CLIMATE CHANGE FRAMEWORK AND OPERATIONAL CLIMATE CHANGE PLAN STRATEGY

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EXECUTIVE SUMMARY

The National Climate Change Response Strategy guides and directs climate change responses, and it recognises that local government has an important role to play in the delivery of these adaptation and mitigation plans. Climate change and variability has already had impacts on the ability of municipality's to perform their task of providing services in a sustainable and equitable manner, facilitating social and economic development and the promotion of a safe and healthy environment for all. Municipalities need to plan and respond appropriately to climate change. This framework and operational plan for Mogale City Local Municipality (MCLM) shows their commitment to respond and adapt to climate change. It aims to highlight the climate change vulnerabilities and impacts in MCLM and it aims to assist the municipality in putting measures in place so as to minimize the climate change impacts and to reduce municipality greenhouse gas emissions.

Mogale City Local Municipality background

MCLM falls within Gauteng Province and is one of four local municipalities (Mogale City, Randfontein, Westonaria and Merafong City) under the West Rand District Municipality (WRDM). It includes a large portion of the Cradle of Humankind World Heritage Site (CoH WHS) falls within MCLM. The municipality experiences typical Highveld climate conditions, with warm to hot summers, fairly high rainfall and moderate to cool winters with little to no rainfall. MCLM straddles the Grassland and Savanna biomes with topography ranging from 1220 m to 1840 m above sea level. There are eight primary ground water aquifers in MCLM, and the dolomite aquifer is a vital water source for Gauteng and Rustenburg. The majority (93%) of the area of MCLM falls within the Crocodile West Marico Water Management Area (WMA) and drains northward via the Crocodile River and its tributaries into the Hartebeespoort dam. A small portion to the south of MCLM, falls within the Vaal WMA and drains via the Kliprivier. The largest part of MCLM is rural in nature. It has a diversified economy, mainly consisting of manufacturing and tourism, and the economic growth is relatively broad-based. In the past gold mining was the core of the region's economy, but due to the closure of mines, the focus has shifted to manufacturing and agribusiness. The dominant economic sector in MCLM is retail; while tourism, eco-tourism, agriculture and business all have the potential to generate economic growth in the local economy.

Past and future climate

South Africa has a semi-arid and temperate climate with an annual average rainfall of 460 mm and mean annual temperatures ranging from temperate to sub-tropical. Climate trends and scenarios for South Africa indicate that the mean annual temperatures have increased by at least 1.5 times the observed global average between 1960 and 2010, with minimum and maximum temperatures showing a significant annual increase. The inter-annual variability in rainfall has increased and there is a tendency towards an increase in the intensity of rain events.

Future climate projections vary considerably, however the overall trends indicate that all regions of South Africa are very likely to be warmer in future. There is a greater uncertainty in the rainfall projections but a general pattern of a risk of drier conditions to the west and south of the country, and wetter conditions over the east of the country seem to be emerging.

Historical daily maximum and minimum temperatures at Deodar near MCLM City show an increasing trend between 1983 and 2014, with a higher increase in minimum temperatures. Rainfall did not show any significant deviation from the current range. Evaporation also appears to have been increasing, although the data set is not a complete. Future climate projections for the North-eastern regions of South Africa show similar trends, with a continued increase in temperatures and evaporation, with little to no change in total annual rainfall.

GHG emissions

Greenhouse gas (GHG) emissions play an important role in climate change and in order to develop appropriate mitigation strategies it is critical that countries adequately account for their GHG emissions. The Energy sector dominates the GHG emissions in South Africa, generating 78% of the total CO_2 emissions in 2000. Industrial processes, Agriculture and Waste contributed 14.1%, 4.9% and 2.1% respectively. The Energy sector is also the largest contributor to the GHG emissions in the Gauteng Province (40 102 Gg CO_2eq), with transport contributing 40% to the Energy sector emissions. Non-territorial electricity (that is electricity that is not generated within the borders of Gauteng) was estimated to produce 46 505 Gg CO_2eq. The Waste and AFOLU sectors contribute 3 246 Gg CO_2eq and 712 Gg CO_2 eq, respectively. The emission inventory is, however, not complete as emissions from the IPPU sector were not reported due to a lack of data.

In MCLM the sectors which are likely to produce GHG emissions are industry, agriculture, biomass burning, transport, landfill sites and waste, and residential fuel burning. Initial estimates of GHG emissions for industry, residential burning, transport and biomass burning in MCLM were calculated from the activity data provided in the MCLM and WRDM AQMPs and the IPCC 2006 Guideline default emission factors. These initial estimates (although incomplete) indicate that industry and road transport are likely to be important emission sources in the municipality. Waste sector emissions could not be estimated due to a lack of data. It is highly recommended that MCLM conduct a full GHG inventory so as to guide future emission reduction actions.

Climate change vulnerabilities and impacts

Vulnerability is a function of exposure (the character, magnitude and rate of climate variation), sensitivity, and its ability to adapt. Even though vulnerability is not strictly synonymous with poverty, the most vulnerable to climate change are often those in the weakest economic position. The case is similar for terrestrial systems as those ecosystems which are in poor condition are more vulnerable because their ability to respond and adapt to the change in climate is reduced. There are direct and numerous indirect impacts of climate change, and the document discusses these impacts in terms of MCLM. A summary of the more important impacts in each sector are provided below.

Sector	Main climate change impact
Water	• Alteration of water quality which has implications for aquatic plants and wildlife; • Increased demand for water • Increases soil erosion and runoff; • Increased flooding; • Increased damage to water infrastructure; • Alters ground water recharge; • Variation in water availability
Agriculture	• Increased water demands for irrigation; • Increase in spread of pests and pathogens; • Increased discomfort levels and heat stress for livestock; • Increased discomfort levels and reduced productivity for the labour force; • Increase in winter temperatures and a decrease in the number of chill units in a year; • Increase in extreme precipitation events which can cause crop damage
Human health	• Increase in heat related illness; • Increase in vector-borne diseases; • Increase in trauma due to loss of property (through increased flooding and fires) which impacts psychological and mental health; • Increase in health effects associated with population displacement; • Increased demand on health care facilities and emergency services
Biodiversity and terrestrial ecosystems	• Biome shifts, with an expected increase in the savanna area and a reduction in the grasslands; • Shifts in climate envelope suitable for various species, which may cause extinction of some species, but increase in others; • Increased disturbances which can lead to an increase in alien species; • Wetland degradation due to changing water temperatures and water quality
Human settlements and infrastructure	• Increase in the urban heat island effect; • Increase in infrastructure damage due to flood and storm surges; • Increase in damage to communication and energy networks; • Increase in damage to property; • increase in income loss due to increased breaks in service deliveries cause by flooding, hail storms or fires; • Increased loss of subsistence crops
Tourism	• Increased discomfort levels and an increased demand for cooling;

	• Tourist experience affected through increased flooding, fires, disruption of access routes and degradation of environment • Increased health risks due to expanded range of pests and diseases; • Alteration of biodiversity and reduced landscape aesthetics affects nature-based tourism

Climate change adaptation and mitigation actions

Adaptation refers to the adjustments that human or natural systems make in response to real or projected climate changes so as to reduce the impacts or take advantages of possible opportunities; while *mitigation* refers to actions which are implemented to slow down the build-up of heat trapping greenhouse gases and remove them from the atmosphere. Vulnerabilities are decreased in response to enhanced adaptation, and without the implementation of any mitigation measures GHG emissions will continue to grow. MCLM needs to start implementing adaptation strategies immediately so as to improve its resilience to future climate change; and at the same time implement mitigation strategies to reduce emissions and thus reduce further changes in climate in the future. This framework discussed various adaptation and mitigation actions for the municipality and these are summarized below. The framework also highlights where communities can get involved and assist in improving the resilience of the municipality.

Sector	**Adaptation action**	**Community involvement**
Water	• Improve climate and water monitoring; • Improve water conservation; • Conserve and restore aquatic ecosystems; • Increase water storage capacity; • Improve flood/storm surge control; • Improve water demand management • Support the use of grey water and rain water	• Reduce water usage by making use of water conservation technologies, watering correctly and reducing water loss (leaks, mulching); • Increase water storage by collecting rain water
Agriculture	• Improve early warning systems; • Preserve agricultural land; • Promote the use of food gardens in residential areas; • Improve crop management and yields by using appropriate crops and species; • Improve and promote sustainable farming; • Improve livestock farm management; • Plant indigenous trees to reduce runoff and provide shade for livestock and labourers	• Establish food gardens
Human health	• Improve monitoring of health impacts; • Reduce air pollution through the use of passive energy measures and non-polluting renewable energy sources; • Maintain and upgrade health care facilities and services; • Increase access to basic services in rural areas	• Make use of the improved domestic stoves which reduce emissions and the formation of particulate matter
Biodiversity and	• Conserve parks and open areas and identify further	• Plant indigenous trees in

ecosystems	areas for protection; • Maintain corridors to facilitate dispersal and migration; • Protect and restore wetlands; • Promote the planting of indigenous trees to reduce runoff and increase carbon storage; • Rehabilitate degraded areas	residential areas; • Assist with conserving and reducing pollution in open areas
Human settlements and infrastructure	• Maintain and upgrade storm water infrastructure; • Improve natural barriers for storm water surges; • Reduce the heat island effect by using 'green' infrastructure (use 'çool' building materials, roof top gardens, open areas); • Make use of sustainable land-use planning and spatial development; • Increase access to basic services in rural areas	• Set-up roof top gardens in urban areas; • Develop communal food gardens in rural areas
Disaster risk reduction and management	• Improve climate monitoring and early warning detection systems; • Strengthen the communication system in order to get the early warnings out to the community	
Waste	• Reduce and recycle waste; • Improve the use of urban plant and tree waste; • Maintain and improve infrastructure for waste collection; • Monitor landfill sites	• Reduce waste production and reuse containers/bags where possible; • Compost food and plant materials; • Make use of recycling bins and recycle waste at the source

Sector	Mitigation action	Community involvement
Energy	• Improve renewable energy supply; • Improve energy efficiency; • Improve water heating efficiency; • Make use of combined heat and power generation where possible; • Make use of energy efficient lighting and appliances	• Reduce energy consumption; • Make use of solar heating; • Use insulation in the houses; • Use energy efficient lights; • Use energy efficient appliances
Transport	• Improve and encourage the use of public transport	• Minimize the use of vehicles by using alternative transport, public transport and car pooling
Industry, commerce and mining	• Implement reporting of GHG emissions by companies in the industrial sector; • Provide incentives for cleaner production technologies; • Improve energy efficiency in these sectors	
Residential	• Promote the use of improved and safer domestic stoves which have higher thermal and energy efficiencies.	• Make use of the improved domestic stoves so as to reduce emissions

Infrastructure	• Promote densification and multifunctional landscapes; • Building designs must incorporate energy and water efficient technologies; • Building designs and town planning must also incorporate 'green' infrastructure	
Agriculture	• Make use of sustainable farming methods; • Encourage efficiency in fertilizer use; • Encourage and promote the generation of biogas from agricultural residue and livestock manure	
Waste	• Promote the adoption of waste-to-energy technologies; • Promote biogas technology at WWTPs; • Improve energy efficiency in WWTPs	
Cross-cutting issues	• Install smart controls in various sectors to improve energy efficiency and to improve transport flows to reduce emissions	

Recommendations and way forward

It is recommended that MCLM (a) conduct a full GHG inventory; (b) improve its local climate monitoring system; (c) incorporate the framework and its climate change adaptation and mitigation actions into the IDP; and (d) incorporate the climate change actions into the agenda of all relevant structures. Budget allocations must ensure spending supports the maintenance of existing structures as well as the development of new infrastructure.

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ACRONYMS

AFOLU	Agriculture, Forestry and Other Land Use
AMD	Acid mine drainage
COH WHS	Cradle of Humankind World Heritage Site
EMF	Environmental Management Framework
GCM	Global circulation models
GHG	Greenhouse gas
GPG	Global Protocol for Community Emissions
GVA	Gross Value Added
ICLEI	International Local Government GHG Emissions Analysis Protocol
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
LED Strategy	Local Economic Development Strategy
MAP	Mean Annual Precipitation
MAR	Mean annual runoff
MCLM	Mogale City Local Municipality
SDF	Spatial Development Framework
SoER	State of Environment Report
SRES	Special Report on Emissions Scenarios
UNFCCC	United Nations Framework Convention on Climate Change
WRDM	West Rand District Municipality
WRI	World Resource Institute

1. INTRODUCTION

Climate change, as defined by the United Nations Framework Convention on Climate Change (UNFCCC), is *a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*. It has been identified as a significant threat to human livelihoods and sustainable development in many parts of the world (IPCC, 2001). Global climate change is possibly the greatest environmental challenge facing the world this century.

There is ever-increasing evidence that climate change is a physical reality. Scientific data shows that, despite the uncertainties, observable human induced climate change effects are emerging as a trend and arguments have shifted from disputing whether climate change is occurring to what the impacts might be and the extent of these impacts. Human-attributed changes to the composition of the atmosphere have begun to increase atmospheric and ocean temperatures, accelerate glacier and polar ice melt, alter the amount of precipitation, cause a rise in the sea levels, increase the likelihood of extreme weather events, induce shifts in timing of growing season and cause shifts in geographic distribution of natural species (Christensen et al., 2007 (IPCC-AR4), Cubasch et al., 2013 (IPCC-AR5); Seneviratne et al., 2012; Parmesan, 2006; Linderholm, 2006; Church and White, 2011). Increases in temperature and rainfall can also lead to direct (such as heat stroke, dehydration) and indirect (such as the spread or increase of infectious vector-borne diseases, water borne diseases or pathogens) health impacts.

Africa is one of the most vulnerable continents to climate variability because of multiple stresses and low adaptive capacity (Meadows, 2006). Davis et al. (2010) indicates that by 2020 a large portion of Africa's population will be exposed to increased water stress and yields from rain-fed agriculture could be substantially reduced in certain areas. These impacts will directly affect people's livelihoods as well as their ability to adapt to climate change as the extent of the impact is linked to the local environmental conditions, the general health status of the community and the socio-economic status of the area. People living in informal settlements (which are densely populated, with high concentrations of poverty and limited access to employment and socio-economic services) are the most vulnerable, particularly to extreme events (flooding, drought, severe storms) and health (direct and indirect) impacts (Davis et al., 2010). The SA National Climate Change Response Strategy highlights South Africa's vulnerabilities as being human health, maize production, plant biodiversity, water resources, rangelands and animal taxa. The strategy also provides guidance on adaptation in the Water, Agriculture, Health, Biodiversity and Ecosystems, Human settlements and Disaster risk management sectors.

1.1. Climate change framework and operational climate change strategy for Mogale City Local Municipality

Although the National Climate Change Response Strategy and other sectoral policies and plans guide and direct climate change responses, on the ground climate change mitigation and adaptation will be driven by local municipalities. There are also important benefits and opportunities for local government in responding to climate change challenges (DEA, 2012), for example:

- Energy efficiency improves economic competitiveness;
- Business opportunities may arise through new 'green' industries;
- Public transport reduces pollution and congestion and improved mobility of people stimulates economic activity;
- Improved building quality, particularly in low-income housing, greatly improves health and quality of life;
- Replenishing the natural resource base through rebuilding wetlands, planting trees and clearing alien plants creates jobs and enhances important environmental services; and
- Urban greening absorbs carbon and provides shade.

For these reasons Mogale City Local Municipality (MCLM) needs to develop a climate change framework and operational strategy in order to put measures in place to minimize its climate change impacts, reduce greenhouse gas emissions and improve the resilience of the municipality.

1.1.1. Purpose and structure of this report

The purpose of this report is to (a) provide a status quo assessment of MCLM; (b) highlight climate change vulnerabilities and impacts in the various sectors of MCLM; (c) provide climate change adaptation and mitigation actions for the MCLM; and (d) make recommendations for the way forward. The report is comprised of the following sections:

- Section 1: Status Quo Assessment
    - MCLM background
    - Climate and climate change (past, present and future)
    - GHG emissions (national, provincial and local)

- Section 2: Climate change vulnerabilities and impacts
    - Introduction
    - Climate change vulnerabilities and impacts on the following sectors:
        - Water
        - Agriculture
        - Human health
        - Biodiversity and ecosystems
        - Human settlements and infrastructure
        - Tourism
- Section 3: Climate change adaptation actions
    - Discusses adaptation measures for the following sectors:
        - Water
        - Agriculture
        - Human health
        - Biodiversity and ecosystems
        - Human settlements and infrastructure
        - Waste
        - Disaster risk management
- Section 4: Climate Change mitigation actions
    - Introduction
    - Discusses mitigation measures for the following sectors:
        - Energy
        - Transport
        - Industry, Commerce and Mining
        - Residential
        - Infrastructure
        - Agriculture
        - Waste
        - Cross-cutting mitigation actions
- Section 5: Planned projects in MCLM
- Section 6: Recommendations for the way forward.

2. MOGALE CITY BACKGROUND

Mogale City Local Municipality is one of the most unique areas in Gauteng and is the tourism focus for the West Rand. MCLM has a rich natural, cultural and international heritage worth conserving for future generations. It is referred to as the treasure chest of the West. MCLM has maintained its standard of average economic performance and the dominant economic sectors currently are: retail services, manufacturing and industry.

2.1. Locality

MCLM falls within Gauteng Province and is one of four local municipalities (Mogale City, Randfontein, Westonaria and Merafong City) under the West Rand District Municipality (WRDM). MCLM is located on the western border of Gauteng (Figure 1), adjoining the City of Johannesburg and the North West Province.

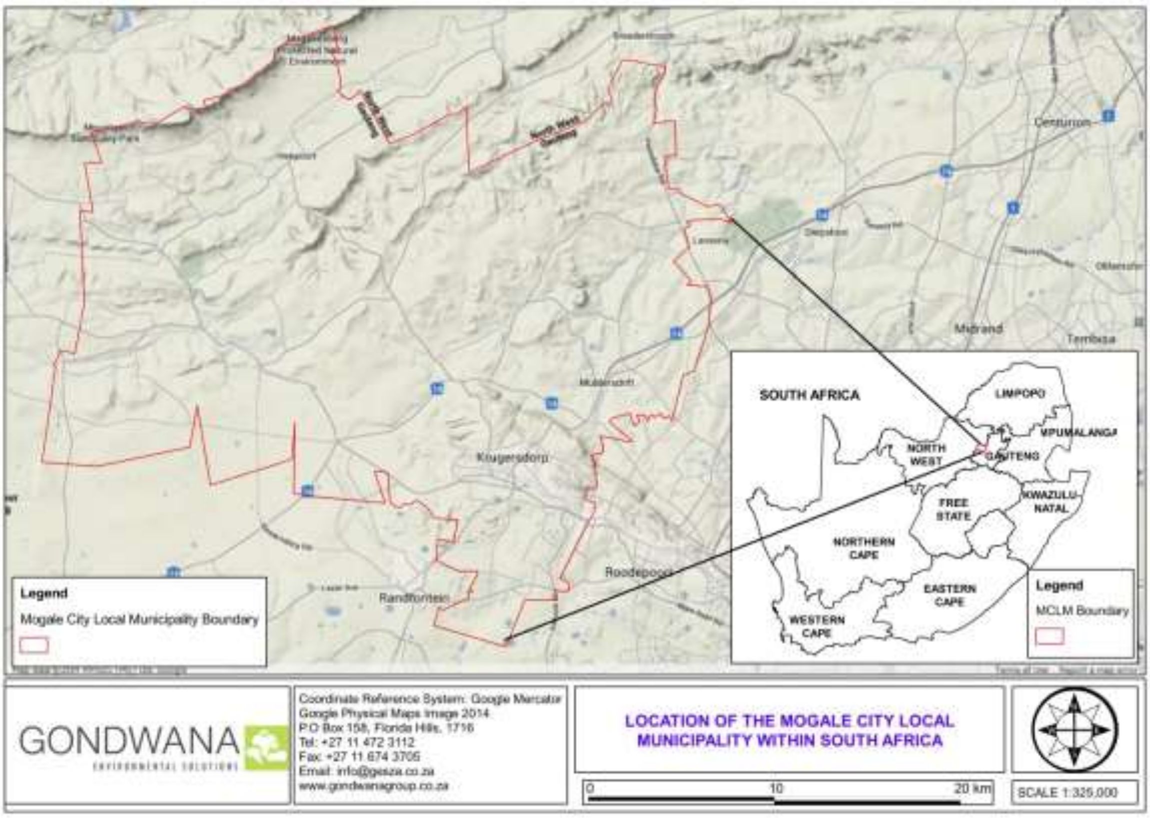

Figure 1: Location of Mogale City Local Municipality within South Africa

It is made up of Kagiso & Rietvallei 1, 2 & 3, Azaadville, Krugersdorp and surrounding areas, Munsieville, Mulderdrift, Tarlton, Magaliesburg and Hekpoort (MCLM IDP, 2013/2014) and includes a portion of the Cradle of Humankind World Heritage Site (CoH WHS). The portion of the CoH WHS that falls within Gauteng used to fall under the West Rand District Management Area but has since 2010 moved to within the jurisdiction of the MCLM. The area of jurisdiction is 134 274 ha, of which 75% is developed (MCLM Municipal Profile, 2013). Spatially it comprises four main development zones, namely, an extensive rural environment, and urban area, the Muldersdrift rural/urban transition zone and a portion of the CoH WHS (MCLM SDF, 2011).

2.2. Biophysical environment

2.2.1. Climate

MCLM experiences typical Highveld climate conditions, with warm to hot summers, fairly high rainfall and moderate to cool winters with little to no rainfall. Cycles of prolonged drought, lasting for several years, are a natural phenomenon. The MCLM weather station recorded average minimum and maximum temperatures of 9.3^{o}C and 22.2^{o}C respectively (WRDM EMF, 2013). The WRDM EMF (2013) reports that the MCLM EMF (MCLM EMF, 2011) indicates an average maximum temperature of 25^{o}C and suggests that this increase could possibly be due to the effects of climate change. The mean monthly mid-day temperatures in the Krugersdorp area range between 18^{o}C and 25^{o}C, while the mean monthly night time temperatures range between 3^{o}C and 14^{o}C. Average monthly data from Krugersdorp over a 29 year period (1961 – 1990) shows that the highest temperatures are experienced between October to March (Figure 2) (Ngubane & Ngetar, 2013). Extreme weather events are extremely rare, although they may start to increase due to climate change. Mean Annual Precipitation (MAP) decreases from 736 mm near Krugersdorp, in the east, to approximately 600 mm for the areas west of MCLM (MCLM EMF, 2011). Most of the annual rainfall falls between November and March (Figure 2Figure 2).

2.2.2. Topography

MCLM has ridge and mountain features in the north-west and more undulating topography towards the eastern parts. The topography of MCLM ranges from 1220 m above sea level in the east (north-east of the Magalies plain) to 1840 m above sea level at the Magaliesberg in the north-west (MCLM EMF, 2011; Ngubane & Ngetar, 2013). The towns of Magaliesberg, Krugersdorp, Muldersdrift and Kagiso are located at higher elevations than Hekpoort and Maanhaarand. The ridges in the western sector of the municipality have a direct impact on development and activities. Municipal services such as sanitation and storm water are directly link to the drainage patterns while the slope of the area determines where and what can be developed. There are limits to the slope on which urban development can take place and severe slopes might restrict crop farming or prescribe mining techniques. The topographical features of the western sector create a niche environment for agricultural, recreational and conservation activities.

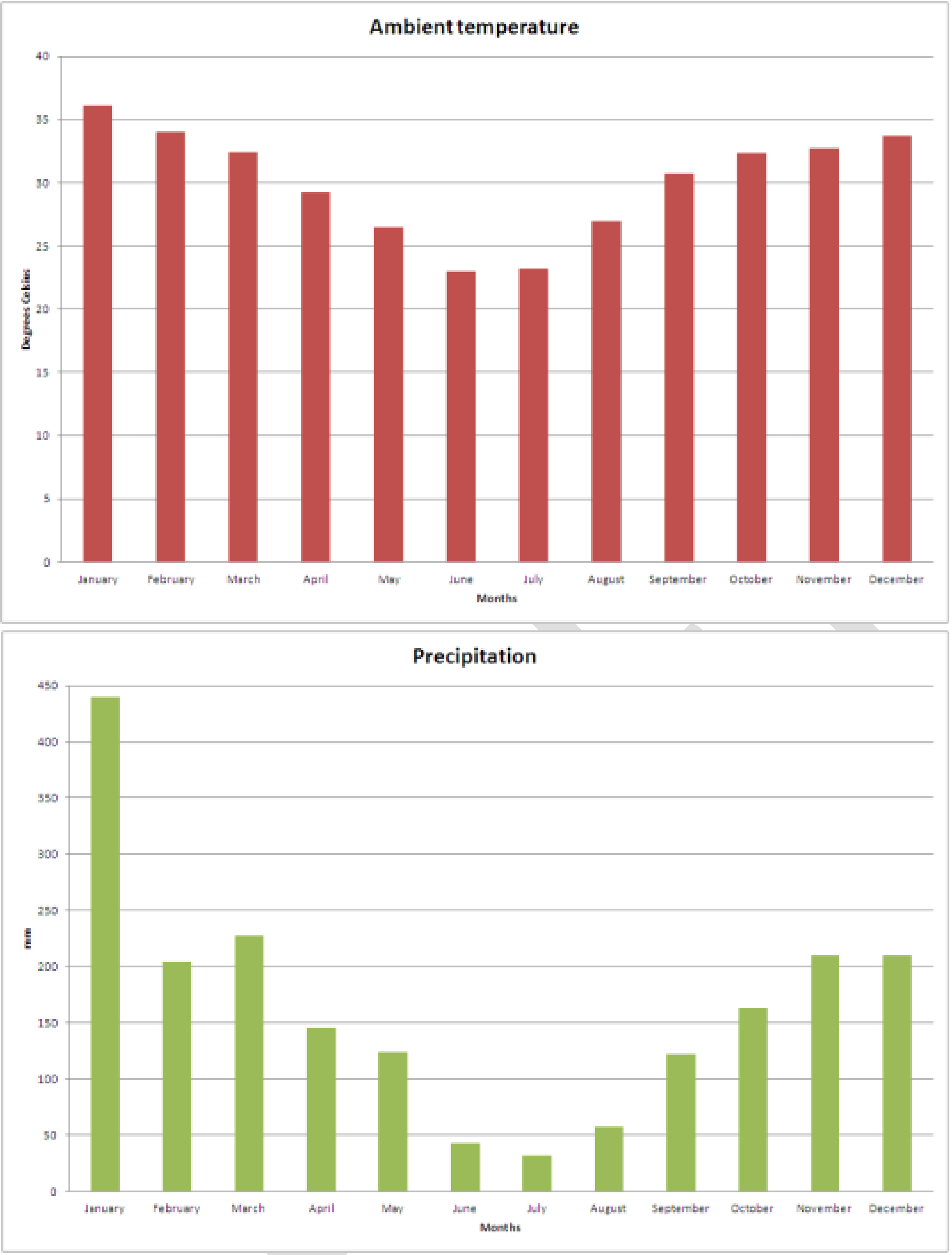

Figure 2: **Average monthly ambient temperatures (top) and precipitation in Krugersdorp over the period 1961-1990 (data from SAWS, Figure taken from Ngubane & Ngetar (2013)).**

2.2.3. Geology

The geology of the area is fundamental in sustaining development over the long term. The eastern portions of MCLM are underlain by a wide variety of geologic materials including granite and gneiss to the north-east of Krugersdorp. The Beaufort Group, which consists mainly of sandstone and shale, is found directly to the east of Krugersdorp, while the Witwatersrand, Dominion and Pongo Groups are located to the south-east of Krugersdorp (MCLM EMF, 2011). This variety of geologic materials has given rise to a diverse range of soils which cover MCLM. The dolomites in MCLM belong to the Transvaal Supergroup (Malmani Subgroup of the Chuniespoort Group) (WRDM EMF, 2013). The COH WHS is predominantly underlain by strata of the Chuniespoort and Pretoria Groups of the Transvaal Supergroup with minor sections underlain by rocks of the Halfway House Granites, Ventersdorp Supergroup and Witwatersrand Supergroup (COH WHS EMF Status Quo Report, 2009).

The existing urban areas are mostly on quartzite which is suitable for urban development, however Muldersdrift is characterised by granite (MCLM SDF, 2009). Shallow dolomites are problematic for development due to the risk of sinkhole development and groundwater contamination. This means building in this area may be prone to collapsible soils, and therefore increase building maintenance costs. Detailed geological studies are required prior to any development commencing in these areas. Climate change may have further impacts if there is an increase in water flow and floods in the area. On the other hand, these dolomitic areas have high groundwater yields and caves have formed as a result (WRDM EMF, 2013). Large numbers of tourists visit these caves so tourism is a major economic activity in karst environments, particularly in the Cradle of Humankind World Heritage Site as a number of ancient fossils have been discovered in these caves.

2.2.4. Water resources

<u>Ground water</u>

There are eight primary ground water aquifers in MCLM (MCLM EMF, 2003). The Zwartkrans Compartment in the Malmani Subgroup is the dolomitic aquifer underlying the COH WHS, and underlies some of the famous archaeological sites including the Sterkfontein caves (AED, 2009).

The dolomite in MCLM is regarded as a major aquifer that can supply large quantities of good quality ground water. It is a vital water source for Gauteng and Rustenburg, and is considered one of the most important aquifers in South Africa (Leyland *et al.*, 2008). Dolomitic aquifers are de-watered for mining purposes and water is abstracted for irrigation and in some cases for domestic use. Ground water quality is however threatened by mining activities, discharge of effluent from wastewater treatment works, and agricultural effluent. There is still a lot of uncertainty around the current state of the groundwater as the monitoring is not adequate to accurately determine the state of the ground water resources. These monitoring networks need to be improved and extended in the future. Substantial groundwater reserves are present throughout the year within the Sterkfontein/Tarlton areas whereas ground water resources are depleted in dry seasons in the granite dome, Muldersdrift areas.

Acid mine drainage (AMD) is one of the biggest ground water related problems facing MCLM due to the extensive mining in the area both historical and current. AMD from the West Rand Mining Basin began in 2002. The Krugersdorp Game Reserve lies immediately downslope of this AMD, with other potential receptors being the neighbouring small holdings and eventually the Cradle of Humankind World Heritage Site (MCLM EMF, 2011). This problem has been treated as a matter of urgency by the DWA and as a result measures have been put in place to stop AMD decant and treat the AMD. Treatment was initiated through a Feasibility Study for a Long-Term Solution (AMD FS LTS) to address the AMD associated with the East, Central and West Rand underground mining basins in Gauteng Province which was initiated by DWA (http://www.dwa.gov.za/Projects/AMDFSLTS). The study consisted of three phases, namely the Initiation Phase (AMD FS LTS Newsletter 1, 2012), the Prefeasibility Phase (AMD FS LTS Newsletter 2, 2012) and the Feasibility Phase (AMD FS LTS Newsletter 3, 2013), which have all been completed. A description of the implementation phases that are likely to be followed for the Western Basin as envisaged by the Feasibility study recommendations are given in Box 1.

BOX 1: Recommended implementation phases for AMD LTS in the Western Vaal Basin (AMD FS LTS Newsletter 3, 2013)

Phase 1A (STI): From 2012 - Upgrade Neutralisation Plant to 32 Mℓ/d capacity.

Phase 1B (STI): 2013 – Upgrade neutralisation capacity to ±40 Mℓ/d and install permanent clarifier and permanent pumps. Alternatively implement joint neutralisation process with mining sector, such as Mintails process.

Phase 2: For 5 to 7 years – Construct ancillary works and commission Pilot Treatment Plants (each 5 to 10 Mℓ/d) to develop Innovative Technologies.

Phase 3: 25 years - Procure new operating contract and process with lowest lifetime costs.

Phase 4: 25 years - Procure new operating contract and process with lowest lifetime costs.

Surface water

For water resource planning and management the Department of Water Affairs has divided the whole of SA into water management areas (WMA). There are 18 WMA in total and each WMA encompasses the drainage basin or catchment of a major river, as well as numerous other minor catchments. MCLM spans over 2 WMA areas, namely the Crocodile West Marico WMA and the Vaal WMA. The majority (93%) of the area of MCLM falls within the Crocodile West Marico WMA and drains northward via the Crocodile River and its tributaries into the Hartebeespoort dam (MCLM SoER, 2011; WRDM EMF, 2013). A small portion to the south of MCLM, falls within the Vaal WMA and drains via the Kliprivier. MCLM encompasses six quaternary catchments and five of these (A21D, A21E, A21F, A21G, A21H[1]) are in the Crocodile West Marico WMA (MCLM EMF, 2011; Crocodile River (West) Catchment ISP, 2004). The major rivers include the Crocodile, Magalies, Rietspruit, Bloubank, Juskei and Tweelopiesspruit (MCLM EMF, 2011).

The natural mean annual runoff (MAR) of the Crocodile West Marico WMA is 855 million m^3/annum (NWRS, 2004); with approximately 75% of the total surface runoff from the WMA flowing down the Crocodile. More than half of the total water use in this WMA comprises urban, industrial and mining use; about a third is used for irrigation, while the remainder is for rural water supply and power generation. Just considering the Crocodile West River catchment area (which excludes the Marico River catchment) the requirement for water for irrigation is projected to remain constant in future (**Table 1**), while the demand will increase in other sectors due to urban and economic growth (CWRRS, 2012). Since these water requirements are more than what can be provided by the current water resources, much of the water in the WMA is imported mainly from the Vaal River System. This water is used predominantly for domestic and industrial purposes.

Table 1: Water requirements per sector for the Crocodile West River Catchment (Source: CWRRS, 2012).

Water use sector	Water requirements (million m^3/a)						
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
Domestic	674	694	766	820	885	927	970
Irrigation	268	268	268	268	268	268	268
Mining, power and industry	93	116	131	133	134	134	133
Total	**1035**	**1078**	**1165**	**1221**	**1287**	**1328**	**1371**

[1] A21D =Blaauwbank Spruit catchment; A21E = Upper Crocodile River catchment; A21F = Magalies River catchment; A21G = Skeerpoort River catchment; A21H = Lower Crocodile River catchment.

The Crocodile West Marico WMA is divided into six sub-areas and MCLM falls into the Upper Crocodile sub-management area. The upper reaches of the catchment are densely settled and urban areas are the main users of water in the Upper Crocodile sub-area (Table 2) (NWRS, 2004). The natural MAR for the Upper Crocodile is 253 million m^3/annum (NWRS, 2004). In 2000 the reconciliation of surface water requirements and available water in this sub-management area was in balance, and with the inclusion of ground water there was a surplus. Water demand in the Upper Crocodile is predicted to increase from 573 million m^3/annum to between 686 and 893 million m^3/annum in 2025 (Table 2), mainly due to an increased urban requirement (NWRS, 2004).

Table 2: Water requirements (million m^3/annum) for the year 2000 and predicted requirements for 2025 for the Upper Crocodile sub-area of the Crocodile West Marico WMA (Source: NWRS, 2004).

Year	Usable return flow						Total local require -ments	Transfers out	Grand total
	Irri-gation	Urban	Rural	Mining & bulk	Power genera-tion	Affores-tation			
2000	208	292	5	38	13	0	556	17	573
2025 (base scenario)	208	409	5	38	13	0	673	13	686
2025 (high scenario)	208	616	5	38	13	0	880	13	893

Wetlands

Wetlands, such as peatlands, pans and marshes, occur extensively across the MCLM and cover an area of ± 280 ha (MCLM EMF, 2003). Wetlands are valuable resources that supply many goods and services, including food, fibre (e.g., reeds), clean water, carbon and other nutrient stores/sinks, flood and storm control, ground water recharge and discharge, pollution control, organic matter or sediment export, routes for animal and plant migration, landscape and waterscape connectivity. Maintaining these wetland systems is therefore vitally important.

2.2.5. Landscape and biodiversity

MCLM straddles the Grassland biome, which is found on the flatter more undulating terrain; and the Savanna biome situated in the more mountainous areas. MCLM has a very varied topography which lends itself to the development of many microclimates. Ten vegetation types have been identified to occur within MCLM (Table 3). The Gauteng Conservation plan (C-Plan version 3.3) designates areas as important or irreplaceable based on criteria such as Red Data species, ecological processes and sensitive vegetation. This plan indicated that 8% of the WRDM is classed as irreplaceable (Figure 3) and the majority of this is found within MCLM.

There are several formal and informal protected areas within MCLM and these include Mogale's Gate Private Game Park, Krugersdorp Game Reserve, Walter Sisulu National Botanical Gardens, Hartebeesfontein Conservancy and the Cradle of Humankind WHS.

Table 3: Description of vegetation types found in MCLM (Source: WRDM EMF, 2013).

Vegetation type	Description	% of total Mogale City land area[a]	Status[b]
Soweto Highveld Grassland	Supports short to medium-high, dense, tufted grassland dominated by *Themeda triandra*.	10.82	Endangered
Eastern Temperate Freshwater Wetlands	Temporarily filled with water and support a zoned system of aquatic and hygrophilous vegetation of temporarily flooded grasslands and ephemeral herblands.	0.45	Least threatened
Carletonville Dolomite Grassland	Slightly undulating plains and is dissected by rocky chert ridges.	17.98	Vulnerable
Egoli Granite Grassland	Occurs on moderately undulating plains and low hills supporting tall, usually *Hyparrhenia hirta*-dominated grasslands, with some woody species on rocky outcrops or rock sheets. The rocky habitat shows a high diversity of woody species, occurring in the form of scattered shrub groups or solitary small trees.	14.33	Endangered
Andesite Mountain Bushveld	Dense, medium to tall thorny Bushveld. A well-developed grass layer usually occurs on hill slopes and landscapes are undulating with valleys.	5.89	Least threatened
Gauteng Shale Mountain Bushveld	Low broken ridges with varied steepness and a high surface rock cover. The vegetation is short, less that 6m tall, and is a semi-open thicket dominated by woody species. Interspersed with the trees there are a variety of grasses.	8.95	Vulnerable
Waterberg-Magaliesberg Summit Sourveld	Higher slopes and summit positions such as crests, steep rocky scarps and cliff faces, which is covered by grasslands.	0.39	Least threatened
Gold Reef Mountain Bushveld	Rocky hills and ridges that are often west-east trending. The south-facing slopes of these ridges mostly support dense woody vegetation. Elsewhere the tree cover is variable.	13.07	Least threatened
Moot Plains Bushveld	Low, often thorny savannah. A variety of *Acacia* species are found on the plains and the herbaceous layer is dominated by grasses.	28.13	Vulnerable
Northern Afrotemperate Forest	Relatively species poor forest vegetation type found in small patches in kloofs. The soils are normally swallow and acidic on sandstones of the Karoo Supergroup.	<0.1	Least threatened

[a]Source: http://bgis.sanbi.org/municipalities/summaries.asp

[b]Source: WRDM EMF, 2013

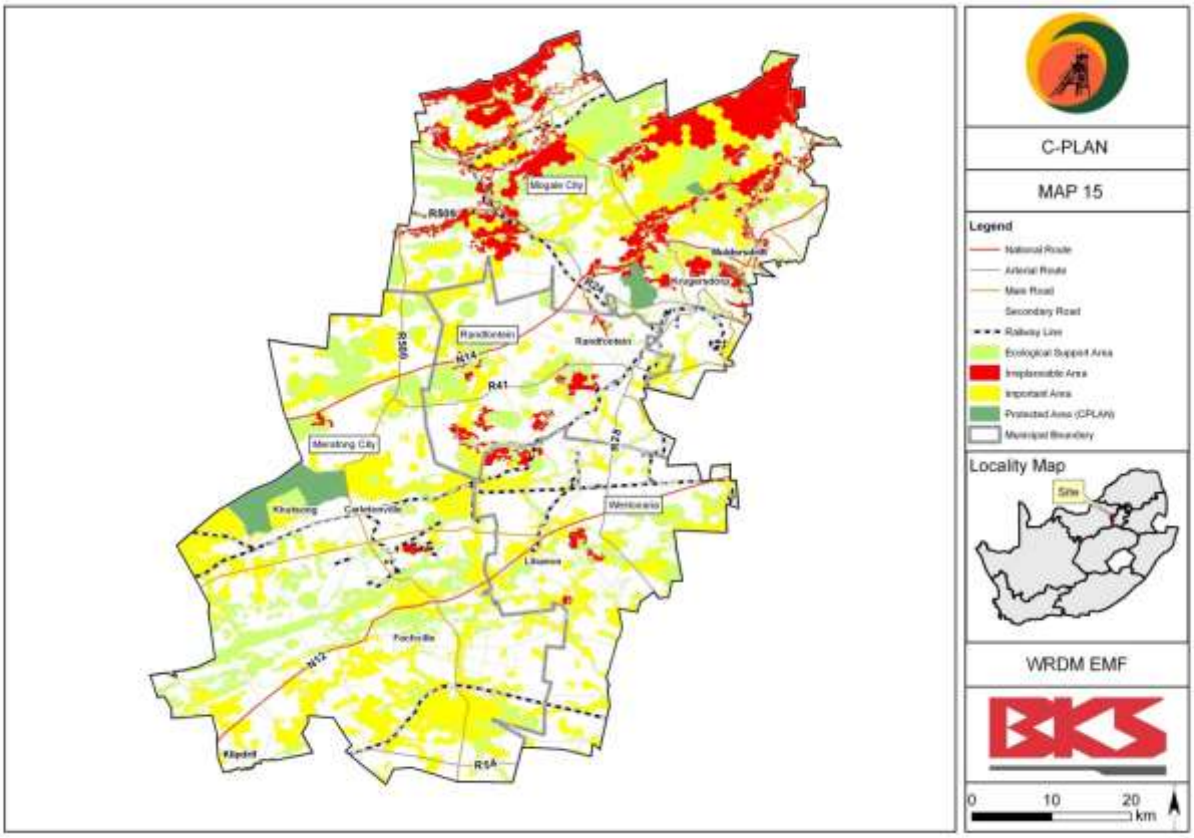

Figure 3: Map showing the irreplaceable (red) and important (yellow) ecological areas found in the WRDM as identified in the Gauteng C-Plan (Source: WRDM EMF, 2013).

Flora

Several Red Data species have been recorded for the whole of Gauteng, and many of these are very likely to occur within MCLM given the abundance of habitat availability. SANBI PRECIS (2010) indicates that 61 South African endemics are present within MCLM, with 1 endangered plant species (MCLM EMF Status Quo Report, 2011), however the State of Environment Report (2011) indicates that there is one near-endemic plant species in MCLM, namely *Erica alopecurus* Harv. var. *glabriflora* Bolus. In 2003 there were 4 Endangered species, 4 Rare species, 6 Near Threatened species, 10 Data Deficient species, 3 Lower Risk species and 1 Vulnerable. Many of the Red Data species and endemic plant species are found in the ridges (GDACE, 2001) and so it is important that these ridge areas be conserved in the future.

Fauna

There is 1 near-endemic red data invertebrate (*Metisella meninx*) and 3 near-endemic rare invertebrates (*Opistophthalmus pugnax, Trichocephala brincki, Hadogenes gunningi*) in MCLM. There are no mammal, bird, reptile or amphibian species endemic to MCLM. Owing to the diversity in microclimates and the prominence of protected areas within MCLM there are a large number of red data species (30 bird species, 33 mammals, 1 amphibian and 9 invertebrates) in the area (MCLM EMF, 2011). The loss of viable habitat due to urban expansion is the main reason for species to become threatened, so it is critical to conserve the available habitat.

2.2.6. Land use and land use change

Land uses within MCLM are natural habitat (63.7%), agriculture (16.1%), urban (16.4%), mining (1.2%), and industry (0.8%) (MCLM Municipal Profile, 2013). Land uses that boost the local economy include mining of minerals, quarrying of stone, the extraction of clay and sandpits, agriculture and various industrial activities. Much of the land use change occurring in MCLM is due to an expansion of the urban area and an increase in the residential density. It is estimated that 10% of the natural vegetation has been converted into urban areas, while 30% of the Grassland Biome has been transformed, mostly due to the increase in cultivation of land (MCLM EMF, 2011). There has also been a loss and inappropriate use of agricultural land due to subdivisions and increased residential density.

2.2.7. Air quality

Combustion processes are key emitters of criteria pollutants (SO_2, NO_x, CO and PM_{10}), and toxic air pollutants (e.g. benzene, toluene and xylene). MCLM has a variety of sources of air pollutants (Table 4) and it is the largest contributor to criteria pollutant emissions in the WRDM (uMoya-NILU, 2012).

Table 4: Sources of air pollutants (Source: uMoya-NILU, 2012).

Source	SO_2	NO_x	PM	CO	CO_2	CH_4	VOCs
Industry (incl mining)	X	x	x	x	x	x	x
Agriculture			X			x	
Biomass burning	X	x	x	x	x	x	x
Vehicle emissions	X	x	x	x	x	x	x
Tailings dams			x				
Domestic fuel burning	X	x	x	x	x	x	x
Waste (incineration, sewage, landfills)	X	x	x	x	x	x	x
Petrol stations	X	x		x	x		x

Industry is the major contributor to the SO_2 and CO emissions in MCLM, contributing 93.1% (3.11 tons/day) and 71.1% (383.68 tons/day) respectively (**Figure 4**). The largest source of SO_2 emissions is Mogale Alloys which produces 2.27 tons/day (uMoya-NILU, 2012). This is mainly due to its large consumption of coal. Vehicles are estimated to be the main source of NO_x. Vehicle emissions are mainly produced as a by-products of the combustion process, but there are also emissions from evaporation of the fuel itself (i.e. from the fuel tank) and some particulate matter is also emitted from brakes and tyre wear. Mogale City is the largest consumer of motor vehicle fuels in the WRDM and therefore produces the most vehicle emissions (approximately 60%) in the district.

Biomass burning produces the largest amount of VOCs and PM_{10} (Figure 4). MCLM was estimated to have 926 fires in 2010 and 815 in 2011 (uMoya-Nilu, 2012). Particulate matters are air pollutants of concern due to their impact on human health. The other contributors to PM_{10} in MCLM are tailings dams[2] (28.6%) and industry (12%). When tailings dams are active and predominantly moist then their contribution to PM in the air is lowered, but they become large sources when they are un-vegetated and left to dry out. Emissions can therefore be reduced through the rehabilitation of these dams. There are 14 tailings dams in MCLM (uMoya-Nilu, 2012) which contribute to the PM emissions. Domestic burning, for cooking, lighting and space heating, contributes only 0.1% to the PM_{10} total for MCLM.

2.3. Socio-economic context

Due to its location on the edge of Gauteng's conurbation, the largest part of MCLM is rural in nature. The rural environment is characterised by intensive as well as extensive agricultural development, agricultural holdings, physical elements such as mountains and rivers, wilderness areas and nature conservation areas. The largest urban concentration in MCLM is found in the south-eastern parts around Krugersdorp and Kagiso. Urban densification and the integration of fragmented urban areas have been identified as priorities in the Integrated Development Plan (IDP) of MCLM.

MCLM has the largest Gross Domestic Product per region (GDP-R) and the highest growth rate in the West Rand. It has a diversified economy, mainly consisting of manufacturing and tourism, and the economic growth is relatively broad-based. In the past gold mining was the core of the region's economy, but due to the closure of mines, the focus has shifted to manufacturing and agribusiness. The dominant economic sector in MCLM is retail (Figure 5). Tourism, eco-tourism, agriculture and business all have the potential to generate economic growth in the local economy. Unfortunately economic activity has had significant negative impacts on MCLM's natural environment, resulting in the alteration of the natural landscape, air, soil and water pollution, and loss of biodiversity.

[2] It should be noted that there was no information on what proportion of the PM from tailings dams was PM10, so it was assumed that all PM is PM10 which is representative of a worst-case scenario.

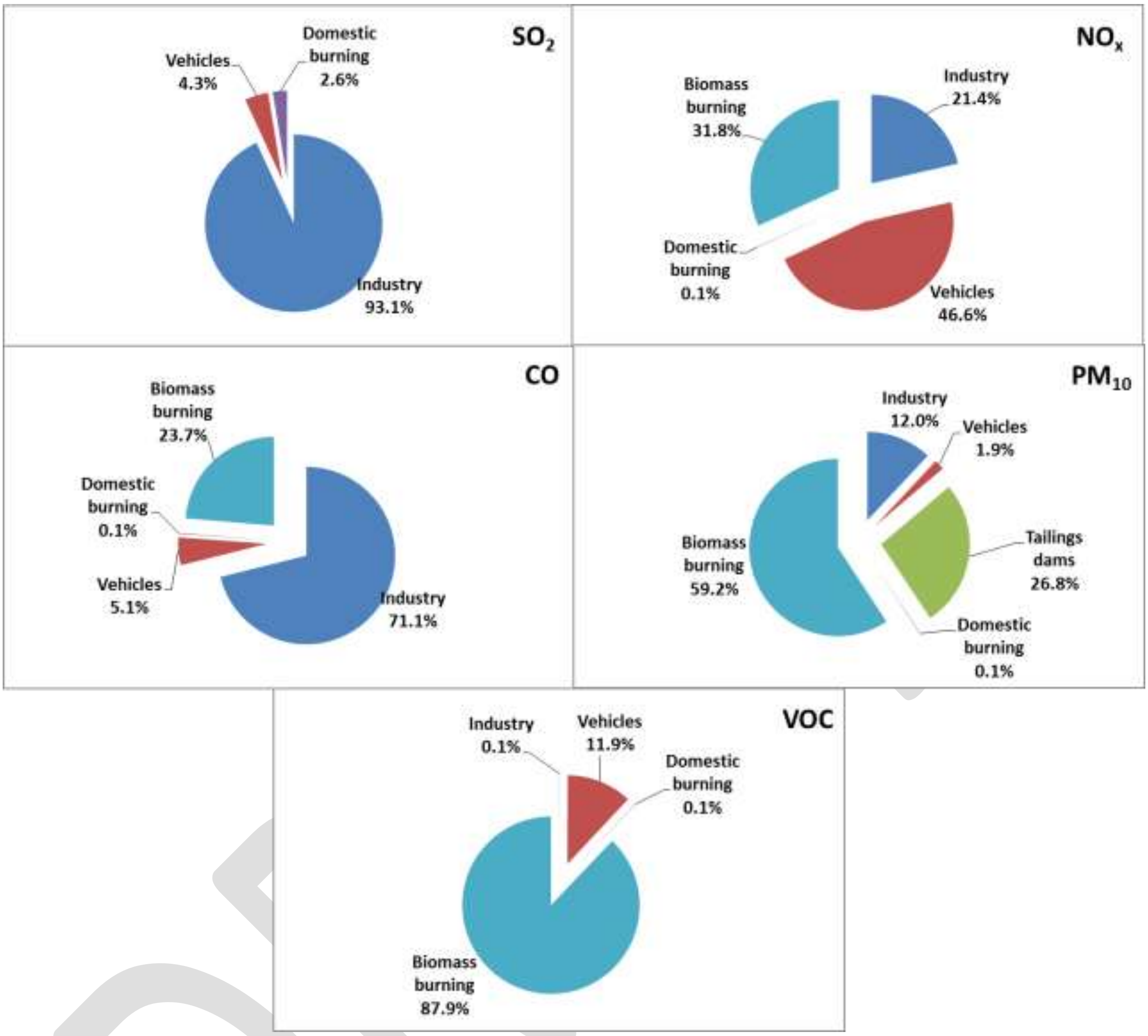

Figure 4: Contribution of the various sectors to air pollution in Mogale City Local Municipality (derived from uMoya-NILU, 2012).

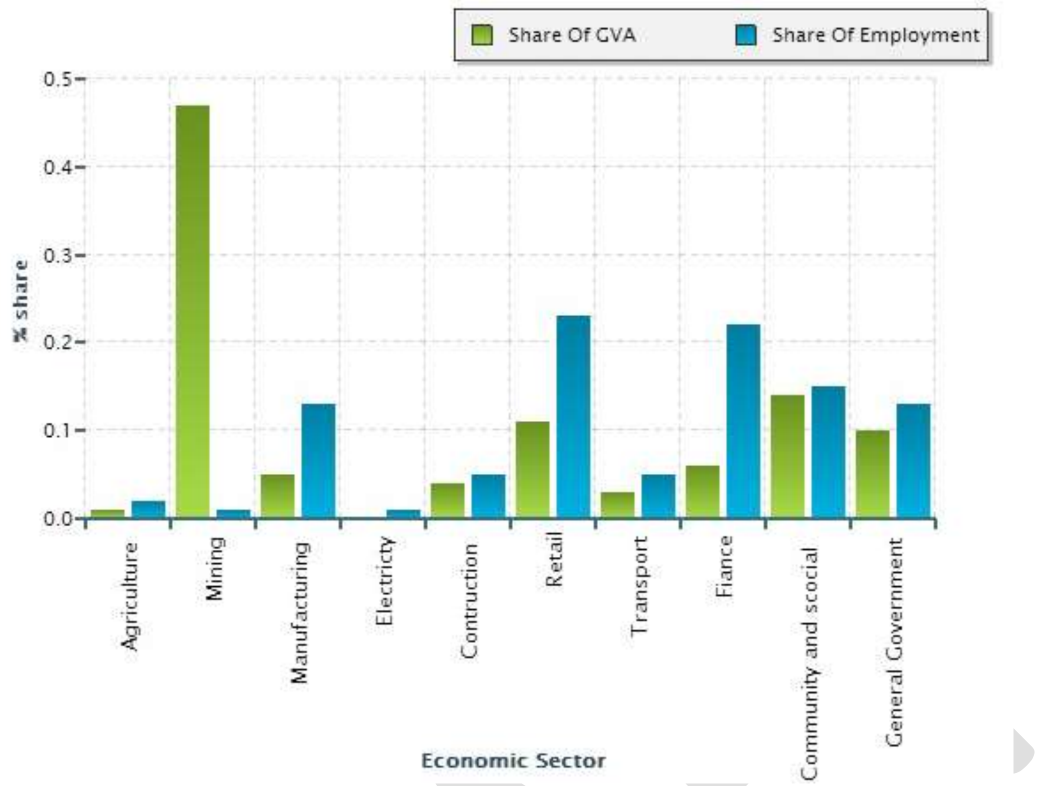

Figure 5: **Economic distribution in MCLM (Source: MCLM: Municipal Profile, 2013).**

2.3.1. Population

Human population is one of the main causes of environmental degradation as a growing population leads to increased demands for goods and services (including housing, water and electricity), increased production of waste, increased use of the environment for economic and recreational activities and increased transportation needs. MCLM is the most populated city in the West Rand region with a population of 362 422. It had a population growth rate of 62% between 1996 and 2011. Population growth rate showed a significant increase between 1996 and 2006, after which the growth rate slowed. Currently the population growth rate is 2.04% per annum (StatSA Census, 2012) and this is forecast to slow to 1.1% by 2016. Unemployment is at 24.6% of the population (StatsSA Census, 2012) which is slightly lower than the 26% reported in the MCLM IDP 2002 report. Trade, manufacturing and households are the major sectors contributing to job opportunities in MCLM (MCLM IDP, 2013/2014).

2.3.2. Utilities and infrastructure

Communities in MCLM are fairly well serviced particularity in the urban areas. A majority of residents (86.4% of households) have access to piped water, with 54.8% having piped water inside their dwellings and 39% in their yards (StatsSA Census, 2011). In terms of sanitation, 78.2% of households have flush toilets connected to the sewage system, 5.8% have flush toilets with septic tank and 4.8% have pit toilets without ventilation (Figure 6). There are still 12 000 households with sanitation below RDP levels. Refuse is removed once a week by the municipality from 79.7% of the households (StatsSA Census, 2011). Eleven percent of households use their own refuse removal, while 4% do not have rubbish disposal facilities. MCLM and Eskom provide Electricity to the study area and 85.9% of households have access to electricity for lighting (StatsSA Census, 2011) (Figure 6). MCLM has an extensive transportation system with good access to road and rail networks.

2.3.3. Economic sectors

The primary sector of the economy has declined since 2003 (Table 5), while the secondary and tertiary sectors have increased (MCLM IDP, 2013/2014). The tertiary sectors have increased the most in terms of production output and this indicates a move towards a service economy.

<u>Agriculture</u>

The agriculture sector incorporates establishments and activities that are primarily engaged in farming activities, but also includes establishments focusing on commercial hunting and game propagation and forestry, logging and fishing. MCLM contributes 22.2% towards the agriculture in Gauteng. Historically the Agricultural sector is MCLM's weakest sector (MCLM LED Strategy, 2011). The total GVA contribution by the Agricultural sector has decreased from 1.5% in 2003 to 0.5% in 2008. Agricultural activities in MCLM are extensive and relatively diverse with 32.29% of the total land surface under some form of agricultural production (Gauteng Agricultural Potential Atlas 3 – GAPA3). In terms of area 38% of the MCLM is classified as having high agricultural potential while 55% of the total land is classified as having low or zero agricultural potential (MCLM EMF, 2011).

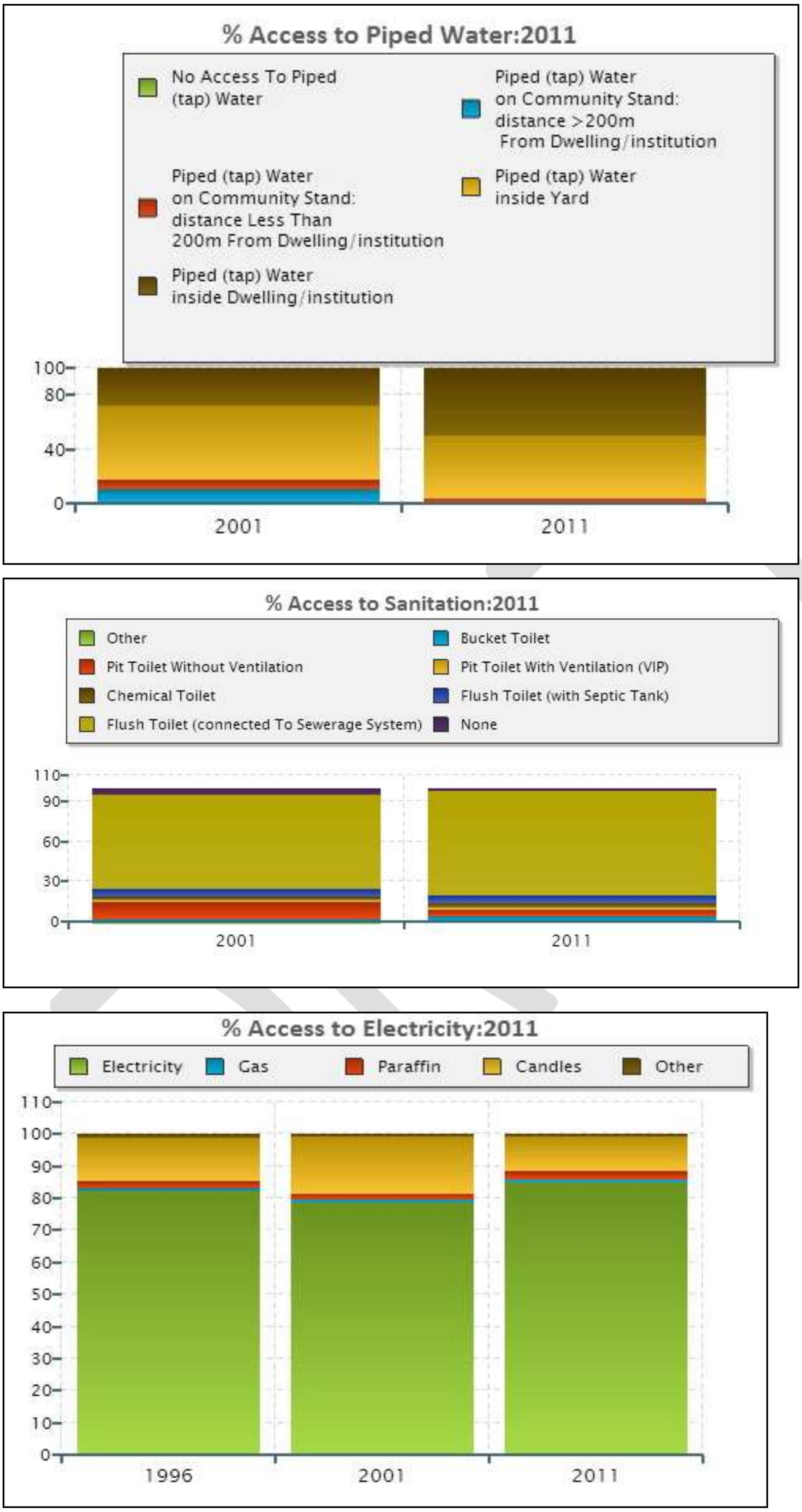

Figure 6: Statistics on access to water, sanitation and electricity within MCLM (Source: MCLM: Municipal Profile, 2013).

Table 5: Production structure (2003 – 2011) of MCLM as percentage contribution (Source: MCLM IDP, 2013/2014).

Sector	Production contribution (%)		
	2003	2007	2011
Primary sectors			
Agriculture	1.6	0.8	0.6
Mining	3.4	3.0	2.6
Secondary sectors			
Manufacturing	23.6	22.8	19.7
Utilities	1.6	2.1	2.4
Construction	3.9	4.6	4.9
Tertiary sectors			
Trade	14.9	15.3	16.0
Transport and communication	9.4	9.6	9.4
Finance and Business services	17.3	19.8	21.9
Community services	4.8	4.4	4.2
Government services	19.5	17.4	18.2

The majority of agricultural activities occur in the south-western region of MCLM around Hekpoort, Thorndale, Mogale City and Battery. This portion of active farmland forms part of the Gauteng Agricultural Hub. Although MCLM is designated in Gauteng as an agricultural hub, the general potential for agricultural development remains low due to low soil potential. The agriculture sector is driven by part-time farmers that are employed in the urban-based secondary and tertiary sectors. MCLM predominantly offers fruit orchards, maize and vegetables (mainly tomatoes, cabbage, carrots and spinach), flower farms that produce a good percentage of flowers required in Gauteng, instant lawn growers, and animal farming (MCLM EMF, 2011). Livestock, poultry and game products contribute 60% towards the total Agricultural Gross Value Added (GVA[3]) of MCLM. Horticulture contributes 38%, while field crops only contribute 0.92% (MCLM LED Strategy, 2011).

Mining

This sector includes the extracting, beneficiating of minerals occurring naturally, including solids, liquids and crude petroleum and gases. It also includes underground and surface mines, quarries and the operation of oil and gas wells and all supplemental activities for dressing and beneficiating for ores and other crude materials. The mining belt in MCLM extends east-west from Johannesburg through to Krugersdorp. The mining sector has limited opportunities as most of the mining activities have closed down and the focus has shifted towards mine rehabilitation. The physical legacy of the mining activity remains in the form of a band of land which has potentially be sterilised and this

[3] Gross Value Added is a measure in economics of the value of goods and services produced in an area, industry or sector of an economy (GVA = GDP + subsidies - (direct, sales) taxes).

band presents a physical barrier between Krugersdorp and the greater Kagiso area, thereby preventing spatial integration between these areas.

Manufacturing and construction

Manufacturing is broadly defined as the physical or chemical transformation of materials or compounds into new products and can be classified into 10 sub-groups (MCLM IDP, 2013/2014) of which the most relevant are:

- Fuel, petroleum, chemical and rubber products;
- Other non-metallic mineral products, e.g. glass;
- Metal products, machinery and household appliances;
- Electrical machinery and apparatus.

The manufacturing sector contributes approximately 20.2% to total GVA and is a labour intensive sector that creates jobs in the municipality. The main local manufacturing activities contributing towards manufacturing GVA include Petroleum, chemicals and rubber (25.4%); Metals, metal products and machinery (25.0%) and Food beverages and tobacco (18.3%).

The construction sector includes the site preparation, building of complete constructions or parts thereof, civil engineering, building installation, building completion and the renting of construction or demolition equipment with operators. This sector has increased its production contribution by 1% between 2003 and 2011 (Table 5).

Tertiary sectors

The trade sector entails wholesale and commission trade; retail trade; repair of personal household goods; sale, maintenance and repair of motor vehicles and motor cycles; hotels, restaurants, bars, canteens, camping sites and other provision of short-stay accommodation. Transport as an economic sector refers to activities concerned with land transport, railway transport, water transport, and transport via pipelines, air transport, and activities of travel agencies, post and telecommunications, courier activities, as well as storage and warehousing activities. Other tertiary sectors are Finance and business services, Community services and Government services. These tertiary sectors have increased their product contribution in MCLM from 65.9% in 2003 to 69.7% in 2011, with Finance and business services showing the greatest increase (4.6%) (Table 5). Community and Government services showed a decline in their contribution between 2003 and 2011.

2.3.4. Tourism industry

MCLM has a strong tourism base in heritage sites and adventure venues (Development of a Tourism Strategy, 2013). MCLM is rich in heritage resources varying from fossils to rock paintings and liberation struggles. To date, 950 hominid fossils, over 9 000 stone tools, 300 fragments of fossil wood and thousands of animal fossils have been excavated in the area (MCLM EMF, 2011). Most of these sites are confined to the Cradle of Humankind (Box 2). MCLM is not known for its rock paintings, but there are about 20 rock engraving sites. There are numerous sites where evidence of Iron Age habitation has been found. In MCLM 17 historic sites, 20 rock engraving sites, 4 cemetery sites and a military site have been identified. The municipality also host various liberation struggles including The Paardekraal Monument (a provincial heritage site). Other attractions in the municipality include the Blaaubank Mine, the Magaliesberg Mountain and Magalies Meander, the Lesedi Cultural Village, a 1400 ha bushveld game reserve and the Lion and Rhino Park.

The northern part of MCLM comprises the bulk of the CoH WHS (Box 2). The MCLM component of the CoH WHS contains some of the key sites of attraction within the area. These include Sterkfontein caves, Maropeng museum and conference venue, the historical town of Magaliesburg, Krugersdorp Game Reserve and Silverstar Casino. In terms of natural attractions, MCLM has a large percentage of land that is considered to have medium to high levels of biodiversity.

BOX 2: Cradle of Humankind World Heritage Site

The main land uses in the CoH WHS are low-density housing, agriculture and tourism-related activities (WRDM, 2005). The CoH WHS is an area of worldwide significance and some of the most significant paleontological and palaeoanthropological evidence of the evolution of humankind have been discovered here. Embedded in the rocks of the numerous dolomitic caves in the area are the fossilised remains of hominids, their lithicultural remains and fossils of other plants, animals and pollen. The high degree of biodiversity within the natural environment of the study area provides for local attractions such as hiking, walking, game viewing, animal petting, and horse-riding. Given its cultural and ecological importance and status, the CoH WHS is a tourist destination for local, national, and international tourists. There are museums, tours, signboards, and other information sharing devices which encourage tourism. Urban development, poor water and air quality, and increasing light and noise pollution are some of the greatest threats to the CoH WHS (CoH, 2008).

2.4. International, national, provincial and local policies

Below is a list of relevant international, national, provincial and local policies, frameworks and development plans which might need to be considered when developing the Climate Change Framework. There are also new emerging legislation/policies that also have potential impacts, such as carbon tax and the urban development framework.

Scale	Policy
International	UNFCCC
	Ramsar Convention
	Montreal Protocol
National	Constitution of the Republic of South Africa
	National Development Plan
	National Climate Change Response Strategy
	National Environmental Management Act
	Municipal Systems Act
	Development Facilitation Act
	National Environmental Management Protected Areas Act
	UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage
	World Heritage Convention Act
	The National Transport Act
	National Housing Act and National Housing Code
Provincial	Gauteng Planning and Development Act
	Gauteng Climate Change Response Strategy and Action Plan
	Gauteng Spatial Development Perspective
	Gauteng Growth and Development Strategy
	Gauteng Spatial Development Framework
	Gauteng Global City Region
	Integrated Report for the Development and Management of the Cradle of Humankind World Heritage Site
	Gauteng Agricultural Hub
	Gauteng Urban Edge
District and local municipality	Integrated Development Plans
	Guide and toolkit to integrating Climate Change Risks and Opportunities into Municipal Planning
	WRDM Air Quality Management Plan
	WRDM Spatial Development Framework
	WRDM Integrated Transport plan
	WRDM Tourism development strategy
	West Rand Rural Housing strategy
	MCLM Spatial Development Framework
	MCLM Environmental Management Framework
	MCLM Air Quality Management Plan
	Cradle of Humankind World Heritage Site EMF

3. CLIMATE AND CLIMATE CHANGE – PAST, PRESENT AND FUTURE

3.1. Global climate change

Natural climate variability is the variation in climate over seasons and years. These changes take place slowly so the environment is usually able to adapt to these fluctuations. Climate change, on the other hand, is the long term (over many decades) continuous change in climate. Human activities, such as burning coal, agriculture and land use change, vehicle exhaust fumes and other industrial activities have led to a rapid increase in the levels of greenhouse gases (GHGs) in the atmosphere causing a globally enhanced greenhouse effect. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water vapour. Atmospheric concentrations of CO_2, CH_4 and N_2O have increased by 37%, 150% and 16% (Christensen et al., 2007 (IPCC-AR4)), respectively, since the industrial revolution. The increased levels of CO_2 are mainly due to fossil fuel combustion, cement production and land use change, while anthropogenic emissions account for 50 to 65% of the total CH_4 emissions. These atmospheric increases are clearly shown in the data from the Cape Point GAW monitoring site (Figure 7, Figure 8). Increased concentrations of these GHGs result in climatic changes.

There is mounting evidence of global climate change. The most dominant global trend is the increase in mean temperature (Figure 9). According to the Intergovernmental Panel on Climate Change (IPCC), between 1956 and 2005 average global temperatures increased at a rate of 0.13^{o}C per decade (IPCC, 2007). Observed temperature trends between 1951 and 2010 are characterized by warming over most of the globe, particularly over the Northern hemisphere continents (Cubasch et al., 2013 (IPCC-AR5). Ambient temperature changes in turn influence rainfall patterns, ocean temperatures and cause a rise in average sea levels. Evidence shows that upper ocean temperatures are increasing, and sea levels have risen by 1.7 mm yr^{-1} since 1901 (Cubasch et al., 2013 (IPCC-AR5)). Precipitation changes are occurring however the confidence in the precipitation data is low due to insufficient data. The IPCC 5th Assessment Report indicates that there is a likely increase in precipitation over the Northern hemisphere land masses, while on average it is decreasing over the land surfaces in the sub-tropics. There have been indications that the number of extreme weather events has increased. Another dominant global trend is the decreasing snow cover and decline in the extent of global ice sheets.

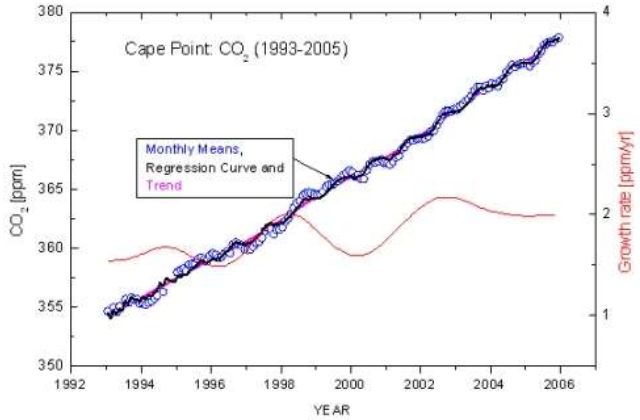

Figure 7: Monthly means of CO_2 (1993 - 2005) at Cape Point together with growth rate curve.

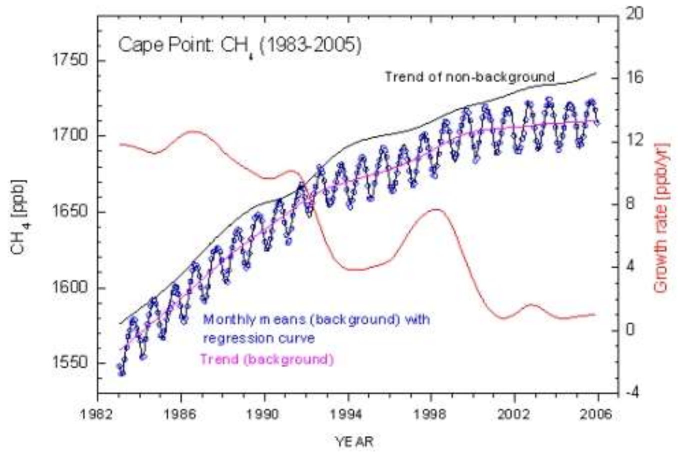

Figure 8: Monthly means of CH_4 (1983 - 2005) at Cape Point together with growth rate curve.

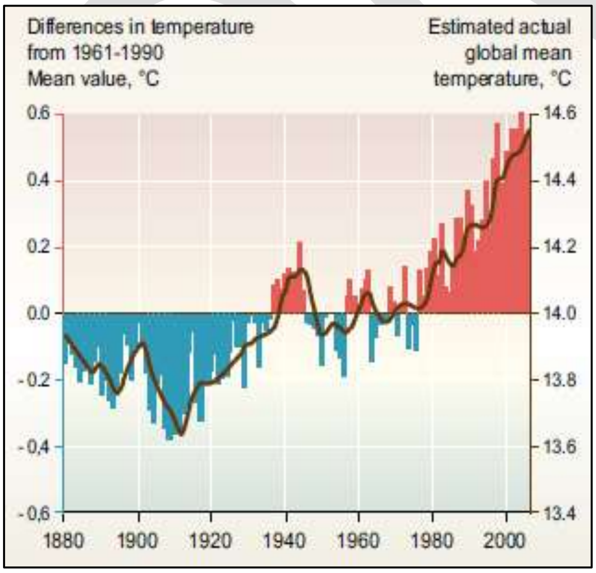

Figure 9: Trends in global average surface temperature (Source: US National Oceanic and Atmospheric Administration (NOAA), 2008).

These human induced changes in climate are occurring too quickly and the earth's system is not able to adapt fast enough to ensure survival. Without any intervention GHG concentrations in the Earth's atmosphere will continue to increase at an accelerated rate.

3.2. Climate in South Africa

South Africa has a semi-arid and temperate climate with an annual average rainfall of 460 mm and mean annual temperatures ranging from temperate to sub-tropical (DEA, 2011). Rainfall is lowest in the north-west and increases southwards towards the Western and Eastern Cape Provinces and eastwards towards the coast of KwaZulu-Natal province. Summer rainfall dominates over much of the interior, while winter rainfall is dominant in the west and south-west. Climate conditions in South Africa are determined mainly by hemispherical-scale atmospheric circulation, together with effects due to ocean circulation patterns.

3.2.1. Historical climate trends for South Africa

South Africa's historical climate statistics and current climatology shown in Figure 10, Figure 11 and Figure 12 has been developed from interpolation of observed data between 1901 and 2006 (Hulme et al., 1999; DEA, 2013a). This data is suited as a general representation of pattern and variability in climate in South Africa but is not suitable for robust trend analysis due to the number of available observing stations fluctuating through the dataset time period. In addition, the interpolated data does not capture the complexity of temperature and rainfall in many mountainous and remote areas due to the lack of station observations in these areas.

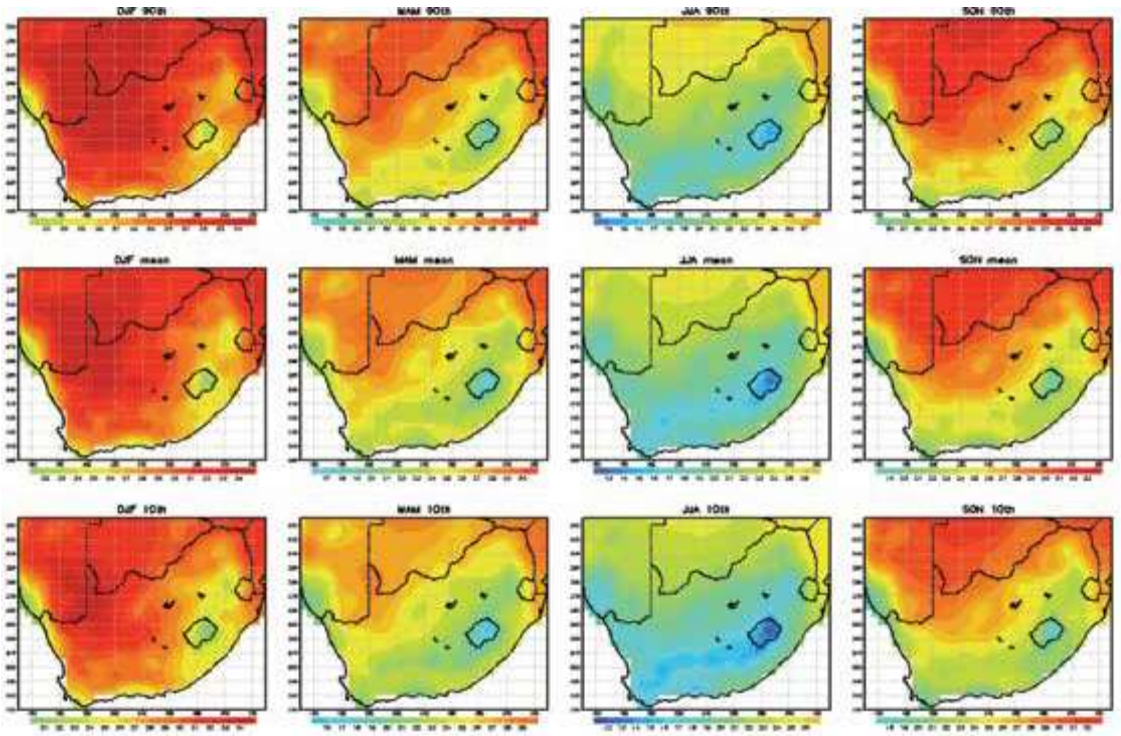

Figure 10: CRU[4] Observed monthly mean maximum temperature for DJF, MAM, JJA, and SON. Top row: 90th percentile, middle row: mean, bottom row: 10th percentile[5]. (Source: DEA, 2013a).

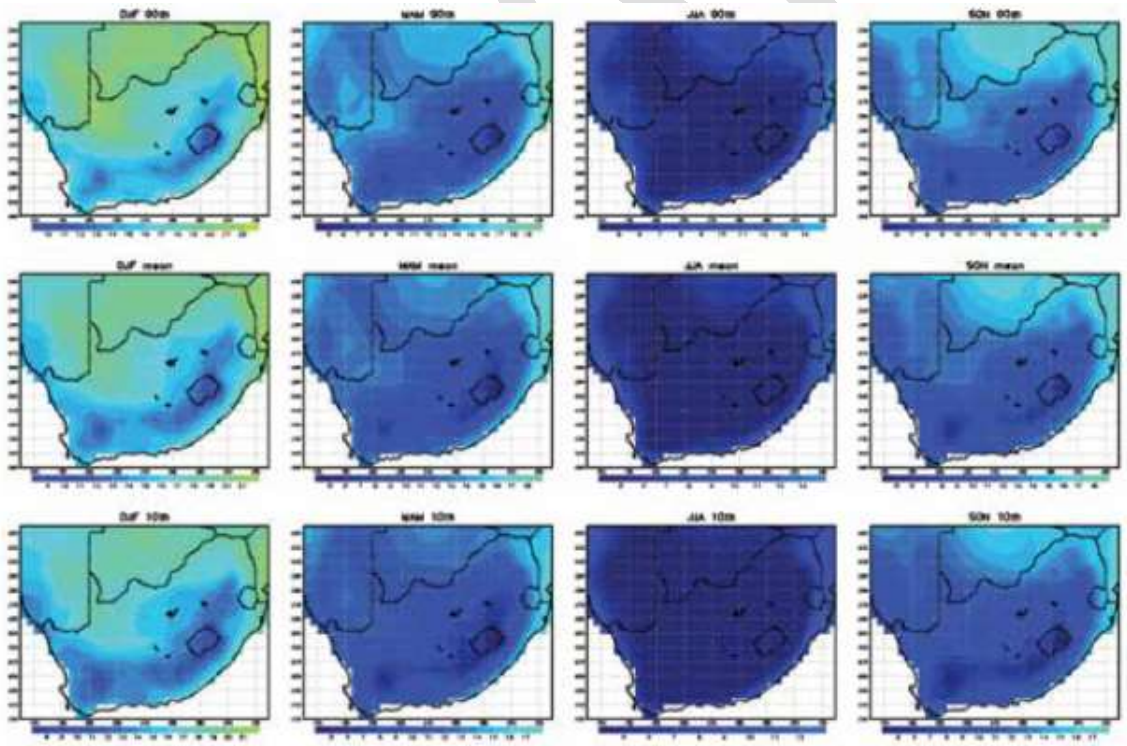

Figure 11: CRU observed monthly mean minimum temperature for DJF, MAM, JJA, and SON. Top row: 90th percentile, middle row: mean, bottom row: 10th percentile[6]. (Source: DEA, 2013a).

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4 Hadley Centre Climate Research Unit (CRU) TS2.0 monthly 50km resolution observed data.

5 The 10th and 90th percentiles for each grid point for the season represent the range in variability.

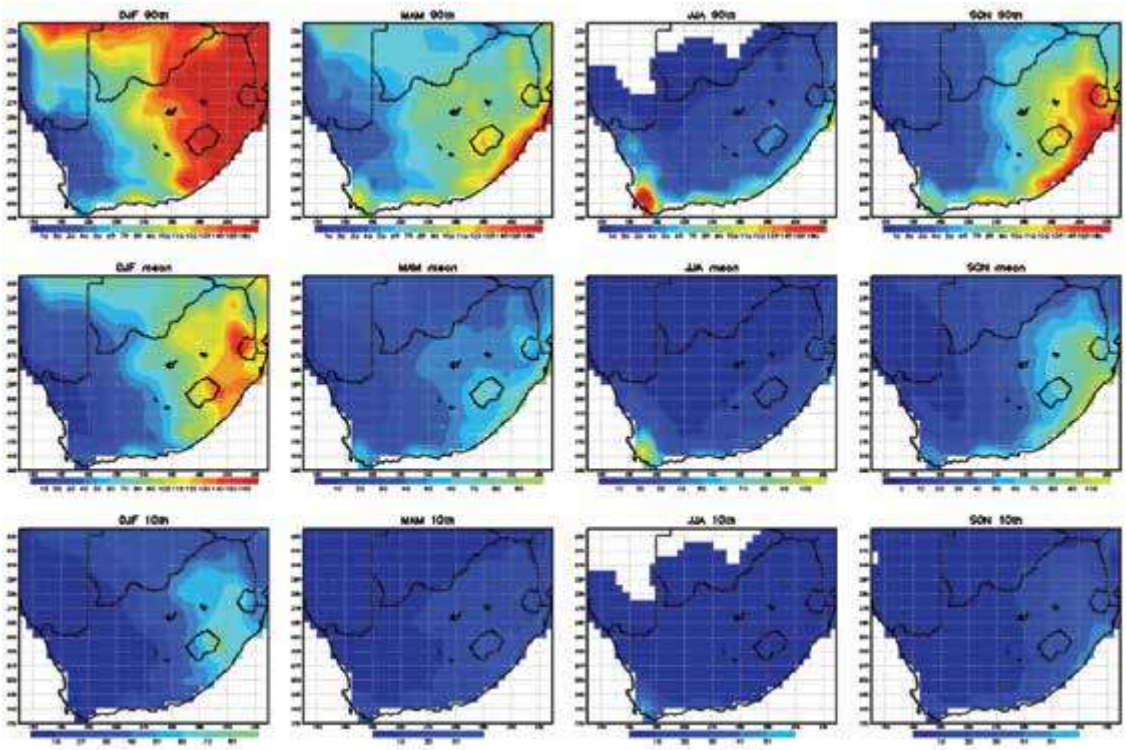

Figure 12: CRU observed monthly total rainfall for DJF, MAM, JJA, and SON. Top row: 90th percentile, middle row: mean, bottom row: 10th percentile. (Source: DEA, 2013a).

The greatest restriction to the study of historical climate is the availability of long-term meteorological station observations, but South Africa has a relatively good network of rainfall and temperature recording stations relative to the rest of Africa (Hughes and Balling, 1995; Easterling et al., 2000; New et al. 2001). There are many published papers on climate trends in South Africa (Easterling et al., 1997 & 2000; Engelbrecht et al., 2011; Groisman et al., 2005; Thomas et al., 2007; Kruger, 2006; Hulme et al., 2001; Kruger and Shongwe, 2004; New et al., 2006; Kruger and Sekele, 2013) but the LTAS report (DEA, 2013a), on climate trends and scenarios for South Africa consolidates and summarizes all this information. This report indicates that the main observed climate trends between 1960 and 2010 are:

- for temperature:
    - Mean annual temperatures have increased by at least 1.5 times the observed global average of 0.65°C reported by IPCC-AR4 (Christensen et al., 2007; Kruger and Shongwe, 2004);

[6] The 10th and 90th percentiles for each grid point for the season represent the range in variability.

- Maximum and minimum temperatures show significant increases annually, except in the central interior where minimum temperatures have been increasing less strongly;
    - High temperature extremes have increased significantly (New et al., 2006), while low temperature extremes have decreased significantly, with the strongest changes tending to occur in the western and northern interior of the country (Kruger and Sekele, 2013).
- for rainfall:
    - High interannual variability has been observed;
    - Annual rainfall trends overall are weak and non-significant because of this high variability (New et al., 2006; Nel, 2009), but there is a tendency towards a significant decrease in the number of rain days;
    - This implies a tendency towards an increase in the intensity of rainfall events, as has been reported by Easterling et al. (2000) and Groisman et al. (2005), and increased dry spell duration (Thomas et al., 2007; Kruger, 2006).

3.2.2. Climate projections for South Africa

Global circulation models (GCMs) (Box 3) have become the primary tool for the projection of climate change. GCM's are models which provide a mathematical representation of the Earth's system, where physical and biogeochemical processes are described numerically to simulate the climate system as realistically as possible (Jacob and van den Hurk, 2009). They are models which are used to estimate three-dimensional changes in the structure of the atmosphere that may take place in response to enhanced anthropogenic forcing. Projections from GCMs may provide insight into potential broad-scale changes in the atmosphere and oceans. Even though GCMs provide useful predictions there are numerous uncertainties associated with these models (Willows and Connell, 2003; Cox and Stephenson, 2007; Giorgi *et al*., 2008; Jacob and van der Hurk, 2009; Schulze, 2010). In addition to this, Schulze (2012) indicates that GCMs are less capable of simulating second order atmospheric processes, such as precipitation, compared to those related to first order atmospheric processes, such as surface heat and vapour fluxes. This leads to reduced accuracy in the precipitation outputs of GCMs.

GCM's are computationally expensive and can only be integrated at relatively coarse horizontal resolutions (spatial scales of 10^4 - 10^5 km^2). At these resolutions the regional details of climate and climate change cannot be sufficiently described, making local decisions and adaptation options difficult. GCM outputs need to be translated from the coarse to more local scales, and this is done by the process of regional climate downscaling (Box 4) (Hewitson *et al*., 2005; Giorgi *et al*., 2008). This process provides high-resolution projections of climate change over areas of interest.

There are several modelling techniques (described in Christensen et al., 2007) and various emission scenarios, based on a range of emission scenarios from the IPCC Special Report on Emissions Scenarios (SRES) and Representative Concentration Pathway (RCP) scenarios, for projecting future climate change in South Africa (TAR Appendix II; AR5 Appendix II (IPCC, 2013); Meinshausen et al., 2011a & b) (Box 4). All of these present varying results (Christensen et al., 2007; Engelbrecht et al, 2009; Malherbe et al., 2013; Kruger & Shongwe, 2004; Schulze et al., 2011), however overall the trends show:

- All regions are very likely to be warmer in the future:
  - Increase in median temperature of more than 3^{o}C over the central and northern interior regions, with coastal regions experiencing a slightly lower increase (of about 2^{o}C) (SA Risk and Vulnerability Atlas; Engelbrecht, 2005; Hewitson et al., 2005; Schulze et al., 2011) (Figure 13);
  - Projections for up to 2050 and beyond under high emission scenarios indicate a very significant warming of 5 – 8^{o}C over the interior by the end of the century (DEA, 2013a);
- Greater uncertainty in rainfall projections but a general patterns of a risk of drier conditions to the west and south of the country, and a risk of wetter conditions over the east of the country (Schulze et al., 2011; DEA, 2013a) (Figure 14):
  - Most of summer rainfall region is projected to become drier in spring and autumn, but increased summer rainfall totals are also projected (SA Risk and Vulnerability);
  - This means more intense rainfall events;
  - Strong drying is plausible over the south Western Cape as well as reductions in rainfall over Limpopo and other parts of north eastern South Africa in the near future (DEA, 2013a).

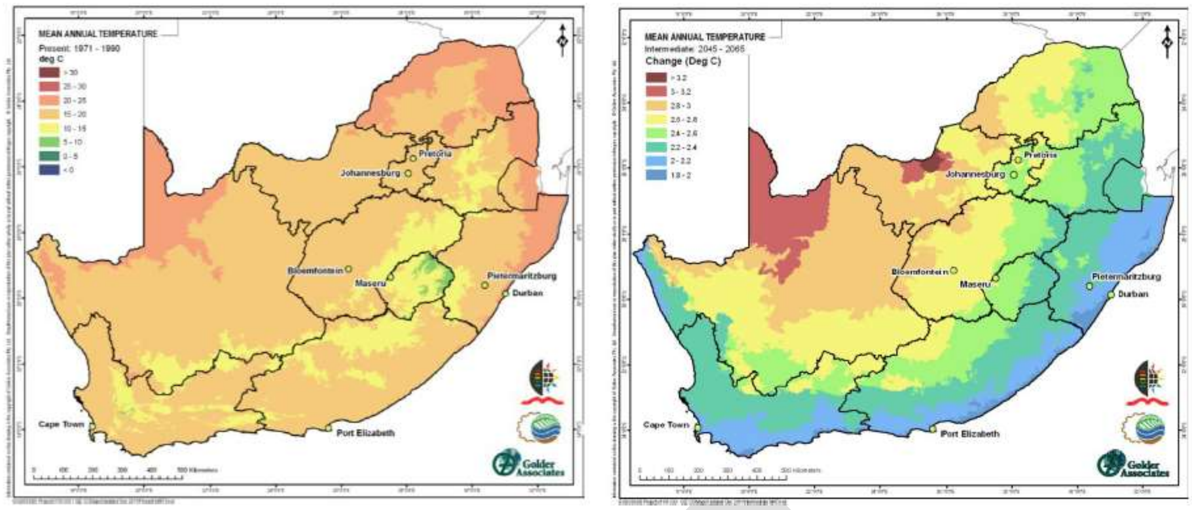

Figure 13: The modelled current mean annual temperature for South Africa (left) and the projected change in mean annual temperature (right) into the intermediate future (2045 – 2065) in degrees Celsius. (Source: DEA & NDT, 2013).

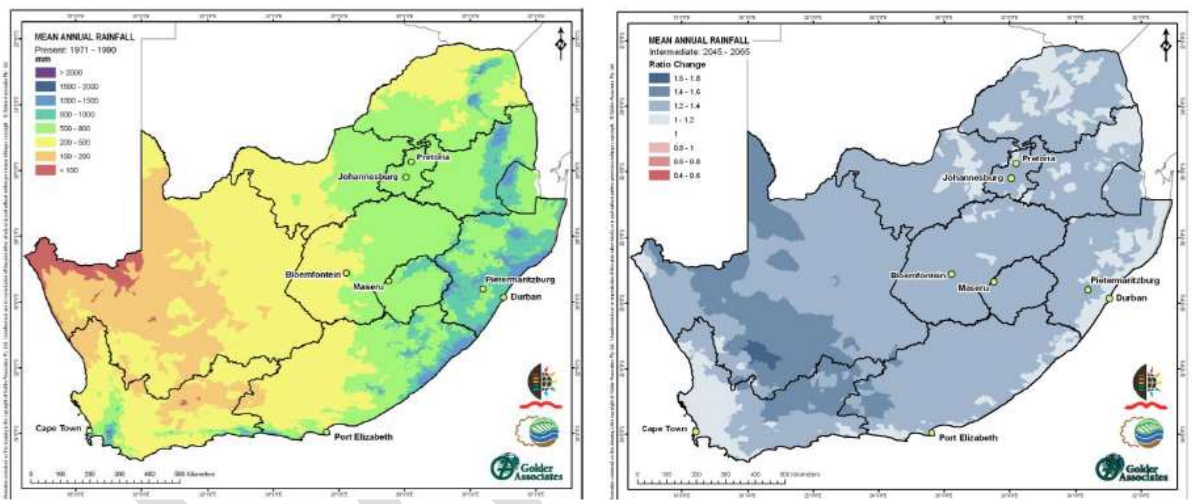

Figure 14: The modelled current mean annual rainfall (in mm) for South Africa (total amount of rain which falls in a year) (left) and the projected ratio of change[7] in mean annual rainfall into the intermediate future (2045 – 2065). (Source: DEA & NDT, 2013)

[7] A ratio change of 1 – 1.5 indicates an increase in rainfall of between 0 and 50%, implying an increase in rainfall of up to half the existing amount.

BOX 3: Regional climate downscaling

There are two methods of downscaling:

- Dynamical downscaling:

  This involves the use of high-resolution regional climate models (RCMs), which are nested within GCMs. The GCM is then used to define the boundary conditions for the RCM, but additional detail is provided regarding complex topographical features and land cover heterogeneity in a physically-based manner, thereby allowing smaller-scale features of the atmosphere to be modelled better than is possible within the GCMs.

  - Disadvantages:
    - RCMs propagate the uncertainties of the GCM; and
    - Are computationally intensive.

- Empirical/Statistical downscaling:

  This involves developing a quantitative relationship between local-scale variables and large-scale atmospheric variables, which is subsequently applied to the GCM output to obtain local and regional climate change signals.

  - Advantages:
    - GCM output can be downscaled to a point, which is useful for obtaining projections at a particular site; and
    - computationally less demanding than RCM approach.
  - Disadvantages:
    - the implicit assumption that these statistical relationships will remain stationary under a future climate

BOX 4: Emission Scenarios

Long-term climate change projections require assumptions on human activities or natural effects that could alter the climate over decades and centuries. Defined scenarios are useful as they assume a specific time series of emissions, land use, atmospheric concentrations and radiative forcing which allows for comparison between models. Scenarios can be formed from simple, idealized structures to inform process understanding, through to comprehensive scenarios produced by Integrated Assessment Models (IAM's).

The socio-economic driven SRES suite of scenarios (Figure B4.1) were developed using IAM's and resulted from specific socio-economic scenarios from story lines about future demographic and economic developments, regionalization, energy production and use, technology, agriculture, forestry and land use (IPCC, 2000). The RCP scenarios are new scenarios that specify concentrations and corresponding emissions, but are not directly based on socio-economic storylines. The RCP scenarios include more consistent short-lived gases and land use changes. Figure B4.2 compares the SRES and RCP scenarios.

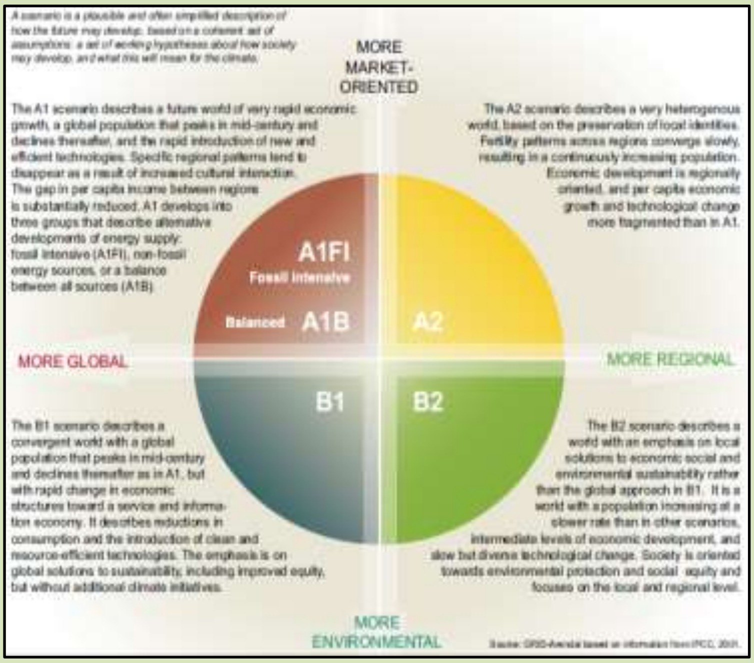

Figure B4.1: Illustration of the SRES scenarios and their descriptions (Source: GRID-Arendal)

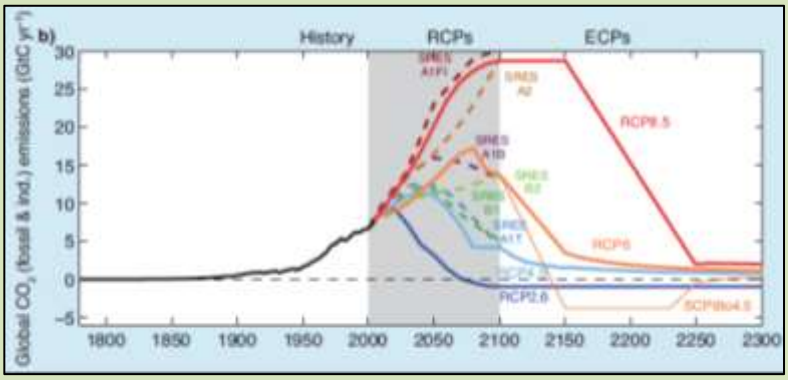

Figure B4.2: CO_2 emissions (except land use emissions) for the four RCP's and their extended concentration pathways (ECPs) as well as some SRES scenarios. (Source: Cubasch et al., 2013).

3.3. Climate in the Northern and Central Interior of South Africa

3.3.1. Historical trends

In the LTAS report (DEA, 2013a) weather station data was collected and trends analysed over the period 1960-2010. South Africa was divided into six hydrological zones (Figure 15) which were developed as part of the National Water Adaptation Strategy process, reflecting boundaries defined by water management areas (WMAs). The historical weather pattern results were reported for each of these six regions. Gauteng falls within the third zone (northern and central interior) and the climate in this zone was reported to have opposing signals at individual stations and so no clear region-wide trend was evident. It also indicated that there had been significant reductions in total rainfall and rain days at some stations in the east between December and May, with some indications of increased rainfall indices in the west throughout the wet season. The strongest increases in maximum temperature are seen over the June, July and August period (Figure 16). It also showed an increased frequency of extremely cold nights.

Figure 15: The six hydrological zones reflecting boundaries defined by water management areas (WMAs) in South Africa and grouped according to their climatic and hydrological characteristics. (Source: DEA, 2013a).

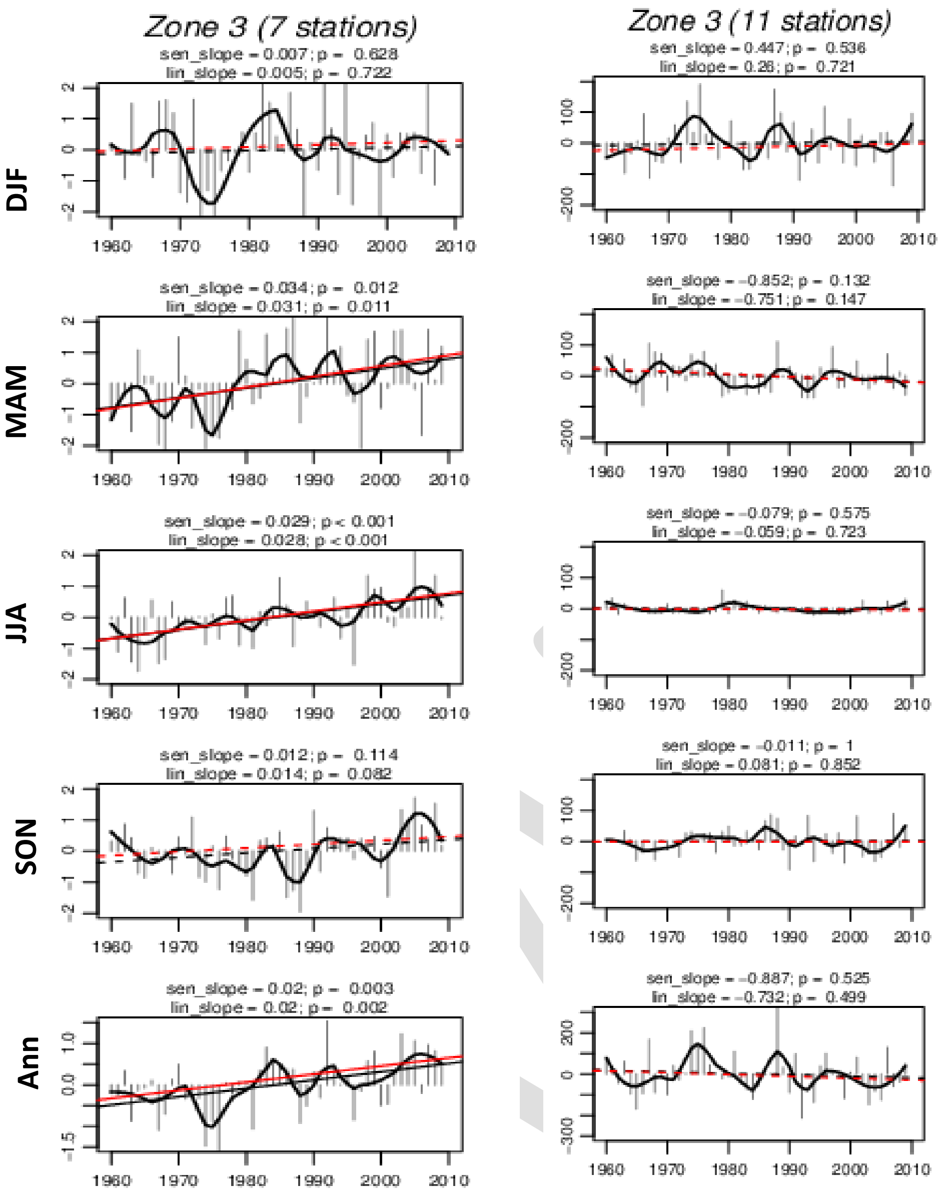

Figure 16: Regional mean time series and trends in maximum temperature (first column) and total rainfall (second column) for stations in zones 3 for summer (DJF), autumn (MAM), winter (JJA), spring (SON) and annual (Ann) means. Grey bars represent departures from the 1960-2010 mean for each year. Black curves are a Loess smoothing of the yearly data with a bandwidth of 0.25. Trend lines are shown for the linear least squares fit (black) and Sen's slope estimate (red). Solid trend lines indicate the trend is significant at the 95% level and dashed lines are not significant at this level. (Source: DEA, 2013a).

3.3.1.1. Historical climate trends near Mogale City Local Municipality

The South African Weather Service has a weather monitoring station in Mogale City; however the long term data for this weather station was not available at the time of completing this report so other climatic data was sought. The Agricultural Research Council (ARC – ISCW) has a network of weather stations across South Africa and the closest station with long term data (12/1982 –

03/2014) was the Krugersdorp-west Deodar/Tarlton station (26.14128°S; 27.57405°E). Even though this station is situated in the Randfontein Municipality just outside of MCLM, it still provides insights into the historical climate in the region.

The historical climate at Deodar shows a very small increase in daily maximum temperature (Figure 17) and daily minimum temperature (Figure 18) of 0.69°C and 1.14°C, respectively, between 1982 and 2014. The increase is slightly greater for the daily minimum temperature, which indicates that the minimum temperatures have been getting warmer faster than the maximum daily temperatures. The daily rainfall shows a great variation between 1982 and 2014, with the overall trend showing an increase of only 0.34mm over the 32 year period (Figure 19). Total monthly rainfall shows a slight increasing trend with the average total monthly rainfall increasing from 50.4mm to 59.7mm between 1982 and 2014 (Figure 20). Most of the rainfall falls between November and March and the time span is not long enough to distinguish any shifts in seasonal rainfall (Figure 21). The evaporation data does not span the whole 32 year period as evaporation was measured between 1990 and 2003, and evapotranspiration was measured from 2004 to 2014. These two sets of data seem to indicate that there has been a slight increase in evaporation (Figure 22) and evapotranspiration (Figure 23) with time, but a longer time series of data would be required to confirm this trend.

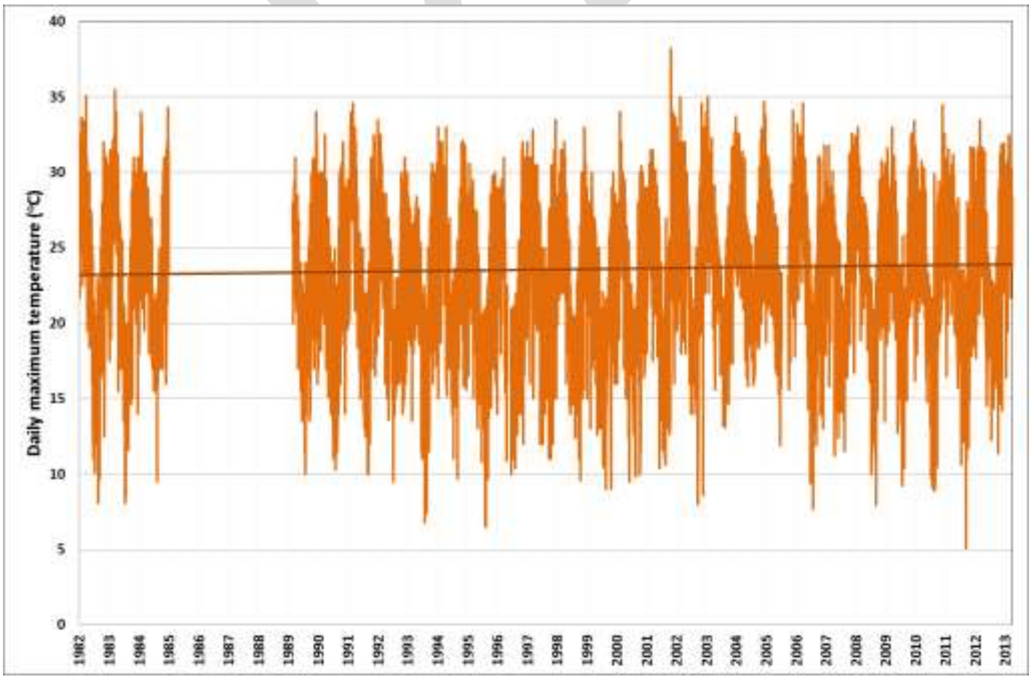

Figure 17: Daily maximum temperature (°C) measured at Deodar between 1982 and 2014 (Source: ARC-ISCW).

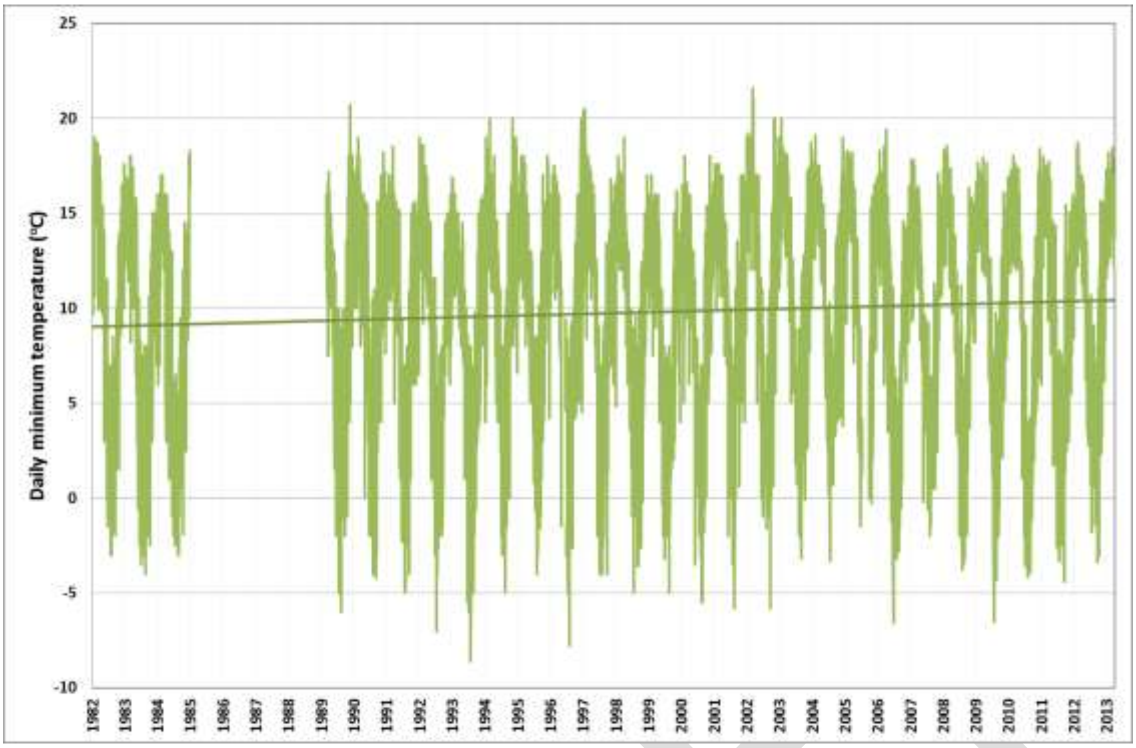

Figure 18: **Daily minimum temperature (°C) measured at Deodar between 1982 and 2014 (Source: ARC-ISCW).**

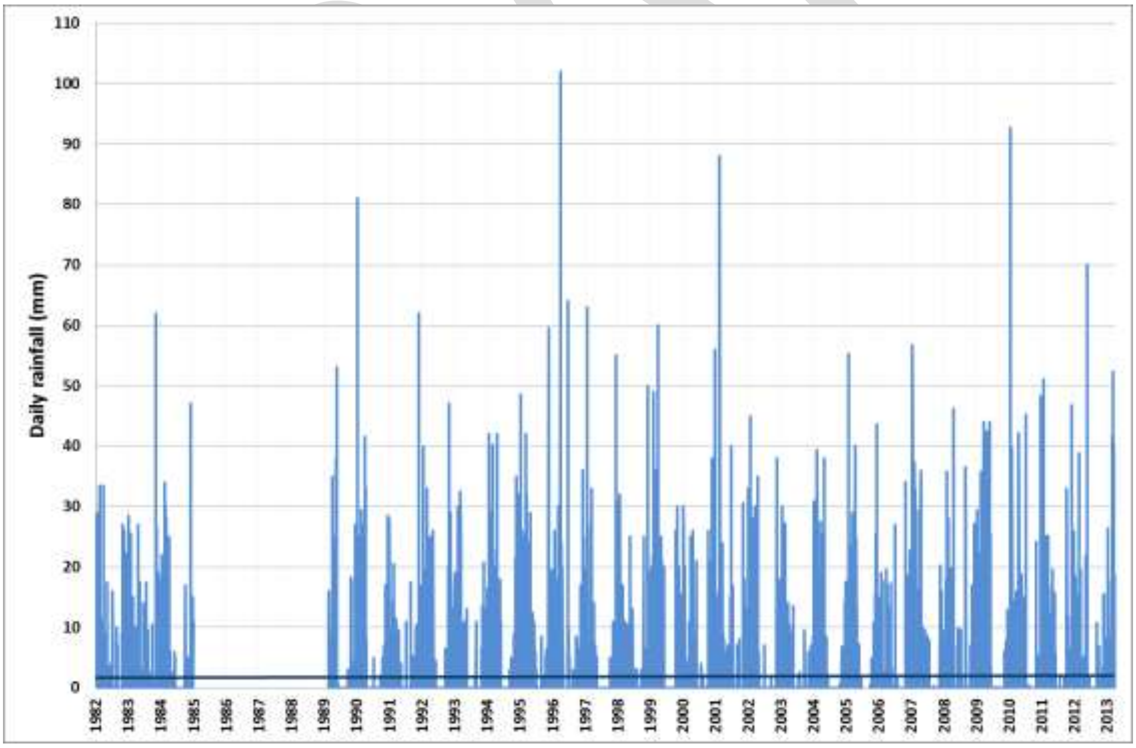

Figure 19: **Daily rainfall (mm) measured at Deodar between 1982 and 2014 (Source: ARC-ISCW).**

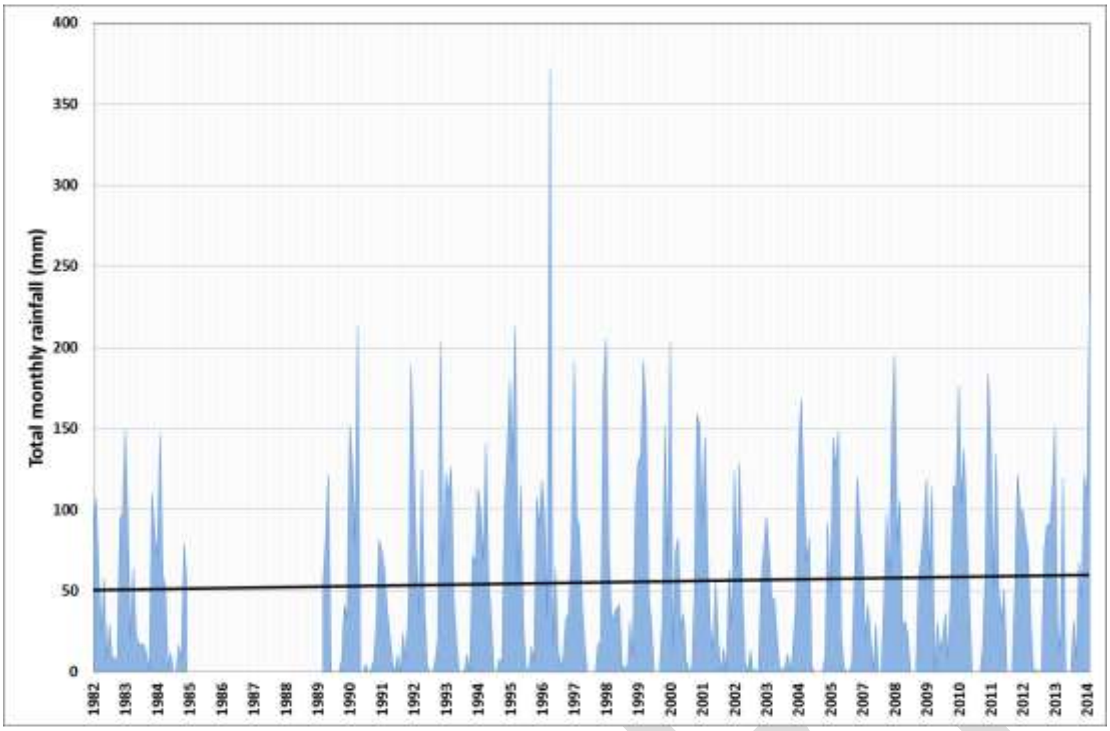

Figure 20: **Total monthly rainfall (mm) measured at Deodar between 1982 and 2014 (Source: ARC-ISCW).**

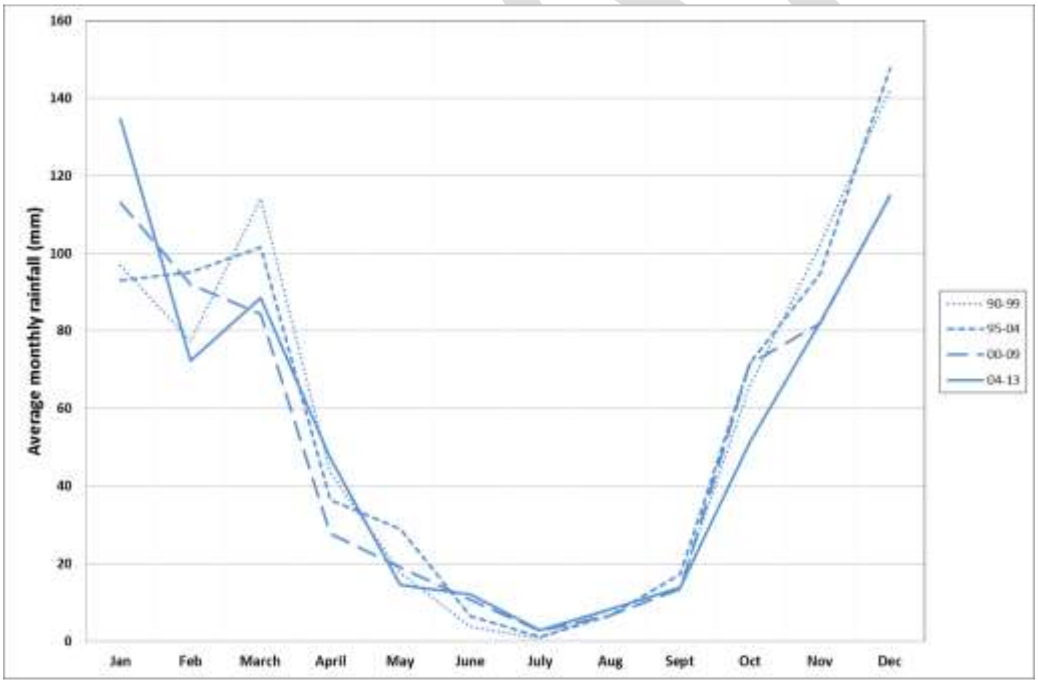

Figure 21: **Ten year averaged monthly rainfall patterns between 1990 and 2013 (Source: ARC-ISCW).**

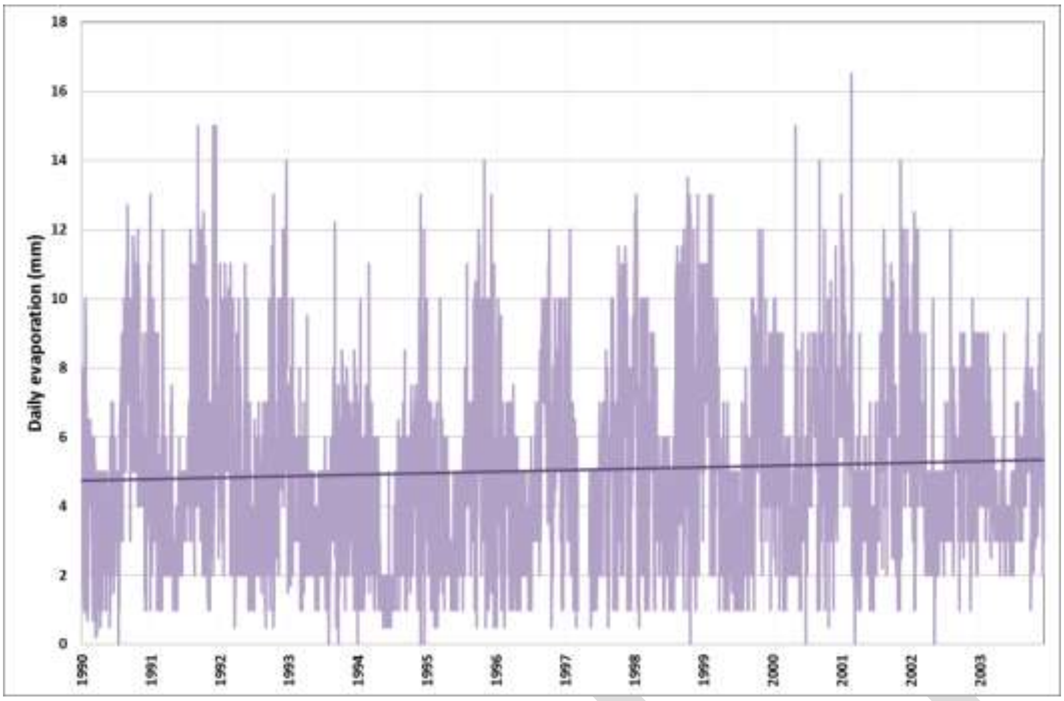

Figure 22: **Daily evaporation (mm) measured at Deodar between 1990 and 2003 (Source: ARC-ISCW).**

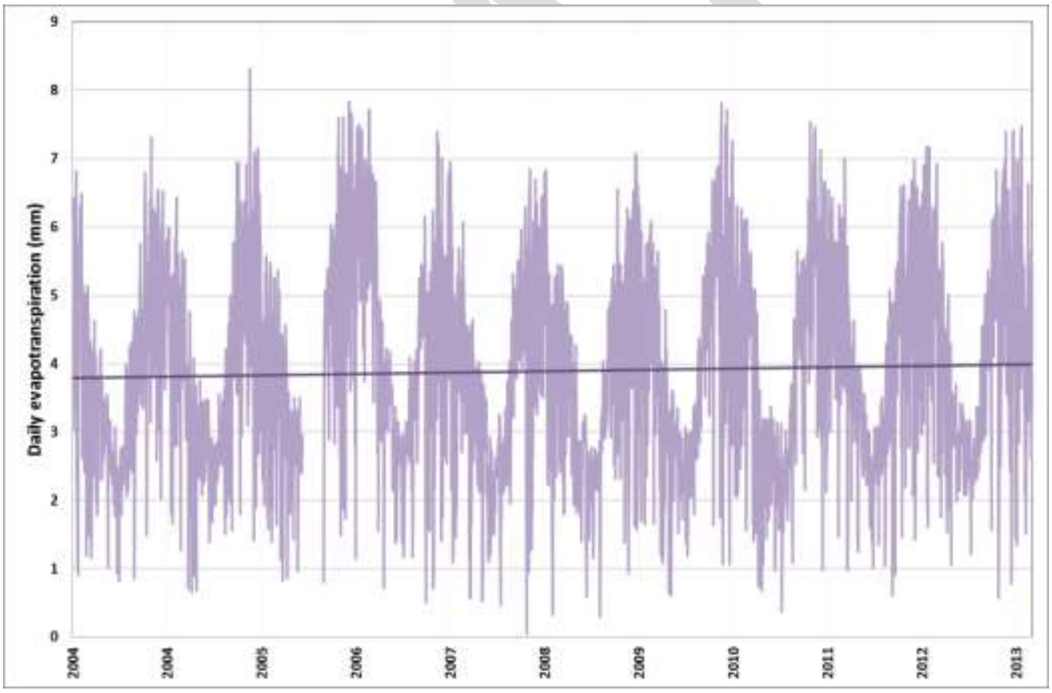

Figure 23: **Daily evapotranspiration (mm) measured at Deodar between 2004 and 2013 (Source: ARC-ISCW).**

3.3.2. Future climate projections

DEA (2013a) provided details of future climate projections for southern Africa. These projections were obtained by dynamic downscaling of the AR4 global climate models using regional climate models. Emission scenarios representing high and mitigated pathways, namely RCP 8.5 and 4.5 Wm^{-2}

(Box 4), were used in this study. Results were reported for the whole of South Africa, but also for the six hydrological zones shown in Figure 15. The key findings from the climate projections for the Northern and Central interior (DEA, 2013a) were:

- Drastic increases in annual average temperature 3 to 6.5 °C (5 to 8 °C) for the period 2080-2100 relative to the baseline period (under the A2 scenario (RCP8.5)). These anomalies are well beyond the natural temperature variability of the region;
- For the mid-future period (2040-2060) temperature anomalies of between 1 and 3 °C (2 to 5 °C) are projected (under the A2 scenario (RCP8.5)). The mid-future anomalies are already beyond the range of the present-day climatology;
- Even for the near-future (2015-2035), annual temperature anomalies under the A2 and RCP8.5 scenarios are drifting outside the present-day climatological regime of the region;
- Projected rainfall anomalies for the North West exhibit a pattern of drying under both the A2 scenario and RCP8.5, however, under both the A2 scenario and RCP8.5, the projected rainfall anomalies remain within the realm of present-day climate.
- The RCP4.5 future implies significantly reduced increases in temperatures over North West, with annual anomalies remaining below 4 °C in the far-future (2080-2100). There are indications of general but modest drying, with negative annual rainfall anomalies projected that are somewhat larger in amplitude than any of those simulated under present-day conditions.

In another study by Davis et al. (2010) a downscaling scenario was carried out for the North-eastern regions of South Africa. Future temperatures were obtained from two regional climate models (PRECIS and MM5), while the precipitation variables were obtained from ten statistically downscaled GCMs. The main findings in this report are:

- Temperature:
  - Increase in annual maximum day temperature of approximately 0.5°C, with a possible decrease for April to July (Figure 24 and Figure 27);
  - Increase of between 0.6°C and 1.16°C in the minimum day temperature (Figure 25 and Figure 27);
- Rainfall:

- An increase (of between 85 and 303 mm) in total annual rainfall is expected for the whole region, with possible decreases along the escarpment (Figure 26 and Figure 27);
- Annual rainfall is expected to range from 301 mm to 758 mm per annum, and the majority of this is expected to fall between December and February;
- An extension of the rainy season may occur into early spring, and Autumn and winter are also expected to receive more rainfall;
- The number of rain events is expected to increase, so chances of floods may increase;
- Majority of rain events to occur in November through to January;
- The number of rain days per month is expected to increase by between 1 and 2 days;
- The intensity of rain events and possibly the severity of rain events may increase;

- Evaporation:
  - Future evaporation is expected to increase (Figure 28);
- Dry-spell duration:
  - Number of dry days per year are expected to decrease due to the increase in mean annual rainfall, and this decrease is expected in autumn (by 0.5 to 3 days) and winter (by 1 to 6 days), with little or no change occurring in summer.

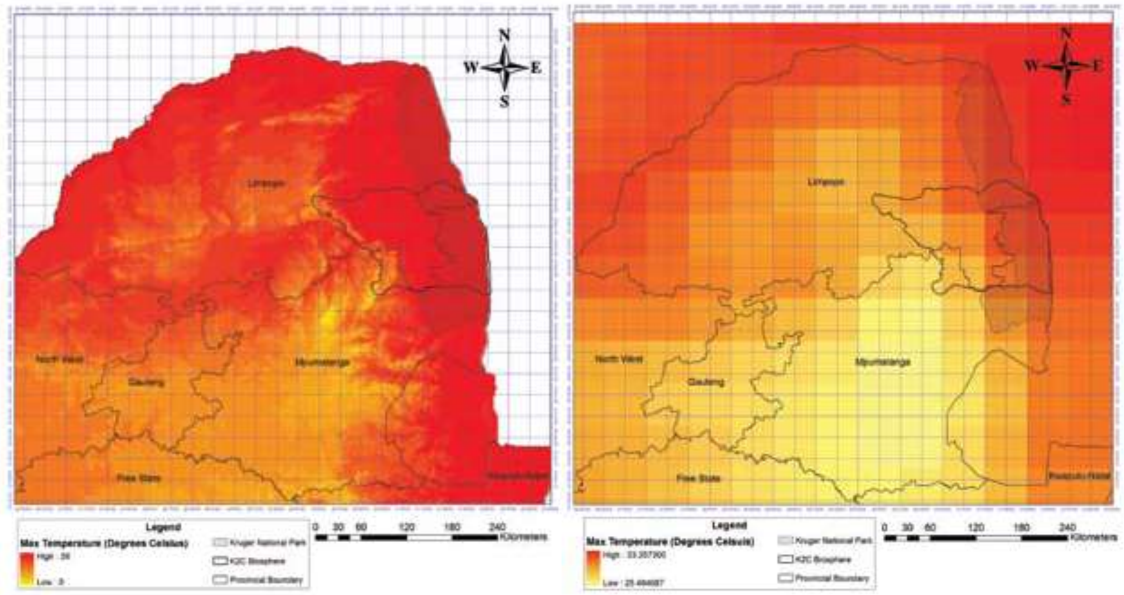

Figure 24: Current (left) and projected[8] (right) mean annual maximum day temperature across South Africa. (Source: Davis et al., 2010).

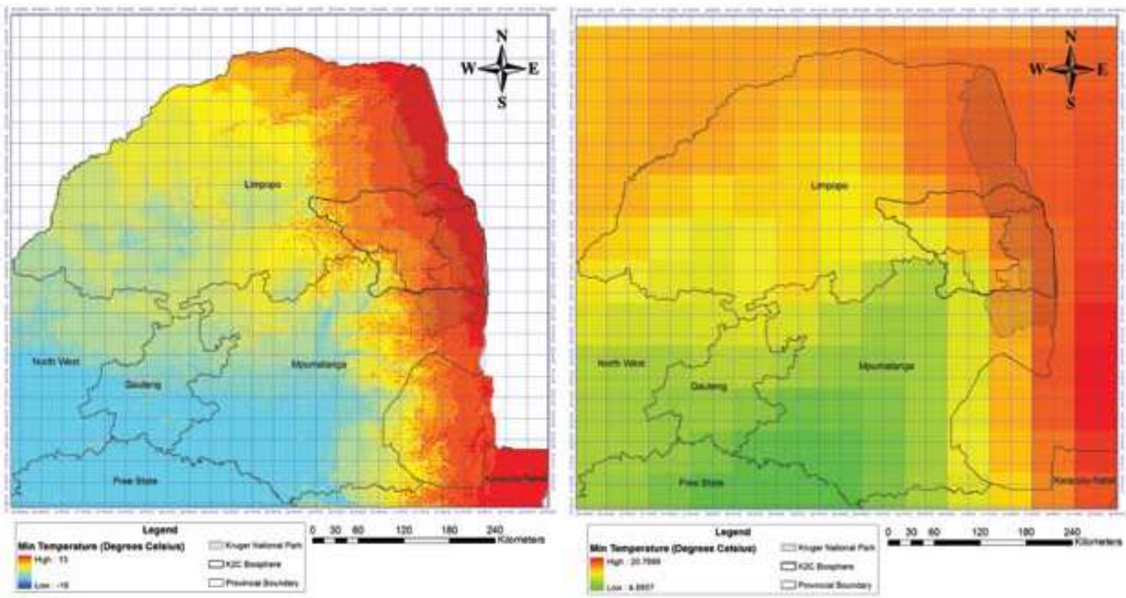

Figure 25: Current (left) and projected[4] (right) mean annual minimum day temperature across South Africa. (Source: Davis et al., 2010)

[8] The PRECIS model was used to create these projections.

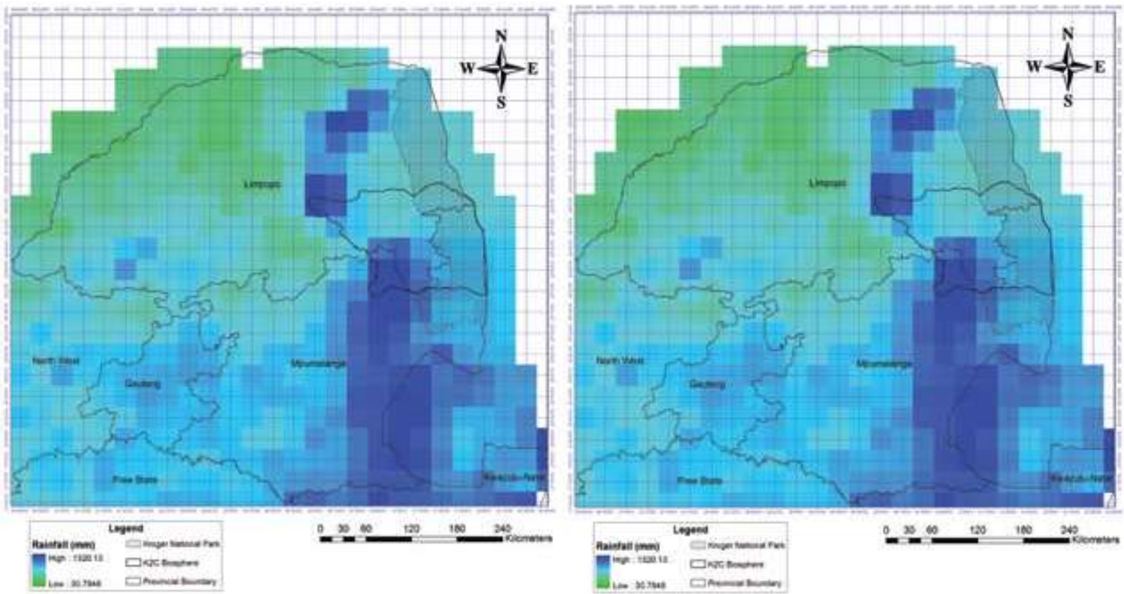

Figure 26: Current (left) and projected[4] (right) mean annual rainfall (average) across South Africa. (Source: Davis et al., 2010)

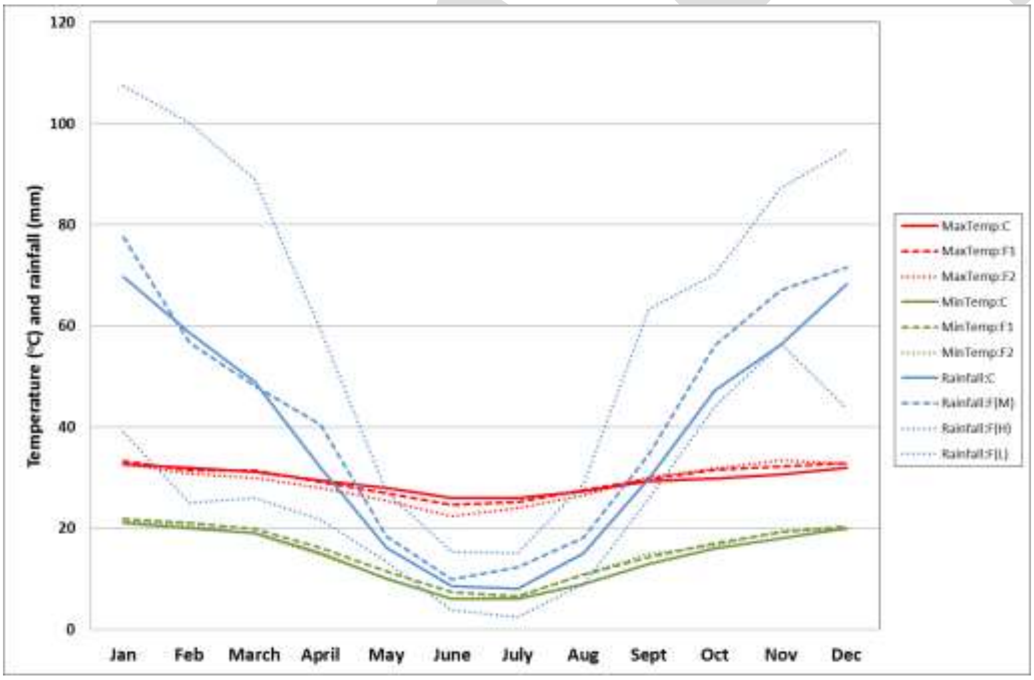

Figure 27: Current (solid lines) and future (PRECIS model – dashed lines; MM5 model – dotted lines) maximum (red) and minimum (green) monthly day temperatures for the north-eastern regions of South Africa. Current rainfall (blue solid line) and the mean (blue dashed line) with low and high (blue dotted lines) projected total annual rainfall for the region. (Source: graph created from data given in Davis et al., 2010.)

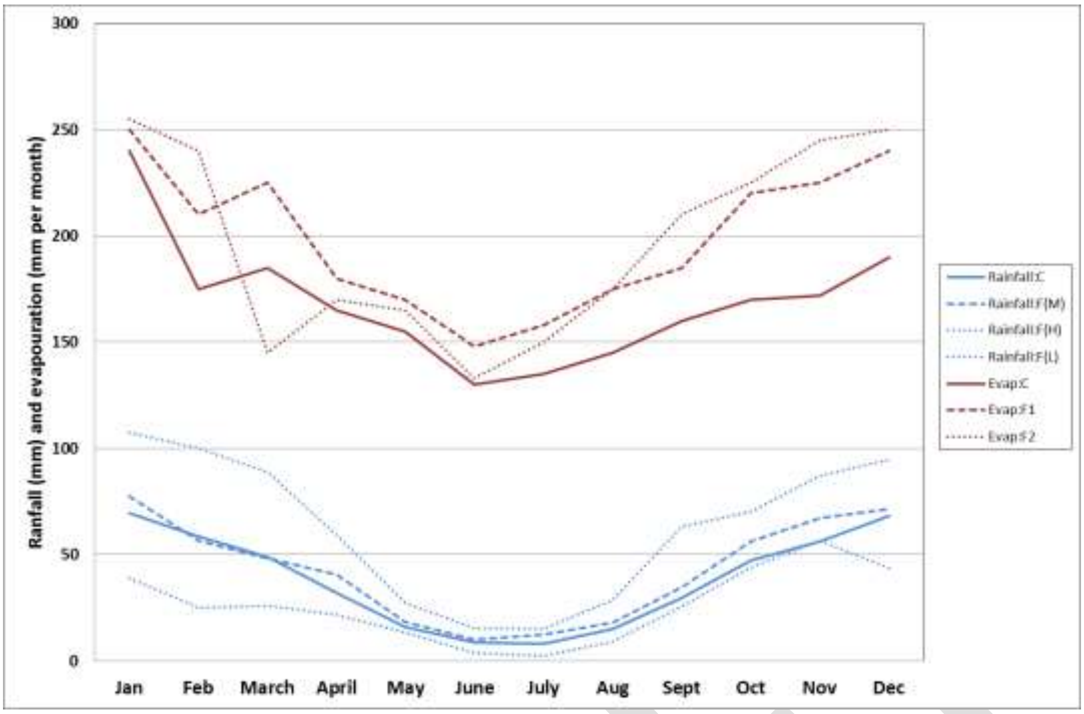

Figure 28: Current (solid brown line) and projected (PRECIS model – dashed brown line; MM5 model – dotted brown line) evaporation for the north-eastern regions of South Africa. This is shown against the rainfall data (same key as described in Figure 14). (Source: graph created from data given in Davis et al., 2010.)

3.3.2.1. Future climate in Mogale City Local Municipality

Due to the scale of the outputs from the regional downscaling of global models it is difficult to predict with certainty what the future climate of a municipality will be. However, both the historical data and the results of the downscaled GCMs in the MCLM indicate an increase in daily and mean temperatures, with the minimum (daily and mean) temperatures showing a slightly higher increase than the maximum temperatures. The rainfall predictions are more uncertain, but the data suggests that total annual rainfall will either stay within current values or increase slightly. The number of dry days is expected to decrease. The intensity of rainfall events and the number of extreme events is expected to increase which could lead to an increase in flooding events. Evaporation is also expected to increase which could reduce water availability slightly if there is no increase in rainfall.

4. GHG EMISSIONS

4.1. GHG emission inventory methodology

Greenhouse gas (GHG) emissions play an important role in climate change and in order to develop appropriate mitigation strategies it is critical that countries adequately account for their GHG emissions by developing GHG inventories.

The IPCC developed guidelines for the methodology used to develop these inventories, so that methodology is fairly standard across countries. GHG emission inventories are compiled for four sectors, namely Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) and Waste, if the 2006 guidelines are followed[9]. These IPCC guidelines allow for variations in the level of detail incorporated for each sector. There are three Tier levels, with Tier 1 being the simplest method which relies on IPCC default factors, and Tier 3 is the most complex in that it incorporates much more country specific data with estimates having a much higher accuracy than in Tier 1. The Tier level selected for each sector or sector sub-category is dependent on how important the emissions from that sector are and the availability of data.

These IPCC guidelines are used for National GHG accounting but they can also be used for provincial and lower scale GHG accounting. It was highlighted in the GDARD inventory report (GDARD, 2013) that there is a need to find the most appropriate way to apply the IPCC guidelines to a provincial level so as to ensure that there is no double accounting of emissions, particularly around electricity consumption and generation, across different provinces in South Africa. At the municipal level there are also other methodologies such as the International Local Government GHG Emissions Analysis Protocol (ICLEI, 2009) and the Municipal GHG Emissions Calculator and Electricity Sector Efficiency Planning Tool (www.cityenergy.org.za). The former method aims to *"…provide an easily implemented set of guidelines to assist local governments in quantifying the greenhouse gas emissions from both their internal operations and from the whole communities within their geopolitical boundaries."* This protocol is currently being updated in a collaborative process between ICLEI – Local Governments for Sustainability (ICLEI), C40 Cities Climate Leadership Group (C40) and the World Resources Institute (WRI) to develop a new protocol called the Global Protocol for Community Emissions (GPC) (http://www.ghgprotocol.org/city-accounting). This will become the global standard for cities wanting to monitor and verify their city-level emissions. On the other hand, the Municipal GHG Emissions Calculator Tool is focussed around quantifying energy consumption

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9 The IPCC 2006 methodology was followed in the National Greenhouse Gas Inventory for South Africa for the period 1990 – 2000 (DEA, 2009), as well as the more recent inventory for 2000 – 2010 which is under review and due for completion by the middle of 2014.

and assessing the related GHG emissions, with the outputs being used for making decisions about electricity planning and mitigation strategies. ICLEI Africa also has another tool called HEAT+ (http://www.heat.iclei.org), which can also be used for conducting a GHG inventory at the municipal level. The accounting and database capabilities of HEAT+ can assist local governments to make informed decisions in formulating targeted action plans to reduce these emissions.

4.1. National, provincial and local GHG emissions

The National Toolkit for integrating climate change risks and opportunities into municipal planning (DEA, 2012) indicates that a section on GHG emissions be included in the analysis report. It is suggested that the Municipal GHG Emissions Calculator and Electricity Sector Efficiency Planning Tool be used to create an emission summary for the Municipality. This requires information on energy and fuel consumption within the local municipality region. A GHG inventory has not been developed for MCLM and this is beyond the scope of this project. It is recommended that the Municipal GHG emissions be calculated (in accordance with international city-level accounting protocols) so as to provide further guidance for mitigation planning in the region. Since there is no specific GHG emission inventory for MCLM, in order to provide some insights into the GHG emissions this section provides a summary of the National GHG Emissions Inventory, the GHG emission inventory for Gauteng province and finally a discussion on possible emission sources and some initial emission estimates for MCLM.

4.1.1. National GHG emissions

South Africa has a very energy intensive economy which is heavily reliant on fossil fuels. Burning fossil fuels leads to the emission of CO_2, so it is not surprising that South Africa is ranked as the 13th largest CO_2 emitter in the world (on an absolute emissions basis) and the largest in Africa. According to the National GHG Inventory for 2000 (DEA, 2009) the energy sector dominated the emissions and generated 78.9% of the total CO_2 emissions in 2000. Energy sector emissions showed an increased trend from 1990 to 2000. Industrial processes, agriculture and waste contributed 14.1%, 4.9% and 2.1% respectively. The agricultural and waste sectors showed significant decreases of emissions from 1990, whereas industrial processes and other product use emissions showed an increase of over 100% from 1990 to 2000. The three main greenhouse gas emissions (CO_2, CH_4 and N_2O) showed a fairly uniform increase in emissions, with CH_4 showing the highest increase of more than 76% between 1990 and 2000.

4.1.2. Gauteng GHG emissions

Phase 1 of the development of the Gauteng GHG emission inventory for 2007 has recently been completed (GDARD, 2013). This is not a final inventory but rather provides an overview of the data required and the data availability in Gauteng. The report was based on the Greenhouse Gas Implementation Manual (Mwakasonda et al., 2010). Provisional estimates show that the Energy sector produces 40 102 Gg CO_2eq, with transport contributing 40% towards the energy sector total. Non-territorial electricity (that is electricity that is not generated within the borders of Gauteng) was estimated to produce 46 505 Gg CO_2eq. The Waste and AFOLU sectors contribute 3 246 Gg CO_2eq and 712 Gg CO_2 eq, respectively. This is, however not complete, as emissions from the IPPU sector were not reported due to a lack of data. The energy sector data was compared to the energy balance developed for Gauteng Province for 2007 – 2009 (Tomaschek et al., 2012). The Energy sector emissions in Tomascheke et al. (2012) were 7.7% higher, and the non-territorial emission estimates were significantly (77.6%) higher.

4.1.3. Mogale City Local Municipality GHG emissions

A GHG emission inventory for MCLM has not been done, but the Air Quality Management plan for MCLM and WRDM (WRDM AQMP, 2010; Ngubane & Ngetar, 2013), as well as the more recent emission inventory for WRDM (uMoya-NILU, 2012), provide some insights into possible emissions in the municipality. These documents provide emission estimates for SO_2, NO_x, VOCs, PM_{10}, CO and benzene as these are the main pollutants in the region; however they do not report GHG emissions. Emissions are usually calculated by multiplying the activity data, such as fuel consumption, by an emission factor. The activity data reported in the AQMPs can, therefore, be used to make an initial estimate of the GHG emissions from some of the sectors in MCLM.

The sectors which are likely to produce GHG emissions in MCLM are:

- Industry (including mining):
  - CO_2, CH_4 and N_2O emissions from industry primarily come from burning fossil fuels for energy as well as emissions from certain chemical reactions necessary to produce goods from raw materials;
- Agriculture:
  - CH_4 from livestock and manure management, as well as N_2O from manure management:
  - N_2O emissions from soils and fertilizers;
  - CO_2 from liming and urea application;

- Biomass burning:
    - CO_2, CH_4 and N_2O emissions through the incomplete combustion of fuels;
- Transport:
    - CO_2, CH_4 and N_2O emissions from transportation primarily come from burning fossil fuel for cars, trucks, ships, trains, and planes;
- Landfill sites and waste:
    - CH_4 from solid waste disposal; and
    - CH_4 and N_2O from wastewater treatment;
- Domestic fuel burning:
    - CO_2, CH_4 and N_2O emissions from businesses and homes arise primarily from fossil fuels burned for heat, light and cooking; the use of certain products that contain greenhouse gases; and the handling of waste.

The WRDM Emission Inventory for 2011 (uMoya-NILU, 2012) provides fuel consumption data for the industrial, residential and transport sectors (Table 6). An initial estimate of emissions from these sectors can be calculated by applying the IPCC 2006 Guideline default emissions factors (http://www.ipcc-nggip.iges.or.jp/public/2006gl/). It must be noted that providing GHG emission estimates is beyond the scope of this project; therefore these values are only to be used to provide a rough guideline of emission sources and should not be taken as official GHG emission estimates for MCLM. These initial estimates indicate that road transport and industry are likely to be important sectors in terms of GHG emissions (Table 7). The emission estimates for domestic burning are very low, however the consumption data reported for the year 2007 (WRDM AQMP, 2010) are much higher. Emissions based on the 2007 data yield estimates of 32.51 Gg CO_2, 0.89 Gg CO_2eq and 0.11 Gg CO_2eq for the residential sector.

The WRDM emission inventory (uMoya-NILU, 2012) provided burnt area data for estimating biomass burning emissions. This was combined with the available fuel data and the combustion coefficient from the national GHG inventory (DEA, 2009) and the IPCC 2006 default emission factors to produce initial emission estimates for biomass burning (Table 7). The results suggest that biomass burning could also be an important source of CH_4 and N_2O in MCLM.

Table 6: Fuel consumption in the various sectors in MCLM. (Source: WRDM AQMP, 2010; uMoya-NILU, 2012).

Sector	Fuel	Units	2011
Estimated consumption for 2011 (uMoya-NILU, 2012)			
Industry	Coal	tons/yr	112 188
	Diesel	tons/yr	16
	Fuel oil	tons/yr	1 416
	Gas	m^3/yr	2 949 562
Residential[a]	Coal	tons/yr	65.85
	Wood	tons/yr	20.07
	Paraffin	tons/yr	446.53
	LPG	tons/yr	5.63
Transport (Road)	Gasoline	kg/yr	71 690 879
	Diesel (passenger cars)	kg/yr	5 693 500
	Diesel (LDV)	kg/yr	36 641 466
	Diesel (HDV)	kg/yr	7 930 735
Estimated consumption for 2007 (WRDM AQMP, 2010)			
Residential[a]	Coal	tons/yr	3 478
	Wood	tons/yr	3 478
	Paraffin	L/yr	7 489 790
	LPG	L/yr	224 646

[a]Domestic burning

Table 7: Initial GHG emission estimates from the various sectors in MCLM in 2011.

Sector	CO_2 (Gg)	CH_4 (Gg CO_2eq[10])	N_2O (Gg CO_2eq)
Industry	213.89	0.51	0.94
Residential	1.49	0.01	0
Transport (Road)	380.25	2.6	5.5
Biomass burning	108.38	3.47	2.92

Landfills and waste disposal are important sources of CO_2 and CH_4. The WRDM AQMP (2010) reported waste generation data for MCLM, but did not report on emissions from waste due to incomplete data. WRDM emission inventory (uMoya-NILU, 2012) also did not cover waste emissions, so there is insufficient data in the literature to make an initial emission estimate for this sector.

These initial estimates provide some guidance on possible emission sources in MCLM; however it is an incomplete picture due to insufficient data in some sectors. It is recommended that a full GHG inventory for MCLM be completed in future in order to obtain more accurate estimates and to provide guidance on where to focus emission reduction actions.

[10] Giga grams of CO_2 equivalents

5. CLIMATE CHANGE VULNERABILITIES AND IMPACTS

Vulnerability, as defined by IPCC Third Assessment Report (IPCC TAR, 2001), is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." Even though vulnerability is not strictly synonymous with poverty, the most vulnerable to climate change are often those in the weakest economic position. Poverty and marginalization are often drivers of vulnerability and the inability to cope and adapt to change. Similarly with terrestrial systems, those which are in poor condition are more vulnerable due to their reduced capacity to adapt and respond to change. Africa is one of the most vulnerable continents because of the range of projected impacts, multiple stresses and low capacity to adapt (Kirby, 2009).

Climate change impacts are the effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts. *Potential impacts* are those that may occur given a projected change in climate, without considering adaptation, while *residual impacts* are those that would occur after an adaptation.

The Intergovernmental Panel on Climate Change (IPCC) conceptualizes vulnerability as a function of exposure and sensitivity to stress, as well as the capacity to deal with the effects of stress. A climate change vulnerability index was determined for all municipalities in SA by Turpie and Visser (2012). The overall vulnerability score was assumed to be the residual of impact (the average of exposure and sensitivity) and adaptive capacity and was composed of the various factors shown in Figure 29. MCLM was determined to have a relatively high exposure (mainly due to high temperature changes[11] in the future and an increase in malaria risk[12]) and sensitivity index (due to high population density), but was also found to have a very high adaptive capacity (due to high socio-economic capacity, high road density, high local government expenditure and good governance) (Turpie and Visser, 2012). MCLM was therefore determined to have a fairly low vulnerability index (Figure 30) and thus suggested to be relatively resilient to climate change.

[11] % change in temperature from past to 2050 (Turpie and Visser, 2012).
[12] Change in exposure period from present to 2100 (Turpie and Visser, 2012)

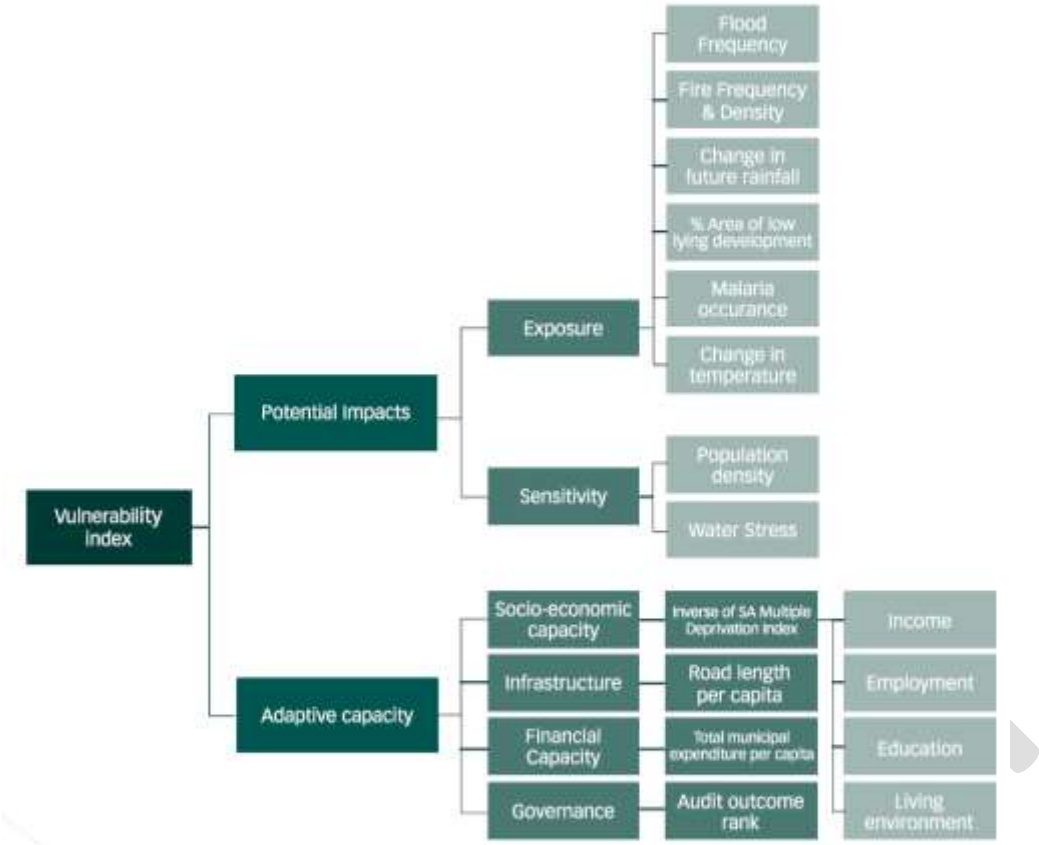

Figure 29: **Composition of the overall vulnerability layer and its various components (Source: Turpie and Visser, 2012).**

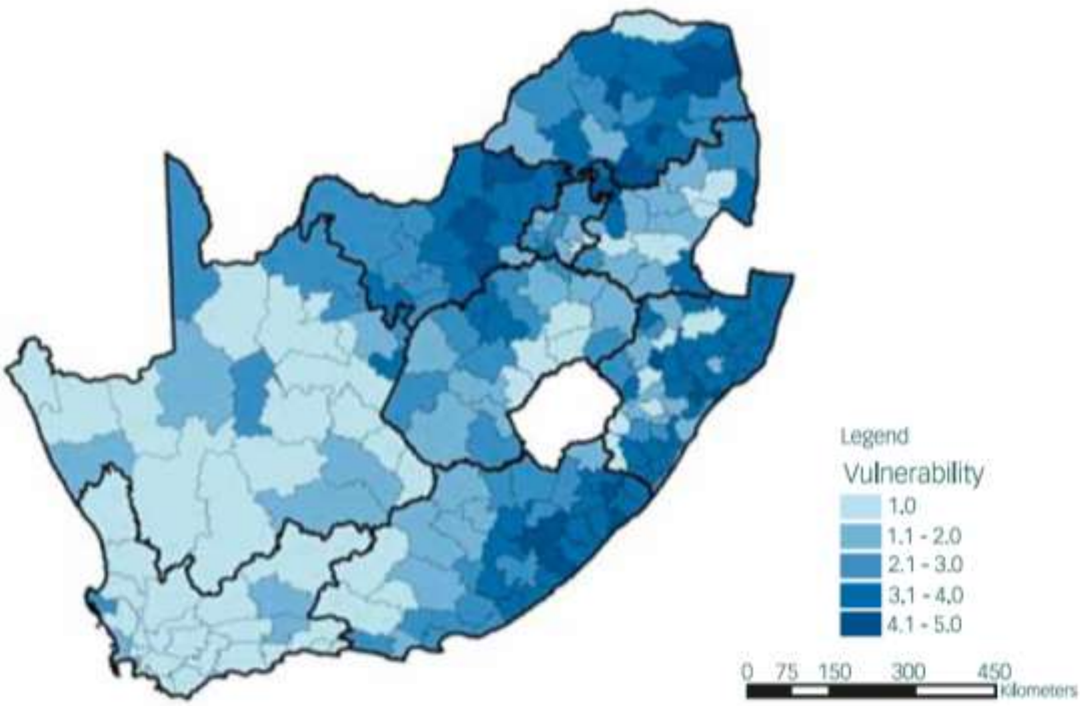

Figure 30: **Vulnerability index to climate change for municipalities in South Africa (Source: Turpie and Visser, 2012).**

5.1. Water sector

Water resources in South Africa are comprised of surface water (77%), return flows (14%) and groundwater (9%) (DAFF, 2009). The biggest users are Agriculture (62%), domestic (27%) and urban (23%). Demand for water across the country is expected to increase in the future due to economic growth, increased urbanization, and population growth. Water demand and availability projections for 2025 (not accounting for climate change) are shown in Figure 31 (National Water Resource Strategy (NWRS), 2004). Ninety three percent of MCLM falls within the Crocodile West and Marico Water Management Area (WMA) and Figure 31 shows that in 2025 this WMA is one of the few where supply is expected to exceed demand, mainly due to the imports from the Vaal River System.

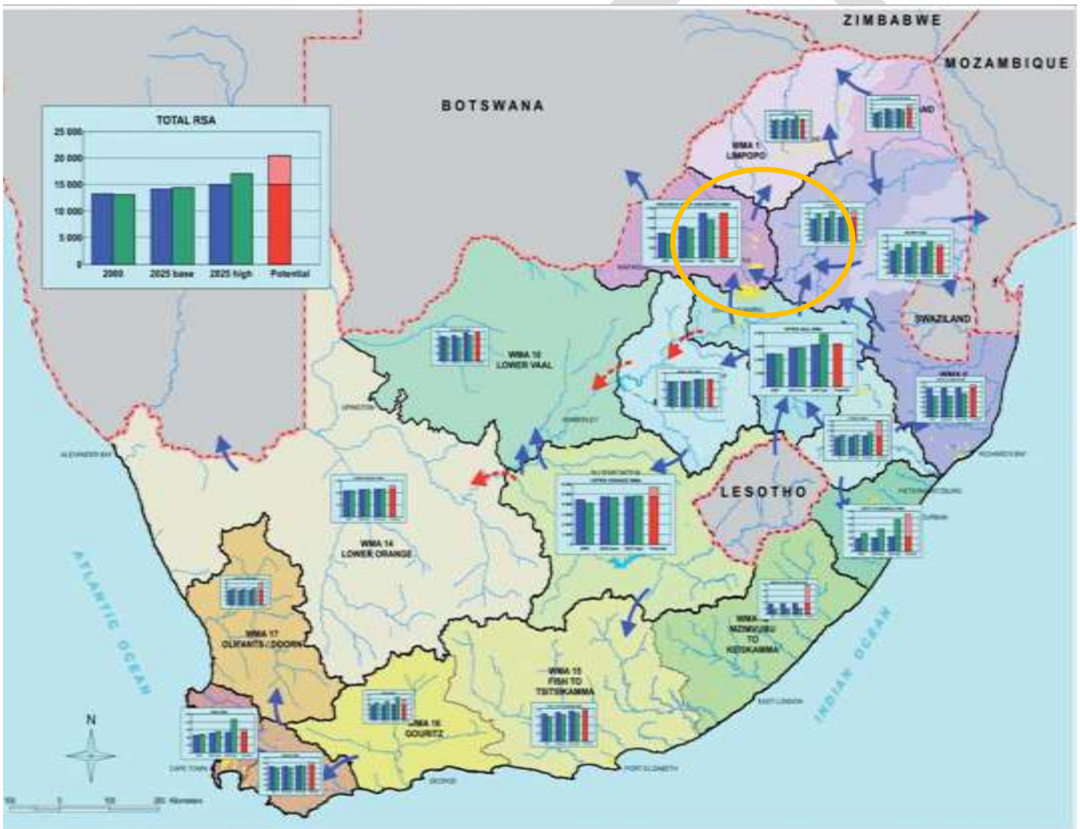

Figure 31: Water demand (green bars), availability (blue bars) and water development potential (red bars) for 2025. Crocodile West and Marico Water Management Area is circled in orange. (Source: National Water Resource Strategy, 2004).

Surface and ground water are also exposed to contamination and increasing pollution which affects water quality. The overall Ecostatus of the rivers in the Upper Crocodile sub-management area, which is where most of MCLM sits, was classified in the River Health Programme (2005) as poor. The ecological importance and sensitivity of the area is marginal to low because the functional habitat types and species diversity is low. Water quality was also indicated to be poor because it has high levels of nutrients and an increased frequency of water quality problems, particularly in urban areas where there are sewage spills and industries discharging polluted water into the sewer network. Sources of water pollution in this area are agricultural activities (fertilizers, pesticides, herbicides), acid and metals from mining, urban and industrial effluent, and excessive sediments. Piggeries and chicken batteries that are situated next to streams can also cause nutrient levels in water bodies to increase dramatically leading to eutrophic (i.e. nutrient loads) conditions.

The volumes of river flows are driven by rainfall and are amplified by climate variability by a factor of two to five times (Schulze, 2005). Flow volumes for the various rivers in West Rand District Municipality (WRDM) between 2008 and 2009 were reported in the WRDM EMF (2013) and it shows there has been a general decline in water volume in the rivers in MCLM (Table 8) as well as the rest of WRDM. This decline could be further enhanced in the future by increased temperature and evaporation, as well as altered rainfall patterns. If there is a slight increase in rainfall, as some model suggest, then the situation could improve, however this would depend on whether the inputs (rainfall) exceed the expected increase in evapotranspiration.

Low flows and poor water quality lead to increased vulnerability due to a lowered adaptive capacity.

Table 8: Flow volumes (million m^3) of various rivers in MCLM in 2008/2009 (Source: WRDM EMF, 2013).

Monitoring point	Volume (million m^3)	Comment
Nouklip Eye at Hartbeeshoek	4.3	Steady decline (approx. 3 million m^3) from 1999 – 2009
Crocodile river at Zwartkop	23.4	Sharp decline (approx. 25 million m^3) between 1999 – 2003; with erratic increase from 2003 – 2009 (approx. 15 million m^3)
Crocodile river at van Wykes restant	13.9	Similar to Zwartkop
Bloubank spruit at Rietspruit at Swartkop	29.6	Similar to Zwartkop
Maloney’s eye at Steenkoppie	5.3	Flow volumes declined steadily from 2000 – 2007. Small recovery from 2007 – 2009.

Climate change is predicted to bring about an increase in variability of rainfall and, even when average annual rainfall remains constant, increased variability will result in less reliable stream flows. Increased temperatures and heat waves will lead to an increase in water demand. The most noticeable change in terms of water requirements will be the impact on irrigation needs. In the Crocodile (West) area the effects of the increased number of dry days between rainfall events will not be significant as it will be offset by the increase in the relative number of days with large amounts of rainfall (DWA, 2008). An increased inconsistency in water supply, along with an increasing water demand, pose challenges to water resource management.

Increased water temperatures could affect the quality of water for irrigation, dissolved oxygen content of water, the rates of chemical and biological reactions in water, and could have wide-ranging repercussions in the health sector through the creation of favourable conditions for the incubation and transmission of water-borne diseases. Heat waves can also lead to short-term water quality impacts and increased fish mortality due to low oxygen concentrations brought about by a rapid increase in decomposition processes. The increased temperatures will also put additional stress on temperature sensitive fish species.

The projected changes in climate, including increasing mean global temperatures, changes in precipitation, and increased frequency and intensity of some extreme climatic events, will impact wetlands and their dependent species. The most pronounced effect of climate change on wetlands will be through the alteration in hydrological regimes. Other variables that will have an impact are increased temperatures, altered evapotranspiration, altered biogeochemistry, altered sediment loading, fire, and oxidation of organic sediments. The amount of water in a wetland and the quality of the water determines the liveable habitat for plants and animals (Poff *et al.* 2002). A loss in wetlands will cause a reduction in habitat important to a variety of animal and plant species, particularly migratory birds. This in turn could impact on tourism. Climate change may also affect the wetland carbon sink, although the direction of the effect is uncertain.

An increase in intense rainfall events and floods leads to increased soil erosion and runoff. This has implications for ground water recharge, water catchment processes, and scouring and erosion of streams. Increases in intense rainfall events place soil dams at risk and increase siltation of dams. These intense storm events can also destroy small alluvial aquifers associated with river channels. Coupled with higher temperatures, these intense rainfall events will also have an impact on water quality. More extreme wetting and drying cycles result in greater soil movement and make water and sewerage pipes more prone to cracking. Flooding can also cause damage to infrastructure in the water sector, as well as other sectors (transport, human settlements).

The effects of increased evaporation due to higher temperatures, particularly in relation to large, shallow dams, need to be considered in deciding upon new dam constructions versus enhancing groundwater resources. Some of these effects could be offset if there is an increase in rainfall in the region. Increased rates of evapotranspiration could cause a reduction in groundwater recharge, while an increase in intense storm events would increase ground water recharge. There is very little research on the effects on ground water, in terms of recharge and water quality, in South Africa and thus such research initiatives should be supported in future.

Areas underlain by dolomite rock are prone to sinkhole formation which may lead to death, injury or structural damage. The primary triggering mechanisms include the ingress of water from leaking water-bearing services, poorly managed surface water drainage and groundwater level drawdown. While climate may have an indirect impact on sinkhole formation through changes in ground water levels, there is no direct evidence to suggest that climate change will result in an increase in sinkhole formation. This is because there are many factors which influence the risk of subsidence, including topography, drainage, the natural thickness and origin of the transported soils and residuum, the nature and topography of the underlying strata, the depth and expected fluctuations of the groundwater level, and the presence of structural features such as faults, fractures and dykes are all factors which influence the risk of subsidence taking place.

The symptoms of climate change can exacerbate the negative effects of AMD on the environment. An increase in intense rainfall events could result in the resumption of or increase in decanting of the AMD into sensitive waterways. Metals are stored in a soluble phase in soil and rocks, and rainfall results in increased runoff and turbulence which causes the release of these metals back into the system. Extreme weather conditions along with poor maintenance may result in the pipes carrying AMD being damaged and leaking from these pipes may occur. Although measures have been put in place to treat AMD these must continue to be monitored, and facilities and infrastructure related to AMD should be maintained so as to prevent any further leakages in the future as the climate changes.

The potential climate change impacts on the water sector (including wetlands) in MCLM are summarized in Table 9.

Table 9: Potential climate change impacts on the Water sector in the region of MCLM.

Change in climate variable	Impact
Increased temperatures and heat waves	⇒ Increase in water temperature: ➢ Increase the rate of chemical and biological reactions in water; ➢ Alters water quality which can affect: • Agriculture through water for irrigation; • human health;

	• aquatic ecosystems and biodiversity ➢ Decreases the dissolved oxygen content of the water which: • promotes denitrification which promotes the growth of nitrogen-fixing bacteria; • can cause fish mortality ➢ creates optimal conditions for blue-green algae which could dominate for longer periods: • implications for wastewater treatment works ➢ Can create favourable conditions for the incubation and transmission of water-borne diseases ⇒ Increased water demand for: ➢ households (e.g. for watering gardens); ➢ industrial purposes; ➢ agriculture ⇒ Increased electricity demand for cooling buildings which will increase water withdrawals for cooling thermal power plants
Enhanced evaporation	⇒ Reduced water availability: ➢ Impacts on water resource management; ➢ Alters soil and water quality by concentrating salts and other constituents: • Impacts on wetland ecosystems; • Impacts agriculture ⇒ Reduction in stream flow: ➢ Impacts on wetland ecosystems
Increased total rainfall[13]	⇒ Increase in soil moisture: ➢ Reduced need for crop irrigation ⇒ Increased runoff ➢ Increase in water available for storage
Change in rainfall intensity; increase in extreme precipitation events	⇒ Increase in soil erosion and runoff: ➢ Causes increased accumulation of pollutants on the surface of the catchment ➢ Affects catchment wash-off processes; ➢ Affects scouring and erosion of streams ➢ Flooding of low lying areas; ➢ Damage to infrastructure: • Damage to water and sewage pipes; • damage to AMD pipes; ➢ Affects groundwater recharge ➢ Cause the release of metals (from AMD) back into the water system; ➢ Flooding of low lying water and waste-water treatment works which contaminates water leading to: • Increased rates of diarrhoeal diseases after floods in areas with poor infrastructure ➢ Can lead to surcharging sewers due to: • Pipe blockages; • Discharge of partially treated waste-water from over-loaded waste-water treatment works which in turn affects water quality
Increased variation in rainfall; shifts in seasonal temperature	⇒ Variation in water availability: ➢ Reduces the usable yield; ➢ Affects water supply for agriculture and electricity generation ➢ Can influence the spatial distribution, intensity of transmission, and seasonality of diseases transmitted by water-borne vectors ➢ Can affect biodiversity by altering spatial distribution of species due to a shift in favourable habitat conditions

[13] Models generally suggest that in the area of Gauteng rainfall will either remain the same or increase slightly hence the possible impacts of increased rain have been included. However, rainfall predictions are highly uncertain due to a lack of long term data and should be treated with caution. Increased monitoring of rainfall is essential for the improvement of future predictions.

5.2. Agriculture

Much of the food production and food security which may be at risk is linked to future projected water supply constraints, declines in water quality and competition from non-agricultural sectors. Water availability remains a major obstacle to the expansion of agriculture. There is evidence that subsistence dryland farmers are more vulnerable to climate change than commercial farmers (as they have limited capital to invest in soil fertilization, seed, and weed, pest and disease control), while large-scale irrigated production is probably least vulnerable to climate change, conditional upon sufficient water supply for irrigation being available (Schulze, 2010; Reid & Vogel, 2006; DAFF, 2013). A vulnerability ranking by province was conducted by Gbetibouo and Ringler (2009) and Gauteng provinces, with its high level of infrastructure development, high literacy rates, and low share of agricultural GDP, had a low vulnerability index (Figure 32).

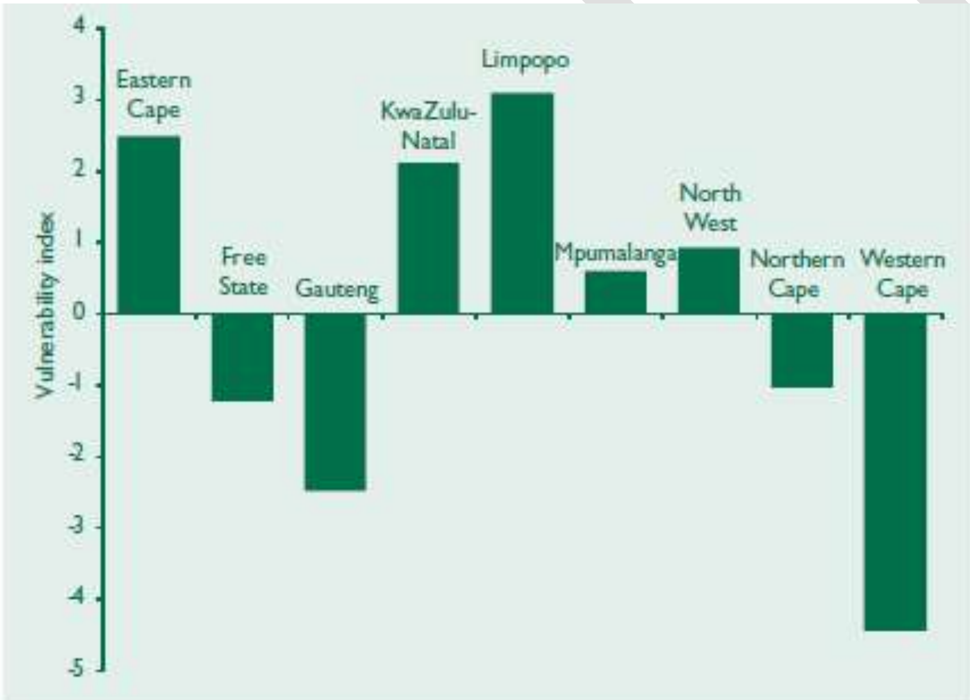

Figure 32: Vulnerability ranking in South Africa by province. (Source: Gbetibouo and Ringler, 2009)

Turpie and Visser (2012) used the Ricardian approach, with average climate data and predictions from the HadCM3 model, to estimate the future impacts of climate change (increased temperature and decreased rainfall) on revenue from subsistence and commercial farming. Results (Table 10) indicate that a simultaneous decrease in rainfall and increase in temperature will have adverse effects on both crop farmers and livestock farmers, and that the effects will be higher among the crop farmers. Mixed farmers are more immune to climate change and mixed farming is an adaptation strategy common among African farmers in response to anticipated undesirable farming seasons (Seo *et al.*, 2009; Nhemachena *et al.*, 2010). Horticulture also appears to be fairly resilience to climate change. An increase in temperature alone was shown to negatively affect net revenue more than a decrease in rainfall.

Table 10: Predicted change in revenue (%) for subsistence and commercial farmers in South Africa under increased temperature and decreased rainfall conditions (adapted from Turpie and Visser, 2012).

	Subsistence			Commercial		
	2020	**2050**	**2080**	**2020**	**2050**	**2080**
Increased temperature and decreased rainfall						
All farmers	43.7	-44.1	-150.7	0.3	-18.3	-110.9
Mixed farmers	14.7	18.3	30.4	-9.2	-19.1	-70.8
Crop farmers	-57.6	-62.8	-144.0	-5.8	-38.4	-146.3
Livestock farmers	70.2	-45.9	-127.7	-0.9	-19.0	-127.3
Horticulture farmers				7.8	-3.6	-84.6
Increased temperature						
All farmers	-8.4	-54.5	-177.2	-6.3	-24.0	-119.2
Mixed farmers	15.0	24.0	44.9	-14.2	-20.4	-74.1
Crop farmers	-1.6	-70.7	-139.7	-7.1	-34.9	-142.3
Livestock farmers	1.2	-37.3	145.4	-6.2	-23.8	-133.3
Horticulture farmers				-1.9	-20.7	-106.2
Decreased rainfall						
All farmers	52.1	10.4	26.5	6.6	5.8	8.3
Mixed farmers	-0.3	-5.7	-14.5	5.0	1.2	3.3
Crop farmers	-55.9	7.9	-4.3	2.4	-2.4	-2.7
Livestock farmers	69.0	-8.6	17.7	5.3	4.7	6.1
Horticulture farmers				9.7	17.1	126.3

These predictions show general trends but do not take into account the possible increase in rainfall in the North eastern regions of South Africa, which is likely to dampen these climate change impacts, or the increase in productivity due to the CO_2 fertilization effect[14]. For example, a 2°C temperature increase alone is projected to reduce maize profits by around R500/ha across the highveld maize region, but CO_2 fertilization may mitigate this loss almost completely (Midgley et al., 2007; Walker and Schulze, 2008). Even for a 10% rainfall decrease, the CO_2 fertilization effect increases profits by up to ~R1500 per hectare. CO_2 fertilization effects are however very uncertain and no local experiments exist through which these projections can be tested.

Climate change is expected to alter crop yields (for example, rainfed maize: Figure 33) and cause a shift in optimum growing areas of various crops (Figure 34) (DEA, 2013d). Sugarcane is one of the few crops that tend to show a strong potential for increased production even under hotter/drier

[14] Increased carbon storage by plants due to enhanced ambient CO_2 concentrations.

future scenarios (DEA, 2013d). On average the projected future changes in crop yield are relatively small despite climate change, since they are partly offset by assumptions of continued productivity gain due to crop genetics and agronomic practices.

Climate change is expected to lead to an increase in agricultural pests as their life cycles are closely related to temperature thresholds. Climate change will accelerate critical life stages, thereby increasing the potential for crop damage and increasing the cost of various forms of control (DEA, 2013d; Schulze, 2010).

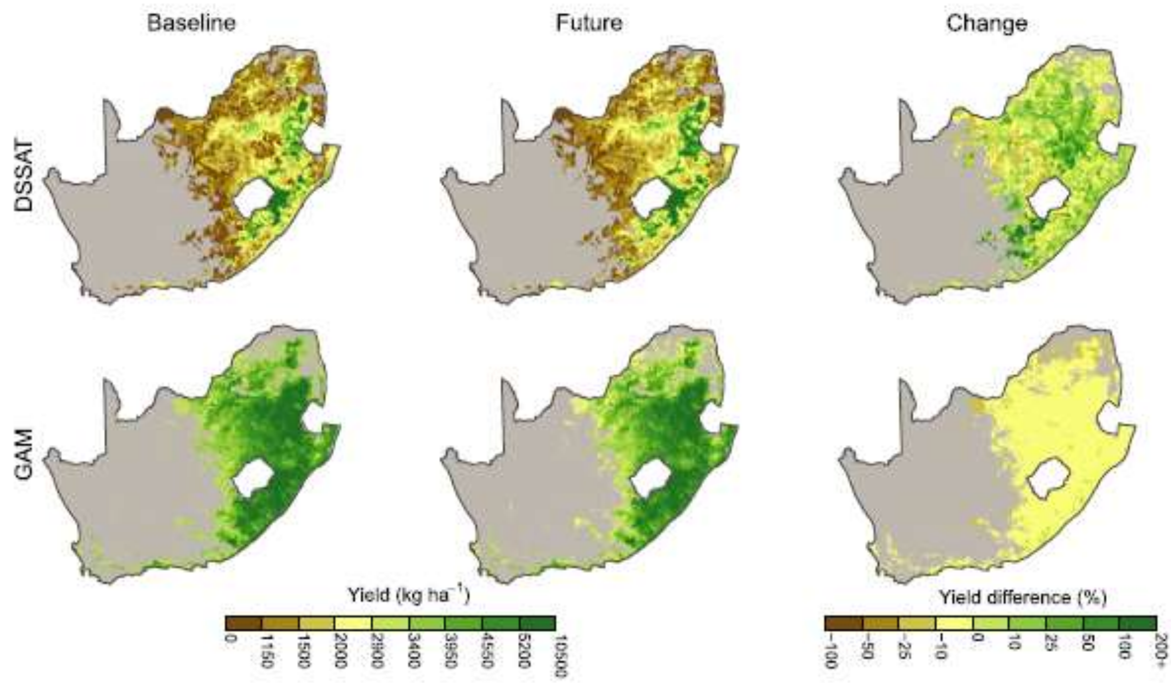

Figure 33: Median change in crop yields for rain fed maize by 2050 under a B1 SRES emission scenario. Top row is the simulation from the Decision Support System for Agrotechnology Transfers (DSSAT) model and the bottom is from the Generalized Additive Model (GAM). (Source: Estes et al., 2013)

In terms of livestock, an increase in temperature will lead to a greater number of days where the thermal tolerance of livestock is exceeded (Nesamvuni et al., 2012; DEA, 2013d). This causes heat stress and even death amongst the livestock population. Heat stress can also lead to reduced productivity. An increase in ventilation will be required in livestock housing units during summer, however one positive impact of climate change is that there will be a reduced requirement for heating during winter. The impact of climate change on rangelands is predicted to be positive, with the fertilisation effect of CO_2 outweighing the negative effects of reduced precipitation (REF??). Increased temperatures will be harmful to commercial livestock owners, especially cattle owners.

Owners of commercial livestock farms have few alternatives either in crops or other animal species. In contrast, small livestock farms are better able to adapt to warming or precipitation increases by switching to heat tolerant animals or crops. Livestock operations will be a safety valve for small farmers if warming causes their crops to fail (Seo and Mendelsohn, 2006).

Other impacts on the livestock farmers are an increase in pests and pathogens, increased risk of new diseases, changes in forage quality and quantity, changes in water quality and quantity, and behavioural and metabolic changes.

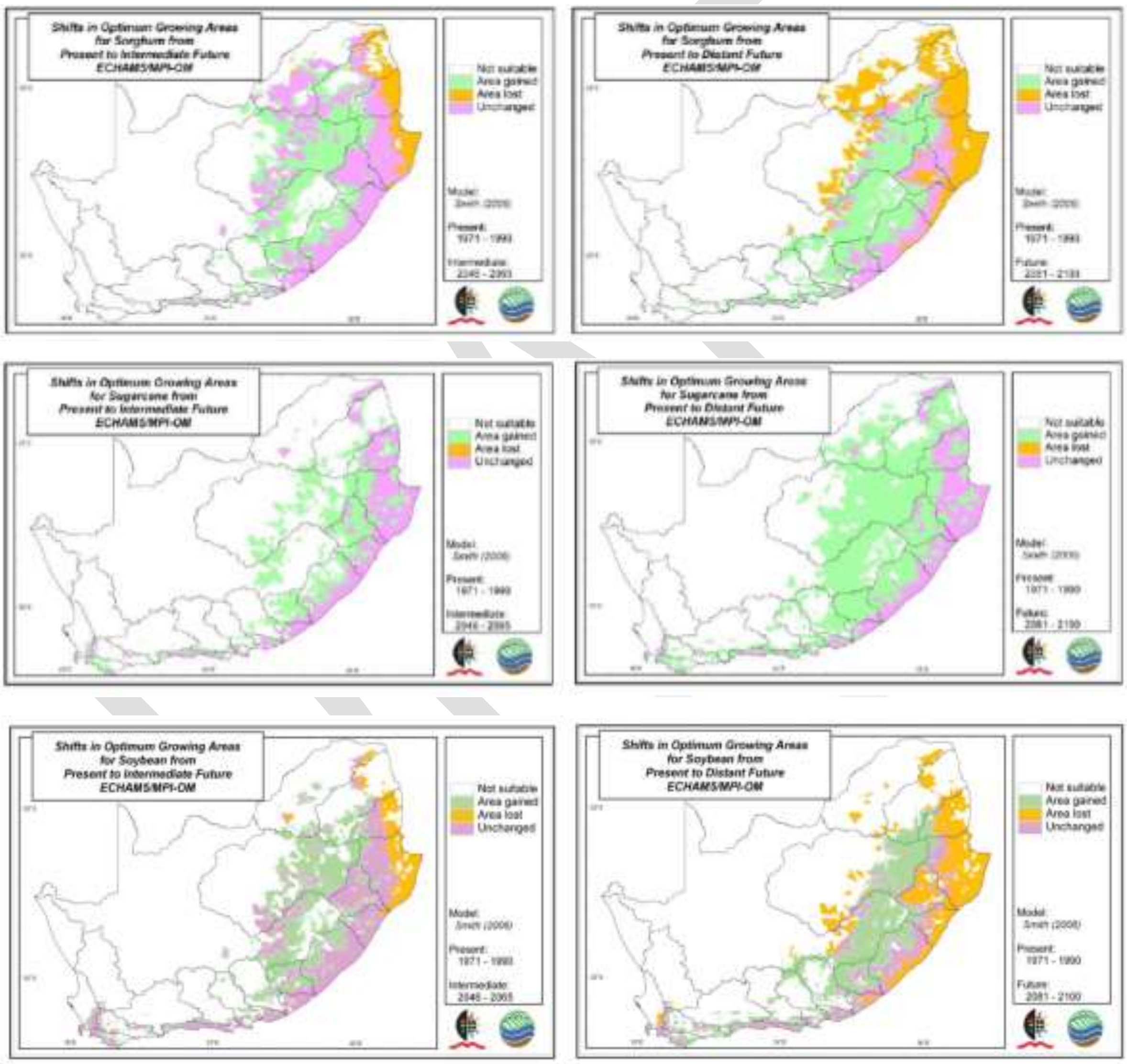

Figure 34: Shifts in optimum growing areas for sorghum (top), sugarcane (middle) and soybeans (bottom) between the present and intermediate future (left) and between the present and distant future (right) derived with the Smith model using outputs from the ECHAM5/MPI-OM GCM. (Source: Schulze and Kunz, 2010).

Climate change will also have an impact on the labour force in agriculture. An increase in thermal discomfort levels due to climate change, especially in summer months, implies a possible reduction in productivity of agricultural labourers (DEA, 2013d), specifically those engaged in operations with summer and with multi-year crops. This could have an impact on the working hours and starting times, and the workday may be required to have longer midday breaks.

The potential climate change impacts on the agriculture sector in the MCLM are summarized in Table 11.

Table 11: Potential climate change impacts on the agriculture sector in the region of MCLM.

Change in climate variable	Impact
Increased temperatures and heat waves	⇒ Crop impacts: ➢ reduction in crop productivity; ➢ increase in demand for water; ➢ soil degradation due to: • increased acidity; • alteration of nutrient concentrations; • declining microbial diversity; • negative effects on soil organic matter; ➢ alters the water quality through a change in nutrient and dissolved oxygen content; ➢ increase in spread of pests and pathogens ⇒ livestock impacts: ➢ increase in exceedance of the temperature thresholds above the thermal comfort zone of livestock: • induces behavioural and metabolic changes • alters growth rate, reproduction and mortality of livestock • reduction in livestock productivity; ➢ Increase in the spread of pests and pathogens • Possible increase in new animal diseases ➢ Increased heat stress means: • Increase in energy consumption for additional ventilation for broilers ⇒ Increase in number of dry days leads to an increased risk of fires ➢ Damages crops and pastures; ➢ Can cause death of livestock • These all impact food security and livelihoods; • Increased requirement for emergency services ⇒ Impacts on labour: ➢ Increase in the level of discomfort: • Reduces productivity of agricultural labour
Enhanced evaporation	⇒ Reduced water availability: ➢ Increased water demands for irrigation: • Increased environmental stress; • Increase in existing competition with other sectors for water ➢ Increased water demands for livestock ➢ Alters soil and water quality by concentrating salts and other constituents

	• Changes in forage quality and quantity: ○ reduction in livestock productivity

Increased total rainfall[15]	⇒ Increased soil water
	  ➢ Reduces demand for irrigation
	  ➢ Increases crop yields

Increase in winter minimum temperatures	⇒ Decreases the amount of chill units in a year which affects:
	  ➢ hormonal responses in plants relating to completion of seasonal dormancy;
	    ○ more difficult to produce chill-dependent deciduous fruits
	⇒ increase in winter temperatures can reduce cold stress experienced by livestock:
	  ➢ reduced energy requirements of feeding;
	  ➢ reduced requirement for heated housing facilities

Increase in frequency of extreme precipitation events	⇒ Increased frequency of floods, violent storms and hail storms which can cause:
	  ➢ Crop damage;
	  ➢ Soil erosion;
	  ➢ Death of livestock;
	  ➢ Increased risk from water-borne diseases:
	    • Impact on labour
	  ➢ Damage to infrastructure (bulk water infrastructure, irrigation systems, water reticulation, and roads)

Variation in rainfall frequency and timing; seasonal temperature variation	⇒ Changes in length of growing season:
	  ➢ Positive or negative impacts on crops depending on local topography, precipitation and crop type;
	  ➢ Can cause spatial shifts in the optimum growing regions for crops and pastures
	⇒ Increased variability and unpredictable timing of rainfall:
	  ➢ affects management of catchments and bulk water infrastructure
	    • threatens water availability
	  ➢ affects farmers ability to predict the timing for planting of crops
	    • subsistence farmers practising rain-fed agriculture are particularly at risk

CO_2 fertilization	⇒ increases crop growth and yield ⇒ increase in invasive alien species in rangelands

5.3. Human health

Climate change affects the fundamental requirements for health – safe drinking water, clean air, sufficient food and secure shelter, and has many direct and indirect adverse health impacts with indirect impacts being extensive (Rao et al., 2010; DEA, 2013c). Direct impacts are from extreme weather events such as anomalous temperature and precipitation, storms, and natural disasters (Samet, 2009; WHO, 2009). Indirect impacts include socially mediated risks (e.g. displacement, conflict, damaged infrastructure, crop failure) and/or ecologically mediated risks (e.g. air, food, water, vectors) (DEA, 2013c; Samet, 2009; WHO, 2009; Abson et al., 2012; Tanser et al., 2003). The indirect impacts are difficult to study and their causal processes and effects are not easily quantified. Figure 35 summarises the main pathways by which climate change can affect population health. The

[15] Models generally suggest that in the area of Gauteng rainfall will either remain the same or increase slightly hence the possible impacts of increased rain have been included. However, rainfall predictions are highly uncertain due to a lack of long term data and should be treated with caution. Increased monitoring of rainfall is essential for the improvement of future predictions.

health effects of climate change are not uniform and will be influenced by local environmental conditions, socio-economic circumstances, and the extent of adaptations implemented.

To date, most of the climate change research has focused on the health of the general population rather than on occupational health and safety outcomes. Figure 36 provides a framework for the possible occupational health impacts. The other aspect which is often overlooked is the psychological effects of climate change and how it affects mental health (Figure 37).

The potential climate change impacts on human health are summarized in Table 12.

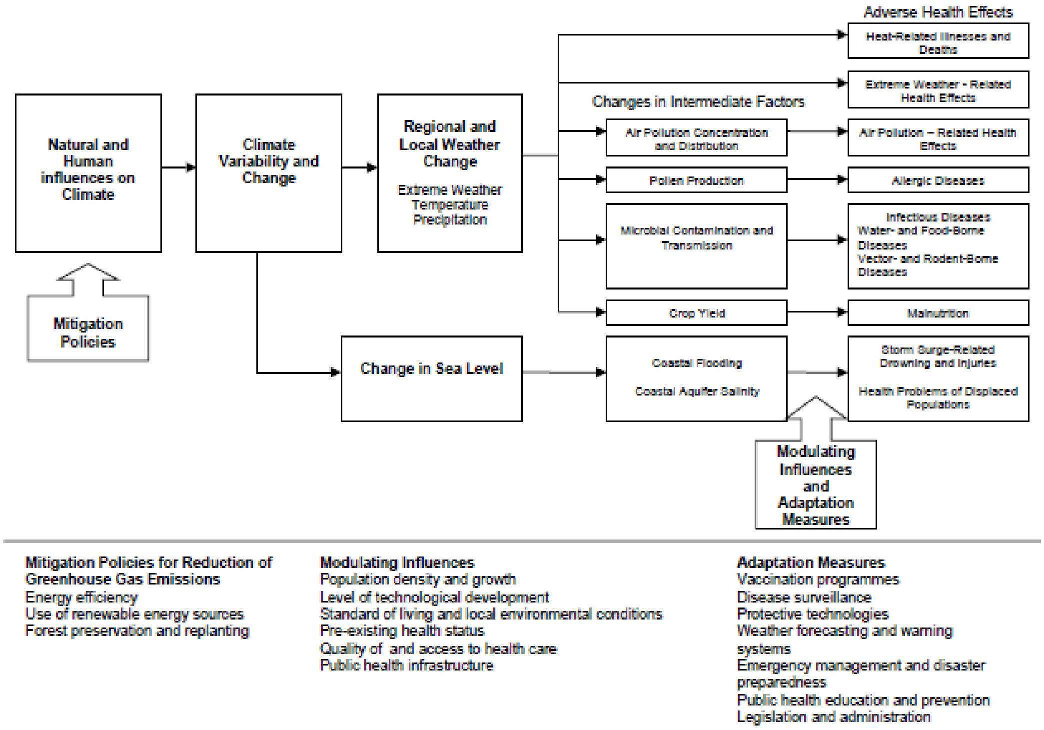

Figure 35: Potential health effects of climate variability and change (Source: Haines and Patz, 2004).

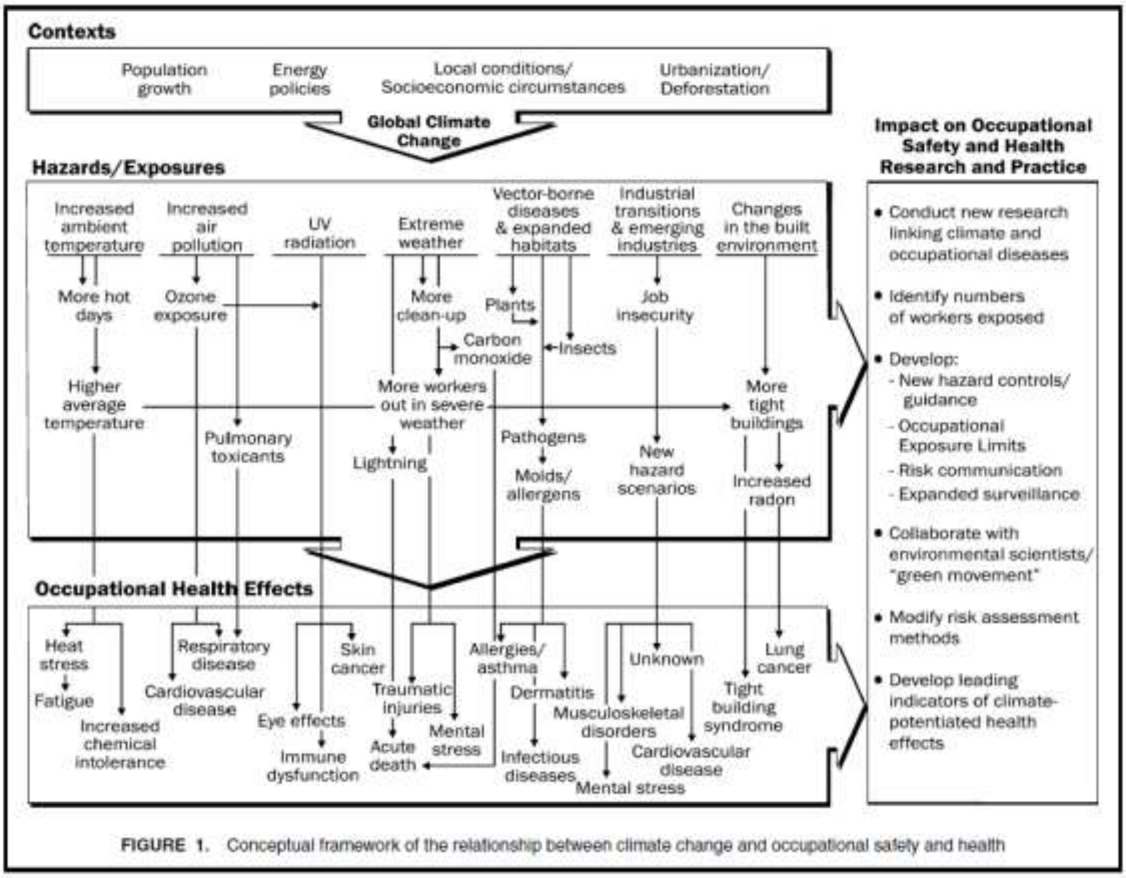

Figure 36: Conceptual framework of the relationship between climate change and occupational safety and health. (Source: Schulte and Chun, 2009; DEA, 2013c)

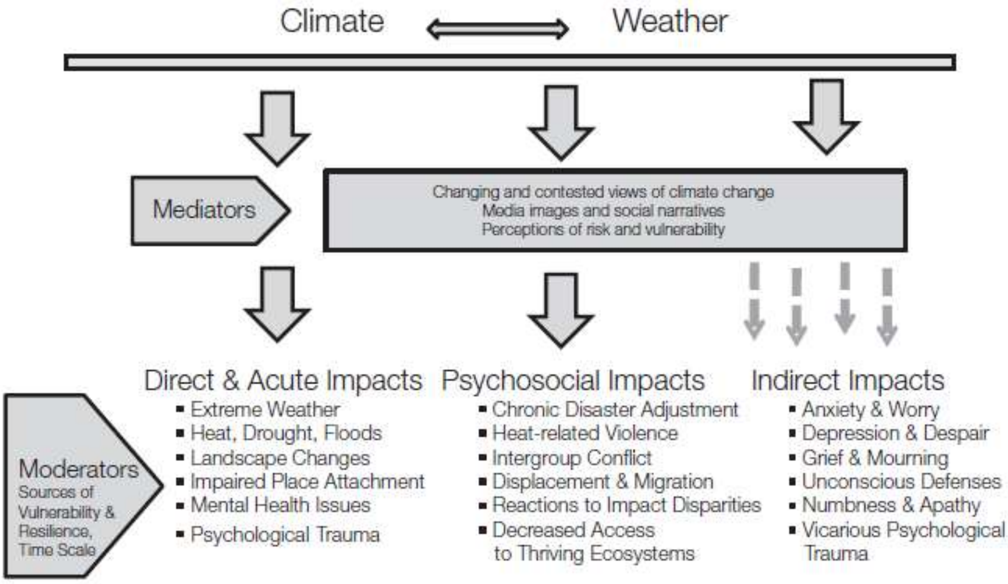

Figure 37: Climate change: differentiating between classes of psychological impacts (Source: Doherty and Clayton, 2011).

Table 12: Potential climate change impacts on human health.

Change in climate variable	Impact

Increased temperatures and heat waves; enhanced evaporation	⇒ Increase in heat related illnesses (heat stress, and respiratory/cardiovascular diseases)
	  ➢ increased emergency room or hospital visits
	  ➢ increased mortality
	⇒ Increase in dehydration
	⇒ Increase in vector-borne diseases (malaria, dengue fever, yellow fever, Lyme disease)
	⇒ Impacts on occupational health, particularly where work is being done in hot environments:
	  ➢ Impacts on work/rest cycles, access to water, access to shading
	  ➢ reduces labour productivity
	  ➢ increases the number of days of sick leave
	    • this all has economic implications (reduced productivity, increases insurance costs, increased labour costs to hire additional workers);
	    • also impacts on poverty levels
	⇒ Increased demand on health facilities and emergency services

Increase in winter minimum temperatures	⇒ Decrease in illness and death associated with colder conditions

Increase in frequency of natural disasters (fires and flooding)	⇒ Increase in injury or death
	  ➢ Impacts on poverty
	⇒ Increase in water-borne infectious diseases (e.g. cholera, dysentery, typhoid);
	⇒ Increase in diarrhoeal diseases due to:
	  ➢ Contamination of water by flooding of low lying water and waste-water treatment works;
	⇒ Increase in burns and smoke inhalation due to fires;
	⇒ Increased trauma which leads to:
	  ➢ A decrease in psychological health;
	  ➢ An increase in psychiatric disorders and mental illnesses;
	  ➢ An increase is substance abuse and substance use disorders
	⇒ Increase in health effects associated with population displacement;
	⇒ Impacts on occupational health:
	  ➢ Workers involved in rescue and clean-up efforts could have more exposure to risky conditions
	⇒ Infrastructure damage can cause delays in emergency response times and inaccessibility to some areas;
	⇒ Increased risk of hospital and emergency admissions

Variation in rainfall timing; seasonal temperature variation	⇒ Extension of hot wet season could lead to longer periods of exposure to vector-borne infectious diseases

5.4. Biodiversity and ecosystems

The economic value of ecosystems and biodiversity is increasingly being recognized and globally ecosystem services have been suggested to have a value equivalent to the global gross national product (Midgley et al., 2007). Climate change and rising atmospheric CO_2 will change the suitability of the environment for South Africa's nine different biome types, with some biomes thriving and expanding under the changing conditions and other biomes shrinking as a result (Figure 38) (DEA, 2013e). The adverse impacts of climate change on South Africa's biomes will be exacerbated by loss of habitat driven by land use change. Rising CO_2 concentrations (Baker and Enoch, 1983; Keeling *et al.*, 1995) have an influence on climate, but it also has a direct, measurable effect on plant growth. Plants tend to grow better under conditions of higher CO_2 levels and this has been termed the 'CO_2 fertilization effect'. Under elevated CO_2 plants increase their photosynthetic rates (Norby et al. 1999, Kimball et al. 2002, Nowak et al. 2004), increase their biomass, have improved, improved water use efficiency, and an increased tolerance of low light levels. Expected increases in growth may be short-lived if other nutrients and resources become limited.

While CO_2 enrichment may have positive carbon sequestration benefits due to increased carbon storage, there are also negative implications for the biodiversity of open grassland and savanna habitats. Trees and grasses differ physiologically in that trees use the C_3 photosynthetic pathway, whereas grasses use the C_4 photosynthetic pathway. Under high temperatures and low CO_2 concentrations C4 plants are favoured, and *vice versa* A doubling of CO_2 concentration from 350 to 700 ppm and a 2–5 ^{o}C increase in temperature will favour trees over grasses (Higgins & Scheiter, 2012). Therefore it is the Grassland biome that is most threatened by climate change because of the expanding woody vegetation. Grasslands also face considerable ongoing loss of habitat due to land use change, which has already caused a 60% reduction in Grassland coverage over the past two centuries.

The shift from grass to more woody plants under future climate conditions could have further negative impacts. The threat on wildlife populations and water supplies may increase, as trees and shrubs use more water than grasses. It could even amplify global warming, since trees, being generally darker than grasses, can absorb more solar radiation.

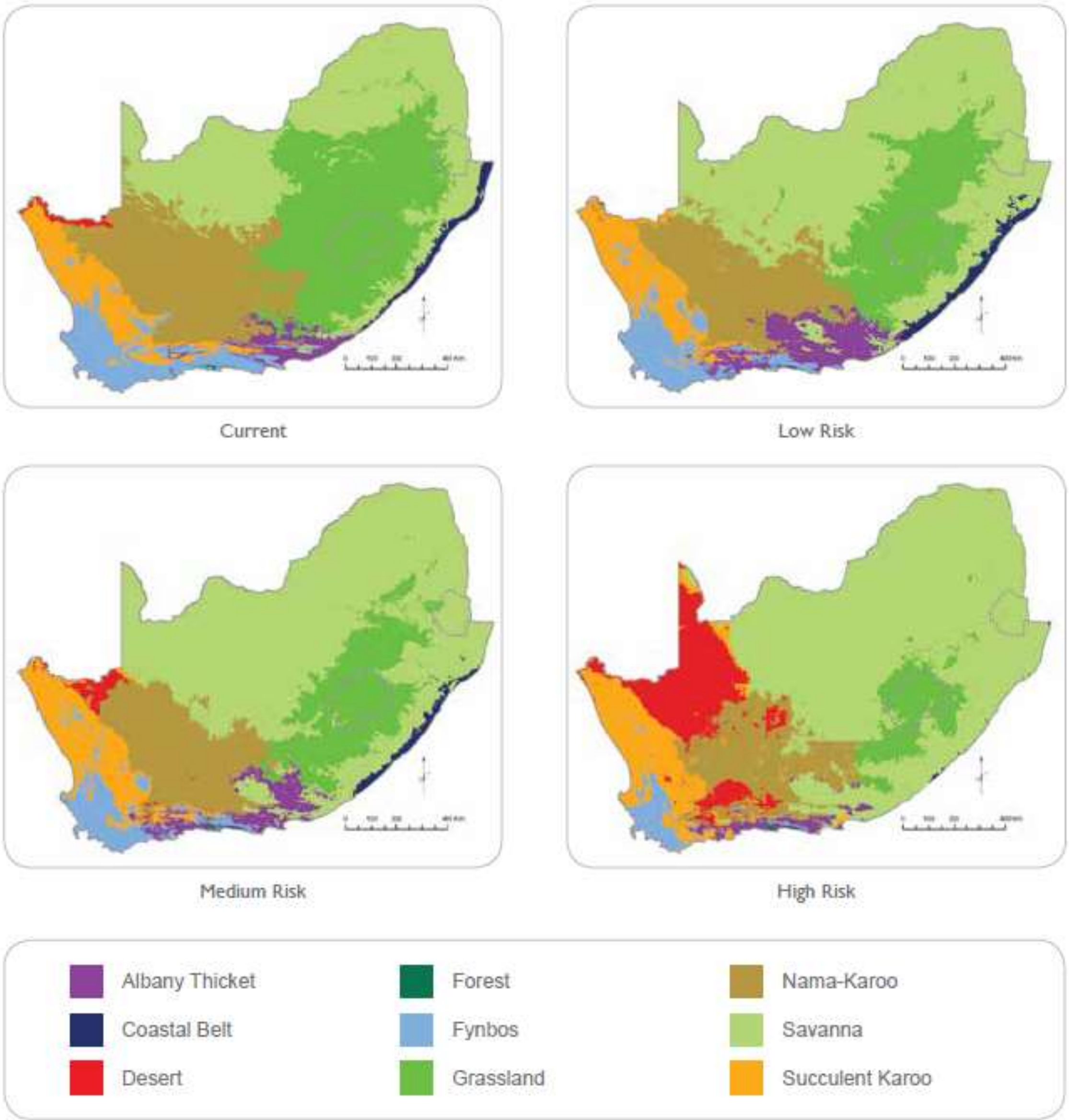

Figure 38: Projections of bioclimatic envelopes under statistically downscaled climate scenarios, looking ahead to approximately 2050. Low Risk: impacts of wet/cool future climate projections; High Risk: impacts of dry/hot projections, Medium Risk: median temperature and rainfall projections (Source: DEA, 2013e).

Savanna and arid grassland ecosystems in the summer rainfall region may store between ~20 and 600% more carbon in the future due to temperature, rainfall and CO_2 fertilization effects, but this will depend to a large extent on future fire regimes (Midgley et al., 2007). Fire is an important component of South Africa's dominant ecosystems as they often determine how much woody growth occurs in an area. Under future climate conditions fire regimes are projected to show a greater frequency and possible increase in mean size due to the prevalence of higher fire risk conditions for longer periods of time. This could also affect the area of Grasslands and Savannahs in particular.

Invasive alien species are successful and adapt faster than indigenous species mainly because they do not have pests and parasites to limit their productivity and distribution. For this reason, they have a competitive advantage over and adapt faster than local indigenous species. It is also possible that new invaders, or established alien species that are currently not invasive, could suddenly take advantage of a changing climate to out-compete local species. Invasive plants are not only detrimental to native biodiversity but often pose a major threat to water security by using more water than indigenous plants.

Climate change is likely to have significant impacts on biodiversity: on ecosystems, species, genetic diversity within species, and on ecological interactions. There is an ever-increasing body of evidence demonstrating that the distribution, composition, structure and function of ecosystems are starting to respond to changes in temperature, precipitation and increased CO_2 levels (Campbell et al. 2009). There is also some evidence of changes in species richness of birds (Erasmus et al., 2002) and alteration of bird migration patterns. The potential climate change impacts on terrestrial ecosystems and biodiversity in the region of MCLM are summarized in Table 13.

Table 13: Potential climate change impacts on terrestrial ecosystems and biodiversity in the region of MCLM.

Change in climate variable	Impact
Increased temperatures with increased evaporation	⇒ Increased heat stress and reduction in water availability: ➢ Extinction of some species and introduction of others ➢ Increase in pests (e.g. bark beetle) and pathogens which could affect some plant species; ➢ Reduced runoff and stream flow which can impact on wetlands; ➢ Alters water quality o Impacts on wetlands and their biodiversity ⇒ Increased number of dry days leading to increased risk of fire frequency: ➢ Could cause extinction of some species; ➢ Increased disturbance: • Increase in alien invasive species moving into disturbed areas as they adapt quicker than the native vegetation o this has implications for water; o alien invasive species generally burn more readily, therefore increasing fire intensity; ➢ physical damage to the soil: • increased soil erosion
Changes in frequency of floods	⇒ Increased flooding can cause: ➢ Increased soil erosion and possible mudslides; • Degradation of landscape;

	➢ Degradation of vegetation in wetland and riverine systems ⇒ Increased runoff in agricultural areas can cause an increase in eutrophication ➢ Increased fish mortality; ➢ Increase in invasive alien species in wetland and riverine systems • affects water availability ⇒ Increase in disturbance: ➢ Creates gaps which leads to: • Increase in alien invasive species as they adapt quicker than the native vegetation ○ implications for water use and fuel wood availability
Variation in rainfall and seasonal temperature	⇒ Causes shifts in the climate envelope suitable for the various biomes: ➢ Decrease in grassland biome ➢ Increase in savanna biome • Can affect fuel wood available for rural communities ⇒ Can affect biodiversity by causing shifts in species ranges ➢ extinction of some and an increase in range for other species; ➢ increasing asynchrony in predator-prey and insect-plant systems ➢ contraction of wildlife species ranges due to shifting ranges and restrictions due to conservation area boundaries: • this can in turn affect tourism and the economy ⇒ Early onset of spring conditions leads to: ➢ advance of spring events (bud burst, flowering, breaking hibernation, migrating, breeding) ➢ altered growing season will have implications for agriculture, as well as tourism ⇒ unpredictable rainfall can alter bird breeding and migration patterns
CO_2 fertilization	⇒ increase in tree cover; ➢ increase in savanna biome; ➢ increase in invasive alien tree species: • decreased biodiversity; • increase in fire intensity; ➢ alteration of species composition; ➢ possible reduction in visibility of wildlife

5.5. Human settlements and infrastructure

Urban areas already face significant climatic and environmental challenges that are independent of climate change, such as the urban heat island effect, air pollution, and existing climate extremes. Urban areas also often have high concentrations of solid and liquid wastes, large areas of impermeable surfaces such as roads that accelerate runoff and disrupt natural drainage patterns and are frequently co-located with hazardous industrial sites (chemical and oil refineries, for example), and toxic pollution which may cause major health disasters if damaged due to conflict, storm or other damaging events. Climate change adds to the existing challenges and impacts the cities in a variety of ways. Some of the impacts include an exacerbation of the urban heat island effect (Box 5) leading to increased risk of heat-related mortality and illness (EPA, 2008); increased demand for cooling and reduced demand for heating; decreased water and air quality; wider geographical incidence of vector-borne diseases; and an increase in disruptions of public water supply, sewer systems, transport, commerce and economic activity due to increased extreme events. Climate change can also impact buildings and sub-structures by causing damage to foundations and sub-structure concrete due to subsoil water; and by causing an increased risk of cracking due to differences in thermal or moisture movements (Graves and Phillipson, 2000). More extreme wetting and drying cycles can also result in greater soil movement and make water and sewerage pipes more prone to cracking.

The rapid influx of people into overcrowded urban areas with large service delivery backlogs can lead to the formation of informal settlements which are often found in vulnerable locations, such as on the banks of streams, on steep hillsides or marshy areas. It is estimated that up to half of all informal dwellings in South Africa can be classified as vulnerable to environmental factors. Current vulnerabilities to floods and fires in informal settlements are exacerbated by location in flood- and ponding-prone areas, the use of inferior building materials, structures built on sand dunes, and inadequate road access for emergency vehicles

Rural populations of the country are the most vulnerable to climate change because they experience the highest levels of poverty and are most dependent on natural resources. Rural communities experience multiple stressors, such as ill health, deteriorating social networks, poor access to basic services, unequal land distribution, poverty, and low levels of education and unemployment. During periods of climate stress these multiple stressors become more pronounced and more challenging to cope with (Reid & Vogel, 2006).

Small-scale and homestead food production are practiced in rural areas and these are particularly vulnerable to climate variability. Climate change will alter the productive capacity of the land and this will lead to negative impacts on the employment and food security of rural dwellers (DEA, 2011). The supply of water is expected to become increasingly erratic with increasing changes in the climate. In many rural areas, lack of managed services means that people rely on unmanaged local resources such as springs and rivers, which are ultimately vulnerable to pollution and drought. Flooding can have catastrophic results for communities and subsistence livelihoods (DRDLA, 2013).

Another big problem with rural areas is that they are the least monitored for climate changes and weather variability and therefore receive little institutional and national support (DEA, 2011).

The potential climate change impacts on human settlements and infrastructure are summarized in

Table 14.

BOX 5: Urban heat island effect

Many urban and suburban areas experience elevated temperatures compared to their outlying rural surroundings (Figure B5.1); this difference in temperature is what constitutes an urban heat island. The annual mean air temperature of a city with one million or more people can be 1 to 3°C warmer than its surroundings, and on a clear, calm night, this temperature difference can be as much as 12°C. Even smaller cities and towns will produce heat islands, though the effect often decreases as city size decreases.

In rural areas, vegetation and open land typically dominate the landscape (Figure B5.2). Trees and vegetation provide shade, which helps lower surface temperatures. They also help reduce air temperatures through a process called evapotranspiration, in which plants release water to the surrounding air, dissipating ambient heat. In contrast, urban areas are characterized by dry, impervious surfaces, such as conventional roofs, sidewalks, roads, and parking lots. As cities develop, more vegetation is lost, and more surfaces are paved or covered with buildings (Figure B2.2). The change in ground cover results in less shade and moisture to keep urban areas cool. Built up areas evaporate less water, which contributes to elevated surface and air temperatures. Properties of urban materials, in particular solar reflectance, thermal emissivity, and heat capacity, also influence urban heat island development, as they determine how the sun's energy is reflected, emitted, and absorbed.

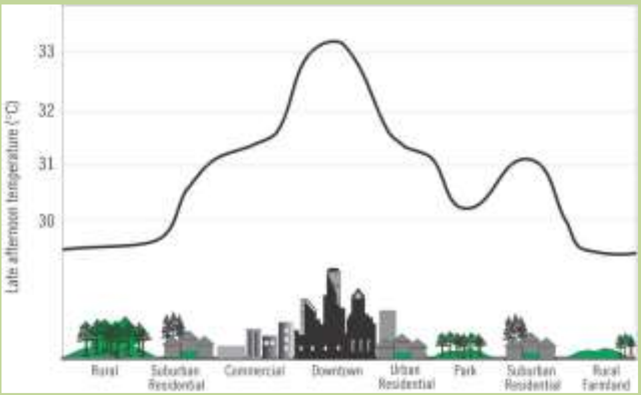

Figure B5.1: An illustration of the relative air temperatures over various land uses (Source: EPA, 2008)

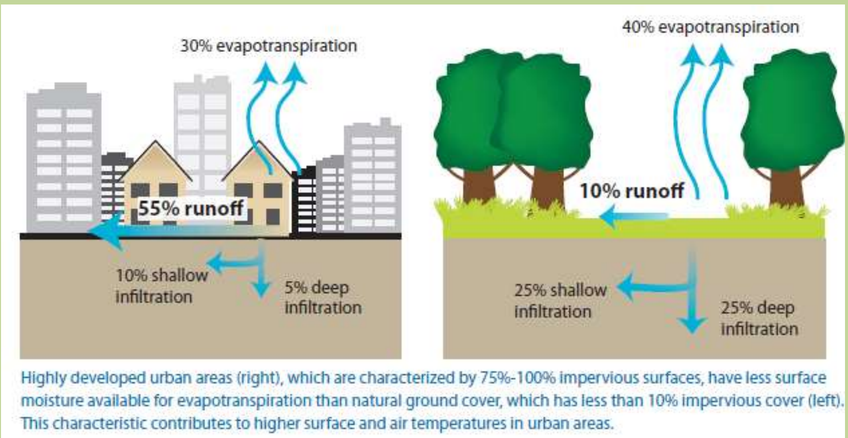

Figure B5.2: Diagram illustrating some factors contributing to the heat island effect.

Table 14: Potential climate change impacts on human settlements and infrastructure in the region of MCLM.

Change in climate variable	Urban impact	Rural impact
Increased temperatures and heat waves	⇒ Urban heat island effect; ⇒ Increased human discomfort: ➢ higher energy consumption in buildings for cooling ⇒ Negative impacts on health due to: ➢ heat stress • possible increase in deaths; ➢ Increase in vector-borne diseases (e.g. malaria, ticks) • Puts a strain on emergency services and health care facilities	⇒ Increase in human discomfort; ⇒ Negative impacts on health due to: ➢ heat stress • possible increase in deaths; ➢ Increase in vector-borne diseases (e.g. malaria, ticks) • Puts a strain on emergency services and health care facilities ⇒ Soil degradation due to increased acidity, nutrient depletion, declining microbial diversity, lower water retention and increased runoff; ⇒ Crop and livestock production reduced due to: ➢ Increased evapotranspiration and decreased water availability; ➢ altered soil and water quality; ➢ affects type of crop that can be grown; ➢ reduced pasture quality; ➢ increased prevalence of pests and pathogens; • all impacts on food security and livelihoods ⇒ increase in number of dry days leads to: ➢ decreased stream flow • affects livelihoods particularly in communities dependent on surface water resources; ➢ increased risk of wild fires: ➢ damage to crops, pastures and livestock; • damage to personal property; • damage to infrastructure; • increased requirement for emergency services o all of these lead to increased costs
Increase in minimum temperatures	⇒ Warmer conditions, especially in winter: ➢ Decrease in energy consumption due to warmer buildings	⇒ Decreased chill unit which means a possible decrease in yield of some crops
Increase in extreme precipitation events	⇒ Floods and storm surges damage infrastructure; ⇒ Damage to communication or energy network lines ➢ affects economy, social, health;	⇒ Increase in storms, floods and hail storms which cause: ➢ damage to houses; ➢ Increased runoff which causes soil degradation; ➢ damage to crops and pastures;

	⇒ Inability to guarantee utilities; ⇒ Floods and hail storms cause damage to personal property ➢ affects insurance costs	➢ increased water logging impacts crop production; ➢ disruptions ecosystem services with threatens livelihoods, housing and infrastructure; ➢ increased damage to infrastructure: • road damage which can lead to some rural areas being cut off; ○ affects service delivery ⇒ Increase in lightening ➢ increased fatalities ⇒ Strain on emergency services due to: ➢ Increase in water-borne diseases; ➢ Increase in injury due to violent storms, hail storms and floods
Seasonal changes in temperature and rainfall; increased precipitation variability		⇒ Alteration in length of growing season: ➢ Positive or negative impacts on crops and growing season length depending on local topography, precipitation and crop types: • Affects crop selection ⇒ Increased variability in rainfall pattern affects farmers ability to predict time of plants for crops ➢ Subsistence farmers practicing rain-fed agriculture are most at risk

5.6. Tourism

Climate change is thought to pose a risk to future economic growth. Any reductions in the global GDP due to climate change would reduce the discretionary wealth available to consumers for tourism and would have negative implications for future growth in tourism.

Tourism in South Africa is closely linked to the environment as it relies heavily on its natural resource base (biodiversity, fauna and flora) to attract tourism. Wildlife is the primary reason for visiting the country for some 36% of international tourists. A loss in biodiversity and a degradation of the landscape due to increased disturbance (fire, floods) and an increase in alien invasive species could lead to a reduction in tourism.

The other aspect that attracts tourists to SA is the weather and this will change in the future due to climate change. An increase in heat waves will lead to an increase in discomfort levels (Figure 39), while an increase in rainfall intensity and floods could cause interruptions in service delivery (electricity, waste removal, internet), impact transport (flight delays, road closures) and alter the attractiveness of the landscape (Golder Associates, 2012). This will all negatively impact the tourist experience. Climate change is also likely to cause an increase in pests and could increase the malaria risk, which will add to the increased discomfort of the visitor’s experience.

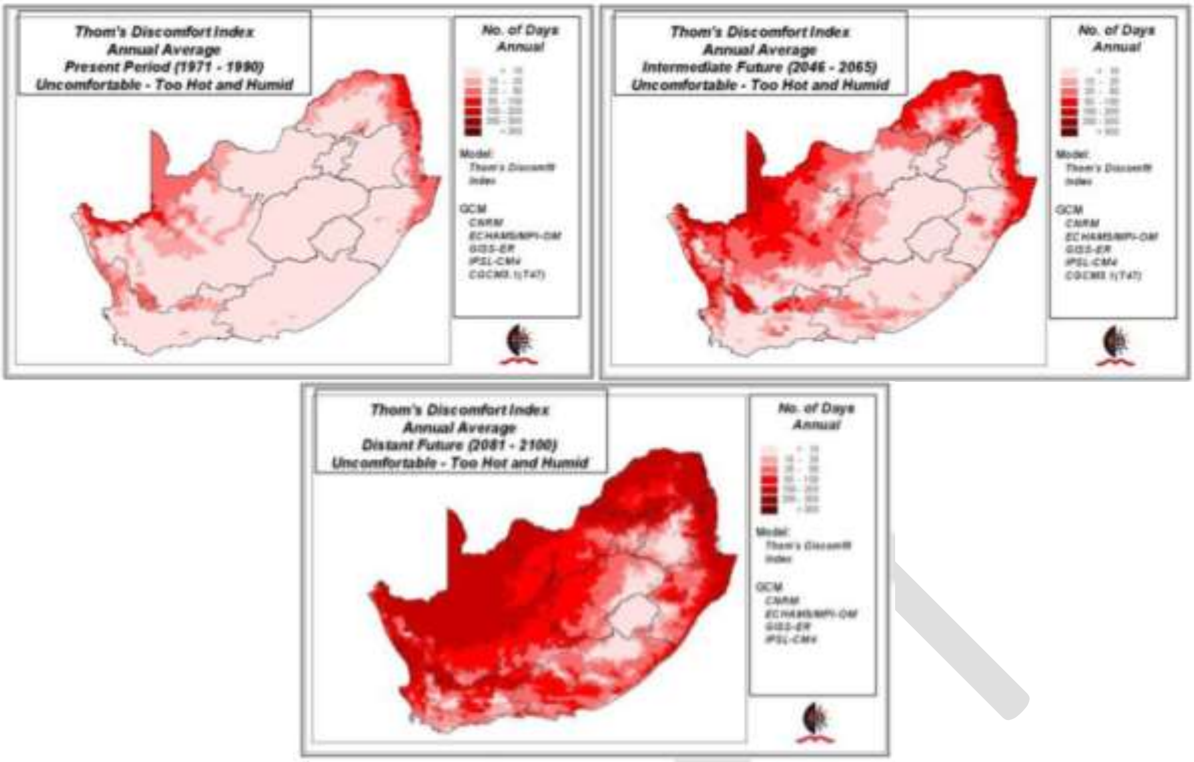

Figure 39: The average of the number of uncomfortable days per annum according to Thom's human discomfort index, derived from daily climate output of 5 GCM's for present (1971-1990), intermediate future (2046-2065) and more distant future (2081-2100) climate scenarios. (Source: DEA, 2013d)

Potential negative impacts of climate change on the tourism sector are also likely to affect economic elements such as job creation and livelihoods dependent on this sector, and consequently wealth and well-being.

The potential climate change impacts on tourism in the MCLM are summarized in Table 15.

Table 15: Potential climate change impacts on tourism in the region of MCLM.

Change in climate variable	Impact
Increased temperatures; increased heat waves	⇒ increased discomfort levels: ➢ Influences the tourism experience and may lead to a reduction in visitors; ➢ increases electricity costs due to increases demand for cooling ➢ increases the load on health care facilities and emergency service ⇒ increased evaporation means a reduction in water availability ➢ competition for water resources ⇒ increased health risks due to: ➢ Extended range of pests and diseases (e.g. malaria); • increases the load on health care facilities and emergency service ⇒ higher rates of refuse decay which means ➢ increased costs due to more frequent waste collection

	⇒ Impacts on nature-based tourism due to: ➢ Biodiversity alteration or loss; ➢ Reduced landscape aesthetics; ➢ Possible increase in the extent of invasive alien species • bush encroachment can reduce visibility for game viewing; ➢ Heat stress in game, so could reduce animal visibility due to animals spending more time resting in the shade; ➢ Decreased water quality; ⇒ possible increase in fires which can cause service disruption; ➢ impacts on emergency service; ⇒ Land-use conflicts between agriculture and conservation for tourism ⇒ Impacts on food production, which has implications for tourism
Changes in frequency and intensity of rainfall events	⇒ Impacts on tourism experience due to: ➢ flooding (bad weather); ➢ disruption of access routes ➢ degradation of environmental resources and heritage sites; ⇒ Increased extreme events can cause: ➢ a decline in landscape aesthetics; ➢ infrastructure damage; ➢ increased erosion and sedimentation in green areas; ➢ increasing vector-borne diseases; ⇒ increased risk of disease due to increased vectors in ponding water; ➢ increases the load on health care facilities ⇒ Stress on sewage systems and storm water infrastructure ⇒ Increases costs due to: ➢ Road maintenance or repair ➢ Emergency preparedness requirements; ➢ Increased operating costs: • Insurance; • backup water and power; • evacuations; ➢ Business interruptions.
Variation in length and quality of seasons	⇒ Implications for competitive relationships between destinations ➢ This can affect the profitability of tourism enterprises ⇒ Impacts on nature-based tourism due to: ➢ alterations of animal and plant assemblages due to a change in the ecological ranges of fauna and flora
CO_2 fertilization	⇒ impacts nature-based tourism due to enhanced tree growth which: ➢ impacts on game viewing visibility ➢ increases invasive alien species which reduces game viewing visibility and biodiversity; ➢ cause the expansion of savannahs and reduction in grasslands • implications for faunal and floral biodiversity

6. CLIMATE CHANGE ADAPTATION STRATEGY

Municipalities are well placed to develop and implement effective adaptation strategies. They are the site of government closest to people, local knowledge and experience. An adaptation strategy should be a systematic, proactive and coordinated response to enhanced climate variability and projected climate change.

Adaptation refers to the adjustments that human or natural systems make in response to real or projected climate changes so as to reduce the impacts or take advantages of possible opportunities (IPCC TAR, 2001). Three types of adaptation can be distinguished, namely: *anticipatory adaptation* (or proactive adaptation) takes place before impacts of climate change are observed; *autonomous adaptation* (or spontaneous adaptation) does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems; and *planned adaptation* is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

A study by Yohe et al. (2006) shows the global distribution of vulnerability in 2050 (Figure 40) as affected by the implementation of enhanced adaptation strategies. It shows that vulnerabilities are decreased in response to enhanced adaptation. It is therefore important to start implementing adaptation strategies immediately so as to improve resilience to future climate change.

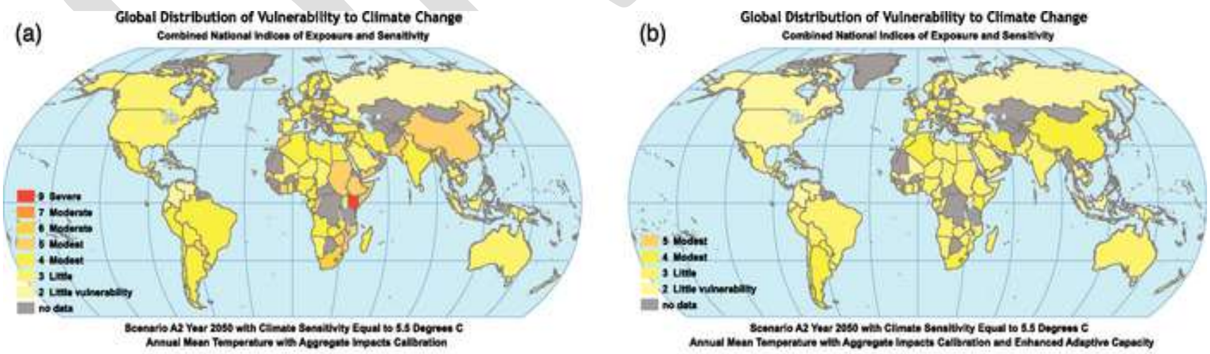

Figure 40: Geographical distribution of vulnerability in 2050 with and without adaptation along an SRES A2 emissions scenario with a climate sensitivity of 5.5°C. (a) portrays vulnerability with a static representation of current adaptive capacity. (b) shows vulnerability with enhanced adaptive capacity worldwide. (Source: Yohe et al., 2006).

6.1. Water sector

Water planning in South Africa occurs at the national scale, WMA or system scale as well as the sub-catchment or municipal scale (Figure 41). The multifaceted planning regime will be central in the development and implementation of adaptive responses to climate change (DEA, 2013b).

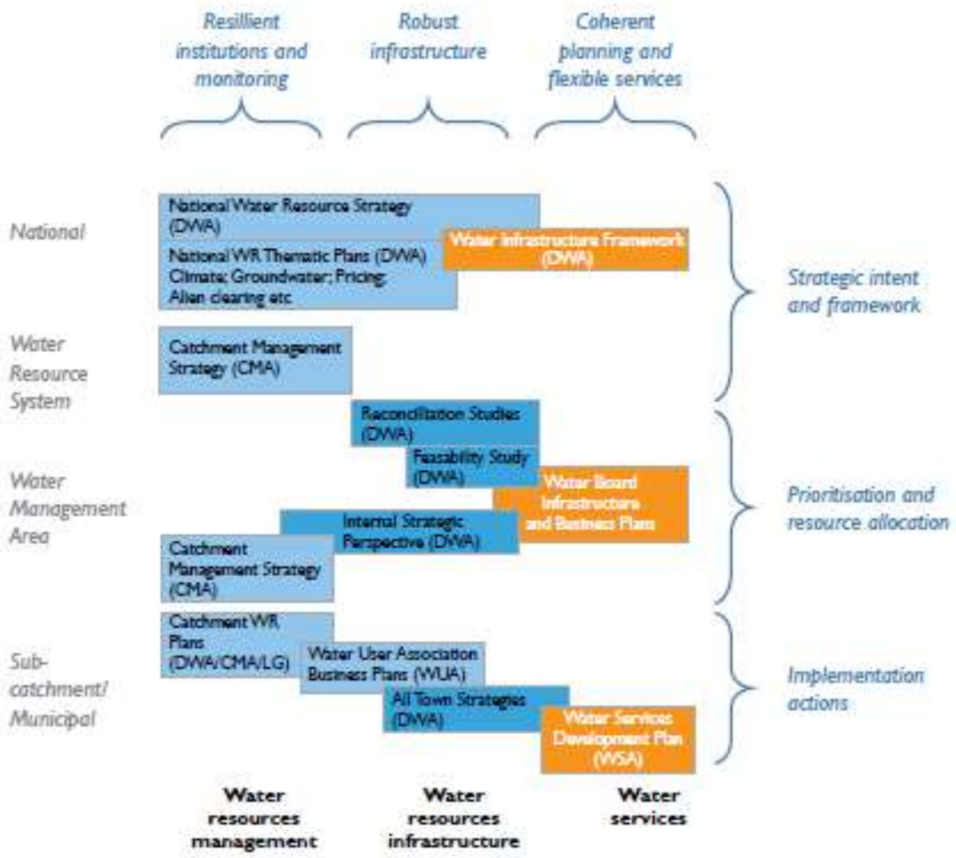

Figure 41: Climate adaptation interventions with reference to the water planning framework (Source: DEA, 2013b)

Due to the increasing demand for water, water conservation and demand management are critical. In the long-term, while surface water will remain the predominant source of water, the Department of Water Affairs (DWA) expects surface water to contribute proportionately less with proportionately significant increases in return flows through the treatment of urban and mining effluent and desalination. Table 16 provides a high level perspective of the potential shifts in the water mix being anticipated by DWA. Local surface water resource development in the Crocodile (West) River catchment has reached its maximum potential (Crocodile River (West) ISP, 2004) and no further viable major developments in this regard are expected in future. Local water resources, including natural runoff and return flow, are not fully utilised and a major part of the water used within the catchment are imported already, so it is suggested that attention rather be given to optimising the use of local resources (including groundwater) and return flows.

Table 16: A long term national view of the potential combination of main water sources (DAFF, 2009).

Water source	2008	Mid-term 2025	Long-term 2040
Surface water	77%	72%	65%
Groundwater	8%	9%	10%
Re-turn flows (irrigation, treated effluent and mining)	15%	17%	22%
Desalination	<1%	2%	3%

The dolomite in MCLM is regarded as a major aquifer that can supply large quantities of good quality ground water. The total volume of available, renewable groundwater in South Africa is 10 343 million m^3/a (or 7 500 million m^3/a under drought conditions), with the country currently using only 2 000 to 4 000 million m^3/a of this groundwater (GWS, 2010). Groundwater should therefore form a very important part of our climate change adaptation strategy in terms of assuring continuity of water supplies. Further research needs to be conducted to determine the effects of climate change on technical issues such as groundwater recharge. Since rainfall is the main source of recharge to aquifers, climate change may have a considerable impact on groundwater resources.

Rainfall projections for the region around MCLM indicate that there may be a slight increase in rainfall, and an adaptation strategy would be to increase water storage capacity in the municipality. While consensus appears to be merging regarding the likely local projected trends in climate change, uncertainty still exists regarding the reliability of the quantitative outputs of projections in local areas, particularly for rainfall. It is therefore important to improve climate monitoring, particularly of rainfall, in the region in order to support models to provide more accurate outputs at the regional and local scale.

Another important aspect is to rehabilitate and protect wetland areas as these are important as natural buffers to attenuate flood and storm water surges. It is also important to monitor and improve the water quality of these wetlands, as this will improve their resilience to climate change and enable them to increase their adaptive capacity.

Communities should be involved and encouraged to conserve water so as to keep the demand to a minimum. It is therefore important to encourage water conservation technologies in households, such as the installation of low flush toilets and low flow shower heads. The harvesting of rain water should be supported. Communities can also reduce consumption by applying water conserving strategies in their gardens, such as switching off irrigation before puddling starts; avoid midday irrigation; use sprinklers with course, low sprays; water slowly to prevent runoff; use mulch on soil surfaces to prevent water loss; use drip irrigation for vegetables and fruit trees; alter automatic watering systems according to the seasons; and fix water leaks.

The potential key strategies for climate change adaptation in the water sector in MCLM are:

- Continuous monitoring of climate, water flows and water quality;
- Water conservation and demand management;
- Re-using water;
- Using ground water;
- Enhancing water storage capacity;
- Improve flood/storm surge control; and
- Rehabilitating and restoring catchments.

The action plans to achieve this are outlined in Table 17.

Table 17: Water sector adaptation action plans for MCLM.

	Adaptation action	**Department responsible**
Climate monitoring	⇒ Develop links with water research institutes to ensure early preparation for extreme events (such as flooding); ⇒ Maintain meteorological monitoring at the air quality monitoring station so as to provide additional climate data in the area ⇒ Work together with GDARD and SAWS to increase the number of rainfall monitoring stations in MCLM	Environmental management
Water monitoring	⇒ Monitor stream flow particularly for improved infrastructure planning and development ⇒ Monitor water quality ⇒ Improve the groundwater monitoring system ⇒ Monitor the AMD	Environmental management; Town planning
Water conservation	⇒ Conduct awareness and education campaigns for water conservation ⇒ Encourage the use of water conservation technology e.g. low flush toilets, low flow shower heads ⇒ In rural areas set up a programme to replace old taps with new low-usage taps and promote placement of water	Water and sanitation; Environmental management; Parks management;

	containers in cisterns to reduce flush volumes ⇒ Encourage rainwater harvesting for flushing toilets, car washing, and irrigation ⇒ Identify water losses in the water supply system to the municipality and implement a programme of fixing leaks and other losses from the water supply chain ⇒ Collaborate with DWA and GDARD to establish water consumption targets for all sectors and monitor water use ⇒ Improve residential, industrial, commercial and shopping centre water usage by regulation of installation of low-usage taps. Use incentives, and water-wise campaigns ⇒ Investigate, regulate and implement water recycling interventions, either at household or company level and/or in bulk-water supply ⇒ Co-operate with DWA initiatives such as the Working for Wetlands and Working for Water programmes ⇒ Collaborate with GDARD to conduct alien vegetation eradication campaigns	Information and communication
Conserve and restore aquatic ecosystems	⇒ Preserve wetlands ⇒ Protect and rehabilitate aquatic systems ⇒ Implement policies that prevent development on wetlands ⇒ Conduct awareness and education campaigns ⇒ Encourage the use of organic fertilizers (instead of chemical fertilizers)	Environmental management; Parks management
Increase water storage capacity	⇒ Promote the use of rain tanks in households and businesses ⇒ Increase the holding capacity of dams	Town planning
Improve flood/storm surge control	⇒ Maintain and upgrade stormwater infrastructure ⇒ Consider permeable pavements, green roofs and rain tanks to increase on-site retention of storm water; ⇒ Build retention dams to accommodate the overflow from Centenary Dam and assist with managing storm water; ⇒ Promote the planting of indigenous trees around river banks to control runoff	Roads and storm water; Parks management
Water demand management	⇒ Implement Water Demand Management and Water Loss Strategies ⇒ Monitor unlawful water use ⇒ Support the WRDM Green IQ Strategy objectives and action plans ⇒ Support new technologies to utilize grey water and rain water ⇒ Work with GDARD to implement a treatment option where acid mine water can be extracted, treated, and supplied to local industries as grey water	Water and sanitation

6.2. Agriculture

The Long Term Adaptation Scenarios Report for Agriculture (DEA, 2013d) indicates that adaptation is about large-scale commercial farmers optimising climatic conditions to maximise output in a sustainable manner and to maintain a competitive edge. At the rural livelihood scale, adaptation needs to focus on the most vulnerable groups and areas so that livelihoods are not eroded by climate events, but rather that the affected communities become more resilient to the expected changes in climate.

MCLM contributes approximately 22.23% of the total income derived from Agriculture within the Gauteng province (MCLM LED Strategy, 2011). In MCLM Livestock, Poultry and Game products (60.65%) are the largest contributors towards the total Agricultural GVA of MCLM. Horticulture also contributes a significant amount (38.01%), whilst Field crops are least productive sub-sector (0.92%). Livestock will be impacted by climate change, but horticulture is suggested to be fairly resilient and should therefore be promoted in future.

The best adaptation option for agricultural farmers is to use practices based on best management and climate-resilient principles, which include restoration and rehabilitation of land, minimization of soil disturbance, maintain soil cover, the use of multi-cropping and integrated crop/livestock production for optimising yields, sequestering carbon and minimising emissions (DEA, 2013d). These concepts are achieved through conservation and climate smart agriculture; hence the adaptation actions for MCLM include the promotion of such agriculture.

Another action is to promote and support the agricultural hub in this region as agriculture could take advantage of the predicted slight increase in rainfall and enhanced CO_2 fertilization. The Ga8uteng Agricultural Hub lies in the south-western part of MCLM, and forms part of one of six such hubs throughout the province. The focus of these hubs is on the creation of centres of high quality agricultural activity, where niche market agricultural products such as vegetables, including indigenous vegetables, flowers, herbs and spices, will be farmed. These areas must be protected from land uses and developments that will diminish the agricultural potential and value of this area (SDF, 2009).

In terms of livestock and game farmers, veld cover and composition are likely to change in future climatic regimes (DEA, 2013d), and farmers will need to adapt their livestock (and game) densities to changing grassveld carrying capacities. This will include reducing stocking densities, providing supplemental feed and water and/or shifting livestock to land with higher carrying capacity and implementing rotational grazing that includes rest periods for rangelands. Overgrazing needs to be minimized as an increase in rainfall intensity and floods could increase erosion. Alien invasive species need to be eradicated so that they don't reduce the palatability of the rangelands and create biodiversity losses.

Adaptation actions in the agriculture sector are centred around protecting agricultural land and supporting agricultural initiatives, improving crop management and yields by promoting specific crops and diversification (to mixed farming), improving flood control and water management, as well as promoting sustainable and conservation farming (Table 18).

Communities should be encouraged to develop food gardens or back-yard gardens as these have several benefits and can increase the resilience of a city by:

- reducing the vulnerability of the poor and enhances their coping capacity by
  - reducing the impacts of floods;
  - enhancing access to food;
  - diversifying income opportunities; and
  - enhancing community building;
- reducing the impacts of increased rainfall by increasing infiltration and reducing storm water runoff;
- reducing the heat island effect by providing shade and enhancing evapotranspiration;
- contributing to the reduction of the urban energy use and GHG emissions by:
  - producing fresh food close to the city so less energy is used for transport, cooling, storage and packaging; and
  - enabling productive reuse of organic wastes which reduces methane emissions from landfills and emissions from fertilizer production.

Food gardens not only provide food for the community or household, but can also lead to poverty alleviation as the produce can be sold. The Gauteng Department of Agriculture, Conservation and the Environment (GDACE) has a Community Food Garden Programme which assists communities to setup and run small income-generating projects. Involving schools in food garden programmes is also beneficial, as learners can be educated about sustainable farming and how to grow their own vegetables, while producing food to supplement school feeding programmes.

Another very important adaptation is the improvement of early warning systems, as this can assist land managers to take appropriate action to minimize the adverse impacts of climate change. It is also important to provide farmers with information on possible pest and disease occurrences. These adaptation options are discussed in the Disaster Risk Management section (section 6.7).

Table 18: Adaptation actions for the agriculture sector in MCLM.

	Short term adaptation strategy	Department responsible
Improve food security	⇒ Preserve agricultural land ⇒ Promote food gardens in residential areas ⇒ Support the Agricultural Hub activities ⇒ Low income housing development should incorporate communal food gardens ⇒ Protect and develop productivity of agriculture potential land through promotions and incentives	Environmental management; Urban development; Rural development; Housing
Improve crop management and yields	⇒ Promote the use of crops with higher heat tolerance, better WUE and shorter growing periods (e.g. cabbage, short season maize) ⇒ Promote the use of crops which can take advantage of higher ambient CO_2 conditions ⇒ Promote diversification: mixed crops or mixed crop and livestock farming	Environmental management
Improve control on flood water	⇒ Promote natural vegetation buffers along rivers on farms ⇒ Decrease wind erosion and flood runoff by using belts of natural vegetation (not alien species)	Parks management
Improve groundwater management	⇒ Improve the groundwater monitoring system ⇒ Work with GDARD to investigate the long-term costs and benefits of groundwater extraction for irrigation purposes	Water and sanitation
Improve water use efficiency	⇒ Promote the use of mulching and crop residues ⇒ Increase efficiency and flexibility of irrigation	Environmental management
Improve sustainable farming	⇒ Promote crop rotation ⇒ Promote the recycling of nutrients and energy on farms ⇒ Promote conservation and climate smart agriculture by incentivising conversion through conditional subsidies and rebates ⇒ Conduct an awareness campaign explaining conservation agriculture and the conversion steps ⇒ Support the activities of the WRDM Green IQ Strategy	Environmental management; Information and communication
Improve livestock farm management	⇒ Monitor stocking densities of farms and provide incentives to reduce stocking densities where housing is used so as to reduce the requirement for cooling ⇒ Prepare veterinary animal health services for the potential spread in animal diseases ⇒ Conduct campaigns to remove alien invasive grass species which have reduced palatability ⇒ Assess the vulnerability of smallholder livestock farmers in marginal areas and facilitate early adaptation	Environmental management
Increase shading on farms	⇒ Promote planting of indigenous trees to improve shading for livestock and labourers	Environmental management; Parks management
Improve early warning systems	⇒ Ensure there is an early warning system in place ⇒ Provide early warnings of eminent disasters, particularly to vulnerable communities (*link to Disaster Risk Management Adaptation Table*)	Environmental management (collaborating with GDMC)

6.3. Human health

Adaptations of both acclimation- and resilience-type are needed that will guarantee adequate and reasonable healthcare delivery services particularly in the rural setting. Both individual and institutional mechanisms are necessary for coping with the adverse effects of climate change. Individual mechanisms may include improving one's socio-economic status in order to afford the necessary means for coping with climate impacts such as air conditioners, medical care, proper nutrition and living in a secure and climate-resilient neighbourhood. Institutional mechanisms may include surveillance and early warning systems, vaccination programmes, treatment facilities, environmental limits or standards, sanitation systems, capacity building programmes, training facilities, public education and communication programmes and research and development programmes.

There is very little research being conducted on the effects of climate change on health, therefore monitoring and research in this area needs to be supported so that more specific adaptation plans can be put in place in the future. Improving early warning systems will assist communities to avoid disasters more effectively and thus avoid health issues and injuries associated with disasters. The other adaptations are related to reducing the vulnerability and improving the resilience of communities, especially rural communities, by improving access to basic resources and improving health care services.

Adaptation action plans for the health sector are shown in Table 19.

Table 19: Adaptation action plans for the health sector.

	Adaptation action	Department responsible
Improve monitoring of health impacts	⇒ Conduct public awareness campaigns on health risks due to increased temperatures and appropriate response actions ⇒ Observe and monitor human health issues relating to extreme events ⇒ Monitor the incident and distribution of disease vectors	Primary health care
Improve early warning systems	⇒ Ensure there is an early warning system in place ⇒ Provide early warnings of eminent disasters, particularly to vulnerable communities (*link to Disaster Risk Management Adaptation Table*)	Environmental management (in collaboration with GDMC)
Reduce air pollution	⇒ Adapt passive energy measures and non-polluting renewable energy sources to reduce air emissions from fuel combustion (*links to next phase of project on mitigation strategies*)	Town planning; Rural development
Improve health care services	⇒ Maintain and upgrade all health care services to deal with heat related and vector-borne diseases ⇒ Maintain health care emergency services	Primary health care

Increase resilience in rural areas	⇒ Increase access to basic water and sanitation	Water and sanitation

6.4. Biodiversity and ecosystems

There are two important adaptation options in the biodiversity sector, namely ecosystem-based adaptation and expansion of protected areas using climate-resilient approaches. In the former approach biodiversity is used to adapt to the adverse effects of climate change by integrating the sustainable use of biodiversity and ecosystem services into the overall adaptation strategy. Some ecosystem-based adaptation options which could be used in MCLM include terrestrial vegetation restoration which includes the control of invasive alien species, and proactive wetland rehabilitation. Efforts for adapting the city to climate change could have positive spin offs that would help achieve biodiversity conservation goals and also increase the city's resilience. Protecting and restoring healthy ecosystems would have a multiplicity of benefits in this regard. Spaces that are well managed would increase resilience of the city to climate change risks as well as ensure that biodiversity is conserved. Building resilience in ecosystems is important as intact terrestrial ecosystems are more resilient to climate change impacts than degraded or transformed land cover; and intact wetlands are more resilient to drought and flooding cycles than degraded or transformed vegetation. Connectivity also forms part of a healthy ecosystem.

In terms of protected area expansion, new areas for expansion should be identified and protected. A vulnerability map should be produced so as to assist in determining which areas are most vulnerable (such as ridges which have high endemism, and grasslands) and are in need of protection. It is also important to consider connectivity when identifying areas that require protection. Keeping natural environments connected allows for a more resilient network of biodiversity whereby species are able to move from one area to another.

The potential key strategies for climate change adaptation in terrestrial systems and for maintaining biodiversity in MCLM are (Table 20):

- Conservation of parks, open areas and wetlands;
- Expand protected areas; and
- Rehabilitation and restoration of degraded ecosystems and wetlands.

Table 20: Adaptation action plans for terrestrial ecosystems and biodiversity in MCLM.

	Adaptation action	Department responsible
Conservation of open areas and wetlands	⇒ Promote the conservation of urban parks and open areas ⇒ Identify further parks and protected areas, taking connectivity into account ⇒ Use land-use planning provisions to prevent further fragmentation of protected areas so as to maintain connectivity between core biodiversity and ecosystem services areas ⇒ Maintain corridors to facilitate dispersal and migration ⇒ Identify habitats of significant value for consolidation through purchase or conservancies ⇒ Protect grassland areas ⇒ Enforce the implementation of policies such as C-plan and the Gauteng Protected Area Expansion Strategy ⇒ Protect wetlands ⇒ Support the activities of the WRDM Green IQ Strategy	Parks management; Environmental management; Town planning
Rehabilitation of natural ecosystems	⇒ Promote the planting of indigenous plant and tree species to green the urban and peri-urban areas (*see Human Settlement Adaptation Table*) ⇒ Collaborate with GDARD to conduct alien eradication campaigns ⇒ Conduct information and awareness campaigns to inform the public about alien species ⇒ Rehabilitate degraded land such as landfill sites, riverine areas, Mine Residue Areas ⇒ Restore and rehabilitate degraded wetlands	Parks management; Environmental management

6.5. Human settlements and infrastructure

In this sector four main areas for adaptation have been identified, namely infrastructure maintenance and improvement, greening of urban areas to reduce the heat island effect, improved land use planning and increasing access to basic resources in rural areas (

Table 21).Infrastructure needs to be maintained and improved so as to reduce the impacts of climate change. In order to reduce the impacts of flooding and increased runoff storm water drainage systems need to be maintained and upgraded, and runoff can be slowed by improving natural barriers and increasing the water holding capacity (harvesting rainwater, increasing vegetation cover). Drainage systems can be designed so that rainwater from gutters is diverted directly to street tree root zone. Other ways to reduce flood risk are to evaluate the flooding zone and avoid development in these areas; construct multi-storey buildings and use the lower levels as non-living space; use water-resistant building materials; ensure that water can easily escape from buildings should there be a flood; and ensure that services (such as hot water, meter boards) are above the flood levels.

To reduce the enhanced effect of the urban heat island surface reflectance can be increased so as to reduce radiation absorption and vegetation cover can be increased, mainly in the form of urban forests and parks, in order to maximize the multiple vegetation benefits in controlling the temperature rises. Reflective surfaces simply results from light coloured or white paint on the surface of a given construction material or from cover the construction material surface with a white membrane (Schaffler et al., 2013). Cool roofs are especially important in commercial and residential buildings, where significant energy demand for cooling can be saved by reducing heat gain to the building. Cool pavements can be created through the use of white chip seals on the surface or coated with a light concrete (Schaffler et al., 2013). Other adaptive building strategies to reduce the impact of increasing temperatures include insulation and the use of high performance glazing; provision of external shading for vulnerable building surfaces; cross ventilation to cool internal spaces; and photovoltaic glazing (Snow and Prasad, 2011). Climate change needs to be considered during the building process otherwise it could lead to costly impacts including sick building syndrome, roof and drainage issues, cladding and exterior façade deterioration, and issues with the foundation of buildings, in the future.

In addition to reducing the impacts of climate change, a pro-active approach to understanding and addressing many of these issues may present an opportunity for buildings to be enhanced with alternative, green technologies. More energy and water efficient buildings will aid in the reduction of GHG emissions and reduce the demand for water (see section 7.5 for more details).

Greening of urban areas improves their resilience to climate change. One option is to promote the planting of gardens on roof tops as this greens the urban area and reduces radiation absorbance by the buildings. The other adaptation strategy is to increase the number of indigenous trees in the cities. Trees play a vital role in regulating climate, since they absorb the carbon dioxide released by industries and release oxygen, which is vital for human beings to breathe. Trees also play a crucial role in providing a range of products and services to rural and urban populations, including food, timber, fibre, medicines and energy as well as soil fertility, water and biodiversity conservation. They also prevent soil erosion by holding water during heavy rainstorms, and provide windbreaks when planted in rows. Trees also reduce smog levels, absorb small particles and gases of air pollution, absorb rain and thereby reduce the amount of water to be removed by storm water drainage. Communities can be involved by planting at least one tree per household. In some areas, particularly rural area, it may be more beneficial to plant fruit tree as this can provide a source of food as well as enhancing the carbon storage.

In rural areas increasing access to basic resources will reduce the vulnerability of these areas to climate change. Other adaptations strategies discussed in the water, agriculture and human health sectors will also contribute to the resilience of rural areas.

Table 21: Adaptation action plans for human settlements and infrastructure in MCLM.

	Adaptation strategy	Department responsible
Improve infrastructure	⇒ Promote rainwater harvesting water storage to slow water surges ⇒ Maintain and upgrade stormwater infrastructure (*link to Water Adaptation Table*) ⇒ Maintain and improve natural barriers for storm water surges (such as wetlands in more rural areas, indigenous trees in urban areas) ⇒ Promulgate by-laws related to green servitudes such as storm water management and open space guidelines ⇒ Consider permeable pavements, green roofs and rain tanks to increase on-site retention of storm water (*link to Water Adaptation Table*) ⇒ Support new housing schemes which introduce innovative water conservation, water efficiency and sanitation measures, as well as energy efficient technologies	Roads and storm water; Town planning; Housing
Reduce heat island effect	⇒ Promote planting of indigenous trees in urban areas; ⇒ Develop a formal process for evaluating green infrastructure ⇒ Promote the reduction of radiation absorbance by buildings and pavements through the use of 'cool' building materials. ⇒ Promote roof top gardens (including vegetable gardens) ⇒ Protect open areas and parks in urban areas	Parks management; Town planning; Housing
Improve land-use planning	⇒ Regulate and enforce sustainable land-use planning and spatial development	Town planning; Rural Development; Urban development
Increase access to basic resources	⇒ Increased access to basic water and sanitation and associated supporting infrastructure ⇒ Encourage the use of communal food gardens	Water and sanitation; Rural development

6.6. Tourism

National or international mitigation policies may have an impact on tourism flows as they are likely to lead to increased transport costs and may foster environmental attitudes that lead tourist to changing their destination choice. South Africa is a carbon intensive destination as it relies extensively on long haul flights from key international tourism markets, so international efforts to promote low carbon tourism destinations pose a significant risk to South Africa's tourism industry. It is therefore very important to promote domestic tourism.

Adaptations for the tourism sector are mainly dealt with through adaptation actions in the water, terrestrial ecosystems and biodiversity, and human settlements and infrastructure sections so there is no specific adaptation action table for this sector.

6.7. Disaster risk reduction and management

Disaster risk management is linked to a variety of sectors and the adaptation options are given in Table 22.

Table 22: Adaptation action plans for disaster risk management.

	Adaptation action	Department responsible
Improve climate monitoring and early warning detection systems	⇒ Strengthen communication with GDMC to obtain early warnings of impending disasters ⇒ Develop links with water research institutes to ensure early preparation for extreme events (such as flooding) ⇒ Work together with GDARD and SAWS to increase the number of climate monitoring stations in MCLM ⇒ Monitor and record changes in temperature and the "urban heat island" phenomenon ⇒ Conduct a detailed GIS mapping project to identify flood prone areas	Environmental management (with GDMC)

6.8. Waste reduction and management

MCLM has two landfill sites, namely Luipaarsdvlei (permitted) and Magaliesburg dump-site (non-permitted) (Pilusa & Muzenda, 2013). There are some adaptation options for the Waste sector (Table 23) which deals mostly with avoiding or reducing the amount of waste produced, and promoting recycling and re-use. This also includes the improved use of biomass waste. In this way the amount of waste being disposed of in the landfill sites is minimized, thus leading to reduced emissions from these sites. The landfill is currently operating above capacity limits, thus it is essential that waste minimisation be built into waste management plans and that the municipality put pressure on communities, business and industry to avoid and minimise waste wherever possible. The Executive Summary of the Mogale City Integrated Waste Management Plan indicates that residual waste forms 32% of the municipal waste stream, and 43% is recyclable. Recycling can be promoted by providing economic incentives such as bulk buy-back facilities where there is cash payment for materials delivered or collected; or providing subsidies for collection and transport of materials for recycling. Garden waste forms 25% of the waste stream in MCLM and so composting at the source should be promoted. Education and awareness programmes to inform the public of what and how to compost would assist the composting within the municipality. Kagiso and Krugersdorp are the main contributors to domestic waste generation in MCLM (WRDM, 2010) so efforts should be focussed around these areas.

Table 23: Adaptation actions for the Waste sector.

	Adaptation action	Department responsible
Improve use of urban plant and tree waste	⇒ Engage with waste collection companies and municipal park services to adapt their current practices for collecting and disposing of woody biomass ⇒ Establish and support recycling and garden waste drop off centres ⇒ Provide facilities for small entrepreneurs to collect and package woody bio-waste from central depots	Park management; Municipal health services
Reduce and recycle waste	⇒ Include recycling options into Integrated Waste Management Plan which is part of the Integrated Development Plan ⇒ Require business and industry to produce recycling plans as part of their broader environmental strategy ⇒ Implement registration of recyclers ⇒ Promote recycling by providing suitable storage bins or facilities for different types of waste ⇒ Support paper recycling pick-up (from offices an houses) programmes and paper banks at schools, offices, complexes ⇒ Support recycling initiatives in the form of bylaws that facilitate the location, operation and use of these facilities ⇒ Provide economic incentives to avoid, minimize and recycle ⇒ Enforce sorting of waste at source ⇒ Municipality should be mandated to use locally –produced recycled paper and to investigate the purchase of other recyclable items for use in municipal departments ⇒ Promote composting of plant and food material ⇒ Conduct public awareness campaigns in residential, commercial, industrial and shopping complexes ⇒ Collect information on recycling material types and quantities for the municipality ⇒ Support and develop waste collection cooperatives so that informal waste collectors can integrate, improve and regularize their operations ⇒ Encourage waste avoidance through immaterialisation of products and services through digitalization ⇒ Promote and regulate reusable shopping bags, unpackaged products and packaging reuse	Municipal health services
Improve waste collection	⇒ Maintain and improve infrastructure for waste collection ⇒ Improve waste collection services in rural areas	Municipal health services
Monitor landfills	⇒ Monitor landfill sites and ensure operators have licenses	Municipal health services

The Luipaarsdvlei landfill site has recycling activities associated with it. In 2009 the total recycled waste from the Luipaardsvlei landfill was estimated at 153 tonnes/month or 1.26% of total waste generated (WRDM: IWMP, 2010). Waste recycling in MCLM is dependent on informal waste recyclers (Bhagwandin, 2013; WRDM: IWMP, 2010), so more formal recycling initiatives need to be established. More buy-back centres could also be established as according to Bhagwandin (2013) there is only one buy-back centre in MCLM (WRDM: IWMP, 2010). The municipality should support the establishment of public-private partnerships (PPPs) and community upliftment programmes to kick-start recycling initiatives within the municipality (WRDM: IWMP, 2010).

Recyclable wastes should be separated as near to source as possible so as to limit the costs of labour and machinery associated with sorting after collection. This also prevents recyclables, like paper, being soiled by other waste products. Once paper or cardboard is soiled, it cannot be recycled. Therefore an important aspect of waste reduction, re-use and recycling is community involvement. Community involvement and commitment is essential for the success of waste minimization initiatives, therefore it is important to conduct public awareness campaigns. Companies, schools, NGO's and community clubs/programmes should also be encouraged to support or promote recycling initiatives. Paper banks can be set up at schools, housing complexes, offices and community organizations. Paper is usually collected by the established recycling companies or their agents, and the business is often paid a sum of money for the material recovered. Thus, not only is the business making money from the paper sold, but also saving money by disposing of less waste. Furthermore, if these initiatives are started in schools it can also be used to educate the learners about the importance of recycling.

The use of recycling bins should be encouraged in residential areas and recycling bins should be placed in public areas around the municipality. In some municipalities, such as eThekweni and Ekurhuleni, there is also kerb-side collection of paper and cardboard. This is done in partnership with Mpact (formerly Mondi Recycling) and there is no cost for the residence. MCLM should conduct a feasibility study to determine whether a similar initiative could be started in the municipality.

6.9. Administration, finance and governance

There are some overarching adaptation actions in terms of administration, finance and governance (Table 24).

Table 24: Adaptation actions for administration, finance and governance.

	Adaptation action	Department responsible
Administration, finance and governance	⇒ Incorporate climate change commitments into IDP's ⇒ Incorporate climate change within agenda of all structures ⇒ Budget allocations must ensure spending supports maintenance of existing structures as well as development of new infrastructure	Budget and treasury

7. CLIMATE CHANGE MITIGATION

Increasing anthropogenic GHG emissions have a severe indirect impact on South Africa's economy, natural environment and people (as discussed in the Adaptation Strategy). Without the implementation of any mitigation measures South Africa's emissions will continue to grow (Growth Without Constraints trajectory in **Figure 42**). South Africa needs to start implementing mitigation measures immediately in order to reduce emissions, and needs to scale up these mitigation plans for future reductions. South Africa's long-term emissions trajectory is to aspire to peak in the 2020 - 2025 period at 500 to 550 Mt Carbon Dioxide Equivalent (CO_2-eq), to remain at that emissions level until 2035, and for emissions to decline to a range of between 200 and 400 Mt CO_2-eq in 2050 (Winkler, 2007). This is referred to as the "peak, plateau and decline" emissions trajectory (Figure 42). Climate mitigation will potentially pose both threats to development and create significant opportunities: on the one hand, some measures could be very costly, but on the other, mitigation programmes offer massive investment opportunities in terms of the development of new industries, and many other potential co-benefits if implemented effectively.

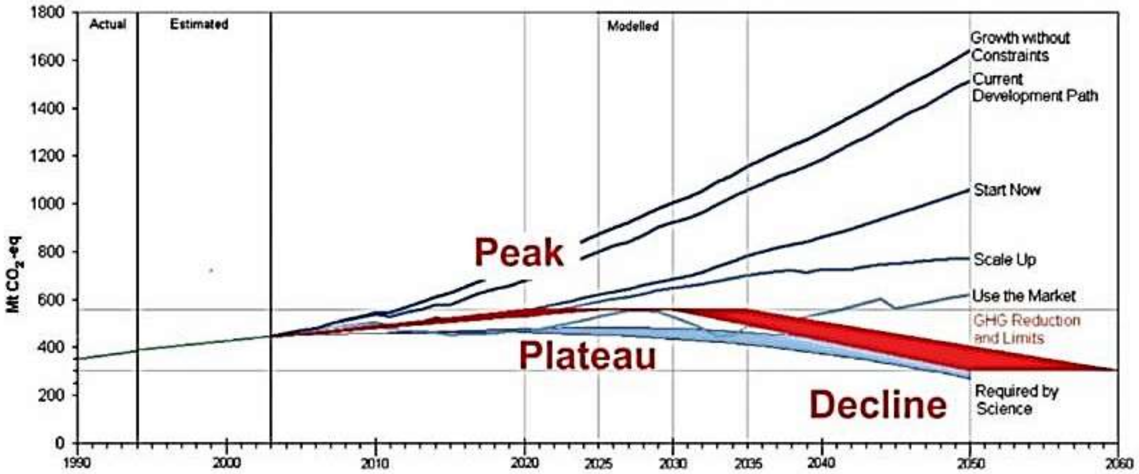

Figure 42: GHG emission reductions and limits under various scenarios (Source: Winkler, 2007; http://www.enviropaedia.com/topic/default.php?topic_id=330)

Marquard et al. (2011) suggested that South Africa adopt a two-stage mechanism for mitigation of GHG emission. Firstly, since it is imperative that climate mitigation actions begin immediately, there should be an immediate implementation of a handful of key flagship mitigation programmes; then secondly, for the longer term actions, a low carbon development plan should be established for future reductions. Some of the flagship programmes they identified were:

- a scaled-up renewable energy programme;
- an aggressive energy efficiency programme in industry;
- a residential energy efficiency programme;
- an expanded solar water heating (SWH) programme and to develop pilot programmes for commerce and industry;
- two government programmes, namely:
  - a building efficiency programme, and
  - a vehicle efficiency programme;
- a public transport programme; and
- a pilot carbon capture and storage (CCS) plant to store the process emissions from the synfuels industry.

Marquard et al. (2011) also provided a ranking of mitigation measures by cumulative emissions (between 2003 and 2050) savings in relation to a Business as Usual trajectory in the short, medium and long term (Table 25). This showed that industrial energy efficiency measures have the highest savings in the short term, but that electricity supply mitigation options had larger savings in the medium and long term.

Table 25: Mitigation measures ranked by impact in the short, medium and long term – largest to smallest for each time period. (Source: Marquard et al., 2011)

2010 – 2020	2021 – 2030	2031 – 2040
Industrial energy efficiency	Electricity supply options	Electricity supply options
Electricity supply options	Industrial energy efficiency	Industrial energy efficiency
Land use - fire/savannah	Synfuels CO_2 CCS	Improved vehicle efficiency
Waste management	Land use - fire / savannah	Synfuels CO_2 CCS
Agriculture - enteric fermentation	Waste management	Passenger modal shift
Residential energy efficiency	Residential efficiency	Electric vehicles / Hybrids
Agriculture - reduced tillage	Commercial efficiency	Residential energy efficiency
SWH	Improved vehicle efficiency	Commercial energy efficiency
Commercial energy efficiency	Electric vehicles	Waste management
Synfuels methane reduction	Afforestation	SWH
Afforestation	Agriculture - enteric fermentation	Land use - fire / savannah
Biofuels	SWH	Cleaner coal
Improved vehicle efficiency	Hybrids	Agriculture - enteric fermentation
Passenger modal shift	Passenger modal shift	Biofuels

Mitigation measures are actions which are implemented to slow down the build-up of heat trapping greenhouse gases and remove them from the atmosphere. Since MCLM has not compiled a GHG emission inventory it is difficult to prioritize the greenhouse mitigation measures. It would appear from the preliminary analysis of possible GHG emissions in MCLM that industry could be the main emitter, followed by transport; however this preliminary analysis did not include emissions from waste or agriculture and land use.

7.1. Energy

According to the Gauteng Integrated Energy Strategy (GPG, 2010) the GHG emission reduction targets for Gauteng are 13% CO_2 reduction by 2014; 27% CO_2 reduction by 2025 and 49% CO_2 reduction by 2050. The majority of South Africa’s emissions come from the energy sector. Electricity supply is the largest source of emissions at the national scale, followed by industry, transport and liquid fuels supply (DEA, 2009). Energy is not produced in MCLM, but reducing energy consumption will reduce the production of GHG gases at the provincial and national scale. Mitigation measures in this sector therefore include interventions in energy supply (using alternative energy sources) and interventions to reduce energy demand by improving energy efficiency (Table 26).

Table 26: Mitigation actions in the Energy sector in MCLM.

		Mitigation action	**Department responsible**
Energy supply	Renewable energy supply	⇒ Develop a plan to subsidise the installation of solar systems for water heating in residential areas ⇒ Collaborate with institutions doing research and innovation in renewable energies	Housing
Energy efficiency	Energy efficiency	⇒ Conduct energy audits in all government facilities to monitor energy use ⇒ Implement awareness campaigns to sensitise users of government buildings on how to optimize energy efficient operation ⇒ If government buildings are old make recommendations for retrofitting ⇒ Install smart meters in all public buildings	Electricity
	Water heating efficiency	⇒ Establish a task team to conduct audits of hot water use and geyser capacities in all public buildings (owned or rented) ⇒ Work with Gauteng Department of Infrastructure to devise a financial and technical plan to install heat pumps in clinics and hospitals ⇒ Engage with small and medium hospitality establishments to encourage group participation in heat pump procurements ⇒ Participate in public information campaigns around the economic and climate protection advantages of heat pumps	Housing; Water and sanitation

	Combined heat and power generation	⇒ Promote the installation of co-generation plants in industry. (Issues could be addressed through Forums).	Electricity
	Energy efficient lighting	⇒ Implement energy efficient lighting and smart controls in all government buildings ⇒ Install automated lighting control devices in all government buildings (administrative buildings, hospitals, clinics, schools) ⇒ Support initiatives to design, manufacture and market energy efficient lighting ⇒ Install energy efficient lighting in street lamps ⇒ Use motion sensors in areas that are not continuously occupied ⇒ Install energy saving light fixtures on high illumination trunk roads ⇒ Install energy efficient light bulbs in public areas ⇒ Install energy efficient light bulbs in traffic lights	Electricity
	Energy efficient appliances	⇒ Procure office equipment that have certified energy conservation performance ⇒ Conduct public awareness campaigns on energy efficient appliances ⇒ Encourage innovation in designing smart-compatible appliances	
	Energy efficient transformers and motors	⇒ Promote the installation of energy efficient electric motors and transformers	Electricity
	Smart energy controls	⇒ Install smart metering devices and public display consoles to monitor energy consumption	Electricity

7.2. Transport

Transport emissions arise from mobile combustion of fuels in vehicles (road, rail, air and water navigation). Mitigation options in the transport sector (Table 27) include the use of alternative fuels, reducing consumption by promoting public transport (modal shifts) and car-pooling, and the promotion of smart controls (see section 7.8).

Table 27: Mitigation action for the transport sector in MCLM.

	Mitigation action	Department responsible
Public transport	⇒ Ensure public safety for commuters ⇒ Promote the use of public transport by increasing frequency and reliability (including rail) ⇒ Regulate and implement further preferential bus and taxi lanes ⇒ Work with other municipalities and GDARD to create financial policies allowing for integrated regional transportation ticketing across municipal boundaries and allow for mode switching ⇒ Refurbish and maintain railway stations and precincts ⇒ Ensure effective railway ticketing to ensure revenue collection ⇒ Promote the use of rail for heavy freight ⇒ Identify and develop suitable park and ride facilities at key public transport interchanges	Public safety; Roads and storm water; Urban development; Town planning

	⇒ Encourage car-pooling with priority/preferential parking at places of work	

7.3. Industry, commerce and mining

GHG emissions from industry, commerce and mining need to be monitored to make sure the reduction targets set out in the Gauteng Integrated Energy Strategy (GPG, 2010) are being met. These economic sectors should also be incentivised to use cleaner production technologies so as to reduce emissions. Dust from mine dumps, which causes respiratory illness, can be prevented through stabilisation of residues, improved mine dump management, and the rehabilitation and re-vegetation of mine dumps. The other important mitigation aspect is that of energy efficiency. Energy efficient interventions, also discussed in the Energy section (section 7.1), should be promoted and implemented in the industrial, commercial and mining sectors. Mitigation actions in these sectors are outlined in Table 28.

Table 28: Mitigation action for industry, commerce and mining sectors in MCLM.

	Mitigation action	Department responsible
GHG emission monitoring	⇒ Implement reporting of GHG emissions by companies in the industrial sector	Environmental management
Emission reductions	⇒ Incentivise cleaner production technologies by giving recognition to the relevant industries	
Energy efficiency	⇒ Promote the installation of energy efficient electric motors and transformers ⇒ Promote new building standards that require all buildings to incorporate energy efficient measures	Electricity; Building control; Urban development

7.4. Residential

This section covers the mitigation options for reducing emissions from domestic burning (Table 29). Many low-income households depend on domestic stoves that use coal, wood and paraffin fuels for cooking and heating. These stoves often have poor combustion efficiencies and lead to the production of high quantities of smoke. This in turn affects the health of the residence. There are several initiatives promoting cleaner and safer stoves but there has been little success in getting people to use these technologies. Therefore, there needs to be a big emphasis on education, stressing the benefits (health and economic) of the improved stoves, and a stronger promotion of the use of these cleaner and safer stoves.

Energy efficiency in residential and public buildings is dealt with under the section on Infrastructure (section 7.5).

Table 29: Mitigation actions for reducing domestic burning emissions in MCLM.

	Mitigation action	Department responsible
Efficient and safe stoves	⇒ Collaborate with GDARD to conduct awareness and educational campaigns on the health and economic benefits of improved and safer stoves ⇒ Collaborate with institutions doing research and innovation in thermal and energy efficient domestic stoves	Rural development; Public safety

7.5. Infrastructure

The main mitigation actions in this sector relate to energy efficiency within residential and public buildings (Table 30). Incorporating energy efficient measures in new and existing buildings as retrofits is an intervention to implement demand-side management and reduce overall GHG emissions. Government should lead by example and implement energy efficiency measures in all its facilities.

Table 30: Mitigation actions for infrastructure planning in MCLM.

	Mitigation action	Department responsible
Densification and multifunctional landscapes	⇒ Promote development of high density and mixed development zones, with delineated areas to encourage the use of public transport	Urban development; Town planning
Energy efficient buildings	⇒ Evaluate all government buildings for retrofit status, potential and requirements, then set priorities to implement such retrofitting where applicable ⇒ Address government procurement policies to add a "green" scoring into point system for awarding tenders for retrofitting and new buildings ⇒ Promulgate regulations that require implementation of energy efficient measures contained in SANS 204 standard for all new buildings and structural renovations of existing buildings ⇒ Enforce the new energy efficient components of building codes ⇒ All new subsidized housing must incorporate basic passive energy saving features e.g. north-facing orientation, ceiling insulation ⇒ Develop contract specifications for new buildings to incorporate energy performance over a defined period as a key deliverable of the contract	Electricity; Housing; Building control

Energy is required in buildings for lighting, heating and cooling, hot water and for powering equipment and appliances. In the future houses should be designed so that they are more energy efficient. Solar water heaters and photovoltaic systems should be installed; cross ventilation and a stack effect system can be used to cool a building; houses should be oriented to face north with the extent of the façade on the north being maximized and those on the east and west minimized.

Energy efficient light should be used and the use of tungsten and halogen lamps should be reduced; houses should be insulated. ; and co-generation (including waste heat) technology.

Current residential settlement planning and implementation is contributing to urban sprawl which is encroaching onto natural habitats and prime agricultural land. This can lead to loss of biodiversity and decrease food security. Densification of new housing developments will aid in the reduction of the urban sprawl.

7.6. Agriculture

Agriculture releases significant amounts of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) into the atmosphere. CO_2 is released largely from microbial decay or burning of plant litter and soil organic matter; CH_4 is produced when organic materials decompose in oxygen-deprived conditions (enteric fermentation, manure management); and N_2O is generated by the microbial transformation of nitrogen in soils and manures. There are some mitigation actions which can be used to reduce these emissions (Table 31).

Nitrogen (N) applied in fertilizers and manures is not always used efficiently by crops, and improving this efficiency can reduce N_2O emissions. This can also indirectly reduce emissions of CO_2 from N fertilizer manufacture by reducing the requirement for synthetic fertilizers (Schlesinger 1999; Galloway et al. 2003; Kool et al., 2012). Improving the efficiency of fertilizer use can be achieved by adjusting application rates based on precise estimation of crop needs; using slow-release fertilizer forms or nitrification inhibitors; avoiding time delays between N application and plant N uptake; placing the N more precisely into the soil to make it more accessible to crops roots; avoiding excess N applications, or eliminating N applications where possible (Smith et al., 2008 and references therein). Other cropland management mitigation options are suggested in this publication, however some of these issues are covered in the Adaptation Strategy and others are not deemed appropriate for MCLM.

Ruminant livestock are important CH_4 emitters and improved feeding practices (feeding more concentrates, adding oils to the diet, improving pasture quality), dietary additives, animal breeding (increased productivity, genetic modifications) and artificial insemination (to reduce the number of bulls and therefore reduce emissions).

Animal manures can release significant amounts of N_2O and CH_4 during storage in a liquid form (lagoons or tanks), but this type of manure management usually occurs in cattle feedlots and piggeries. Neither of these is prominent in MCLM. For other animals, including chickens, manure happens in the field or is handled in a dry form thus methane emissions from manure in MCLM are thought to be small, so are not expected to be a major mitigation option.

Table 31: Mitigation actions for the agriculture sector in MCLM.

	Mitigation action	Department responsible
Agricultural baseline	⇒ Map agricultural areas as well as details and type of agriculture taking place, including conservation agricultural as a category	Environmental management
Sustainable farming	⇒ Collaborate with GDARD to develop an agricultural subsidy system for small scale organic and other alternative farmers	Social upliftment; Enterprise development
Cropland management	⇒ Encourage efficiency in nitrogen fertilizer use ⇒ Conduct education campaigns to inform farmers of good practices	Environmental management
Biogas generation and use	⇒ Encourage and promote the generation of biogas from agricultural residues and from animal manure ⇒ Promote CNG for transport fuel, heating, cooking and power generation	Environmental management

Agricultural crops and residues are seen as a source of feedstock for energy to displace the fossil fuels (Brent, 2014). In 2011, the national Department of Energy (DoE) published draft regulations for public comment on the mandatory blending of biofuels with petrol or diesel. The finalised regulations were released a year later (RSA, 2012) and stipulated the standards of blending a minimum of 5% (by volume) of biodiesel into diesel, and between 2 and 10% (by volume) of bioethanol into petrol. These regulations will come into effect in October 2015 (DoE, 2013). Waste-to-energy initiatives should be supported by the municipality.

7.7. Waste (landfills and WWTPs)

Waste decomposes without the presence of oxygen (anaerobic fermentation) and slowly produces landfill gas. Landfill gas contains 40-60% methane and the global warming potential (GWP) of methane is 23 times that of CO_2. Burning methane produces energy, carbon dioxide and water. Waste-to-energy initiatives should be promoted (

Table 32) as they reduce emissions and provide an alternative source of energy. Accurate waste data should be collected at landfill sites so that a feasibility study can be conducted to determine whether methane recovery could be developed in MCLM.

Currently there is a Blue Waste initiative in MCLM, where all waste is compressed into pellets and these are then utilized for energy production. This initiative has not yet progressed to the implementation phase, so it is recommended that this initiative be supported and implemented as part of the waste mitigation plan.

MCLM has three Wastewater treatment plants (WWTP) (Flip Human WCW, Percy Stewart WCW and Magaliesburg WCW). WWTPs consume large quantities of electricity, and it has become imperative to optimize energy efficiency and develop opportunities for energy generation from wastewater and sludge as part of the municipal wastewater business. International best estimates indicate that energy gains and savings of 5-30% are realistic (Scheepers & vd Merwe-Botha, 2013). Several of the suggested mitigation actions therefore relate to the improvement of energy efficiency at wastewater treatment plants (

Table 32). Key energy demand areas are: pumping over wide service areas, asset condition and pipe leakage, treatment by aeration and pumping raw and treated effluent (Global Water Research Coalition, 2010). Up to 50% energy savings have been demonstrated by case studies in wastewater processes focused on aeration, therefore the installation of speed controls mechanisms for aerators is included as a mitigation action. MCLM should conduct energy audits at the wastewater treatment plants to identify the energy saving opportunities.

Table 32: Mitigation actions for landfills and wastewater treatment plants in MCLM.

	Mitigation action	**Department responsible**
Waste-to-energy	⇒ Promote the utilization of methane from anaerobic digesters ⇒ Promote the adoption of waste-to-energy technologies ⇒ Provide incentives for power generation from waste and support the Blue Waste Initiative ⇒ Support LFG flaring from small landfills where it is uneconomical to capture the gas ⇒ Promote biogas technology at WWTPs to enable self-sufficient energy supplies at these sites	Municipal health services
Energy efficiency in wastewater treatment	⇒ Conduct an energy audit at all wastewater treatment plants ⇒ Regular maintenance of pumps and motors ⇒ Promote the use of high-efficiency motors ⇒ Replace oversized motors with the correct size motors ⇒ Introduce solar water pumping systems to suitable applications that only require pumping during the day ⇒ Promote combined heat and power (CHP) generation ⇒ Implement a variable speed drive programme for appropriate motor technology ⇒ Install control mechanisms to control the speed of aerators ⇒ Installation of automatic controls	Municipal health services

Scheepers & vd Merwe-Botha (2013) also indicated that 100% self-sustainability in power supply is possible at wastewater treatment sites. Up to 60% of the energy requirements can be achieved by the implementation of cell lysis processes with combined heat and power (CHP) production. Biogas production can be used to provide essential on-site power at WWTPs. The three major classes of wastewater with the greatest potential for energy recovery are sewage, animal husbandry wastewaters, and food and beverage processing wastewaters (Burton, 2009). Biogas technology is suggested to be the most appropriate technology available for application as it can be located in municipal, industrial or agricultural plants.

7.8. Cross-cutting mitigation action

The installation of smart controls should be supported (GPG, 2012) in various sectors, and the introduction of these controls should be integrated into the overall government infrastructure. Smart controls enable loads and consumption to be managed in a dynamic manner to meet the needs of the users and to optimize the use of energy and infrastructure. The controls use digital technology to manage integrated systems such as buildings, equipment and appliances. Smart controls for transportation and logistics are systems that monitor movement and destination in real time in order to improve transportation efficiency and effectiveness. They ensure efficiency in fuel consumption and thereby reduce GHG emissions, optimization of capital resources, reduced congestion, speed control and safety (GPG, 2012). The introduction of smart energy controls on an urban scale will require the development of a “smart grid” which entails overlaying the existing electrical grid with a digital electricity information network (GPG, 2012), and this should be taken into consideration in future developments in the municipality.

8. PLANNED PROJECTS

MCLM has several projects which are planned or have recently been initiated (**Table 33**) which would contribute to climate change adaptation and mitigation in the municipality. It is recommended that, while other plans are being put in place, these projects form part of the immediate term adaptation and mitigation strategy.

Table 33: Planned projects in MCLM which would contribute towards climate change adaptation and mitigation.

Sector	Planned project
Energy	• Implement the use of gas produced by WWTWs to generate energy and drive the plant. This will reduce the load on the municipality and Eskom. • Implement the use of photovoltic panels in the municipality. • Implement the use of solar geysers with no electricity supply (Eskom). • Implement the use of sodium vapour lights as they are the most efficient. • Implement a remote controlled traffic light system to ensure traffic flow synchronisation and reduce vehicle emissions.
Agriculture	• Preserve land with agricultural potential. • Develop communal food gardens to preserve resources for food security.
Water	• Building of retention dams to accommodate the overflow from Centenary Dam and assist with managing storm water.
Biodiversity and ecosystems	• Initiate a nursery project which is aimed at growing trees for the region. • Initiate a programme to monitor greenhouse gasses. • Develop natural systems such as artificial wetlands to eradicate the effects of increased amounts of rainfall and surface water flow. • Maintain wetlands and identify gaps in knowledge regarding wetland assimilation. • Develop a formal process for evaluating green infrastructure in Mogale City. • Implement the development of parks in Muldersdrift, Mogales and Munsiville.
Waste	• Implement waste recycling across the district. • Liaise with Rand Water to reuse treated waste water effluent in areas where water is scarce. • Implement the use of sludge to make and sell animal feed. • Implementation of the Blue Waste initiative that will turn waste into pellets and these pellets will be used to generate electricity. • Implement the extraction of methane from landfill sites. • Implement the development of recycling facilities at landfill sites.

9. WAY FORWARD

This report discusses climate change vulnerabilities and impacts in MCLM and highlights climate change adaptation and mitigation actions required to improve the climate change resilience of MCLM and reduce its contribution to the overall GHG emissions in Gauteng. This Climate Change Framework and Operational Plan now needs to be taken forward and included in the IDPs Strategic Focus Areas. Sector Plans and all related development plans also need to be aligned with this framework.

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