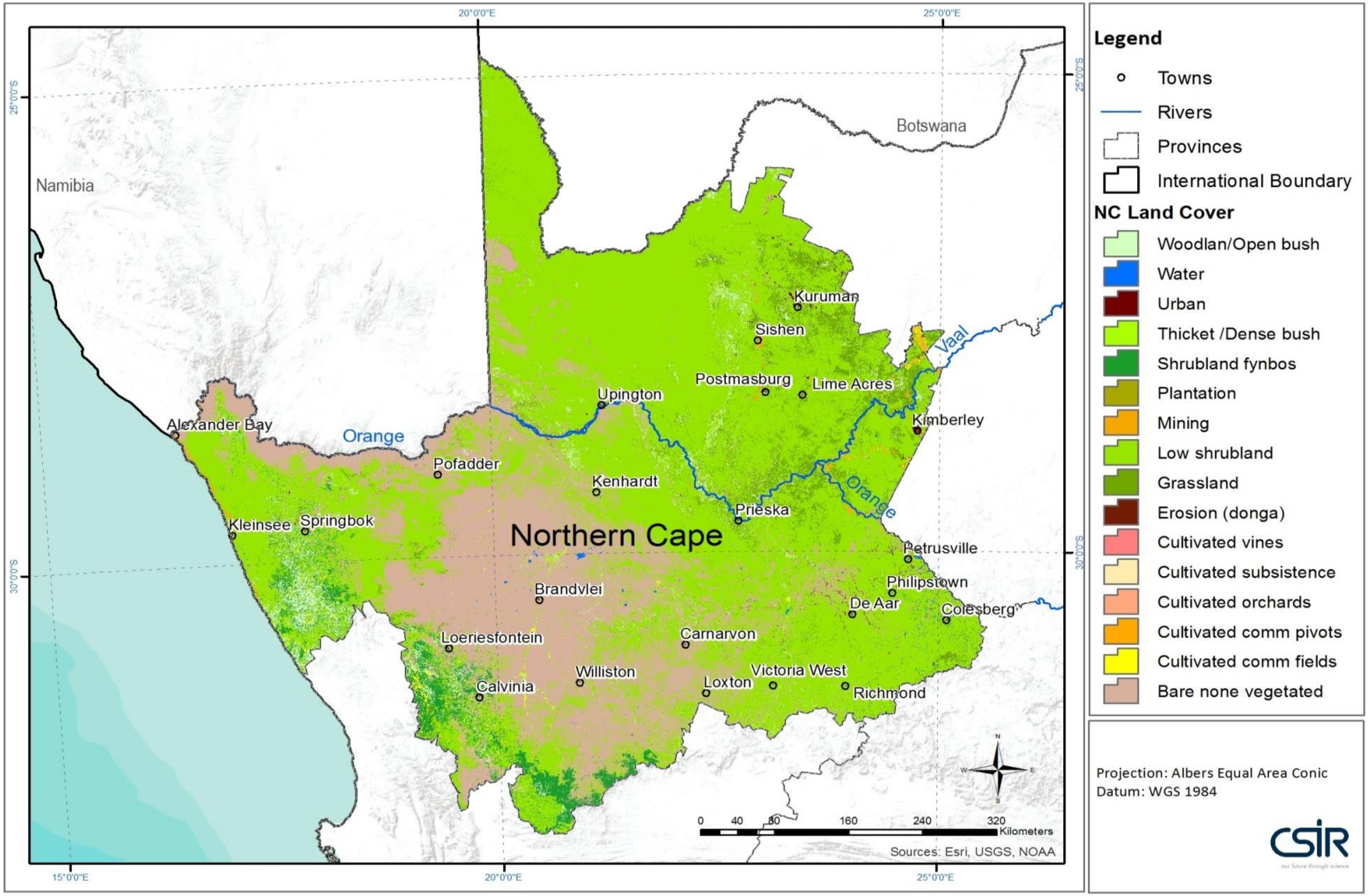

Figure 2.1: Land cover map of the Northern Cape showing the different types of agricultural activities (CSIR, 2015)

The agricultural sector in the Northern Cape is one of the potential economic growth sectors. In 2011, the sector contributed 5.8% to the GPD of the province, (approximately R1.3 billion) and employs at least 19.5% of the population in the province (Northern Cape Province, 2011). Commercial agriculture is the most principal land-use activity, with most of the area classified as farmland, due to the semi-arid condition. These areas are appropriate for extensive livestock ranching with a few exceptions where irrigation along the Vaal and the Orange allows for intensive agriculture of high value produce. The high value horticultural crops grown along the Orange River include table and wine grapes, sultanas, dates, nuts, cotton, fodder and cereal crops. The Vaalharts Irrigation scheme grows huge amounts of wheat, maize, cotton, ground nuts and fruit while other irrigation schemes on the Vaal and the Orange grow vegetables and cereals crops as well. The Northern Cape is also noted for the production of wool, mohair, karakul, Karoo lamb, ostrich meat and venison. In addition, the province is a big exporter of dried fruit and table grapes and meat to international markets, thus contributing to the country's foreign exchange earnings (Northern Cape Province, 2011).

2.1.1 Climatic factors affecting the Agricultural Sector

Numerous factors which are both climate and non-climate related affect agriculture in South Africa. The following section will discuss only the climatic factors which will be affected by climate change, for example rainfall, as one of the most important climatic factors influencing agriculture, especially determining the suitability areas where of crops will grow and livestock farming across the country. Rainfall variability presents a fundamental risk to agriculture, particularly in the areas of different seasonality and where the quantities of rainfall are sensitive to and are vulnerable to changes in climate. The dependence on water presents a critical vulnerability for all agricultural activities, particularly irrigation which the single largest water consumer in South Africa, using at least 60% for agriculture alone and 65% for other agricultural related activities (DEA, 2013a).

Irrigated agriculture is the biggest water consumer in South Africa, and this dependence on water poses the biggest vulnerability for all agricultural activities. There is confirmation that that small holder or subsistence dryland farming is the most vulnerable to climate change in comparison to commercial farming activities. On the other hand low scale irrigation agriculture will be least affected as long as there is sufficient rain (DEA, 2013a).

Evaporative losses, in South Africa are already high ranging from 1400 to 3000/mm per year and are caused by extremely high atmospheric demand. High evaporative losses when combined with unreliable rainfall often lead to semi-arid conditions. In some instances this is the case even where rainfall is adequate. Evapotranspiration from crops, which determines the amount of water a crop needs, and it is related to evaporation. An analysis to measure the sensitivity of crops to evapotranspiration indicates that during summer (January) a temperature increase of 2°C will increase the evapotranspiration from crops by 3.5%, with a much higher percentage increase in winter. While the percentages of increase varies, the consensus is that they will increase especially in the interior in the near, intermediate and far future (DEA, 2013a).

Temperature is another critical factor for agriculture, affecting a wide range of agricultural processes as well as being used as an index of energy status of the environment Temperature is one of the factors and has been modelled with certainty and is expected to increase with global warming (DEA, 2013a). Increases in temperatures bring about a myriad of additional issues for agriculture. The projected temperature increases range between 3.0 - 3.5°C and these are expected to increase up to 6°C by the turn of the century. Increases in temperatures are associated with heat waves which are defined as 3 or more consecutive days where temperatures are above 30°C and extreme heat waves above 35°C. Heat waves are expected to increase in the near and far future with the extreme heat wave day expected to double in the intermediate future, Areas already experiencing high temperatures will be the most affected (DEA, 2013a).

Other climatic factors important for agriculture are heat units and cold spells which are essential for crop growth and have an influence of crop pest life cycles. These are expected to increase in future, with moderate increases in the summer for heat units and higher in ecological sensitive areas. On the other hand cold spells defined as 3 or more days when temperature is less than minimum of <2.5°C for 3 or more consecutive days or extreme cold spell days where temperatures are expected to be <0°C) for 3 consecutive days. It is projected that the will be a reduction of at least 70% in the cold spell and extreme cold spell days in the South African interior (DEA, 2013a).

Positive chill units are defined as a period of winter chilling that is essential for particular biennial plants to complete their dormant season in order to produce high quality fruit. The chill units are measured in positive chill units based on hourly temperatures over and below the essential thresholds. It is estimated that a 2°C increase in temperature will cause reductions of approximately 14-60% but with an average of 40%.

2.1.2 Climate Change and Agriculture in the Northern Province

The myriad of climatic factors and their impacts on agriculture has been discussed above. Of special interest are the impacts of increases in temperature and the various temperature related complications it brings which are detrimental to agriculture, given the different agricultural activities in the Northern Cape.

According to the climate modelling projections the temperature in the Northern Cape is expected to increase by 1 to 3 °C by 2050, and may rise by as much 3°C under low mitigation scenarios. There are anticipated temperature increases of 1-2° C across the province under high mitigation scenario, with as much as 2.5 °C over the northern parts of the province. These temperature increases as discussed above will result in high evaporation rates with the threat of increasing aridity conditions as well as increases in evapotranspiration rates, which will increase the demand for water by plants. The other impacts of temperature changes as such as heat units, chill units all serve to affect crop (grains) and fruit production which are important agricultural crops in the Northern Cape. The expected increases in the number of heat wave days and the very hot days in the province from 30 – 60 day under low mitigation and 20 – 50 under high mitigation (DEA 2013) will affect livestock, as well affect crop yield and the possible increase in veld and forest fires in the province.

The Northern Cape is already an arid to semi-arid region, experiencing only 500mm of rain in the eastern areas and is getting even more arid towards the western parts of the province. The projected changes on rainfall are shrouded with a degree of uncertainty. However, there are general decreases in rainfall projected for the Northern Cape under both high and low mitigation, by most ensemble members, for the period 2020-2050, relative to the present day condition. However, most ensemble members project rainfall increases over the north eastern parts of the province. It is important to bear in mind that according to DEA (2013) the LTAS projections for rainfall presented on a river catchment scale indicate the same level of uncertainty under the different climate futures. The projected climate futures for the country from 2015–2035 (near future), 2040–2060 (medium future) and 2070–2090 (far future) indicate the following in terms of scenarios:

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

These scenarios were further elaborated regarding rainfall projections at sub-national level e.g. for South Africa's six hydrological zones (see Table 4.1 below).

Table 2.1: Rainfall projections over six of South Africa's hydrological zones (DEA, 2013)

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

The hydrological zones of interest to the Northern Cape include the Vaal, the Olifants (small extent) and the Orange indicate the same trends under the different scenarios, with decreases expected in both the Orange, the Olifants and the Vaal during the summer, autumn and spring seasons which are most critical for agriculture under scenarios 1 and 3 but with increases under scenarios 2 and 4 (DEA, 2013).

The projected changes in temperature coupled with the uncertainly of rainfall will put strain on the agricultural sector, especially the demand for irrigation which is expected to increase under all scenarios, with the exception of the eastern part of the country (DEA, 2013). Irrigation demand over the Northern Cape increase under warmer/wetter future scenario across the province see Figure 2.2) (left map) with minor increases of up to 1.0 – 1.10, with increases of 1.10 to 1.20 under the hotter/wetter future scenario (Schulze & Kunz, 2010). This will have a detrimental impact on grain crops such as maize in summer and wheat in winter (DEA, 2013a). However, these increases and decreases are marginal.

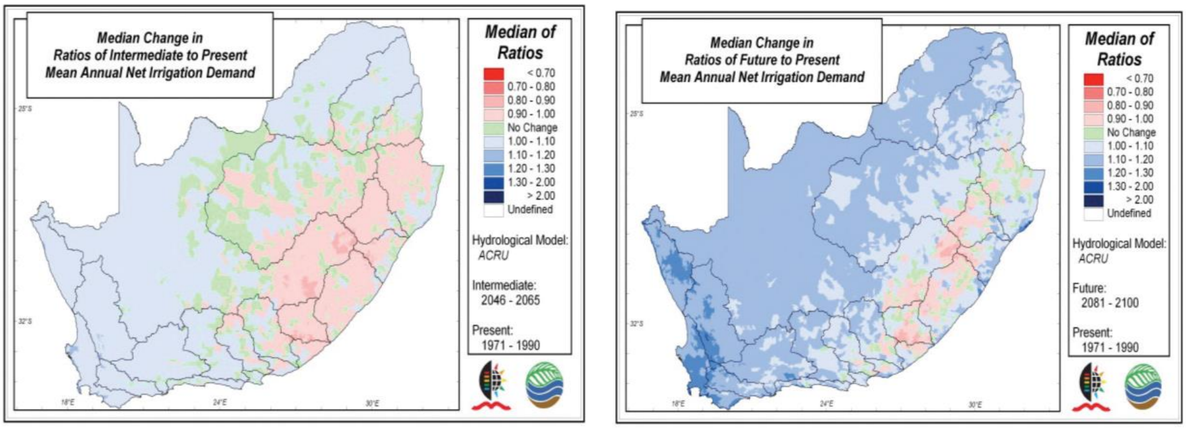

Figure 2.2: Modelled future of irrigation demand over South Africa from 2046 – 2065 (left) and 2081 – 2100 (DEA, 2013)

One of the most important high value produce is both table and wine grapes, with table grapes being key for the Northern Cape wine sector. The changes in climate as expected bring about spatial shifts in the suitable areas for grapes or viticulture crops. However, most of the anticipated changes in temperature are predicted for the western and southern Cape but spatial shits may still be experienced with a preference for higher altitudes and cooler climate (DEA, 2013a) compared to the warmer Northern Cape. The Northern Cape, where the vines are grown along the banks of the fertile Orange River is the fourth largest region characterised by warm climate and both white and red grapes are grown (Northern Cape Province, 2011). In terms of climate change, water rather than temperature will be the key issue with an increase in demand for irrigation being expected. An estimated 30% decrease in the yield is expected for the marginal non-irrigated vineyards in the country by 2050. The vineyards are dependent on rainfall (DEA, 2013a).

Other crops in the Northern Cape that will be affected by climate change include rooibos tea, for which decreases or a lack in rainfall at critical times will affect yield with as much 40% reduction in yield expected in a drought year. Maize, wheat and other cereal crops in the province will also be affected by changes in the areas of suitability to grow these crops as well as the changes in the availability of water rather than temperature (DEA, 2013a). This has potential impacts on the yield but it is important to note that a decrease is plausible under certain scenarios while other scenarios predict increases especially for maize. It is not yet clear how the Northern Cape will be affected by the predicted changes in rainfall and how this will affect the suitability of growing areas of some of the crops, especially maize.

Climate Change and Livestock

Meat production is one of the key agricultural sectors in the Northern Cape, as well as in the country. The modelling of the impacts of climate change on livestock has been premised on heat stress and humidity indices, especially the upper and lower temperature thresholds for thermally comfortable zones for livestock, which influence optimum development and production. Heat stress is likely to increase in the future with temperature as high as 30°C for all or at least two of the summer months considered given the projections
Archer van Garderen (2011). This is very critical in the Northern Cape where temperatures exceed 30°C in all summer months.

Feedlot cattle are undesirably impacted by high temperatures, relative humidity, solar radiation, and low wind speeds with the tolerance levels having been reached in the Northern Cope and other provinces during the summer months with expectations that these thresholds will be exceeded by the turn of the century. In terms of dairy cattle, the Northern Cape is already experiencing moderate to severe heat stress, affecting milk production (DEA, 2013a).

The impacts of climate change on agriculture, including livestock, one of the most important industries in the Northern Cape has highlighted the importance of temperature and rainfall both of which are affected by climate change, with possible losses and gains in both grains, fruits and livestock.

Marine and Fisheries

The west coast, along the Northern Cape Province is acknowledged as one of the most diverse marine ecosystems in globally, with unpolluted water hosting an abundance of marine life. Port Nolloth is the centre of fishing industry and while the increase in the issuing of fishing quotas, these are strictly enforced. The main catch is hake, with processing plant in the province. Further, the province has a growing mariculture industry where species such as abalone and oysters which are farmed for the export market. Aquaculture development is considered a potential growth area as a way of diversifying from agriculture, where farmers can incorporate aquaculture within their farming activities (Northern Cape Province, 2011). Fish products are utilised as a source of food, as well as being processed and added in other products such as animal feed and fertilisers as well as value added fish products through smoking, canning, filleting and salting. Details of the fish and marines species located in the province as well as the impacts of climate change on this sector are discussed in detail under biodiversity in section 4.2.4., Coastal and Marine Ecosystems.

According to the climate modelling projections (Chapter 3.2.1), the temperature in the Northern Cape is expected to increase by 1 to 3 °C by 2050, and may rise by as much 3°C under low mitigation. There are anticipated temperature increases of 1-2° C across the province under high mitigation, with as much as 2.5 °C over the northern parts of the province. These temperature increases as discussed above will result in decreased yield for most of crops as well as high value produce such as grapes in the province. The increases in temperature will affect viticulture particularly, resulting on consequences for the wine industry in the Northern Cape. The temperature change will increase heat stress which further affects both big and small livestock, while rainfall variability and increases in CO_2 in the will affected rangelands for livestock. The fisheries programmes will be affected by the availability of water issues related to climate change.

2.2. Biodiversity and Ecosystems

Healthy, functioning and biodiverse ecosystems are critical for human wellbeing, health and food security, by providing essential services such as formation of soil, provision of food and fresh water wood, fibre and fuel. Ecosystems also provide the regulation of climate, floods and protection from storm surges as well as diseases (DEA, 2013b; Driver et al., 2012). Ecosystems further serve a social, cultural and recreational role. A huge number of people and communities directly depend on ecosystems as a livelihood and safety net for food, energy, water and medicinal plants especially for rural populations (Murombedzi, 2008). South Africa has a wide range of habitats with 6% of the world's plant and mammals species, 5% of reptile species and 8% of birds all endemic to South Africa (Driver et al., 2012).

Mapping and classification of ecosystems into different ecosystem types is a first step in the assessment of the threat status and protection levels and classification system for South Africa, these include vegetation types, rivers, wetlands marine, coastal and estuary ecosystems. This further allow for ecosystem monitoring, assessment and planning (Driver et al., 2012).

2.2.1 Ecosystems in the Northern Cape Province

South Africa's biodiversity consists of nine biomes, six of which are found in the Northern Cape Province, namely Grassland; Savanna, Nama-Karoo; Succulent Karoo; Fynbos and Desert Biomes (see Figure 2.3).

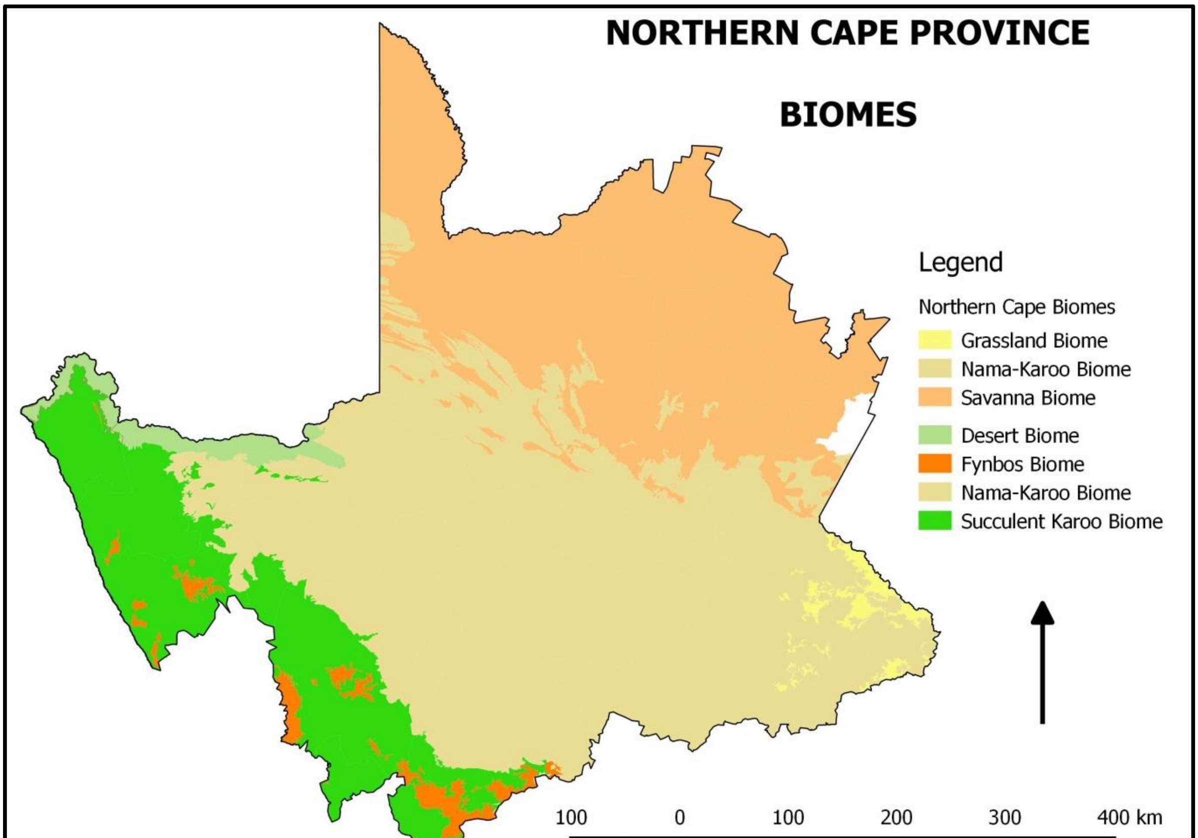

Figure 2.3: Biomes in the Northern Cape Province (map compiled using data from BGIS – SANBI)

The Nama-Karoo biome covers most of the province, and is dominated by grassy dwarf shrubland with an abundance of shrub available, while grasses are common in the landscape depressions as well as on sandy soils. The Nama-Karoo comprises of 25% of the total land area in South Africa, 50% of which is located in the Northern Cape. While the Nama-Karoo is well endowed in species richness or endemism, the biodiversity of this region is, well remarkably adapted to these climate extremes. The non-climatic factors affecting this biome are grazing by sheep and goats, within the farm boundaries. Not much of the Nama-Karoo is protected. The Nama-Karoo is the second most threatened biome in the country after the grasslands biome (which is the most threatened) (Driver et al. 2012). The key ecosystem service for the Nama-Karoo is the water due to the few perennial rivers and streams as well as shallow lakes found in this biome (Mucina et al, 2006b).

The second biggest biome in the Northern Cape is the savannah, located to the north of the province. The savanna is characterised by a grassy ground layer with upper woody plants, covering from shrubveld to woodlands. The savanna biome supports millions of people especially the rural population through the direct utilisation of the savanna goods. It is estimated that at least 9 to 12 million people use biomass for energy derived from savannas while a net worth of resources consumed from the savannah is estimated at R8 billion (Driver et al., 2012). The savanna also houses medicinal plants. The protection level of the savanna biomes vary based on their spatial location, with those savannas located in national parks being more protected (Driver et al, 2012). Factors affecting this biome include lack of adequate rainfall, fires and grazing for both livestock and game, which has assisted the grasslands in this biome to remain prominent (Northern Cape Province, 2011).

The succulent Karoo is the third largest biome in the Northern Cape, and is an international biodiversity hotspot, mainly located on the western part of the province, including the Namaqualand and Rischtersveld regions. This biome is well endowed with the richest succulent flora globally, 69% of which is endemic, and this includes some of the smallest perennial plants as well as over 630 species of geophytes. The biodiversity in the succulent Karoo is extremely adapted to the severe dry summers (Northern Cape Province, 2011). The vegetation of the succulent Karoo is characterised by dwarf shrubland dominated by succulents, and a diversity of the bulbs. Unlike other desert regions in the world, the succulent Karoo receives reliable and predictable rainfall in the winter months, while lengthy droughts are not common). Overgrazing in the communal lands, as well as mining activities are non-climatic drivers of change in the biome (Northern Cape Province, 2011). The succulent Karoo provides forage, soil nutrient recycling, soil water retention and pollination as part of it ecosystem services (DEA, 2013b).

The **grassland** biome covers small areas in the southern-eastern areas of the Northern Cape, and is one of the most threatened biomes, with low protection rates (Driver et al., 2012). The grassland biome is a second priority in terms of threatened ecosystems but despite its threatened status, grasslands have an estimated value of over R8 000/km^2 per year for grazing and livestock (Driver et al. 2012). The grasslands also contains a sizable amount of plants used for medicinal purposes a third of which are traded on the medicinal markets (Driver et al., 2012). Grasslands are essential for water production as well as being the backbone of the beef, wool and dairy product through the provision of fodder (DEA, 2013b).

The Fynbos biome occupies rather small areas in the Northern Cape, and is located in the following areas,

- Hantam Local Municipality - Bokkeveld Sandstone Fynbos and Niewoudtville Shale Renosterveld
- Kamiesberg Local Municipality - Namaqualand Granite Renosterveld and Kamiesberg Granite Fynbos - the Kamiesberg Protea is endemic to the Kamiesberg area

According the Long Term Adaptation Scenarios (LTAS) DEA (2013b), the Fynbos biome is the third most threatened in the country after the Nama-Karoo and Grasslands. The sensitive environments of the Fynbos are susceptible to degradation from due to over grazing, invasive alien species and mining (CEPF, 2003).

2.2.2 Threatened Ecosystems in the Northern Cape Province

Ecosystems are under immense pressure with threats of natural habitat due to land use and land cover change such as cultivation, mining and forestry as well as urban growth (Driver et al, 2012). Ecosystem threat status demonstrates the extent to which ecosystems are still pristine or are otherwise losing vital aspects of their structure, function and composition, which negatively impact on their ability to provide ecosystem services.

Figure 2.4 shows three ecosystems threat classifications, premised on the percentage of the ecosystem in good ecological condition relative to a number of thresholds. These are as follows:

- Critically Endangered (CR)
- Vulnerable (VU)
- Least Threatened (LT)

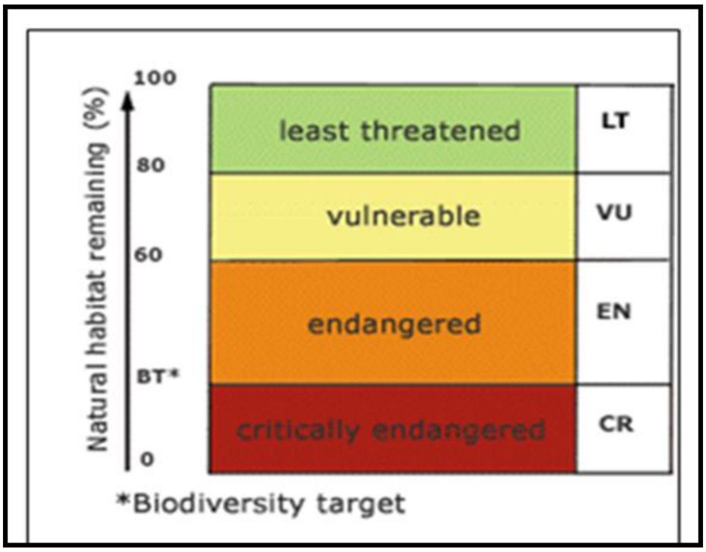

Figure 2.4: Threatened ecosystem ranking

The threshold beyond which an ecosystem becomes critically endangered varies from 16% to 36%, and is dependent on the ecosystem, for example, ecosystems that are species-rich have a higher threshold, which is also known as the biodiversity target. In terms of classification, the **least threatened** ecosystems are still mostly intact while the **vulnerable ecosystems** are sensibly intact, but are on the verge of reaching thresholds beyond which they will begin to lose some ecosystem function. The endangered ecosystems have lost substantial quantities of their natural habitat, prejudicing their functionality and the **critically endangered** ecosystems have diminutive natural habitat remaining and not only has their functioning been severely compromised, but species associated with the ecosystem are also being lost (Driver et al., 2012). Threatened terrestrial ecosystems have a tendency to be to be concentrated in areas that are centres of economic production, with the remaining fragments of these ecosystems entrenched in production landscapes. The remaining natural habitat in critically endangered and endangered ecosystems makes up less than 3% of the country's area (Driver et al., 2012).

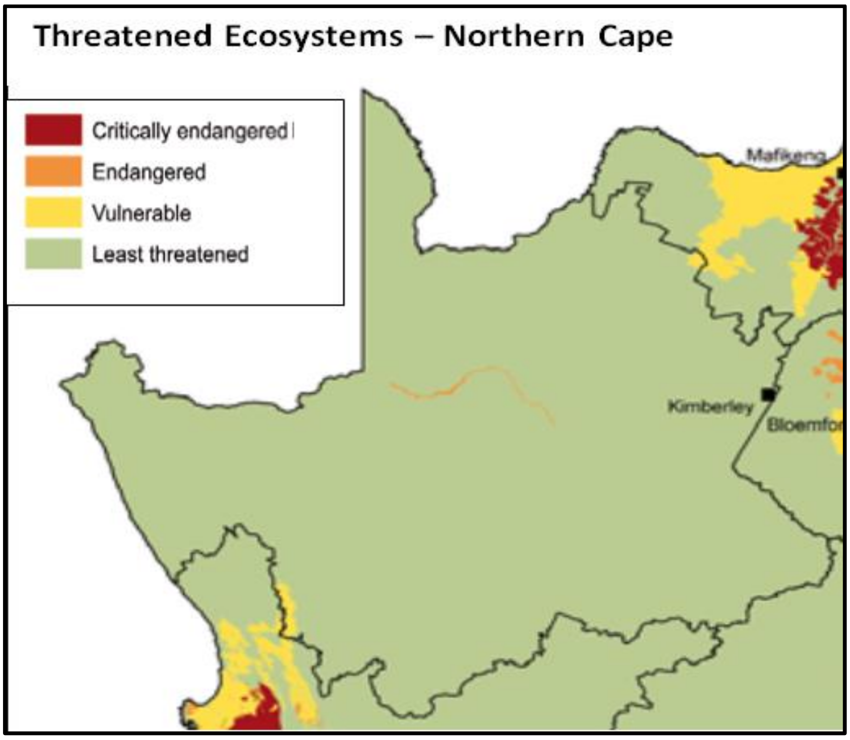

Figure 2.5: Threatened Ecosystems in the Northern Cape (Driver et al., 2012)

The Northern Cape Province has only two classes of threatened ecosystems, the endangered and the vulnerable ecosystems (see Figure 2.5). The Northern Cape Province with the exception of very small areas in the Fynbos Biome and the Nama-Karoo is classified as least threatened as evidenced by the green colour in Figure 2.6. The Fynbos biome will face threats from the succulent Karoo, this modelled under all climate scenarios (DEA, 2013b) While the Nama-Karoo is not flagged as threatened, changes in the this biome could still impact ecosystem services such as the seasonal provision of water as well as the provision of fodder for livestock grazing. This biome is not protected (Mucina et al, 2006b). The Savanna Biome is not threatened and it is anticipated that this biome will increase, replacing grasslands in some areas. This does not imply that changes in these biomes will not affect the provision of a myriad of ecosystem services such as carbon sequestration, soil retention, and climate regulation in terms of woody Savannas. Other services provided include water, fodder for livestock grazing (Rutherford et al, 2006b) as well as significant wild fauna and diversity for recreation and subsistence livelihoods (DEA, 2013b).

2.2.3 Climate Change Impacts on Biodiversity in the Northern Cape Province

Bioclimatic envelopes are characteristic or a series of patterns of temperature, and rainfall within which each biomes is found, which makes it a suitable habitat for certain species. The changes to the temperature and rainfall suitable a particular biome might cause the changes to suit another biome, putting ecosystems and species in the biome under stress. Time of the essence when such changes occur given that if the change is long, occurring over thousands of years and where the biodiversity is in pristine condition, the ecosystem and the species are able to shift in response, However, when the changes in climate are rapid, and the ecosystems are degraded, over shorter periods of time such as decades the capacity of the ecosystem and the species to respond are not fully known. Nonetheless, the predictions of changes in climate based on the temperature and rainfall highlight three plausible climate futures premised on 15 global circulation models that were statistically downscaled for South Africa up to the year 2050 (Driver et al., 2012). These are:

- Best case scenario: smallest predicted increases in temperature and changes in rainfall.
- Intermediate scenario: middle of the range (median) predicted increases in temperature increases and changes in rainfall.
- Worst case scenario: greatest predicted increases in temperature and changes in rainfall.

The results of the modelling based on the 15 different models are presented in Figure 2.6 below. Bearing in mind that the condition of the ecosystem is essential in its response to changes in the climate, the above section highlighted that most ecosystems in South Africa are no longer in pristine condition, most of them impacted by landuse change as well as the anticipated impacts of those changes on the biomes found in the Northern Cape. This will hinder the capacity of the ecosystems to respond to bio climatic change.

The degradation of these essential ecosystems disturbs their capability to provide ecosystem services, which in turn directly negatively impact on human well-being and socio-economic conditions, especially for the poor populations. Climate change is plausible to cause stress to ecosystems through the alteration of their functioning ability thereby compromising individual species (IPCC, 2007c). Overall, climate change will exacerbate the challenges already faced by the ecosystems. Climate change presents both direct and indirect threats though the intensifying of the existing stresses. The direct threats on ecosystems include:-

- habitat degradation and changes in landscapes through the clearing of vegetation,
- introduction of pests and weeds,
- Highly modified and overcommitted water resources
- altered fire regimes
- widespread use of fertiliser and other chemicals,
- urbanisation, mining and, for some species, over-harvesting (DEA, 2013b).

An assessment of the spatial shifts of biome under the different climate scenarios (see Figure 2.6) below.

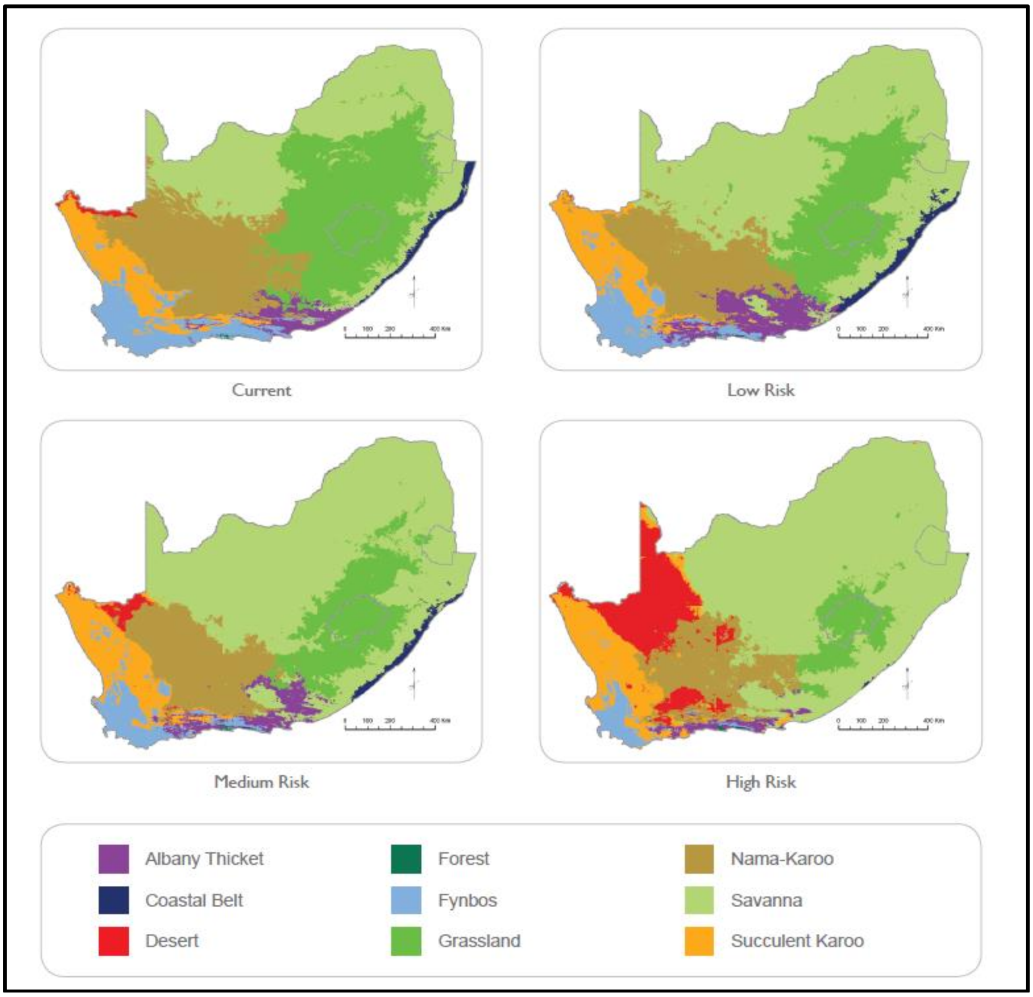

Figure 2.6: bioclimatic envelopes under statistically downscaled climate scenarios ahead to approximately 2050. Low Risk map simulates impacts of wet/cool future Projections of climate projections. High Risk simulates the impacts dry/hot projections. Medium Risk the median temperature and rainfall projections (DEA, 2013b)

An assessment of the spatial shift of the ideal climatic conditions for the biomes under low, intermediate (median) and high rick climate scenarios highlights that :-

- the Nama-Karoo is the second most threatened under all climate scenarios. The climatic envelope located in large spatial areas that are currently Nama-Karoo is likely to look like an arid savanna under the low-risk and intermediate scenarios, and a desert climate envelope under the high-risk scenario, presenting the threat of Nama-Karoo being replaced by savanna and desert in some areas (DEA, 2013b).

- the climate envelope ideal for the biome savanna will is possibly expand significantly in the future, with particular savanna species benefiting. However, this does not necessarily benefit current habitats and species groupings.

- the grasslands biome seems to one of the most threatened under all climate scenarios with significant changes anticipated in most the most grassland areas. The bioclimatic envelop for grasslands will be significantly reduced under all climate scenarios with the likelihood of grasslands being overtaken by savanna and in some areas forest vegetation (Kiker, 2000).

- The desert bio-climatic envelop increases in the extent, under the high-risk scenario, encroaching on present succulent and Nama Karoo biomes. Under the low risk scenarios, there are is not anticipated changes in the biome. On the other hand, the climate envelop for the succulent Karoo will persist under all climate projections (DEA, 2013b) (see Figure 2.6 (High Risk map).

- The northern and eastern areas of the fynbos will possibly experience climate stress, as a result of the climatic conditions resembling those of the succulent Karoo or Albany thicket, under all climate scenarios (DEA, 2013b).

It is important to note that the assessment of bioclimatic envelops was conducted using two models both of which showed consistent results and while the assessment used was based on the statistically down scaling the trends for both the statistically an the dynamic downscaling in climate science chapter are also consistent. There are however some differences on the extent of change.

The same models have modelled the ecosystem location where the current climate envelops are expected to persevere, where the areas are expected to have stability in the ecosystem composition and structure (see Figure 2.7) (Driver et al., 2012).

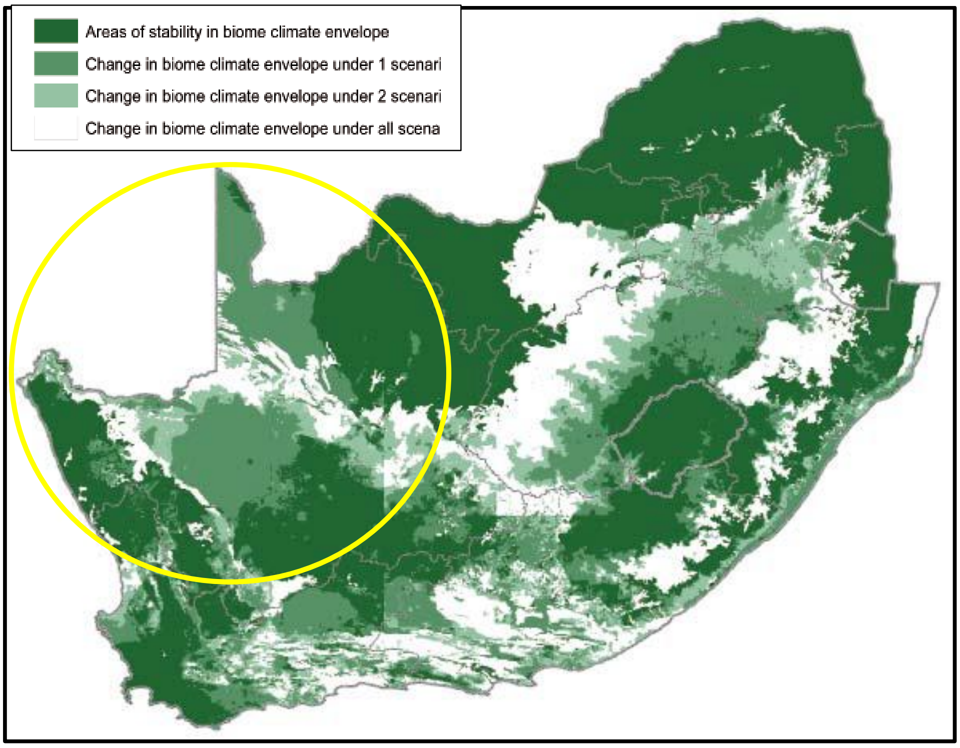

Figure 2.7: Areas of biome stability in the face of climate change, under a range of climate scenarios, according to niche modelling results using statistically downscaled future climate scenarios only (DEA, 2013b)

According to the modelling, the darkest green areas are predicted to stay within their current climate envelopes under all three climate scenarios, and will thus most probably maintain a stable ecological composition and structure. The white areas however indicate areas where biomes are most at risk of change in composition and structure in the face of climate change (Driver et al., 2012). It is important to note that parts of the Nama-Karoo ecosystem on the border with the savanna as well as the Nama-Karoo on the border with the Fynbos biome (see Figure 2.6) is at most risk of climate change under all scenarios, some areas under risk under scenarios 1 and 2. Another observation is that the Nama-Karoo is also highlighted in white, showing risk under all 2 out of all scenarios.

The future implications for these losses are severe especially for the livelihood and economic sectors dependent on the ecosystem function and services such as agriculture including livestock will be severely affected by the increases in temperature, increased water insecurity in some areas of the Northern Cape and overall human wellbeing. Adaptation responses to these changes need into account the multi stressors affecting biodiversity over and above climate change.

2.2.4. Coastal and Marine Ecosystems

South Africa’s estuarine and coastal ecosystems can be divided into the following three biogeographic regions which are described below in Figure 2.8:

- Cool-temperate (Orange River to Cape Point)
- Warm-temperate (Cape Point to Mbashe Estuary)
- Subtropical (Mbashe Estuary to Kosi Bay).

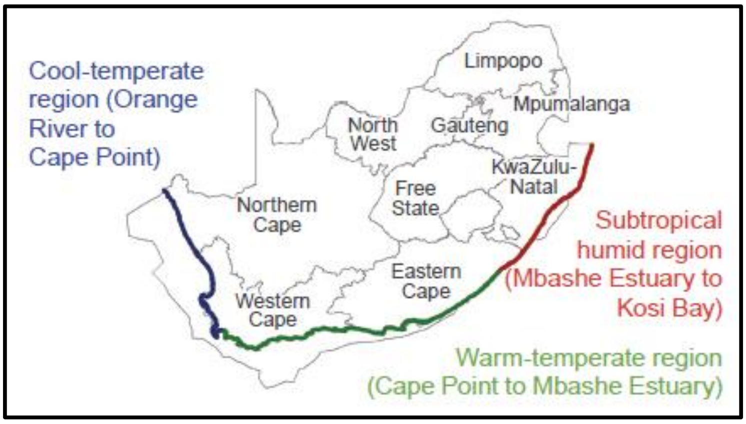

Figure 2.8: Biogeographic regions for South African estuaries. Red shading indicates the position of the subtropical humid zone, green shading indicates warm-temperate and blue shading indicates cool-temperate (Lamberth and Turpie, 2003). Other coastal and offshore ecoregions are shown in Figure 2.9 below

The Northern Cape coastline falls within the cool-temperate region, which is extremely dry, with erratic rainfall (van Nierkerk and Turple, 2012; DEA, 2013m) and includes the Namaqualand coastal region. This coastline is spread over three municipalities, namely;

Richterveld, Nama Khoi and Kamiesberg, in the Namaqua District Municipality (Northern Cape Province, 2011). This coastline is sparsely populated and characterised by hot dry climate, receiving only 100mm of rainfall annually and coupled with lack of development in the areas which is attributed to this lack of adequate freshwater resources, especially for coastal communities, which also have inadequate access to coastal resources. The presence of an abundance of offshore and marine deposits of diamonds is a high value marine and coastal resource in the Northern Cape and has led to the development of a significant diamond mining industry along the coast. This coastline also has natural gas and oil reserves which are currently not being exploited.

In terms of the fisheries in the Northern Cape, the presence of the Banguela Current Large Marine Ecosystems (BCLME) is beneficial to the industry (see Figure 2.9) below. The icy Banguela presently maintains a wide range of marine life, with the upwelling and cooling of the current bringing moist sea air to the west coast. The BCLME is a critical core of marine biodiversity as well as marine food production. The ecosystem supports significant marine population of fish, including the small pelagic species for example anchovies, red-eye, sardines and sardinelas. Midwater species found in this ecosystem include Cape Horse Mackerel, Hake and west coast lobster. In terms of the bigger species, the Southern Right whale, the Cape Fur Seal, and the Heavenside dolphin are also found. The ecosystem also hosts numerous endangered species such as the African penguin, the leatherback and loggerhead turtles, and the black African oystercatcher. It is also one of the most primary productive regions globally, with an estimated 1.25 grams of carbon m^2 per year (Northern Cape Province, 2011).

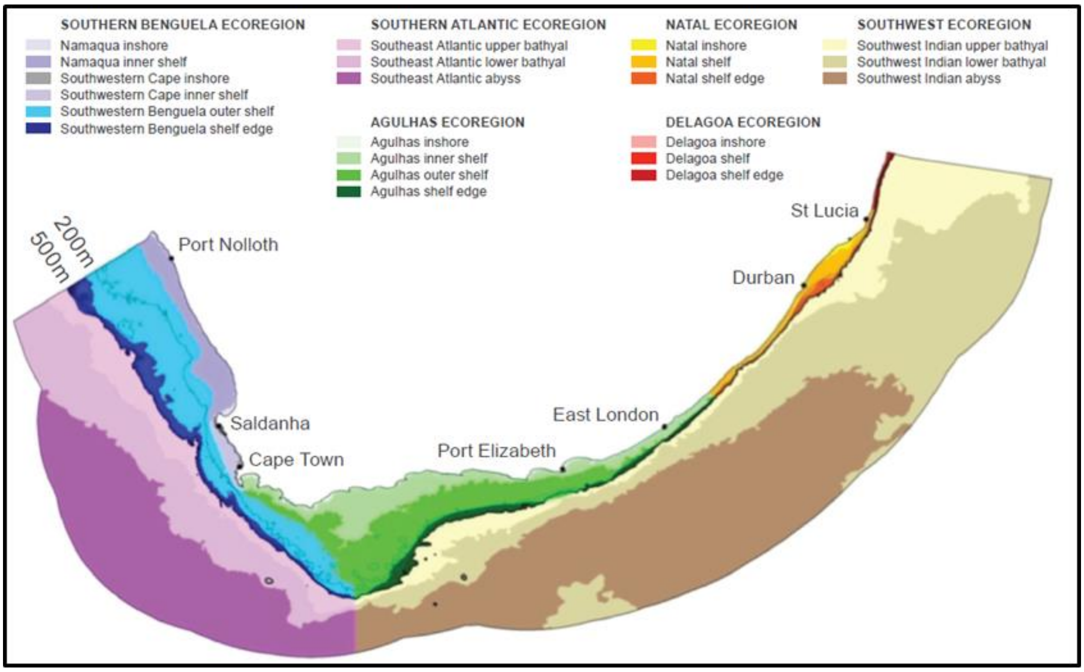

Figure 2.9: South Africa's coastal and marine inshore and offshore ecoregions and ecozones (Sink et al., 2012)

2.2.4.1. Climate Change Impacts on Coastal and Marine Ecosystems

A variety of climate related and socio-economic factors affect the BCLME, which is a sizable ecosystem which already face sever challenged in terms of a changed food-webs, migration of fish, bird and animal species, due to El Niño. The ecosystem already faces degradation and destruction of habitats, changes in the lagoons and wetlands as well high levels of pollution from oils spills, solid waste and radionuclides (Northern Cape Province, 2011). Other challenges experienced in this area are a reduction in the fish stokes, lack of protected bays for ports and this is worsened by poor road infrastructure. The livelihood options for the local communities are limited, despite the potential availability of marine resources such as mussels and limpets as a small-scale industry (Northern Cape Province, 2011).

The Banguela current system, encompassing its marine and coastal environment is highly vulnerable to climate variability and change and this will have longer term impacts on the sustainable management of these precious resources and the economy of the province. The table below highlighted the climatic factors that will affect the ecosystem (the Cool Temp Column).

Table 2.2: Climatic drivers, key variables and intensity of response in different coastal and inshore regions within the three major marine biogeographic provinces in South Africa. Intensity ranges from high (dark shading) to low (light shading) (van Niekerk et al., 2012)

DRIVERS	RESPONSE	SUB-TROPICAL		WARM TEMP		COOL TEMP
		KwaZulu-Natal	Wild Coast	Eastern Cape	Southern Cape	Western Cape
Ocean circulation	Current speed	+	+	+	+-	+-
	Current position	?	?	?	?	
	Upwelling	+	+	+	+	+
Precipitation	Runoff	+	+	+	+-	-
	Mouth closure	-	-	-	+-	+
	Salinity	-	-	-	+-	+
	Nutrients fluxes	+	+	+	+-	-
	Floods & sediment	+	+	+	+-	-
	Droughts	+	+	+	+	+
	Flushing pollutants	+	+	+	+ -	-
Sea level rise	Salinity	+	+	+	+	+
	Increased tidal prism	+	+	+	+	+
	Mouth closure	-	-	-	-	-
Rising temperatures	Species range extensions	+	+	+-	+-	-
	Community composition	-	-	-	+	+
Acidification	Calcifying organisms	-	-	-	-	-
Coastal storms	Mouth closure	+	+	+	+	+
	Overwash	+	+	+	+	+
	Marine sediment	+	+	+	+	+

As highlighted in the table above, temperature increases, extreme rainfall events (storms) and runoff as well as sea level rise will affect the west coastline, with these increased occurrences affecting the marine habitats and fisheries (DEA, 2013m). Precipitation and river flow is expected to be reduced. The impacts are as follow:-

- Sea level rise may reduce estuarine nursery habitat, which is critical for many species found in estuarine and coastal fisheries.
- Decreased rainfall may result in temporarily open/closed estuaries to close more frequently leading to possible closure of permanently open estuaries. This will also affect fisheries negatively.

The bulk of the fish species found in the BCLME, which are already over-exploited will be affected negatively by these changes, particularly the changes in temperature and sea level rise.

According to the climate modelling projections (presented in the climate science projections modelling chapter), the temperature in the Northern Cape is expected to increase by 1 to 3 °C by 2050, and may rise by as much 3°Cunder low mitigation . There are anticipated temperature increases of 1-2° C across the province under high mitigation, with as much as 2.5 °C over the northern parts of the province. These temperature increases as discussed above will result in increased vulnerability for the biomes already under threat from land use change such as grasslands, while the increases in temperature will favour the savanna biome which is expected to encroach on the grasslands as well as the Nama-Karoo biomes in the province. Biomes such as the desert biome will benefit from the more arid condition and the increases in temperatures. The expected increase in the savanna biome will benefit rural communities dependent on it for their livelihoods. Temperature changes are also expected to negatively affect the Northern Cape west coast, especially the diverse marine and coastal ecosystem.

2.3 Water Sector Vulnerability Assessment

South Africa as an already water stressed country faces numerous challenges with the management of its scarce water resources. The country, which is described as arid to semi-arid also, has to contend with climate change and variability which affect especially surface water availability. Currently, only 12% of the land areas provides up to 50% of the water resources. Further, decadal rainfall variability has resulted in dry and wet periods on the country, in a country were the water demand is very high and is expected to worsen with increases in population, urbanisation, changes in the standard of living and economic development (DEA, 2013c).

The projected changes in climate and climate variability as described in climate science modelling chapter will exacerbate the already strained water resources as well introduce new challenges as a result of variability and extreme weather events such as droughts and floods, changing rainfall seasons as well as the overall increase in temperatures which will lead to increased evaporation and surface water losses (DEA, 2013c). Water resources availability and management are key to the country’s development, especially for the economic and agricultural sectors, infrastructure development as well as livelihoods. Water availability further affects human health and sanitation.

2.3.1 Surface Water Resources in the Northern Cape

Water availability is a critical factor in the development of the Northern Cape, which already has an arid to semi-arid climate. The province has a significant agricultural industry which is a major income earner as well as employer. The main sources of surface water in the Northern Cape are the Orange and the Vaal River and their tributaries, which are managed under water management areas. A total of five main Water Management Areas are found in the Northern Cape. Water Management Areas (WMAs) were designed to assist with the catchment level management of the extensive water resources and fall under the Water Resources Planning Framework.

The Orange River and its sub-catchments comprise of the Upper and Lower Orange catchment areas, the Lower Vaal and the Olifants/Doorn. Two other very small water management areas are found in the Northern Cape and these are the Gouritz and the Fish to Tsitsikama management areas (see Figure 2.10). The surface water ecosystem for the Northern Cape consists if a myriad of river catchment and sub catchment, dams as well as the extensive network of wetlands (see Figure 2.10). Wetlands are an essential factor for ecosystem service for the provision of safe water.

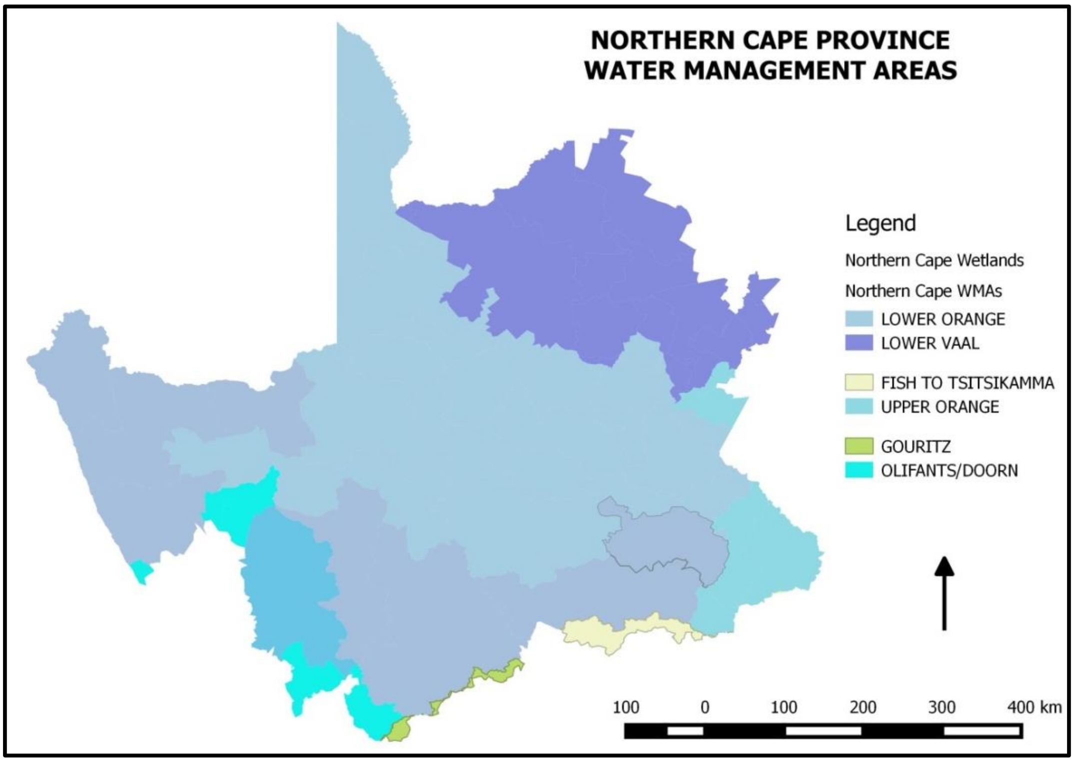

Figure 2.10: Water Management Areas for the Northern Cape Province per municipality

4.3.1.1. The Lower Orange

The Lower Orange is on the boundary of Botswana, Namibia and the Northern Cape, with smaller areas in the Western Cape and the Free State. This WMA receives the least annual rain and depends heavily on the dams in the Upper Orange catchment to fulfil its water requirements. The areas is further susceptible to prolonged droughts often mixed with severe flooding with approximately 57% of the natural runoff being generated in Lesotho, 33% in the Upper Orange and the last 10% in the Lower Orange WMA making this WMA rather dependent on water transfers from upstream WMAs. Evaporation rates in the management area can be as high as 3000 mm per year as well as evapotranspiration rates from the riparian vegetation along the rivers, leading to negative yield within the Lower Orange management area. In terms of non-climatic factors affecting the catchment, up-stream development is key (Northern Cape Province, 2011).

2.3.1.2. Lower Vaal WMA

The Lower Vaal WMA is located downstream of Bloemhof Dam and upstream of the Douglas Weir. The Vaal River is the only major river in this catchment linking the middle and the upper Vaal. Annual rainfall ranges in the WMA from approximately 500 mm in the east to as low as 100 mm in the west. However, the potential evaporation can be as high as 2 800 mm per annum, significantly exceeding the rainfall. Vegetation over the WMA is sparse, consisting mainly of grassland and scattered thorn trees and alluvial diamonds are found in the vicinity of Bloemhof. Issues of concern in this WMA include the high rates of water use for both the surface and ground water. Further, the impact of activities in the other WMAs impact on the lower Vaal and these include pollution which affects water quality as well as the over exploitation of ground water resources (PSDF, 2013).

The Vaal River is home to one of the largest irrigations scheme in the country, located at Vaalharts, most of which is located in the Northern Cape Province. The climate in this area varies gradually according to the regional patterns, with rainfall ranging between 500 mm in the east to as low as 100 mm in the west.

2.4.1.3. Upper Orange WMA

The Upper Orange lies predominantly within the Northern Cape, with the Caledon River as the largest tributary to the Orange River within the Upper Orange WMA. There twenty dams located in this WMA, with the main ones being the Gariep, Vanderkloof, Kalkfontein, Krugersdrift, Rustfontein and Knellpoort dams. This WMS is subjected to summer thunder showers for rainfall and most of the water in this catchment comes from Lesotho (Basson and Rossouw, 2003). The Upper Orange water management area has the highest yield in the country and has potential for increased water development. The climate of this WMA is cool to temperate and ranges from arid to semi-arid. The area receives summer rain and thunder showers but has high evaporation rates which are beyond the rainfall received.

Some key developments in the Upper Orange include the Lesotho Water Highlands Project. This WMA is essential for the transfer of water to other WMAs in the country such as the Tsitsikama and the Lower Orange WMA. Other issues include the flood management at the Gariep and Vanderkloof Dams and flood management along the Vaal River is essential for the river bank development along the Lower Orange river. Hydropower for peaking purposes is generated at the Gariep and Vanderkloof Dams and is an important factor of Eskom’s peak generation capability, thus changes in the water availability in the catchment will also affect hydro power generation.

2.3.1.4. Olifants / Doorn WMA

The main river in the area is the Olifants River with the Doring River as its main tributary. The Olifants / Doorn WMA is primarily a winter rainfall region, with only the south-eastern region receiving more than 300 mm of rain annually (DWAF, 2004). This is the least populated WMA in the country.

2.3.2. River and Wetlands Ecosystems in the Northern Cape

2.3.2.1. River Ecosystem

In a country where water is a scare resource, river ecosystems play a key role in the supply of fresh water through the storage and transportation of water and when integrated with constructed water storage, supply urban and rural areas as well as agriculture through irrigation. Rivers are also essential for the removal of waste and the provision of recreation. In addition, healthy tributaries assist in the maintenance of natural flow pulses and the removal of pollutants from larger rivers, thereby contributing to water quality and quantity (Driver et al, 2012).

River ecosystems are under immense pressure from abstraction of water and other modifications to the timing and flow due to the dams being built between catchments as is the case on the Orange River. Issues of pollution are also becoming a major issue impacting on the river ecosystems exacerbated by the removal of riverine vegetation causing irreparable damage to river and hindering their provision of ecosystem services (Driver et al., 2012).

In South Africa, at least 57% of the river ecosystems are threatened, with 25% critically endangered and 13% being vulnerable. Of the river ecosystems, tributaries are less threatened with the proportion of threated river ecosystems higher in the lowlands and the lower foot hills and mountain streams highlighting that agricultural and urban areas are contributing to the degradation of the river ecosystems (Driver et al., 2012).

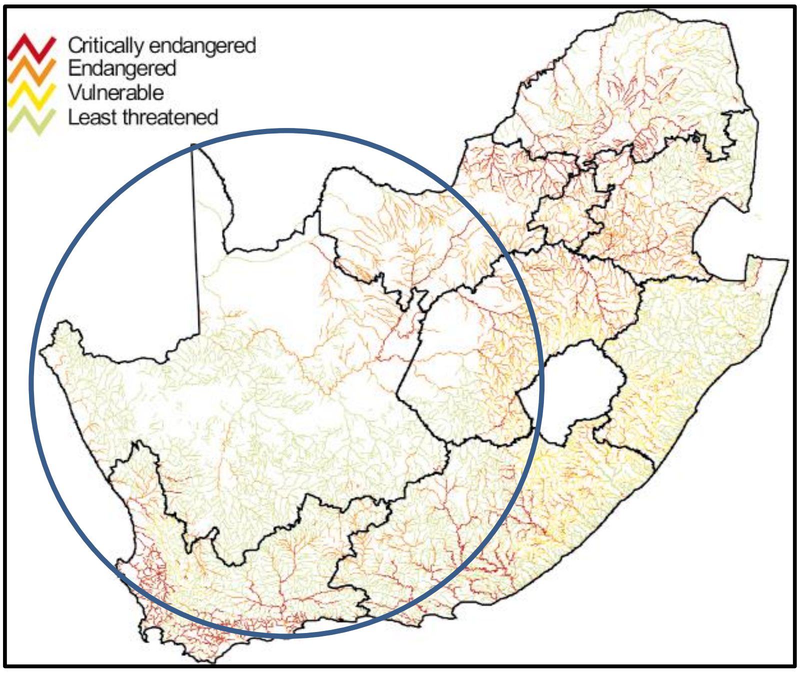

Figure 2.11: Critically endangered and endangered ecosystem types are concentrated around major cities and in production landscapes, where pressures on water resources are highest and catchments have lost much of their natural habitat

The river ecosystem in the Northern Cape is overall least threatened however there are a few rivers which are critically endangered, endangered and vulnerable and these are located mainly in the north east on the border with the Free State and the North West province (Driver et al., 2012).

2.3.2.2. Wetland Ecosystems

While wetlands would be ideally discussed under biodiversity, they are discussed under water given the contribution of wetlands to water security as well as the extent of wetlands in the Northern Cape Province. Wetland ecosystems are recorded as the most threatened in the country with at least 48% of all wetlands classified as critically endangered. Despite occupying only 2% surface areas, wetlands provide critical ecosystem services such as water purification and flood control, contributing towards water security (Driver et al., 2012).

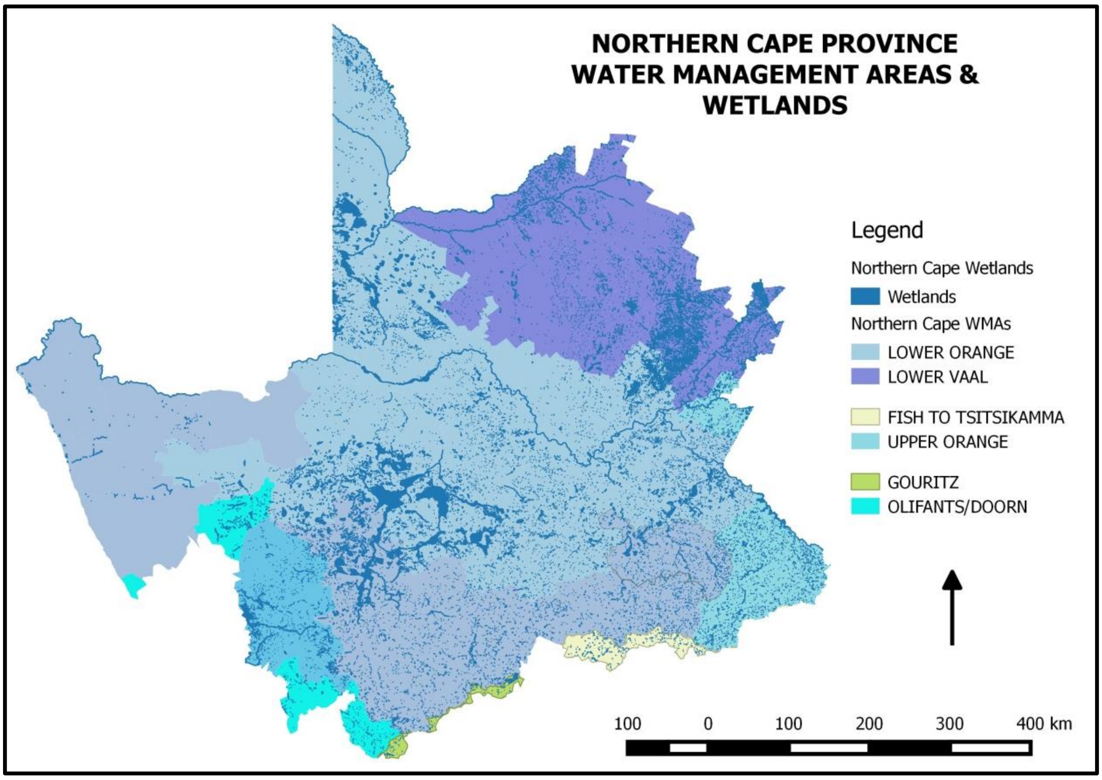

Figure 2.12: Water Management areas with wetlands overlay (BGIS, 2015)

4.3.2.3. Wetland Ecosystems Status

According to Figure 2.12 above, the Northern Cape has a sizable number of wetlands that already classified as least threatened. There are a few wetlands in the south east of the province that are classified as vulnerable (Figure 2.13).

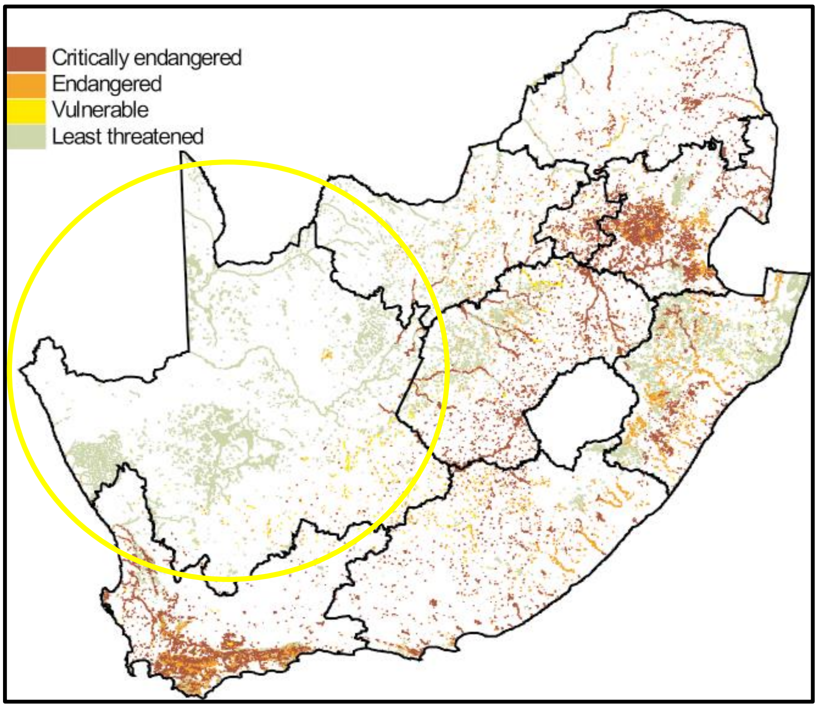

Figure 2.13: Ecosystem threat status for wetland ecosystem types. Consistent with the picture for rivers, high numbers of critically endangered and endangered wetland

ecosystem types are associated with production landscapes and urban centres (Driver et al., 2012)

2.3.3. Climate Change impacts on Water Resources in the Northern Cape

The impacts of climate change on the water sector are discussed based on a catchment scale and are mainly extracted from the Long Term Adaptation Strategies flagship programme, in particular the water sector report. As highlighted above four catchments provide water to the province and this catchment will be affected differently by climate change.

2.3.3.1. Climate Change and River Ecosystems

The Lower Orange, which covers a sizable area of the province, will be extremely vulnerable to temperature and the projections indicate that temperatures in this catchment will increase at twice the national rate with detrimental impacts for especially the agricultural sector. Increasing temperature will cause dry areas to lose more water in an area where the demand for irrigation is expected to increase (DEA, 2013c). Water availability and quality is further compromised by the accumulation of salts leading to higher salinity as well as effects from the mining and irrigation upstream. It is anticipated that the increased temperatures will consequently lead to increased water losses from the catchment, impacting on mining and agriculture (DEA, 2013c).

The Vaal covers a substantial area in the Northern Cape with only the Lower Vaal management areas being found in the province. Climate projections for the Vaal indicate that rainfall will either remain unchanged or will increase, while the mean annual temperatures are expected to increase but not radically. Climate variability will immensely impact on the rainfall and runoff in the catchment and thus there is a need to understand this more, especially at a sub-catchment scale of the rivers that feed into the catchment such as the Inkomati. Extreme rainfall events such as flooding will be experienced in some parts of the catchment (DEA, 2013c).

The Agricultural sector will be the most affected by issues of climate change in this catchment, given the threats posed by the increases in temperature, making the future of agriculture uncertain especially the dependency on irrigation. The continual increases in the cost of water will impact on water use. The potential water insecurity in the catchment will further impact on the selection of crops with a need for diversification in the location and type of crops grown as an adaptation measure (DEA, 2013c). The other sector to be affected is mining, which forms part of the mining belt. Mining will be affected by Acid Mine Drainage (AMD) and this may be exacerbated by the potential increases in rainfall. The last sector is urban or the built up areas, especially the economic growth and increase in demand for a growing population and quality of living (DEA, 2013c).

The upper Orange River covers a sizable area of the Province. However, no extensive climate change studies have been conducted on the Upper Orange catchment but according to the LTAS phase 1 report (DEA, 2013c), there seem to be no any major vulnerabilities in the catchment, and that the risks that exist are not related to climate change (DEA, 2013c).

All river ecosystems are also susceptible to alien invasive species which consume an estimated 7% of all runoff in the country. Changes in rainfall and temperature will have an impact on the growth and extent of alien invasive species, as well as impact on the river flows (Driver et al., 2012).

Apart from the myriad of ecosystem services provided by wetlands which contribute to water quality and supply, they are also a key response to climate change. Given that climate change will bring with it climate variability and intense rainfall events among other impacts, wetlands mitigate extreme floods and droughts, by attenuating floods and combating desertification as well reducing vulnerability to droughts. Wetlands also support rich biodiversity which is of both intrinsic and economic value. Similarly to the grassland biome, wetlands also provide medicinal plants (Driver et al., 2012).

2.3.3.2. Ground Water Resources for the Northern Cape

Ground water is an essential resource and performs a key function, especially for settlements located far from major rivers and water sources. Currently, groundwater is used for rural domestic supplies, livestock as well as supplying towns where surface water supply is insufficient or bulk water supply is not monetarily feasible. In all areas of the Northern Cape, with the exception of areas along the Orange and Vaal rivers, the population is dependent on groundwater.

An aquifer is defined as a geological formation which has structures or textures that hold water or permit appreciable water movement through them. The aquifer yield and type description of the aquifer type (a fractured aquifer indicated that groundwater is located with fractures in a hard rock formation. An intergranular aquifer indicates groundwater flows in openings and void space between grains or weathered rock. The karst is used to describe an area of limestone or other highly soluble rock, in which the landforms are of dominantly solutional origin and in which the drainage is underground in solutionally enlarged fissures and conduits (caves).A karst Aquifer indicates the yield of the volume of water that can be abstracted from an aquifer over the long term (SARVA, 2015). For a detailed description of aquifer type in the Northern Cape as well their yields see Figure 2.14.

The middle Vaal WMA is generally underlain by fractured aquifers (Figure 2.14), which are well utilised for rural supplies, with little un-used volumes happening. These are part of the layers of rock deposit with high inter-granular to fractured permeability meaning that they usually provide a high level of water storage and may support water supply and or river basin flows on a strategic scale. In terms of the Lower Vaal, groundwater resources are the only source of water over much of the WMA. It is mainly used for supply of water to several towns, rural domestic supplies and stock watering (DWA, 2012). The Upper Orange has relatively large quantities of ground water that can be abstracted from fracture zones along dolorite intrusions. The recharge rates and consequently the sustainable yields are low. The higher recharge occurs in localised areas especially in areas where lime bogs are located. Where the drier parts, are located, groundwater constitutes the main and frequently the only source of water for rural domestic supplies and stock watering as in the case in the Northern Cape.

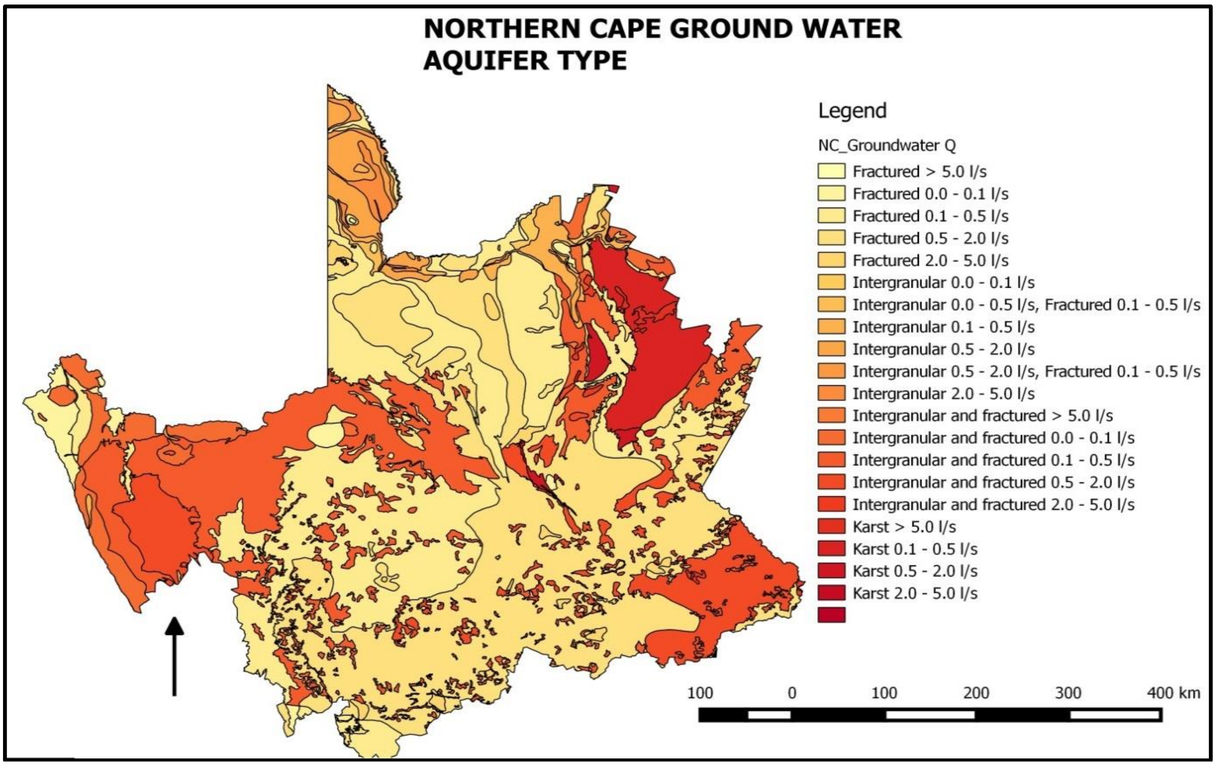

Figure 2.14: Ground Water Resources (Aquifer types) complied by data from BGIS-SANBI, 2015)

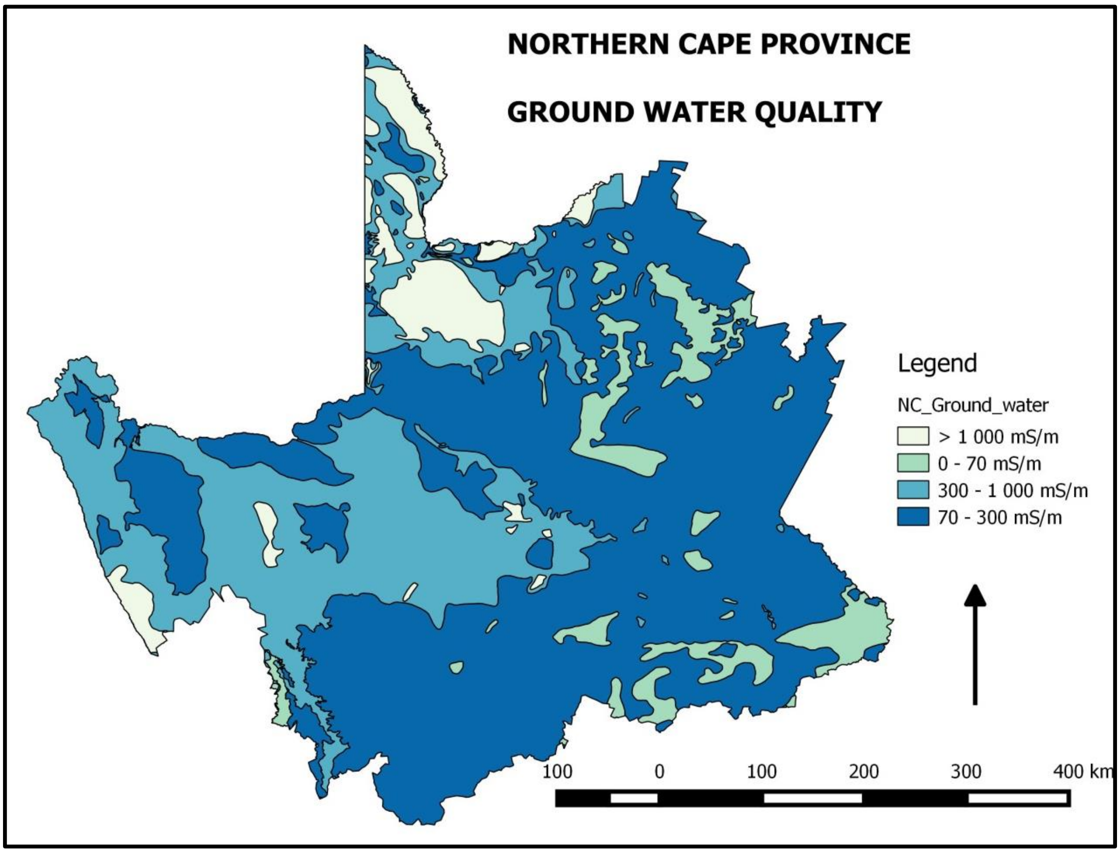

Figure 2.15: Ground water quality in the Northern Cape (compiled from data provided by BGIS-SANBI, 2015)

The water quality map indicates the expected groundwater quality of the area. It is measured in EC electrical conductivity which is a measure of how well a material accommodates the transport of electric charge. The more salts dissolved in the water, the higher the EC value and it is used to estimate the amount of total dissolved salts, or the total amount of dissolved ions in the water. The ground water quality in the Northern Cape ranges from 300 up to 1000mS/m in the west which is rather high indicating poor water quality while for the rest of the province the quality of good to moderate (see Figure 2.15). Human activities such as agricultural and mining contributed to the poor water quality for both surface and ground water in the Province.

2.3.3.3. Climate Change Impacts on Ground water

Precipitation is the main source for ground water and climate variability and change affect rainfall, resulting in the impact on ground water supply. Some of the impacts of climate change on ground water are discussed below.

Recharge

Groundwater recharge happens locally from surface water bodies or through diffusion from precipitation through the unsaturated soil zone Rainfall is the principal climatic driver for groundwater recharge, with temperature and CO_2 concentrations influencing the evapotranspiration rates as well as the amount of rainfall draining through the soil profile to aquifers. Changes in the extent of groundwater recharge will not always follow the same trend as precipitation changes given that recharge is not only influenced by the extent of precipitation, but also by its intensity, seasonality, regularity, and nature. The non-climatic factors, such as changes in soil properties or vegetation type and water use can also affect recharge rates as well as land cover and aquifer type. Furthermore, groundwater recharge rates are highly dependent on the geological setting of the area (Clifton et al., 2010).

Discharge

The impacts of climate change on groundwater discharge are not yet fully recognised and well understood. This has been attributed to the focus being more on the quantity of water getting into the aquifers and its quality, but also reflects the difficulty of measuring ground water discharge with even less attention given ground water support such as ground flow springs, streams, wetlands, oceans and terrestrial vegetation (Clifton et al., 2010).

The direct impacts of climate change on evapotranspiration are discussed below and listed as follows:

- changes in groundwater use by vegetation as a result of increased temperature and CO_2 concentrations,
- changes in the availability of water to be evaporated or transpired mainly as a result of changes in the rainfall system.
- Exploratory evidence on heightened levels of atmospheric CO_2 may cause a reduction of stomata in plants, resulting in lower transpiration rates. Further, the effects of CO_2 are comparable but opposite to the magnitude of predicted temperature induced increases in evapotranspiration.
- It is important to note that the influence of CO_2 in water balance is not yet fully understood (Clifton et al., 2010).

- Augmented duration and occurrence of droughts, as a result of increased temperatures and increased variability in rainfall will probably cause greater soil moisture insufficiencies leading to heavy reliance by vegetation on ground water in cases where the ground water is within the root zone. This could lead to increased evapotranspiration from ground water during dry periods. Non-climatic factors related to land use change could also affect evapotranspiration (Dragoni and Sukhija, 2008).

Ground Water Storage

Groundwater storage is the variance between recharge and discharge over the time scales that these processes occur, from days to thousands of years. Ground water storage is subjective by particular aquifer type, size and properties due the deeper aquifers having a delayed reaction to large-scale climate change but not to short-term climate variability. On the other hand, shallow groundwater systems (especially unconsolidated sediment or fractured bedrock aquifers) are more receptive to smaller scale climate variability (Kundzewicz and Doll, 2008). Further, the impacts of climate change on storage are dependent on whether or not groundwater is renewable (contemporary recharge) or comprises a fossil resource (Clifton et al., 2010).

Water quality

Maintaining of ground water quality in the aquifers is a critical water supply for communities and agricultural activities. The properties of ground water, both thermal and chemical may be affected by climate change, especially for shallow aquifers where ground water temperatures may increase due to increased temperatures. In semi-arid and arid areas, increased evapotranspiration may lead to ground water salinisation. Further, variations in recharge and discharge will probably increase the vulnerability of aquifers to diffuse pollution (van Vliet, 2007). In terms of increases of rainfall intensity, pollutants such as organic matter, pesticides and heavy metals will pollute ground water sources, especially where recharge aquifers are present (IPCC, 2007). In cases where recharge is expected to lessen, water quality may reduce due to intrusion of poor water quality from adjoining aquifers (van Vliet, 2007).

According to projected future climate modelling findings , the general projected decline in rainfall in the province will be detrimental to surface water availability except for the north-eastern part of the province were increases in rainfall are plausible. The increases in the average temperature by as much as 3° C under low mitigation scenarios, the increase in the number of very hot days and heat wave days as well as the increase in dry spell days by as much as 180 days per year will all have a negative impacts on water availability given the high evaporation and evapotranspiration rates which will increase the demand for water by crops and livestock as well as increase the demand for irrigation. Increases in extreme rainfall events (see section 3.2.6) will however benefit ground water resources through recharging of the ground water systems, which is a critical resource in the province.

Issues of water availability, from both surface and ground water are critical especially in the face of climate change and implications of these changes will be detrimental to agriculture which is one of the critical economic sector for the Northern Cape Province; both for development as well as food security for subsistence farmers who are dependent on rainfall as their livelihood. Water security is also a critical resource for human health and sanitation.

Climate change adaptation options need to seriously consider the impacts of water insecurity and the future of the development of the province.

2.4. Human Health

The impacts of climate change on human health resulting from expected increases in the frequency, intensity and duration of extreme weather events are likely to have a major effect on public health (DEA, 2013). Human exposure to climate change may be direct and/or indirect, and will be determined by the character, magnitude and rate of climate variability (WHO, 2003 in DEA, 2013). Among the leading causes of death on the Northern Cape are respiratory diseases, both natural and non-natural, as well as cardio-vascular conditions. These two diseases are affected by climate change, especially extreme temperatures.

2.4.1. Human Health Vulnerability

A key consideration for climate change and human health is the vulnerability of the population to the impacts and the ability to cope and or respond. In this instance, vulnerability is defined as the extent to which the population/health target group is prone to the effects of climate change, exposure being the contact between public health system with climate change and the extreme weather events and lastly sensitivity will be defined by the characteristics that inform the response of the system to the effects of climate change and adverse weather events (DEA, 2013h)_.In terms of adaptive capacity, this depends on the capacity of the health system to respond to climate change and extreme weather. The social and bio-physical factors of a population may alter the outcome of the relationship between climate change and human health. These factors include poverty, urbanisation and its associated problems (DEA, 2013h); and are covered in detail in the social Vulnerability section below.

The impacts of climate change maybe direct or indirect with the impacts projected to affect agricultural production, leading to food insecurity and malnutrition. The Northern Cape Province has the highest percentage of malnutrition in South Africa, which will only be exacerbated by climate change. This will be credited to the accelerated frequency and intensity of dry spells and flooding events that will concede food availability, access and utilisation (DEA, 2013h). The climate change impacts on agriculture will pose a threat to food security. This will be further worsened by the loss of ecosystem services for the ecosystems that support agriculture and livelihoods; thus worsening the situation (DEA, 2013h).

Climate change will further affect communicable diseases as well as assist in the transmission of non-communicable diseases mainly influenced by temperature, rainfall and wind (DEA, 2013h). For example cholera, deahorrea and water related diseases are well-recognised communicable diseases, in the country (DEA, 2013h).

2.4.2. Climate change and vector-borne diseases

According to the LTAS Human Health Report (DEA, 2013b), little is known about disease vectors in South Africa. Vectors of concern include mosquitoes (malaria, dengue fever and yellow fever) and ticks (Lyme disease). According to the Clifton et al., 2010, the risk from these diseases is expected to rise because of climate change due to the increased extent of areas with conditions conducive to vectors and pathogens (Clifton et al., 2010, 2013 in UNEP, 2014; WHO, 2014). There was however, a significant decrease in the cases and deaths of malaria recorded in South Africa between 2000 and 2011 (DOH, 2012 in DEA, 2013b).

Changes in temperature and precipitation directly affect vector borne diseases (VBD) and zoonotic diseases (ZD) through pathogen-host interaction (e.g. VBDs are transmitted by the bites of infected mosquitoes and other insects (vectors), and indirectly through ecosystem changes and species composition. Where mosquitoes are the vectors, temperature plays an important role. The optimum temperature for transmission is an annual average of 22 °C (DEA, 2013b, p25), with the parasite not developing at temperatures below 16 °C and the mosquitoes not surviving temperatures above 40°C. There is an association between availability of water (for breeding) and rainfall and an increase in mosquito population; thus more droughts will have the opposite effect (DEA, 2013h, 2013). However, heavy rainfall may wash breeding sites away, while a little pool of stagnant water after normal rainfall could become a breeding site, thus the association is not linear (Thomson et al., 2005 in DEA, 2013b). The life cycle of pathogens inside vectors is shortened under warmer conditions. Table 2.3 from Friel et al., (2011) indicates the direct and indirect pathways from climate change to non-communicable diseases (NCDs).

2.4.3. Human Health and Extreme Weather Events

Direct climate change exposures include atypical temperature and precipitation, storms, and natural disasters (Samet, 2009; WHO, 2009a in LTAS, 2013). Indirect exposures may include increased air pollution, pollen production, constraints in the agriculture sector leading to food shortages and malnutrition, an optimised environment for the production and distribution of disease vectors, and ecosystem changes leading to loss of ecosystem goods and services (Samet, 2009; WHO, 2009; Abson et al., 2012 in DEA, 2013). Climate change may thus also affect social and environmental determinants of health such as clean air, safe drinking water, and sufficient food and secure shelter (WHO, 2013). Given these wide range of exposures, it is important that both direct and indirect climate exposures are addressed when dealing with vulnerability to climate change (DEA, 2013, p 24).

2.4.3.1 Heat

Extreme high air temperatures as predicted will contribute directly to deaths from cardiovascular and respiratory disease, affecting elderly people in particular (WHO, 2013). High temperatures also result in increased levels of pollutants in the air such as ozone that exacerbates cardiovascular and respiratory disease (WHO, 2013). Pollen and other aeroallergen levels are also elevated in extreme heat, which can trigger asthma (WHO, 2013). Local studies on heat stress are however limited. There are projections from the present to 2100 on the potential impact of climate change on increasing the number of “hot days”. The study indicates that heat-related impacts (heat stress symptoms) are likely to increase in the future, and that these impacts are likely to be exacerbated by socio-economic vulnerability of the population. However, the relevance of this temperature-health impact relationship and the vulnerability factors applicable to the South African population are not well documented.

2.4.3.2 Droughts

Rainfall patterns are likely to be increasingly variable, thus affecting the supply of clean, fresh water. This in turn can compromise hygiene and increase the risk of diarrhoea disease (WHO, 2013). In extreme cases, water scarcity results in drought and famine. It has been predicted that, by the 2090s, climate change is likely to widen the area affected by drought, double the frequency of extreme droughts and increase their average duration six-fold (Arnell, 2004 in WHO, 2013).

2.4.3.3 Floods

Floods have also been increasing in frequency and intensity, contributing to contaminated freshwater supplies, a heightened risk of water-borne diseases and breeding grounds for disease-carrying insects such as mosquitoes. Physical hazards from floods include drowning and physical injuries, damage to homes and disruption in the supply of medical and health services (WHO, 2013). The combination of increased temperatures and variable precipitation contribute to a decrease in the production of staple foods which will increase the prevalence of malnutrition and under-nutrition (WHO, 2013).

Table 2.3: Direct and indirect impacts of climate change on NCDs (from Friel et al., 2011)

Climate change impacts	**Pathway for climate change to NCDs**	**NCD outcome**	**Direction of health risk**
Direct			
More frequent and increased intensity of heat extremes	Heat stress	Cardio-vascular diseases (CVD)	Increased risk
Increased temperatures and less rain	Higher ground-level O_3 and other air pollutants Increases in airborne pollens and spores	CVD; Respiratory disease	Increased risk
Changes in stratospheric O_3, precipitation and cloud cover	Decreased exposure to solar UVR	Autoimmune diseases Skin cancer	Reduced risk
High winter temperatures		CVD; Respiratory disease	Reduced risk
Extreme weather events (fires, floods, storms)	Structural damage	Injuries	Increased risk
Indirect			
Drought, flooding	Impaired agriculture, reduced flood yields, nutrition	Poor general health	Increased risk

	insecurity		
Extreme weather events (fires, floods, storms)	Trauma	Mental health (post-traumatic stress disorder)	Increased risk
Extreme weather events (fires, floods, storms)	Impaired livelihoods, impoverishment	Mental health (anxiety/depression)	Increased risk

2.4.4 Air Quality Rating Map for Northern Cape

Air quality rating information for the Northern Cape Province was retrieved from Scott (2010). The status of air quality in municipalities were characterised as acceptable and potentially poor. The locations of air quality monitoring stations were retrieved from the SAAQIS (DEA, 2015). The map was compiled in ArcGIS and projected using the Geographic Coordinate System Hartebeeshoek 1994.

The status of air quality in the Northern Cape is mostly unknown (Figure 2.16). The province initiated the process of developing an Air Quality Management Plan (AQMP) (Mdluli, 2015). Frances Baard District Municipality has developed and implemented an AQMP and has a draft Air Quality Management By-law (Frances Baard District Municipality, 2011; Mdluli, 2012). The Siyanda, Namakwa and John Taolo Gaetsewe District Municipalities initiated the process of developing their AQMPs (Mdluli, 2012). The air quality status of the Sol Plaatjie Local Municipality which is situated within the Frances Baard District Municipality has been rated as potentially poor. The //Khara Hais and Gamgara Local Municipalities were rated as having acceptable air quality. The Karoo air quality monitoring station is located in the Hantam Local Municipality and is the only local air quality monitoring station operating in the province which currently measures the concentrations of particles smaller than 10 µm (PM_{10} concentration) (Ngcukana, 2014).

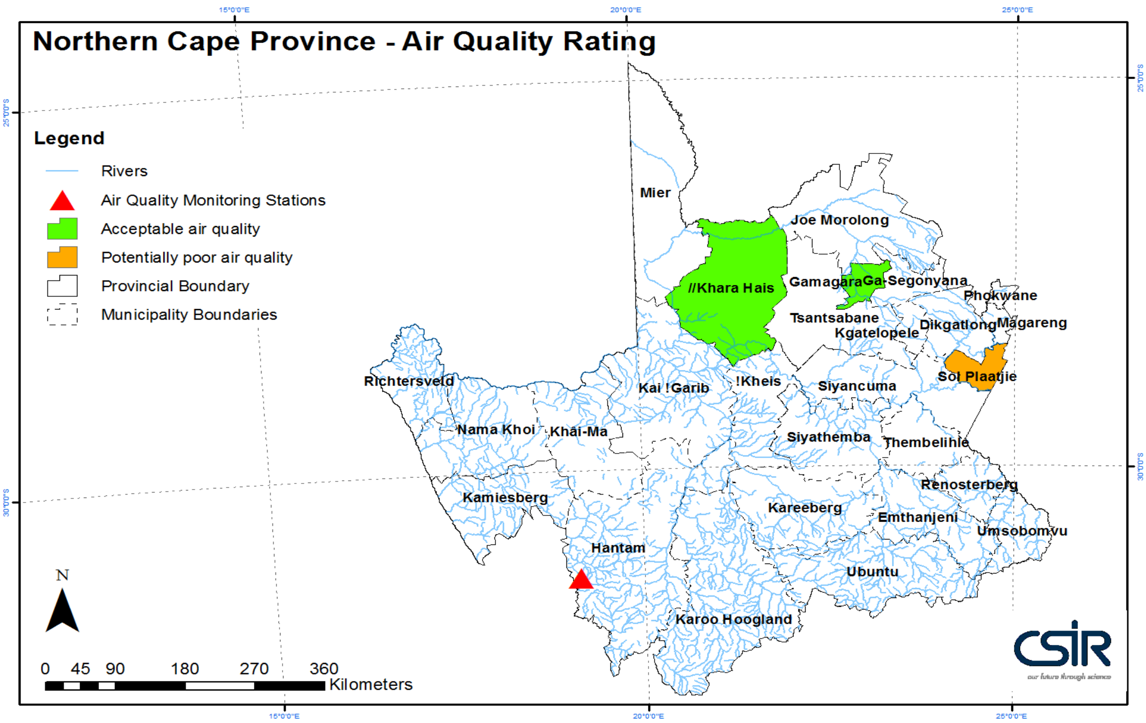

Figure 2.16: Air Quality Status of Municipalities in the Northern Cape (Mdluli, 2012)

2.4.4.1 Climate Change, Human Health and Air Quality

Climate change may have an effect on air quality in the country through effects on the weather, thus influencing pollutants such as particulate matter (PM), sulphur dioxide, ozone, carbon monoxide, benzene, lead nitrogen oxide in the province. The health impacts of these gases and elements lead to acute respiratory infection, eye irritation, chronic respiratory disease and TB which sometimes leads to death. Table 2.4 shows details of the impacts of air quality on human health (DEA, 2013h). The air quality of the province is good with the exception of two municipalities (//Khara Hais and Ga-Segonyana which has an acceptable air quality and Sol Plaatje that has potentially poor air quality).

Table 2.4: Air Quality impacts on human health (DEA, 2013h)

Criteria pollutant	Health impact	References
PM	• Respiratory diseases (including lung disease) • Premature death	• Atkinson et al., 2011 • Dominici et al., 2006 • Schwartz, 1994 • Balakrishnan et al., 2011 • Schwartz et al., 1994 • WHO, 2003
SO_2	• Respiratory problems • Eye irritations • Cardiac disease • Premature death	• Fenger, 2002 • WHO, 2011b
O_3	• Increase in morbidity rates • Increase in mortality rates • Asthma • Damage to lung tissue • Bronchitis	• Jacob et al., 1996 • Seinfeld and Pandis, 1998 • Jacob et al., 1996
CO	• Cardiovascular disease • Cerebrovascular impacts • Behavioural impacts	• Australian Government, 2009
C_6H_6	• Skin irritations • Hematologic impacts • Reproductive and development effects • Cancer risk	• US EPA, 2012
Pb	• Neurologic impacts • Hematologic impacts • Gastrointestinal impacts • Cardiovascular impacts • Renal impacts	• WHO, 2013e
NO_2	• Wheezing • Coughing • Colds • Flu • Bronchitis	• WHO, 2013d

2.4.5 Vulnerable populations in the context of climate change

In general the population play a key role in the vulnerability to climate change, particularly when social vulnerability factors are at play. As indicted in Table 2.5 below, the response of the Northern Cape to climate change risks and extreme events differs significantly when population is considered. The impacts of the risks on the province were consistent between all the municipalities making them highly vulnerable to gradual and long term increase in temperature as well as a decrease in rainfall coupled with a variation of extreme hot days. Most of the municipalities were considered highly vulnerable to gradual long term increases in temperature (the red cells in Table 2.5 below) with the exception of seven municipalities (yellow cells) that have moderate vulnerability. Only three municipalities are moderately vulnerable to extreme precipitation, hail, wind storm and flooding, with rest being highly vulnerable. Eleven municipalities are highly vulnerable to extreme hot days. When population was added to the analysis, only Sol Plaatje Municipality remained highly vulnerable to all three elements, three municipalities Joe Morolong, Ga Segonyana and //Khara Hais, the rest of the municipalities were not vulnerable. This is attributed to the low population densities across the whole province.

Table 2.5: Ranking of regional vulnerability of Northern Cape Municipalities to climate change, before and after adjusting for population size (red=high vulnerability; yellow = medium/moderate vulnerability; green=low vulnerability).

	Vulnerability before popuplation size considered			Vulnerability after popuplation size considered		
	Gradual/longer-term incr in temp, decr in rainfall	Extreme precipitation, incl hail, wind storm, flooding	Extreme hot days (heat waves)	Gradual/longer-term incr in temp, decr in rainfall	Extreme precipitation, incl hail, wind storm, flooding	Extreme hot days (heat waves)
Joe Morolong	Red	Red	Red	Yellow	Yellow	Yellow
Ga-Segonyana	Red	Red	Red	Yellow	Yellow	Yellow
Gamagara	Yellow	Red	Red	Green	Green	Green
Richtersveld	Yellow	Yellow	Yellow	Green	Green	Green
Nama Khoi	Yellow	Yellow	Yellow	Green	Green	Green
Kamiesberg	Red	Red	Yellow	Green	Green	Green
Hantam	Yellow	Yellow	Yellow	Green	Green	Green
Karoo Hoogland	Red	Red	Yellow	Green	Green	Green
Khâi-Ma	Yellow	Red	Yellow	Green	Green	Green
Ubuntu	Red	Red	Red	Green	Green	Green
Umsobomvu	Red	Red	Red	Green	Green	Green
Emthanjeni	Red	Red	Yellow	Green	Green	Green
Kareeberg	Red	Red	Yellow	Green	Green	Green
Renosterberg	Red	Red	Red	Green	Green	Green
Thembelihle	Red	Red	Red	Green	Green	Green
Siyathemba	Red	Red	Red	Green	Green	Green
Siyancuma	Red	Red	Red	Green	Green	Green
Mier	Red	Red	Yellow	Green	Green	Green
Kai !Garib	Yellow	Red	Yellow	Green	Green	Green
//Khara Hais	Red	Red	Red	Yellow	Yellow	Yellow
!Kheis	Red	Red	Red	Green	Green	Green
Tsantsabane	Red	Red	Red	Green	Green	Green
Kgatelopele	Yellow	Red	Yellow	Green	Green	Green
Sol Plaatjie	Red	Red	Red	Red	Red	Red
Dikgatlong	Red	Red	Red	Green	Green	Green
Magareng	Red	Red	Red	Green	Green	Green
Phokwane	Red	Red	Red	Green	Green	Yellow

This highlights the importance population size when considering vulnerability especially where population is high with key issues such as poverty level, education, employment status as well as disability. While all populations will be affected by climate change, some are more vulnerable than others , such as the elderly and children (due to their physiological development), people with pre-existing medical conditions and those considered 'special needs populations' such as the physically or mentally challenged (WHO, 2013). Vulnerable population groups have decreased ability to cope with climate change and the socio-economic status of such communities is as important as their susceptibility/sensitivity in terms of their coping capacity (WHO, 2013).

The changes in the extreme weather events projected for the Northern Cape highlight an increase in the number of heat wave days by approximately 10 events per year under high mitigation scenarios and 20 events under low mitigation scenarios (See climate science modelling projections chapter) will pose serious health risks to the vulnerable population, given the effect of heat stress on cardio-vascular diseases which is already a leading cause of death in the province. It is expected that the increase in temperature as well as increases in very hot will exacerbate the occurrence of this disease, with a likely going to result in increases in reported cases. Increased temperature as well as reduced rainfall will also exacerbate the occurrence of respiratory diseases and it is possible that the number of deaths or reported cases of this disease will increase in the province. The state of air quality will further have an influence on respiratory diseases as well as on TB (tuberculosis) which is already a major killer in the province. The projected increases in the number of extreme rainfall events will severely affect the vulnerable and in the case of Northern Cape, the isolated communities causing wide-spread destruction and a host of waterborne diseases. The health care system in the province needs to put in measures in place to prepare for these changes.

The impacts of climate change on human health resulting from expected increases in the frequency, intensity and duration of extreme weather events are likely to have a major effect on public health (DEA, 2013). Human exposure to climate change may be direct and/or indirect, and will be determined by the character, magnitude and rate of climate variability (WHO, 2003 in DEA, 2013).

2.5 Built Environment and Human Settlements

The built environment is classified as the structures and infrastructure that is found prevalently in cities, towns and other built up areas. The built environment can also include man-made outdoor environments and provides the basic necessities for human well-being and is closely linked to delivery of basic services, especially in South African cities and urban areas. Some of the examples of infrastructure include water and sewer lines, electric lines and other utilities, roads, bridges and even pavements. The built environment has an impact on human health and well-being, especially for the unemployed and low income earners, given the areas and spaces these population groups occupy within the built environment. Issues of climate change impacts will only serve to exacerbate these already vulnerable populations groups unless planned for at a local level. Climate change, particularly extreme climate related events such as floods, will also result in extensive damage to infrastructure that will cost governments immense financial resources to repair, maintain and upgrade such infrastructure especially where the demand on infrastructure are exacerbated by increases in population.

Cities, towns and settlements are key in the development of South Africa and according to the updated settlement and town typology conducted by the CSIR, BE (2011) these settlements or functional urban areas house more than 70% of the SA population and more than 90% of all economic activity, and thus, the need to understand settlement dynamics within the context of risk and vulnerability for municipalities is clearly essential. The settlement typologies found in South Africa include City regions; Cities; Regional service centres (large and medium sized towns); Service towns; as well as Local & niche nodes (CSIR BE, 2011). Typologies also encompass urban formal, urban informal and former homeland areas.

2.5.1 Built Environment in Northern Cape

The settlement pattern in the Northern Cape is comprised of various small settlements, most them isolated urban and semi-urban, dispersed across the vast province. The province has an estimated 115 urban areas of different sizes, some with strong economic base to economic growth, while some of the municipalities are losing their economic base, their service-capability and infrastructural power. The majority of these settlements face challenges in providing basic services for their populations as a result of inadequate income generated by the municipalities within which they are located.

2.5.2 Human Settlements in the Northern Cape Province

Housing is one of the basic human needs that have a profound impact on the health, welfare, social attributes and economic productivity of people. It is used as an indicator of a person's standard of living and place in society and is one of the Millennium Development Goals and the provision of proper housing by the government is part of the National Development Plan. In order to achieve this goal, the government plans to eliminate all informal dwellings, bucket type toilets, and ensure that all citizens have access to electricity for lighting, and access to clean, safe water within a reasonable distance (Stats SA, 2007). The Northern Cape Province had estimated 245 086 households in 2001 which increased to 264 653 households by 2007 (see Table 2.6 below).

Table 2.6: Number of households in the districts of the Northern Cape for the 2001 Census and 2007 Community Survey

REGION	CENSUS 2001 (DECEMBER 2005)	COMMUNITY SURVEY 2007
Northern Cape	245 086 (991 919 persons)	264 653 (1 058 060 persons)
John Taolo Gaetsewe	44 218 (191 539 persons)	42 151 (173 454 persons)
Namaqua	27 776 (108 111)	36 437 (126 494 persons)
Pixley ka Seme	41 135 (164 607 persons)	43 285 (166 849 persons)
Siyanda	48 100 (202 160 persons)	59 893 (238 063 persons)
Frances Baard	83 857 (325 503 persons)	82 887 (353 200 persons)

The settlement typology for the province in relation to its people indicated that in 2007, at least 80.4% of the population lived in formal housing with only 10.5% living in informal housing (see Table 2.7) below. The Community Survey (2007) highlighted that there was a housing backlog of 51 570 houses in the province in 2007, which has been reduced to 45 994 currently. The other dwelling types in the Northern Cape are traditional housing and back yard houses which are estimated to be 24 174 (Community Survey, 2007).

Table 2.7: Percentage distribution of households by type of main dwelling in the Northern Cape according to the 2007 Community Survey

DISTRICT MUNICIPALITY	FORMAL DWELLINGS	INFORMAL DWELLINGS
John Taolo Gaetsewe	70.9%	8.5%
Namaqua	85.5%	5.1%
Pixley ka Seme	93.9%	3.2%
Siyanda	92.7%	6.4%
Frances Baard	83.3%	13.3%
Northern Cape	80.4%	10.5%

2.5.2.1. Informal Settlements

Informal settlements are unplanned settlements that develop and change as people settle in areas closer to employment opportunities. While the location of these unplanned settlements may differ, these are usually located within planned townships, open land within the urban and peri-urban areas which develop on farm or small holdings on the outskirts of urban areas (Department of Human Settlements, 2005). The locations are often unsuitable for human settlement, characterised by unstable soils, wetlands and some are located in the flood lines, which are prone to flood risk. This normally results in annual flooding of these settlements.

These types of settlements consist of a range of housing, such as backyard shacks and free-standing structures, normally without services, with some being illegal, while others are on communal land, or on land on which tenure has been secured following settlement (Department of Human Settlement, 2005). The substantial backlog of the delivery of basic services in the country is associated with informal settlements which are often characterised by high poor population, who are socially vulnerable to climate and its impacts (see Section 2.7) (DEA, 2013 h).

Mixed settlements comprise a mix of urban and rural settlements and not as densely populated, with most them support peri-urban intense agriculture. The housing typology can include formal, informal and back yard shacks and are sometimes associated with former homeland areas which were not properly planned (DEA, 2013 h). Rural settlements are predominantly dependent on agriculture, herding and tourism, and are affected by the drives of social vulnerability that affect informal and mixed settlements. The dependence of poor rural populations to subsistence agriculture makes them highly vulnerable to climate change, given the reduced and degraded ecosystem upon which they rely. Other rural communities are also isolated due to poor transport network, increasing their vulnerability to in the cases of extreme events such as flooding (DEA, 2013 h).

There are currently 27 735 informal housing units in the Northern Cape Province. This is an increase from the 26 601 in the 2001, and 26 581 in Census 1996. Pixley ka Seme is the District Municipality with the largest housing backlog of 15 419 dwelling units (Northern Cape Province, 2011). At least 45% of the informal dwelling units are not back yard shacks, being located in urban settlements which are not designated as informal settlements. Furthermore, at least 64% of shacks are not located in the backyards with only 8% being located in the back yard. While it is acknowledged that most service delivery backlogs occur in informal settlements, some services are provided such as refuse collection which is given to 56%, access to water to 51%, electricity to 51% and flushing toilets to 17% of the population in informal settlements in the Northern Cape (The Housing Development Agency, 2012).

It is important to note that people residing in informal housing and settlements are at highly at risk to climate change impacts related to extreme temperature and rainfall events such as flooding. In addition, informal housing increases their vulnerability due to the nature of the building materials used as well as the location of these informal settlements, which often lack access to basic services. It is encouraging to note that according to the Housing Development Agency (2012); 40% of the informal dwellings in informal settlements in the Northern Cape are earmarked for upgrading.

2.5.2.2. Basic Service Delivery

The provision of basic services such as water and sanitation, as well as electricity are critical for human wellbeing, especially for sanitation which extends beyond just the provision of a toilet and sewerage infrastructure but has to do with human dignity while providing a healthy living environment. Sanitation overlaps a number of sectors which include housing and settlement development, water and environment resource management, while poor sanitation leads to the spread of cholera and other diarrhoeal diseases, worms and parasites which are detrimental to children's growth (DEA, 2013h).

2.5.3. Climate Change and Human Settlements

Human settlement are vulnerable to climate change based on their exposure to the climate risks and the degree to which the communities can adapt and respond, which has been discussed above is strongly influenced by social vulnerability. The impact of climate change on human settlements is location based being affected by climate, topology, and the settlement patterns. Some of the impacts include and are not limited to:

- **Increased temperatures** – heat stress impacts on human health exacerbated by urban heat, islands; loss of productivity; declining air quality in cities; and increased demand for cooling.
- **Extreme weather: heat waves and droughts** – increased water demand, water quality problems, heat-related deaths and reduced quality of life, food insecurity.
- **Extreme weather**: heavy rainfall and violent storms – water quality problems; deaths and injuries, infections and water-borne disease; damage to infrastructure and economy, loss of property.

The social drivers of human settlements vulnerability include but are not limited to:-

- **Access to basic services**: households without access to electricity, water, and sanitation and waste management services are more impacted by climate extremes.
- **Type of dwelling**: Houses that are poorly built, are poorly located, or lack flood and lightning protection, efficient water systems, cool spaces, heat-reflective surfaces or damp-proofing are a source of climate vulnerability. Informal housing (shacks) are particularly vulnerable.
- **Health**: climate resilience is dependent on baseline health, including age. Children and the elderly are more susceptible to illness, heat stress, food insecurity and malnutrition, all of which are climate hazards that are projected to increase in the medium to long term.
- **Economic factors** such as poverty and unemployment link to many of the abovementioned factors and reduce the ability of households to recover from climate shocks. Land tenure status is another important factor: households with insecure tenure such as squatters are less likely or able to invest in adaptation.
- **Demographic factors** including **age** and **gender**. In addition to age-related vulnerabilities to health impacts, asymmetrical power relations may increase the vulnerability of women. Communities with a smaller than average proportion of working-age adults, are particularly vulnerable (DEA, 2013hs).

The urban settlement environment will face more complicated challenges due to rapid urbanisation which is currently adding undue pressure on existing infrastructure. Urban growth is being exacerbated by migration trends to urban areas. As a legacy of apartheid, spatial planning in some urban areas is not up to standard, placing, historically disadvantaged households on the urban periphery, far from economic opportunities. This forced the poor household to spend a substantial amount of their earnings on transport, which was neither safe nor affordable (DEA, 2013hs).

The expected impacts of climate change on urban economies are multifaceted and varied, and can be both direct and indirect. They include but are not limited to:-

- Direct impacts of weather on construction and other industries in terms of loss of production
- Increases in the costs of water, liquid fuels and electricity as industrial inputs
- Increased costs of labour linked to food, energy, water and transport costs
- Potential impacts arising from regulation of carbon emissions
- Disruptions to water and electricity supply reducing productivity

Extreme weather events will add to the woes of urban settlement in terms vulnerability to climate change and will cause extensive damage to infrastructure such as electricity transmission lines, roads, rails, bridges, airports, tunnels. Other damage will be residential infrastructure such as houses and buildings as well as other infrastructure that supports settlement such as water, energy and telecommunications.

Extreme weather events such as floods are expected to increase in the future as a result of climate change, in the country, including the north eastern part of the Northern Cape (see Figure 2.17).

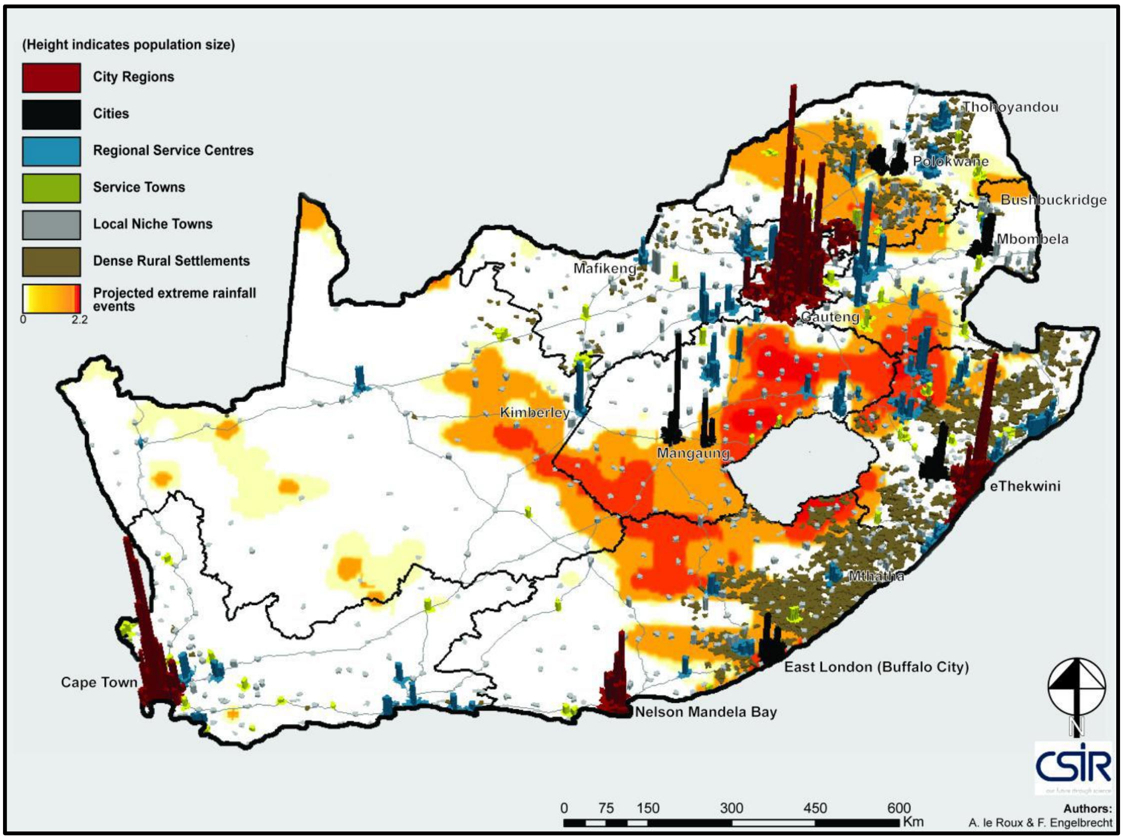

Figure 2.17: Population density and risk of extreme rainfall events (SARVA, 2015)

2.5.4. Infrastructure

The infrastructure in the Northern Cape includes, water and sanitation as well as telecommunications and energy which has been briefly discussed above. Extreme weather events will further cause damage to all infrastructure most of which is in dire need of upgrading. For example, higher temperature will increase heat stress on the construction material.

Transport infrastructure both public and private is essential for the development of the economy, providing access to employment opportunities, and increased social integration as well as providing mobility to urban and rural communities. Further, transport allow for the movement of goods to markets and services (Northern Cape Province, 2011). In terms of the transport network of the province, it is not sufficient and effective, and has been cited as one of the hindrances of the development of rural areas. The poor transport network restricts the mobility of communities resulting in decreases opportunities for socio-economic growth, especially for the isolated communities (Northern Cape Province, 2011).

Telecommunications infrastructure is mainly for landlines provided by Telkom, as well as for cell phones. The **health** infrastructure includes 15 hospitals, 25 community hospitals and 136 clinics in the Province.

Electricity and Energy infrastructure in the province is centred on the provision of electricity to its population of which 70% has access for cooking, lighting and heating. In terms of energy generation in the province, Eskom (the national power generator) has two hydro power generating stations on the Orange River and plans are underway by the power utility to strengthen the current transmission power line within the Northern Cape and a total length of 155 kilometres (km) line is expected. The province is also gearing up for the renewable energy sectors of which solar will be the critical component as well as the development of a green economy sector. The province had an advantage on the establishment of solar technologies and energy due to its proximity to the national electricity grid, access to water from the Orange River, a good transport network, a flat terrain as well as an abundance of solar radiation for generating solar power. This initiative would also need capital investment for transmission lines and other infrastructure (Northern Cape Province, 2011). Wind energy is another possibility for renewable energy for the Northern Cape, especially along the coast.

The Northern Cape is a water scarce province, with water shortages already being experienced in some of the municipalities; while about 280 communities which is approximately 465 000 people are dependent on ground water. A total of 31 Water Services Authorities deliver water in the province, through 155 drinking supply systems with an average of 402.1 million litres per day consumed. At least 94.4% people in the province have access to piped water (Northern Cape Province, 2011).The water infrastructure comprises a series of dams such as the Gariep, the Vanderkloof, the Boegoeberg Dam and the Spitskop Dam as well as a few weirs. All these are used for the provision on water for irrigation for agriculture, urban use and energy generation.

2.5.5 Climate Change and the Built Environment

Table 2.8 below highlights the impacts of climate change on human settlement as well as to a small extent on roads, water and transport infrastructure within the built environment as well as some health impacts on the population.

Table 2.8: Possible impacts of climate change phenomena on human settlements

Change Phenomenon	Consequences for human settlements
General warming – less intensely and fewer cold days and nights, more frequent and intense hot days and nights	• Intensified heat island effect • Increased energy demand for cooling • Declining air quality in cities • Reduced energy demand for heating • Reduced disruption to transport due to snow, ice
Extreme weather – heat waves and drought	• Increased water demand • Water quality problems • Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and poor. • Reduction in quality of life for people without appropriate housing
Extreme weather – heavy precipitation events and violent storms	• Adverse effects on quality of surface and groundwater, contamination of water supply • Increased risk of deaths, injuries, infectious, respiratory and skin diseases water and food-borne diseases; and post-traumatic stress disorders • Disruption to commerce • Large displacement of people and distress migration to urban areas • Pressures on urban and rural infrastructure, including power outages, disruption of public water supplies and transport • Loss of property and withdrawal of risk coverage in vulnerable areas by private insurers
Sea level rise and storm surges	• decreased freshwater availability due to salt-water intrusion • increased risk of deaths and injuries by drowning in floods and migration-related health effects • loss of property and livelihoods, loss of property and withdrawal of risk coverage in vulnerable areas by private insurers • permanent erosion and submersion of land • Costs of coastal protection versus costs of land-use relocation and damage to natural infrastructure - potential requirement for movement of

	populations and infrastructure

The option for renewable energy available for the Northern Cape are both dependent on climate change and its impacts, which is will also affected the availability of both rain for hydro power and solar radiation for solar energy. While the anticipated increases in temperature will continue to boost solar radiation and solar power, there is uncertainty around hydro power, given the uncertainty over projected rainfall in the country and in the Northern Cape Province.

The projected changes in climate will have a lasting effect on human settlements as well as the infrastructure located in the urban and to an extent in the rural settlements. The impact of extreme rainfall events such as flooding as indicated in the climate science modelling projections will result in damages to houses, buildings, as well as energy infrastructure such as solar panels and transmission lines. Other critical infrastructures that will be destroyed include roads, bridges as well as dams and wiers and other infrastructure used to deliver water for domestic and agricultural uses. Increases in temperature will on the other hand affect the construction material used for some of the infrastructure such as steel. In terms of roads, heating of the tar surfaces could result in cracks and could lead to potholes. This will lead to poor road conditions and will affect the transport sector as well as the economies that depend on it for survival. This is particularly pertinent for the Northern Cape given that some of the settlements are already isolated and the dependence and good road condition of mobility and growth. Maintenance and upgrading of infrastructure is already a challenging task without adding the complications of climate change impacts.

2.6. Extreme Weather Events

The Northern Cape Province is prone to numerous extreme climate events such as floods, heat waves, droughts, sea level rise, amongst others; and most of these occur frequently. The Northern Cape west coast is vulnerable to sea level rise over and above the main land events such as extreme temperature increases, storms, floods and fires. Bearing in mind the projected increases of these extreme events as well as the increases in temperature related extreme events such as heat wave days, very hot days and high fire danger day, disaster preparedness need to be key priority for the province in light of these climate related impacts.

There are various temperature related factors that will affect the different sectors and natural resources. These include increases in the average temperature, increases in evaporation rates, as well changes in rainfall patterns over and above the increased occurrences in flooding and drought events and sea level rise (see Figure 2.18). Sectors affected by climate variability include water, (i.e. both surface and ground water resources), including water availability and quality; agriculture and marine and coastal environments. In addition, increases in rainfall intensity will results in impacts such as storm water drainage systems blockages, soil erosion and water contaminants collecting on the surface of catchments (WSS NC, 2015).

2.6.1 Drought

Drought is currently one of the major extreme events affecting the Northern Cape, province (WSS NC, 2015). The impacts of drought on agriculture cannot be under estimated, especially for small holder and subsistence farming communities that has no access to irrigation. Drought will also extensively affect marine and coastal environments, especially the habitats for many of the fish and marine species that are commercially viable for the province (DEA, 2013m). The lack of adequate fresh water has already been cited as a hindrance to the development of both agriculture and fisheries in the province; and drought is exacerbating this situation through water insecurity, and this affects economic development of the province. Currently, a drone is being used to assess the extent of the current drought in the province (SABC News, 2015).

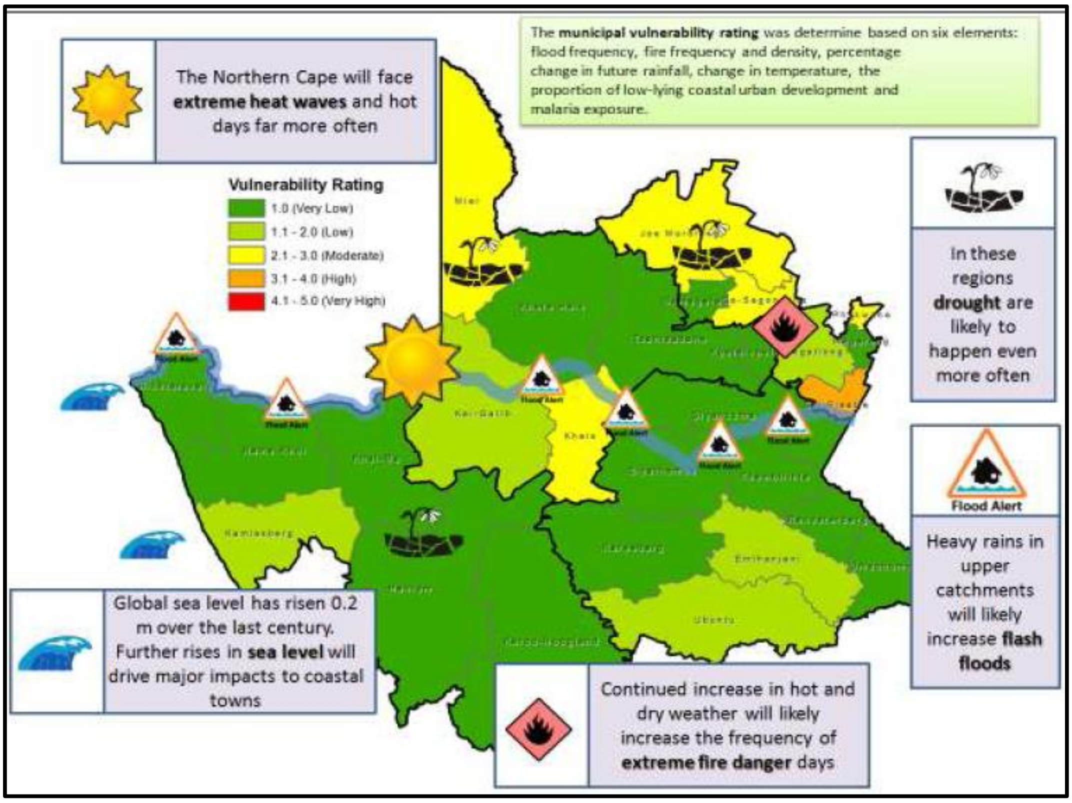

Figure 2.18: Predicted impact of climate change in the Northern Cape (DWS- NC, 2015)

2.6.2 Flooding

Flooding, including flash floods is one of the most common hazards, affecting most parts of the Northern Cape, especially those areas with the flood lines of the perennial rivers. For example, wide scale flooding of the Orange River in 2011 resulted in the overflow of the Gariep dam which threatened to wash away the Kakamas Bridge, forcing the construction of a weir to divert the water to protect the dam. The floods also threated to cut off some of the isolated communities. While no loss of lives were recorded many families had be evacuated. The floods left some areas around Upington under water (News24, 2011).

The impacts of the flood would be more severe in built up areas causing wide spread destruction of buildings and infrastructure for all the economic sectors within the province, such as transport, telecommunications, energy and water. These impacts are worse in areas with informal settlements, particularly areas that are characterised by high social vulnerability since their adaptive capacity is dependent on social vulnerability status.

2.6.3 Veld Fires

The occurrences of fires as a hazard is not very high, with the province generally classified as having low risk with the exception of areas towards the north –east of the province that are considered having high risk with a few specs of extreme risk to fire. The areas towards the south-east of the province are classified as having medium risk to fires (see Figure 2.19). Heat waves are often accompanied by high fire danger day warnings and are frequent in the province.

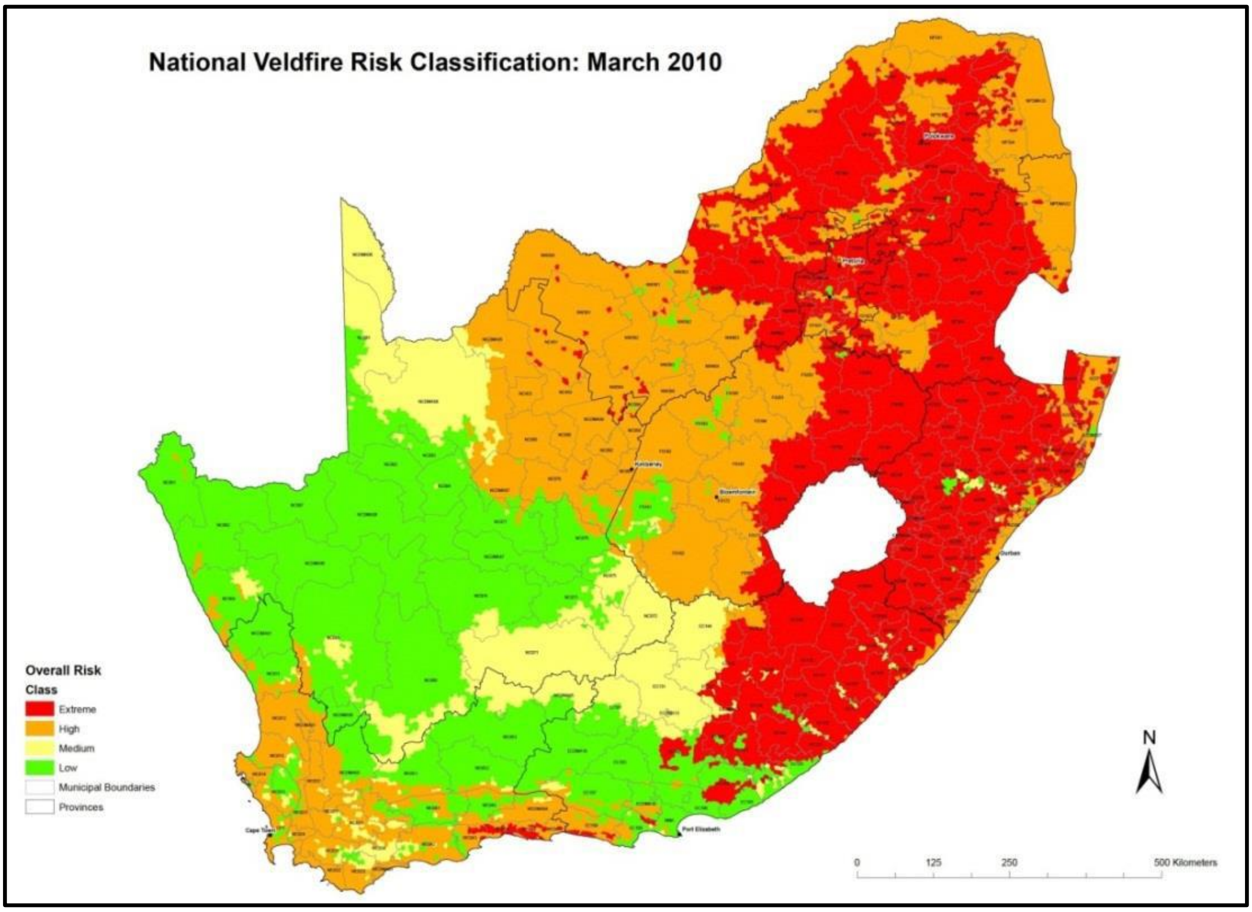

Figure 2.19: National map of Veld Fire Risk Classification (SARVA, 2015)

2.6.4 Sea Level Rise and Coastal Storms

The Northern Cape, being coastal province is affected by increases in incidents of sea level rise as well as increases in coastal storms which occur on the west coast. These two events are expected to cause wide spread damage on the habitat for both fish and marine species, along the west coast, especially intertidal, shallow coastal and off shore species (DEA, 2013m). Furthermore, these sea level rise and coastal storms will also affect the fisheries industry in the province as well as threatening any coastal settlements and towns along the coast, including infrastructure in the areas. The following are some examples of the impacts of sea level rise and storm surges on settlements (DEA, 2014):

- Decreased freshwater availability due to salt-water intrusion
- Increases risk of death and injury by drowning and migration-related health effects
- Loss of property and livelihoods coupled with the withdrawal of risk coverage in vulnerable areas by private insurers.
- Permanent erosion and submersion of land.
- Impacts on fresh water resources as well as biodiversity found in estuaries (DEA, 2013m).

2.6.5 Other Hazards

The Northern Cape also experiences other hazards such as severe winds and thunder storms particularly during summer months. The impacts of extreme weather events in any environment can have devastating effects, especially in areas or sectors were disaster preparedness is poor or not property coordinated. The ability of the affected population to responded to and/or cope with the impacts of the events, especially quick onset events such as floods is dependent mostly on the socio-economic status and the social vulnerability of the vulnerable communities or sectors. The section above has highlighted some of the extreme events affecting the Northern Cape Province and are all expected to increase in frequency and intensity as a result of climate change.

2.7. Social Vulnerability Assessment of the Northern Cape Province

The definition of social vulnerability “the state of individuals, groups, or communities defined in terms of their ability to cope with and adapt to any external stress placed on their livelihoods and well-being”. Social vulnerability is regarded as one aspect of vulnerability in the broader disaster risk assessment field (Taspell et al., 2010). Profiling of social vulnerability of people and communities is essential in order to identify and understand their vulnerability; in particular the ability of the identified population and places to cope with and respond to the various impacts of climate change (van Huysteen, 2013). Therefore, the first step in starting to plan for resilient communities would be to profile spatial and social vulnerability in order to better understand the risks to communities and to permit planners and decision makers to effectively develop local based climate change responses and adaptation (Tapsell et al., 2010; Cutter and Finch, 2007). Determining socially vulnerable communities assists decision makers with appropriate information to effectively measure inequalities, identifying priority intervention areas and a better understanding of the drivers contributing to making communities more or less vulnerable (le Roux et al., 2015). Social factors, while being non-climatic, have a key role to play in enhancing vulnerability to climate related events. It is important to note that different social clusters and population groups have different strengths and needs. Social factors such as social cohesion play a pertinent role in community coping capacity – resilience vs. vulnerability.

2.7.1. Approach

Two methodologies were used to illustrate the vulnerability of communities within the different municipalities of the Northern Cape.

- A Social Vulnerability Index (SVI), which was developed by Le Roux et al. (2015) in support of national decision-making in South Africa. This index provides a comparison of vulnerability of municipalities in Northern Cape to those in the whole of South Africa (classifying them from the least to the most vulnerable). This index was built for the purpose of developing an appropriate index to measure social vulnerability across South Africa by performing principal component analysis of 14 unique (South African-specific) variables. This index was required by the South African National Disaster Management Centre in terms of the National Disaster Management Framework of 2005 (Le Roux et al., 2015).

- In order to show the drivers of social vulnerability within the Northern Cape, a provincial composite index was derived using the same type of indicators as used by Le Roux et al. (2015). The indicators also used the 2001 Census data. Each indicator was looked at on an individual basis. The dependency indicator were derived by considering the dependency ratio ((<15, >65) / (15-65)), with all other indicators using a proportion of the total population in the ward. Indicators were summed and the total used to rank the municipalities.

A myriad of social and economic factors play a crucial roles in the vulnerability as well as the coping capacity and adaption of the different population groups to the various impacts of climate change. Factors such as demographics, economic status, education and employment status as well as types of residences or dwelling all contribute to this profile. In particular, the types of housing may either increase or decrease vulnerability, with informal settlements as a case in point. The social factors in the Table 2.9 below were considered for social vulnerability.

Table 2.9: Social attributes used for the different climate scenarios

Attribute	**Gradual/longer-term increase in temperature, decrease in rainfall**	**Extreme precipitation, including hail, wind storm, flooding**	**Extreme hot days (heat waves)**
Type of housing (shacks)	y	y	y
Education (older than 25 years, no education)	y	y	y
Employment: unemployed	y	y	y
Household density (> 4 people/room)	y		y
Poverty line (hh earning < R400/month)	y		
Economic dependency (young and old compared to economic active population)	y		
Physiological vulnerability (young and old)		y	y
Air pollution (fuel use other than electricity)			

Access to water (no piped water)	y	y	y
Single parents (female-headed households)	y		
Child-headed households	y	y	y
Access to transport (no car)		y	
Access to information (neither radio or cell phone)	y	Y	y
In need of assistance (determined by problems with hearing, mobility, seeing, self-care, speaking)	y	Y	y
Social cohesion (non-South Africans in informal areas for < 2 years).		y	y

2.7.1. The Northern Cape

The main drivers of social vulnerability in the different municipalities are access to transport and economic dependency. Vulnerability to a particular climate scenario was determined by summing the proportions of the individual risk factors and determining the percentile of each municipal score as compared to the maximum score for that scenario. Vulnerability was therefore relative to the municipality with the highest vulnerability. This was done before and after adjusting for population size. Before considering population size, the relative vulnerability for the three climate scenarios was classified as high at all municipalities for the first two scenarios, and at 12 of the 20 for extreme hot days.

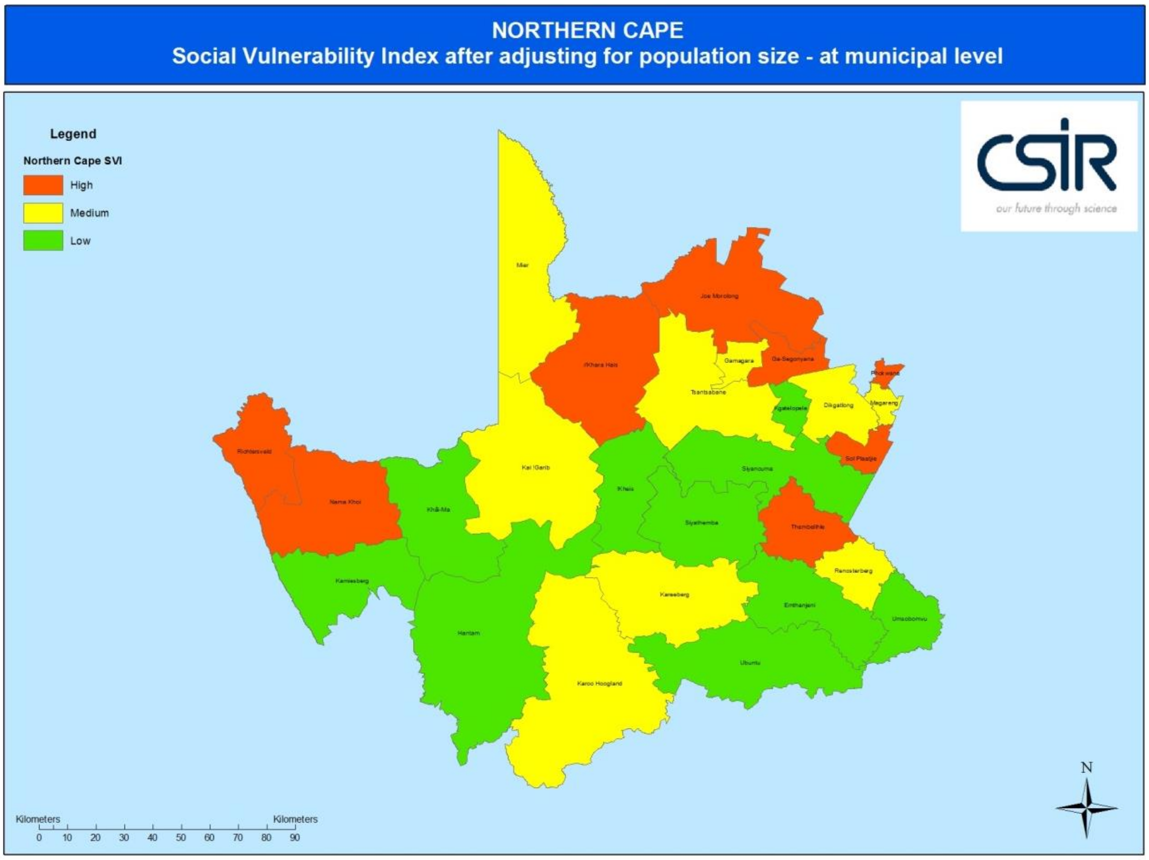

Figure 2.20: Social Vulnerability of the Northern Cape Province

Issues of social vulnerability, especially population dynamics are key factors in the response of the affected population to climate change and thus should be regarded as such in an attempt to make or improve the resilience of a population to climate change. The social factors considered (see Table 2.9) determine the capacity of the population to respond to climate change. In the Northern Cape, access to information proved to be one of the key drivers of vulnerability, (see Table 2.10) including type of housing and education. While other factors such as poverty are important, these are not well highlighted due to the low population density of the province.

The most vulnerable municipalities highlighted with the red colour (see Figure 2.20) include Joe Morolong, Thembelihle, Richtersveld, Nama Khoi, Sol Plaatje, Ga-Segonyana, Phokane and //Khara Hais. Medium social vulnerability is identified in the following municipalities include Kai !Garib, Mier, Gamagara, Magareng, Tsantsabane, Karoo Hoogland, Kareeberg and Renosterberg cloloured in yellow on the map. The rest of the municipalities are considered to have low vulnerability. For the detailed breakdown of the social vulnerability factors per municipality see Table 2.7.

Issues of poverty, unemployment and education are key in the development of the population of this province, with recorded 42.8% of household living below the poverty line in 2009. In terms of employment, 44.7% of the household in the province earn less than 9.8% as income, with household not earning an income at all, and 27.9% of the population earning some form of grant.

Given that social vulnerability is a critical factor in the response of the province's population to climate change, and given the vulnerability status of some of the municipalities, extreme weather events will cause a wide range of challenges especially for the poor population in the informal settlements. Projected increases in extreme rainfall events (Section 3.2.6) will result in extensive damages to informal housing due the types of materials used to construct these houses, and other infrastructure which is essential for human wellbeing such as clinics and schools. Extreme temperature changes which are also expected to increase will result in the increased heat stress and together with air pollution will bring about respiratory diseases as well as high levels of human discomfort during both hot and cold months, affecting mainly informal settlements more than the other forms of settlements. Extreme rainfall events will also exacerbate service delivery in the province and this will not improve the social vulnerability status of the poor population. Issues of drought will bring about more water- related and communicable diseases as well as other sanitation challenges in a province that is already experiencing water problems (WSS NC, 2015).

At this point, it is therefore important to highlight that addressing inequalities of the past as well as service provision of the basic services will go a long way to reduce the social vulnerability of the province especially in highly vulnerable municipalities and it is also important to note that social cohesion is essential as a community coping mechanism.

Attribute	Joe Morolong	Ga-Segonyana	Gamagara	Richtersveld	Nama Khoi	Kamiesberg	Hantam	Karoo Hoogland	Khâi-Ma	Ubuntu	Umsobomvu	Emthanjeni	Kareeberg	Renosterberg	Thembelihle	Siyathemba	Siyancuma	Mier	Kai !Garib	//Khara Hais	!Kheis	Tsantsabane	Kgatelopele	Sol Plaatjie	Dikgatlong	Magareng	Phokwane
Type of housing (shacks)	0.042	0.111	0.230	0.045	0.026	0.013	0.015	0.019	0.035	0.089	0.106	0.030	0.075	0.048	0.211	0.106	0.248	0.040	0.063	0.230	0.318	0.258	0.095	0.172	0.169	0.121	0.138
Education (older than 25 years, no education)	0.130	0.061	0.075	0.018	0.015	0.037	0.100	0.129	0.028	0.105	0.106	0.071	0.124	0.104	0.099	0.076	0.108	0.059	0.061	0.046	0.085	0.091	0.081	0.047	0.113	0.107	0.112
Employment: unemployed	0.101	0.171	0.115	0.126	0.116	0.152	0.060	0.079	0.152	0.181	0.169	0.145	0.130	0.143	0.155	0.127	0.135	0.135	0.067	0.118	0.157	0.160	0.124	0.180	0.175	0.171	0.194
Household density (> 4 people/room)	0.012	0.015	0.011	0.001	0.002	0.002	0.007	0.004	0.006	0.011	0.011	0.007	0.013	0.007	0.017	0.017	0.010	0.024	0.010	0.008	0.036	0.015	0.004	0.008	0.012	0.007	0.019
Poverty line (hh earning < R400/month)	0.783	0.702	0.492	0.495	0.558	0.565	0.560	0.544	0.496	0.629	0.649	0.616	0.607	0.594	0.590	0.609	0.640	0.634	0.460	0.600	0.651	0.578	0.590	0.607	0.673	0.670	0.680
Economic dependency (young and old compared to economic active population)	1.108	0.754	0.482	0.524	0.640	0.739	0.699	0.746	0.565	0.785	0.754	0.772	0.746	0.783	0.753	0.730	0.775	0.805	0.524	0.712	0.837	0.599	0.637	0.649	0.739	0.769	0.789
Physiological vulnerability (young and old)	0.454	0.364	0.278	0.292	0.324	0.358	0.351	0.368	0.309	0.383	0.366	0.370	0.367	0.385	0.368	0.363	0.374	0.383	0.291	0.349	0.393	0.319	0.331	0.333	0.364	0.373	0.370
Air pollution (fuel use other than electricity)	0.429	0.124	0.152	0.069	0.076	0.187	0.262	0.391	0.137	0.212	0.198	0.105	0.316	0.157	0.322	0.165	0.232	0.304	0.154	0.111	0.416	0.194	0.099	0.174	0.278	0.178	0.217
Access to water (no piped water)	0.082	0.014	0.005	0.032	0.030	0.042	0.010	0.006	0.026	0.010	0.012	0.007	0.011	0.007	0.004	0.011	0.034	0.064	0.068	0.024	0.118	0.032	0.007	0.004	0.028	0.045	0.032
Single parents (female-headed households)	0.128	0.116	0.077	0.108	0.107	0.121	0.096	0.091	0.101	0.097	0.120	0.102	0.094	0.101	0.085	0.097	0.094	0.074	0.106	0.103	0.083	0.090	0.087	0.108	0.097	0.113	0.106
Child-headed households	0.010	0.008	0.004	0.002	0.002	0.002	0.002	0.002	0.004	0.006	0.005	0.007	0.002	0.006	0.003	0.008	0.005	0.003	0.004	0.004	0.004	0.004	0.005	0.003	0.003	0.003	0.005
Access to transport (no car)	0.838	0.728	0.578	0.641	0.617	0.733	0.677	0.706	0.728	0.764	0.784	0.728	0.742	0.721	0.698	0.753	0.734	0.697	0.785	0.664	0.781	0.691	0.652	0.665	0.807	0.806	0.776
Access to information (neither radio or cell phone)	0.110	0.053	0.044	0.067	0.062	0.146	0.121	0.157	0.182	0.157	0.142	0.125	0.136	0.191	0.175	0.165	0.140	0.180	0.180	0.101	0.187	0.085	0.067	0.081	0.131	0.096	0.100
In need of assistance (determined by problems with hearing, mobility, seeing, self-care, speaking)	0.260	0.142	0.192	0.158	0.264	0.127	0.136	0.097	0.142	0.141	0.154	0.117	0.064	0.090	0.048	0.148	0.180	0.043	0.155	0.273	0.175	0.131	0.107	0.120	0.160	0.076	0.245
Social cohesion (non-South Africans in informal areas for < 2 years).	0.296	0.225	0.123	0.033	0.067	0.017	0.071	0.115	0.027	0.306	0.199	0.129	0.082	0.079	0.118	0.245	0.175	0.026	0.068	0.077	0.104	0.187	0.160	0.106	0.202	0.130	0.206

Table 2.10: Social Vulnerability indicators for the Northern Cape Municipalities, indicating their relative vulnerability (green: lowest → red: highest)

3. Conclusion

This chapter has reviewed the vulnerability of the different sectors in the Northern Cape Province, both environmental, economic and social that will be affected by climate change and extreme events. The key issues for vulnerability, affecting the economic development of the province include the loss of the grassland biome, availability of water as well temperature changes, as well as changes in the intensity and magnitude of rainfall; all of which will have detrimental impacts on all economic sectors of the province, including agriculture, biodiversity, water, human health and well-being, built environment and the energy sectors. These identified vulnerabilities are the starting point to devising appropriate response plans and adaptation strategies to combat climate change impacts in the province while building communities resilient to climate change, through identifying their locations and nature of their vulnerability.

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