Strategy Development

Draft Climate Change Adaptation and Mitigation Strategy for Mangaung Metropolitan Municipality

Presented to: Mangaung Metropolitan Municipality

Submitted by: Dr Chartiy Mbileni

Designation: Managing Director of NM Envirotech Solutions (Pty) Ltd

Date: 16 November 2015

Contact details: charity@nmenvirotech.co.za 082 880 8912 www.nmenvirotech.co.za

Table of Contents

ABBREVIATIONS AND ACRONYMS

ACCESS 1-0	Australian Community Climate and Earth System Simulator
AFOLU	Agriculture, Forestry and Other Land-Use
AR4 and AR5	4th and 5th Annual Report
BUM	Botshabelo Unemployment Movement
CBD	Central Business District
CCAM	Conformed Cubic Atmospheric Model
CMIP-5	Coupled Model Intercomparison, phase 5
CMRM-CM5	Centre for Metereological Research Coupled Global Climate Model, version 5
COP	Congress of Parties
CORDEX	Coordinated Downscaling Experment
CR	Critically Endangered
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Indistrial Reserch Organisation
CVD	Cardio-Vascular Disease
DEA	Department of Environmental Affairs
EC	Electrical Conductivity
ECD	Early Childhood Development
EE	Energy Efficiency
EN	Endangered
IDP	Integrated Development Plan
GCM	Global Climate Model
GDP	Gross Domestic Product
GFDL-CM3	Geographical Fluid Dynamic Laboratory Coupled Model 3
GHG	Green House Gas
GIS	Geographical Information System
GIZ	Deutsche Gesellschaftfür Internationale Zusammenarbeit
IPCC	Intergovernmental Panel on Climate Change
LED	Light Emitting Diode
LED	Local Economic Development
LT	Less Threatened
LTAS	Long Term Adaptation Strategy
LTMS	Long Term Mitigation Strategy
MMM	Mangaung Metropolitan Municipality
MPA	Mitigation Potential Analysis
MTREF	Medium Term Revenue and Expenditure Framework
NAEIS	National Atmospheric Emissions Information System
NAMA	Nationally Appropriate Mitigation Action
NCCRP	National Climate Change Response Policy
NCD	Non-Communicable Disease
NDP	National Development Plan
NGO	Non-Governmental Organisation
PPE	Personal Protective Equipment
RDP	Reconstruction and Development Programme
SAPS	South African Police Service
SAWIS	South African Waste Information System
SDF	Spatial Development Framework
SGB	School Governing Body
SMME	Small Micro and Medium Enterprise

SOC	State Owned Company
SRC	Student Representative Council
SST	Sea Surface Temperature
StatsSA	Statistics South Africa
UNCED	United Nations Conference on Environment and Development
UNEP	Uited Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
VU	Vulnerable

Executive Summary

The National Climate Change Response Policy highlighted the need for all government departments to review all policies, strategies, legislation, etc. within their jurisdiction to ensure full alignment with this policy. This alignment will allow for more effective interaction between municipal, provincial and national government. It will further ensure that there is alignment between national flagship programmes, provincial and municipal focus areas and plans such as Integrated Development Plans (IDP), enabling the municipal programmes to contribute to national targets. This also allows for access to national and international funding streams that will benefit South Africa as a whole. The National Development Plan (NDP) further recognises that in the long-term the country should be able to manage its transition to a low-carbon economy without negative consequences for economic growth (RSA, 2011b).

In recognition of the urgent need to act now to reduce greenhouse gas emissions and adapt to climate change impacts already being experienced, the Free State Province's Mangaung Metropolitan Municipality (MMM) recognises the need to contribute to both national and global efforts to reduce its carbon dioxide and other greenhouse gas (GHG) emissions, particularly with a longer-term view to mitigating the effects of climate change. Equally significant, the MMM also recognises the need to adapt to the impacts of the unavoidable climate changes occurring in both the shorter and longer term. Planning, preparedness, and innovation will therefore be required to maximise the MMM's adaptive capacity to this global threat. Taking action now will limit damages, loss of life, and costs over the coming decades and, if strategically well considered, will add to the MMM's national competitive edge into the future.

The Status Quo of MMM was established. MMM comprises of a number departments that have policies, plans, frameworks, projects, etc. that are linked to climate change mitigation and/or adaptation. Importantly, the municipality has an Integrated Development Plan (IDP) that guides development and planning within the municipality. Furthermore, separate documents were also obtained from the departments outlining various initiatives undertaken to address climate change within the municipality. In terms of Climate Change Adaptation, it was noted that Mangaung is prone to a myriad of extreme climate events because of its geographic location. These events are classified under the three climate that are plausible to affect South Africa in the future due to climate change; namely extreme temperature, extreme rainfall and extreme weather. Mangaung suffers from all three. However, MMM has enhanced the municipality's capacity to adapt to extreme climate events, by preparing for disaster risk reduction and management (i.e. Disaster management plan in place, Early warning systems available, Disaster Management Centre and Research input from university and other research institutions).

A key outcome of the IDP relates to environmental management and climate change with a focus on energy efficiency and clean energy use. In Mangaung, grid-supplied electricity is considered to be the largest contributor to GHG emissions, followed by petrol and diesel use Notably, the residential, commercial and transport sectors emerge as key users of energy that are responsible for the most GHG emissions.

The climate science projections downscaled represent both high (RCP4.5) and low (RCP8.5) mitigation scenarios. The projections obtained were interpreted within the context of the Global Climate Model (GCM) projections described in the 4th Annual Report (AR4) and 5th Annual Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) and the regional projections of the Long Term Adaptation Senarios (LTAS) of Department of

Environmental Affairs (DEA). The projected changes are presented for the period 2021-2050 relative to the 1971-2000 baseline period.

Under low mitigation, temperatures are projected to rise drastically, by 1-3 °C over the central South African interior for the period 2020-2050 relative to the baseline period. These increases are to be associated with increases in the number of very hot days, heat-wave days and high fire-danger days over South Africa. Key implications of these changes for Mangaung may include an increased risk for veld fires to occur in the grasslands areas. The household demand for energy in summer is also plausible to increase, to satisfy an increased cooling need towards achieving human comfort within buildings. Under high mitigation, the amplitudes of the projected changes in temperature and extreme temperature events are somewhat less, but still significant. The projected changes in rainfall and related extreme events exhibit more uncertainty than the projected temperature changes. A robust signal of increases in dry-spell-day frequencies is evident from the projection.

For example, the model-simulated and bias-corrected annual average number of very hot days (days when the maximum temperature exceeds 35 °C, units are number of days per model grid point) are displayed in Figure 0.1, for the baseline period 1971-2000. Over the western Free State, more than 70 very hot days occur on the average annually.

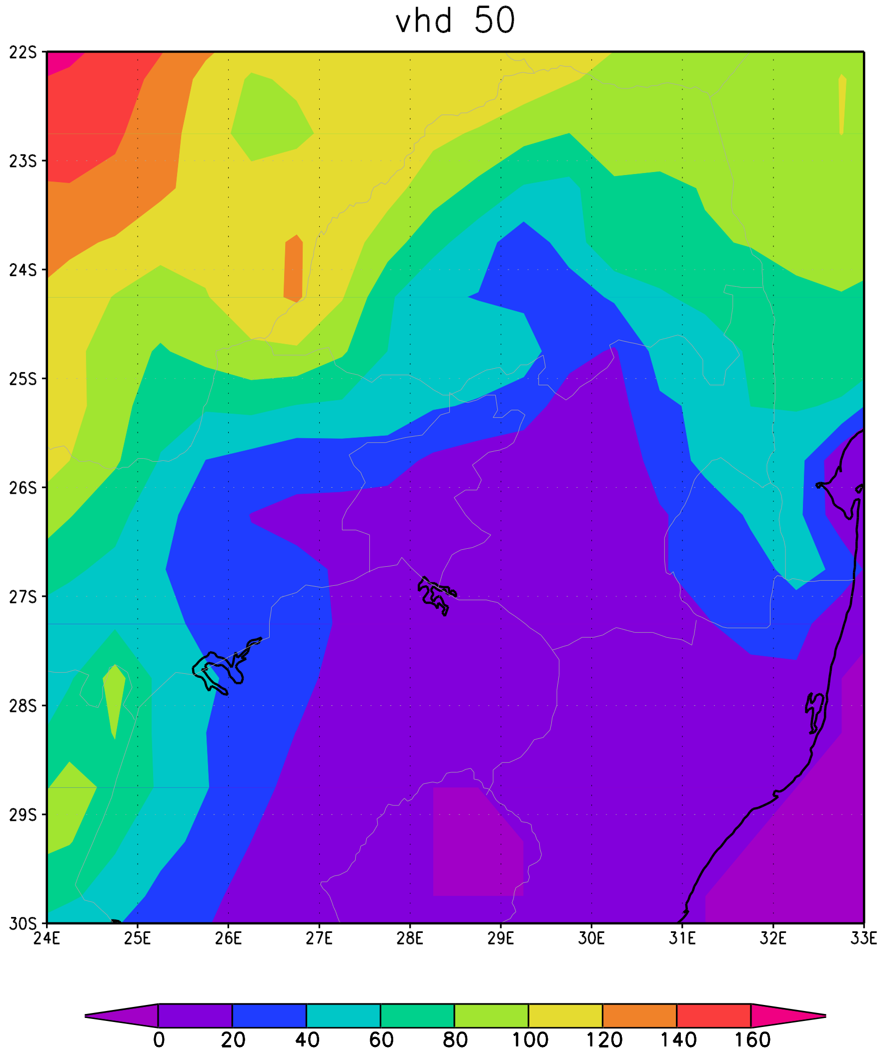


Figure 0.1: CCAM simulated annual average number of very hot days (units are number of days per grid point per year) over central South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.

In association with drastically rising maximum temperatures (Figure 0.2), the frequency of occurrence of very hot days is also projected to increase drastically under climate change. For the period 2020-2050 relative to 1971-1990, under low mitigation, very hot days are projected to increase with as many as 40 days per year in the western part of the domain (Figure 4.4). More modest increases are projected for the eastern parts. Even under high mitigation, the increase in the number of very hot days may be as high as 40 days over the western Free State (Figure 0.2).

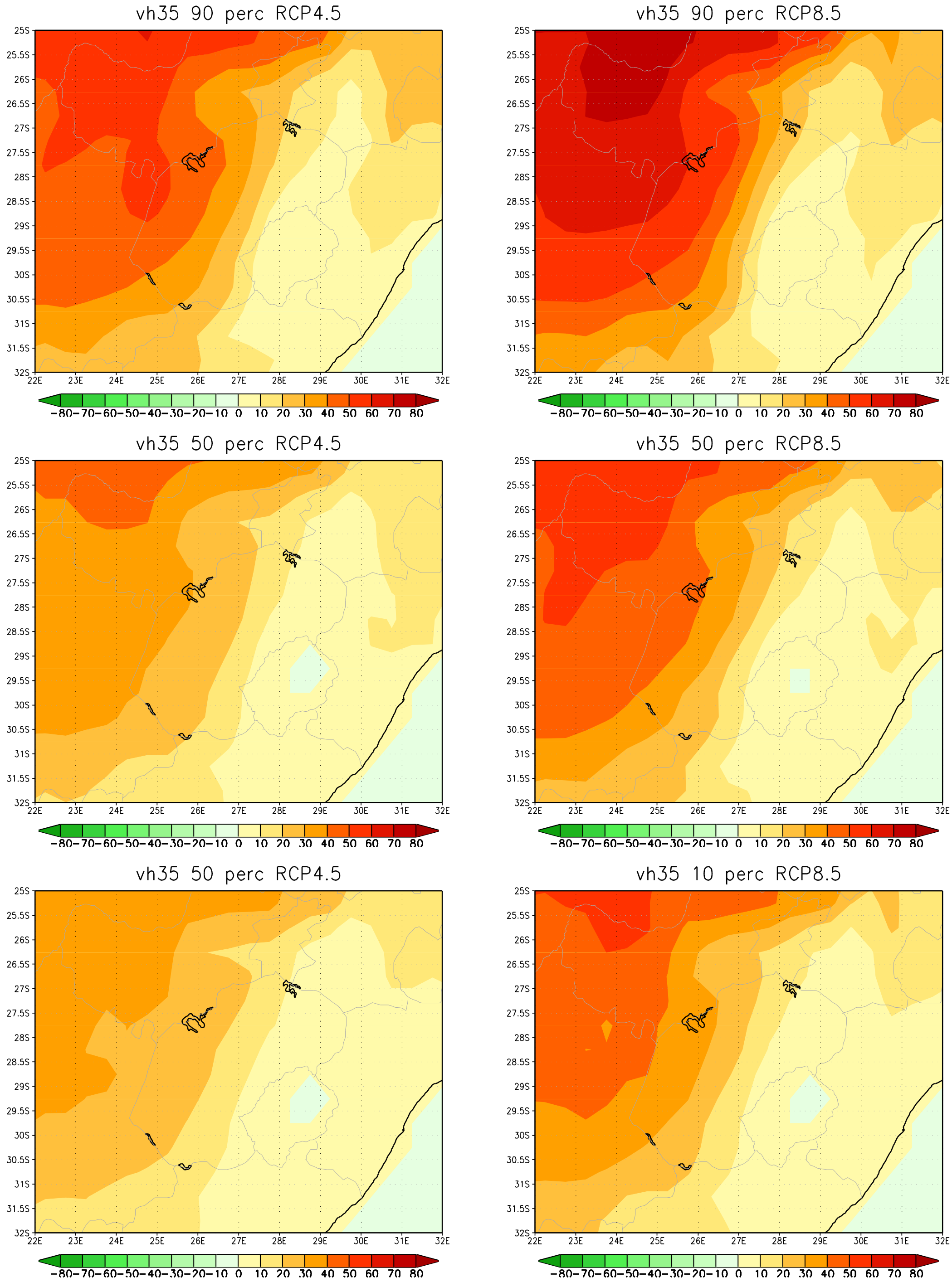


Figure 0.2: CCAM projected change in the annual average number of very hot days (units are days per grid point per year) over central South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th, 50th and 90th percentiles are shown for the ensemble of downscalings of six GCM projections under RCP4.5 (left) and RCP8.5 (right).

The vulnerability of both economic and social sectors in the municipality to climate change, both the current climate and the projected climates based on the climate change projections are provided. For example, in terms of economic sectors, Agriculture is one of the most vulnerable sectors in MMM. It has been identified as the biggest consumer of surface water in the country, with at least 60% of the water being used for irrigation as well as a significant amount being sourced from ground water resources. This dependence on water represents an insurmountable amount of vulnerability for all agricultural related activities. This is makes agriculture a key sector for the adaptation interventions including for the water sector, food security and other socio-economic impacts (DEA, 2013).

Rainfall is one of the most important factors in agriculture as it determines the types of agricultural activities and suitability of the type of farming. Rainfall is also the factor to be most affected by climate change, posing a threat to the sector and livelihoods that depend on it. Rainfall further has a direct impact on the dependence of agriculture on water, resulting in high vulnerability. Approximately 60% of the country's water resources are channelled for irrigation, while all the other activities in support of agriculture consume at least 65% of water. Evaporative losses are a climatic factor influenced by the unreliable rainfall especially in arid and semi-arid conditions (DEA, 2013 – agric). Other climate related conditions that affect agriculture are related to temperature variations and these include heat waves, cold spells and crop evaporation (DEA, 2013 – agric). Rainfall variability further exacerbates agriculture, all affecting crop potential and yield.

In terms of social Vulnerability, the following wards are highlighted are highly vulnerable: 12, 27, 31 – 34, 36 – 39, 41, 45, 46. The wards are highlighted with the orange colour in the map (Figure 0.3) and are mainly located in the south – eastern corner of the municipality, in and around Botshapelo and Thaba Nchu. These wards are characterised by high economic dependency, poor access to transport, poor access to information and physiological factors. Some and not all are also affected by high unemployment, poverty and access to water. Of these wards, ward 27 emerges as one of the most highly vulnerable, showing high ranking in type of housing (informal settlements), poverty, unemployment, education, access to water and economic dependency.

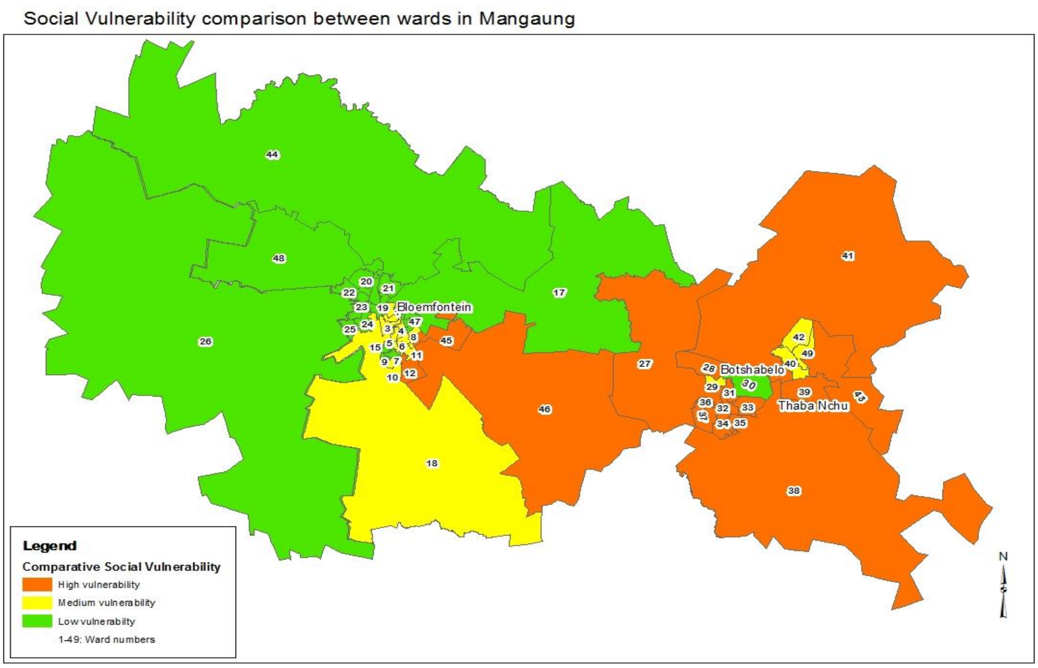


Figure 0.3: Social Vulnerability in Mangaung

A summary of climate change interventions / options that are focused on Adaptation are presented in Table 0.1 below.

Table 0.1: Summary of Adaptation Options

Sector	Adaptation options	Priority areas
Agriculture	• Promote investment in community food production • More efficient management of applications of nitrogen fertilizer and manure in agricultural areas.	• Climate smart agriculture • Minimize pollution of water sources by fertilisers
Energy	• Assessing and investing in renewable energy for cooking, heating and lighting e.g. biogas and solar • Add thermal heating to low cost houses • Smart meters for energy management	• Investing in solar energy and other renewables for heating and lighting at different scales
Transport	• Provide the public with affordable, comfortable, safe and reliable public transport	• Provide infrastructure for public transport and low carbon transport systems
Water	• Early warning system to inform people of upcoming climate extremes • Farmers need to increase water storage capacity in drier periods • Wetland rehabilitation and management • Removal of alien plants and replacing them with indigenous plants	• Vulnerability mapping or rivers that supply water to MMM and considering ecosystem based risk reduction
Biodiversity and Ecological infrastructure	• Wetland rehabilitation and management • Removal of alien plants and replacing them with indigenous plants • Build capacity within communities to engage in green jobs • Protect fresh water habitats and resources to promote growth of marines species	• Biodiversity stewardship programmes to help communities to understand the link between biodiversity and ecosystem services in their area
Human settlements	• Promote mixed land use developments • Restrict development within flood lines • Curtail urban sprawl to avoid uneconomic spread of development which will be difficult to provide with basic services	• Mixed land use developments to curb urban sprawl and cut down travel distances for communities in Thaba Nchu and Botshabelo
Infrastructure Development	• Upgrade and maintain storm water in all regions to keep them clear of any sand and rubbish • Maintain waste management facilities and equipment	• Identification of critical infrastructure hot spots • Maintenance of infrastructure
Social, health and community	• Upgrade sanitation systems to curb seepage of sewage into underground water and the spread of disease	• Keep track of health trends related to climate in MMM

MMM's Mitigation Strategy will provide the overarching approach that should be taken towards reducing GHG emissions that will support national and provincial goals for mitigation and developmental growth. The first step in Mitigating climate change in Mangaung is for the Municipality to **develop a GHG Inventory** - This will provide the baseline of current GHG emissions levels for MMM and will be used in monitoring projects' implementation progress. Table 0.2 presents GHG emissions from energy use and other related sectors in MMM.

Table 0.2: Energy use and related GHG emissions by sector in MMM excluding Eskom distribution data (Adapted from SEA, 2015).

Sector	GJ	tCO2e
Residential	2 566 386	686 325
Commercial	2 340 899	666 727
Industrial	608 530	149 964
Transport	9 406 084	647 151
Government	192 091	52 474
Total	15 113 990	2 202 641

The following is the proposed mitigation intervention measures that are proposed for MMM (see Table 0.3):

Table 0.2: Proposed Mitigation Interventions for MMM

Sector	Proposed Mitigation Interventions/Projects	Details of the Interventions
Energy	Renewable Energy	Build Solar parks that will feed electricity to the National Grid, use of Solar in residential areas and industry
	Energy Efficiency (EE)	Refurbish MMM buildings (Government buildings hospitals, clinics and schools with EE equipment)
		Refurbish street lights with LED lights
		Encourage EE by industry processes
Water	Rain Water harvesting	Encourage rain water harvesting by installing rain water harvesting tanks in residential areas
	Efficient water use –	Fix leaking water infrastructure
	Alien plant species removal	Remove alien plant species to reduce water usage
Human Settlements	Insulate RDP houses	To reduce heating and air conditioning need for human comfort
	Renewable Energy	Install Solar Water Heaters or heat pumps in Residential areas (existing and new houses and RDP houses)
	Energy Efficiency	Refurbish residential areas with LED Lighting
Agriculture	Smart Agriculture	• Agricultural practices that reduce methane emissions
		Encourage organic farming (Introduce vermiculture – organic manure)
Transport	Public Transport – Bus	Introduce BRT bus system like GP 'Reya Vaya'

Sector	Proposed Mitigation Interventions/Projects	Details of the Interventions
	rapid Transport system	and 'A re yeng'
	Introduce bicycle lanes	Encourage bicycle use
Waste Management	Waste to Energy	Convert Landfill gas to electricity
		Use waste to generate biodiesel for MMM bus fleet and Biogas (Biofuels)
	Recycling	Reduction, Recycling, Reuse of waste material
		Separation at Source
		Introduce Manufacturing Plant industries using Recycled materials to create jobs
Biodiversity	Plant indigenous trees to act as carbon emissions sinks	Remove invasive alien plant species and plant indigenous plants
	Protect parks and open spaces to maintain their role as carbon sinks	e.g. MOSS study
Commercial and Industry	Energy Efficiency	Encourage and incentivise EE initiatives by industries

Implementation of the Strategy needs to take a co-ordinated approach. The following cross cutting parameters on Table 0.4 are critical for an integrated and inclusive Strategy approach.

Table 0.4: Cross cutting parameters for Strategy Implementation and M&E

Parameter	Intervention / Options
Governance	• Inter-organizational and governance cooperation
Monitoring and evaluation	• Develop GHG inventory structure and monitor emissions • Conduct monitoring for MMM
Public Awareness, Education and Training	• Public awareness campaigns on climate change • Promote SMME development business incubator for climate smart technologies • Continued support on waste management initiatives
Research and Development (R&D)	• Partnerships between provincial and municipal government and research organizations to conduct on-going research in climate change and interventions

The above-mentioned interventions present opportunities for MMM for the creation of new manufacturing industries and SMEs, and requisite service sectors.

As a critical and vital aspect to the development of a sound and robust climate change strategy for MMM, stakeholders both from the Municipality (different departments), civil society, industry / business were gathered for three (3) engagement and capacity building workshops that took place on the 10th September 2015, 08 October 2015 and 29th October 2015 at Indaba auditorium (Bram Fischer Building – MMM) to be introduced to the study, empowered, capacitated, create a network of climate change community and finally, contribute to the development of the Strategy.

1. Introduction

The opening statement of the Intergovernmental Panel on Climate Change's (IPCC's) 5th Assessment Report (AR5), Climate Change: The Physical Science Basis, states that "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased". The IPCC report continues by stating that it is 95% sure that human influence is the dominant cause of the observed warming since the mid 20th century (AR5, 2014).

In 1992, countries joined an international environmental treaty, the United Nations Framework Convention on Climate Change (UNFCCC), to cooperatively consider what they could do to limit average global temperature increases and the resulting climate change, and to cope with whatever impacts were, by then, inevitable (www.unfccc.int). The UNFCCC was produced at the United Nations Conference on Environment and Development (UNCED) (or informally known as the "Earth Summit"), held in Rio de Janeiro in 1992. The objective of the treaty is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The treaty provides a framework for negotiating specific international treaties (called "protocols") that may set binding limits on greenhouse gases. The parties to the convention have met annually from 1995 in Conferences of the Parties (COP) to assess progress in dealing with climate change.

South Africa ratified the UNFCCC in August 1997 and acceded to the Kyoto Protocol in July 2002. In 1997, the Kyoto Protocol was concluded and established legally binding obligations for developed countries to reduce their greenhouse gas emissions. The 2010 Cancún agreements state that future global warming should be limited to below 2.0 °C relative to the pre-industrial level. One of the first tasks set by the UNFCCC was for signatory nations to establish national greenhouse gas inventories of greenhouse gas (GHG) emissions and removals, which were used to create the 1990 benchmark levels for accession of Annex I countries to the Kyoto Protocol and for the commitment of those countries to GHG reductions. Updated inventories must be regularly submitted by Annex I countries.

South Africa acknowledges that addressing climate change issues is an integral part of achieving sustainable development. According to the National Development Plan (NDP), rising temperatures, more erratic rainfall and extreme weather events are likely to take a heavy toll on Africa, with an increased spread of tropical diseases and growing losses (human and financial) from droughts and flooding. Climate change has the potential to reduce food production and the availability of potable water, with consequences for migration patterns and levels of conflict.

Furthermore, one of objective of the NDP with regard to Environmental Sustainability and Resilience is improved disaster preparedness for extreme climate events. To address agriculture and food security within the Environmental Sustainability and Resilience thematic area, the NDP intends, as one of the actions, to: channel public investment into research, new agricultural technologies for commercial farming, as well as for the development of adaptation strategies and support services for small-scale and rural farmers.

In 2011, South Africa developed the National Climate Change Response Policy (NCCRP), which strives to develop climate change adaptation strategies based on risk and vulnerability reduction, in collaboration with its neighbours where appropriate, and seek to share resources, technology and learning to coordinate a regional response. The NCCRP presents the South Africa's vision for an effective climate change response and the long-term, just transition to a climate-resilient and lower-carbon economy and society. South Africa's response to climate change has two objectives:

- Effectively manage inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity.
- Make a fair contribution to the global effort to stabilise greenhouse gas (GHG) concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a timeframe that enables economic, social and environmental development to proceed in a sustainable manner.

The economic and social impact of climate change on communities cannot be understated. Local government is ultimately responsible for the realisation of policy in practical terms. Section 10.2.6 of the cabinet endorsed National Climate Change Response White Paper recognises the important role of provincial and local government in meeting the challenge of climate change (Figure 1). For local government, it particularly identifies the areas of planning and urban development, municipal infrastructure and services, notably water, energy, waste demand management and local disaster response.

Figure 1.1: Schematic diagram linking international, regional, national governments' commitments on climate change

The delegation of environmental functions to the lowest possible level has placed increasing responsibility on local government, and expanded its role from mainly service provision to that of an active development agent (Fakier et al., 2005). This is not unique to South Africa, internationally municipal and provincial government often have considerable authority sometimes extending to legislation, planning and investment decisions including those related to climate change (Kotzé, 2006). In addition, committed local government can play an important role in supporting behaviour change among its citizens.

The National Climate Change Response Policy highlighted the need for all government departments to review all policies, strategies, legislation, etc. within their jurisdiction to ensure full alignment with this policy. This alignment will allow for more effective interaction between municipal, provincial and national government. It will further ensure that there is alignment between national flagship programmes, provincial and municipal focus areas and plans such as Integrated Development Plans (IDP), enabling the municipal programmes to contribute to national targets (Figure 1 above).

Local government is responsible for taking a wide range of decisions and is at the forefront in the implementation of climate change programmes with a high level of success. This work is premised on the notion that projects delivered locally reflect local circumstances and it is these tailor-made solutions that will lead to actions effectively addressing adaptation to climate change.

The Long-Term Adaptation Strategy (LTAS) research programme provided national and sub-national adaptation scenarios for South Africa as well as evaluating the socio-economic and environmental implications of potential impacts of anticipated climate change across three time frames, namely short (<2030), medium (<2050) and long term (<2100) for the water, agriculture and forestry, human health, fisheries, biodiversity, disaster risk reduction and human settlements (urban, rural and coastal) sectors at a national level. In addition, this project developed a logical view of South Africa's climate change trends, current variability and future projections to provide a set of climate change scenarios based on the latest available methodologies, downscaled for the South African context. The scenarios considered climate trends and variability, climate change projections and impacts in selected sectors and the development growth pathways for these sectors.

Findings from the LTAS study assert that the Free State Province is vulnerable to climate change, given its meteorological conditions. The vegetation and agricultural conditions are therefore largely unique to the Province, resulting in a particular climate vulnerability which in some respects is different to the rest of the country. In most cases these changes threaten to amplify existing vulnerability entrenched within the socio-economic inequality characteristic of South Africa. These climate projections for this region indicate not only a warming trend as with the rest of the country, but also projected drying in many areas, with longer time periods between increasingly intense rainfall events. The latter is of particular concern to the already water stressed Free State Province, particularly the Mangaung Metropolitan Municipality.

These broad projections raise the risk profile of the Province which is already vulnerable to droughts, floods and fire, thus posing a significant service delivery challenge to MMM and its local municipalities.

In recognition of the urgent need to act now to reduce greenhouse gas emissions and adapt to climate change impacts already being experienced, the Free State Province's Mangaung Matropolitan Municipality recognises the need to contribute to both national and global efforts to reduce its carbon dioxide and other greenhouse gas (GHG) emissions, particularly with a longer-term view to mitigating the effects of climate change. Equally significant, the MMM also recognises the need to adapt to the impacts of the unavoidable climate changes occurring in both the shorter and longer term. Planning, preparedness, and innovation will therefore be required to maximise the MMM's adaptive capacity to this global threat. Taking action now will limit damages, loss of life, and costs over the coming decades and, if strategically well considered, will add to the MMM's national competitive edge into the future.

Mangaung Metropolitan Municipality is the economic hub of the Free State Province and the only Category A municipality (i.e. a municipality which executes all the functions of local government for a city or conurbation. This is by contrast to areas which are primarily rural, where the local government is divided into district municipalities and local municipalities) in the Province. The economy of MMM is strongly driven by the government sector, which has seen the fastest growth in the last five years as a result of increased government programmes in livelihoods improvement interventions (www.statssa.gov.za).

1.1 Overview of Mangaung Metropolitan Municipality

The Mangaung Metro Municipality is a huge area covering a radius of 6863 km^2. It comprises three prominent urban centres, which are surrounded by an extensive rural area.

Bloemfontein which is the 6th largest city in South Africa. It is the capital city of the Free State Province and therefore, serves as the administrative headquarters of the provincial government. It is the Judicial Capital of South Africa. Bloemfontein is de facto the economic hub of the local and regional economy. Attached to Bloemfontein is a large township; Mangaung. Unlike other townships in the Municipality, Mangaung Township is relatively well serviced. This is obviously due to its proximity to the economic hub. However, its relative development has become a magnetic force that attracts people from other townships in search of improved livelihoods – thereby placing undue pressure on existing infrastructure.

Bloemfontein has a well-developed Central Business District (CBD) which forms a strong business and services node, supported by a variety of mixed activities and community facilities. There are also two very large regional shopping centres in the city in addition. Bloemfontein has three industrial areas. Moreover, the city has educational institutions, recreational and welfare facilities.

Botshabelo is located 55km to the east of Bloemfontein. It is the single largest township development in the Free State. However, it is highly under-developed and lacks most basic services. As a result, the majority of its residents rely on the City of Bloemfontein for employment and other economic activities. It is estimated that more than 17 000 people commute between Botshabelo and Bloemfontein and Thaba Nchu and Bloemfontein daily. This has prompted Mangaung Metropolitan Municipality to subsidise transport to the tune of R80m annually.

Botshabelo has a very low base of CBD. Limited commercial activities are spread all over the area. It is characterized by an oversupply of school sites and public open space. Commercial activities include an industrial park with factories and infrastructure worth R500m. There are presently 138 factory buildings in Botshabelo with a total floor area of 200 000m^2. Fully serviced stands are available for further development.

Thaba Nchu is situated 12km further to the east of Botshabelo. It used to be part of the Bophuthatswana 'Bantustan'. As a result it exhibits large areas of rural settlements on former trusts lands. In addition Thaba Nchu has a scattered settlement pattern with 37 villages surrounding the urban centre – some as far as 35km from the centre.

Population	**Mangaung population distribution, 2007**
In the first decade of the 21st Century Mangaung has experienced exponential growth in population size. For example, the population figure for Mangaung has increased from 645 440 in 2001 to 752 906 in 2007 (Stats SA, 2007) which indicates a combined growth rate of 16.6%.	Bloemfontein: 52% Botshabelo: 28% Thaba Nchu: 14% Rural Area: 6%

The Economy of MMM

Mangaung has a relatively well developed economy and is the largest contributor to the GDP of the province at 31.35% (Stats SA, 2011). Its economic growth has remained consistent at 3% per annum. However, the economy of Mangaung is mainly characterised by reliance on service industries and unequal distribution of economic activities. This growth trajectory is largely responsible for the triple crises of high levels of unemployment, poverty and inequality.

Development challenges for MMM

Like most municipalities in South Africa, MMM is facing daunting challenges regarding service provision and eradicating the legacy of high levels of unemployment, poverty and inequality. Research indicates that poverty levels in Mangaung are very high with more than 50% of the residents earning less than R1 000 per month [Stats SA, 2011]. Township dwellers in Botshabelo, Thaba Nchu and Mangaung township residents are disproportionately affected.

Due to its relatively high state of development, Bloemfontein inevitably attracts more migrants, especially in the township of Mangaung. This state of affairs results in incessant services backlog. For example, backlogs for water stood at 8.7%; 6.9% for sanitation; 15% for roads and 26% for storm water in 2009 (MLM, 2010). Due to shortage of housing for new incomers, informal settlements are mushrooming on a daily basis. It is estimated that there are approximately 45 informal settlements in Mangaung (MMM). A number of municipal strategies, plans and frameworks that have relevance to climate change have been considered in the development of MMM Climate Change Response Strategy to ensure alignment and integration. The focus on addressing the strategic goal relating to climate change involves mitigating and adapting to climate change, decreasing environmental stress, managing resource constraints and reducing energy and water consumption.

1.2 Limitations experienced in the development of the Strategy for MMM

1.2.1 Information gathering

There is scarcity of information with respect to greenhouse gas (GHG) emissions in the Mangaung Metropolitan Municipality (MMM) as no complete GHG emissions inventory has been compiled. There is little to no information available on GHG emissions related to production and processes in the industrial, agriculture and waste sectors.

1.2.2 Stakeholder Participation in Capacity Building Workshops

The consultant was working with MMM's Project Office where the Strategy was initiated and resides, it was expected of the officials at MMM in charge of the project to assist the consultant with names of key stakeholders in MMM. The names of all Stakeholders in charge of projects and / or managing different units were provided and invitations were sent out to the stakeholders engagement workshops. Only between 35-60 people per workshop attended. This number includes civil society, NGOs, business and MMM officials. The participation number could have been more if more people from private sector and MMM officials that were invited to the workshops, had attended.

2. Objectives and Scope of Work (Terms of Reference)

The main objective of this proposed study is to develop a comprehensive climate change mitigation and adaptation strategy that will:

- Establish the current climate change status quo at Mangaung Metropolitan Municipality
- Determine the projected localised impacts of climate change, and
- Develop strategies and plans to respond to the anticipated impacts.

2.1 Scope of work

Specifically, the following activities must be carried out to realise the above objectives, as per the terms of reference outlined in the tender document:

2.1.1 Status quo

- Take stock of existing information on climate change in MMM, and develop an executive summary for policy decision makers to mobilise high level support;
- The executive summary should be accompanied by an initial analysis of the causes of the problem (climatic and non-climatic) as well as main barriers impeding implementation of immediate adaptation and mitigation strategies and measures;
- Adaptation opportunities and alternatives should be highlighted as this will constitute the basis on which the proposal will be built;
- The analysis should be supported by all necessary data and information, where possible;
- Main counterpart will be the Environment Management sub-directorate, which will co-ordinate with the other stakeholders.
- The assessment will include the following elements:

a. Current vulnerability assessment:
  - Characterisation of climate conditions and natural hazards
  - Impact on climate change in MMM, including impact considerations in National Development Plans and objectives
  - Assessing current vulnerability of development objectives to climate change
  - Assessment of current socio-economic conditions and vulnerability (e.g. Exposure)
  - Preidentification of the critical threshold

b. Future climate risk assessment:

- Climate scenarios / projections in mean and variability for MMM
- Assessing future climate change risks to the development objective
- Extrapolations of existing socio-economic trends
- Expected/ potential impacts on the priority sector(s)
- Economic and Financial impacts of climate change
- Climate risk analysis

✓ Develop an executive summary for policy and decision makers

✓ Discuss the findings with relevant project counterparts, stakeholders and the project staff

2.1.2 Based on the previous findings, the consultant will prepare an Adaptation and Mitigation Strategy on Climate Change for MMM.

- The strategy should consider all components which need to be in place, such as regulatory, technical, legal, capacity development, institutional, among others.
- It will address the following but not limited to:
- The analysis of the situation in MMM and the assessment prepared in the previous step
- Assess the information gap of the exiting documentation, such as National Plans and Strategies.
- Linkages between Adaptation and Mitigation and sustainable development at the local level, sectoral level (agriculture, water resource management, and disaster), national / provincial level (planning and co-ordinated actions may be necessary)
- Linkages between the different conventions
- How to mainstream the climate change risks and adaptation / mitigation into local policies, programmes and priorities ensuring that information about climate-related risk, vulnerability, and options for adaptation are incorporated into planning and decision making in key sectors, such as agriculture, water, health and disaster risk management as well as into existing local assessments and action plans
- Ensure that plans and priorities identified in development co-operation frameworks incorporate climate change impacts and vulnerability information to support development outcomes
- Define strategic partnerships with national bodies, local authorities and civil society
- Check for complementaries and synergies with similar existing or planned interventions in the country and the region. Lessons learnt from related previous interventions should be incorporated.
- Outline the key components of the Monitoring and Evaluation Framework of the Adaptation and Mitigation Strategy
- Discuss the Adaptation and Mitigation Strategy to Climate Change for MMM with relevant project counterparts, stakeholders and project staff and agree on the final version.

2.1.3 Within the Framework of the Adaptation and Mitigation Strategy to Climate Change, s/he will identify and formulate a Program for Adaptation and Mitigation to the Climate Change for MMM

- When preparing the programme Document, the consultant will consider the following but not limited to:
- Ensure it includes a legal and institutional analysis. This comprises of a comprehensive description of the main roles, regulatory issues, policies, actors and planning processes relating to the system targeted by the project.
- Ensure the problem analysis is done logically and is based on the preliminary assessments of the current vulnerability and future climate risks.
- Develop the reason of the intervention and describe both baseline and adaptation and mitigation scenarios.
- <u>Baseline scenario</u> is to identify what course of action would be taken in the absence of climate change adaptation / mitigation, and how climate change is likely to affect development activities. It seeks to answer the question: 'what development activities would be pursued by MMM in the absence of climate change How would the targeted human systems develop without adaptation / mitigation?'. Without adaptation / mitigation, how would development activities be affected by climate change? This scenario should also include a description of the adaptation / mitigation baseline, to the adaptations to current climate that are already in place. A short discussion on the current baseline effectiveness, gaps and additional needs is also expected.
- Adaptation / Mitigation scenario: the purpose of this scenario is to identify the course of action that will have to be taken to respond to the adverse impacts of climate change, so as to achieve sustainable results. It seeks to answer the question: 'How should the development objective be achieved, taking into account the impacts of climate change and what immediate and urgent measures are necessary to respond to such impacts?' This scenario description must include a description of the activities to be implemented to address the adverse impacts of climate change in the short term. These activities should include:
    - Mainstreaming of short term adaptation / mitigation strategies into local development frameworks
    - Implementation of pilot adaptation / mitigation measures
    - Institutional capacity building and awareness raising.

✓ Determine the programme's goals, objective, outcomes and outputs that arise logically from the problem analysis and address issues for which climate change is a significant driver.

✓ Undertake a project risks analysis in line with the MMM Risk Management Strategy.

✓ To present the risks in the programme document along with the relevant mitigation measures.

✓ Outline the key components of the Monitoring and Evaluation Framework of the programme.

✓ Propose adequate measures to ensure sustainability of the intervention. This requires a brief description of the mechanisms needed to ensure recurring costs are financed, local ownership of ideas will guarantee on-going involvement, sufficient capacity exists at the end of the project, and other issues that the consultant might consider relevant.

- ✓ Outline the programmes' replication strategy: All activities (and its outcomes) should be replicated in other project sites or vulnerable systems. Knowledge management should be explained.
- ✓ Ensure cost effectiveness of the intervention scenario
- ✓ Prepare MMM Programme document
- ✓ Discuss Programme documents with relevant stakeholders, counterparts and the project staff.
- ✓ Establish the future Monitoring and Evaluation process: involves implementing, monitoring, evaluating, improving and sustaining initiatives launched by the adaptation / mitigation programme.

3 Approach / Methodology

The overall process and methodology proposed for this project provides opportunities to integrate climate change risk management and resilience planning into existing governance structures, strategies and Integrated Developmental Plans (IDP) for MMM. In line with the National Climate Change Response Policy, the proposed strategy development process took a two-pronged approach to addressing climate change:

- **Adaptation** - which will focus on reducing MMM's climate vulnerability and increasing the adaptive capacity of its economy, people, ecosystems and critical infrastructure in a manner that simultaneously addresses the municipality's socio-economic and environmental goals.
  - ✓ The information collected from status quo analysis and vulnerability assessment processes was used to fine tune projections, simulate climate change in the planning area and integrate exposure data (and adaptive capacity as appropriate) into the simulations in order to summarise vulnerability and the risk profile of MMM. Critical to this process was the data about the phenomena, potential impacts, existing stressors, physical geography of the MMM and exposed assets (exposure). As the project progressed, relevant maps and datasets in a geographic information system (GIS) were collected. GIS played an important role in this assessment as it was used to store, manage, analyse, and display spatial data collected. GIS allowed the project team to compare the extent of impacts and consequences across scenarios and better understand where the biophysical factors and social vulnerability is greatest (hot pots identification), which will support decision making

- **Mitigation** - which will focus on contributing to the global, national, provincial and MMM's efforts to significantly reduce GHG emissions and support the municipality's transition to a sustainable and low carbon economy, which simultaneously addresses the need for economic growth, job creation and improving socio-economic conditions.
  - ✓ Owing to MMM not having an inventory of energy demand and carbon dioxide emissions in place, the information collected from status quo analysis was used as a starting point for prioritising greenhouse gas mitigation measures. Therefore, mitigation interventions were identified to "*push-start*" a coordinated and scaled process of climate change mitigation in the short- to medium-to-long term.

This Strategy is an integrated and coordinated climate change response for MMM and will guide the collective development and implementation of adaptation and mitigation, innovative projects, as well as exploring opportunities that combine a sustainable and low carbon development trajectory with increased climate resilience, enhancement of ecosystems and the services they provide, as well as economic growth and job creation.

Each Chapter of this Strategy document comprises of its own introduction, methodology - based on critical design principles, observed results and conclusion.

The following were the chapters that were covered in the development of the Strategy:

- ✓ Introduction
- ✓ Approach / Methodology
- ✓ Purpose / Objectives and Scope of Work (ToR)
- ✓ Status Quo
- ✓ Climate Science Modelling / Projections
- ✓ Vulnerability Assessment
- ✓ Climate Change Adaptation Response Measures
- ✓ Mitigation and Intervention Measures
- ✓ Capacity Building and Stakeholder Engagement Process
- ✓ Implementation Framework
- ✓ Monitoring and Evaluation
- ✓ Conclusions

4 Status Quo Analysis

4.1 Introduction

Using the framework designed by MMM in the terms of reference (ToRs) provided, NM Envirotech Solutions' team took stock of best practice exercise by reviewing:

- ➢ National strategic documents which relate to weather and climate change related activities, sustainable development programs and national disaster management plans, including their action plans.
- ➢ Provincial strategic documents from a climate risk and resilience perspective focusing on the water biodiversity, human settlements, health, livelihoods, and infrastructure and utilities sectors as per the Long Term Adaptation Study (LTAS) outcomes.
- ➢ MMM's strategic and planning documents that relate to climate change issues.

The above points set the initial reference points / points of departure for this document to be developed into an Adaptation and Mitigation Strategy, with intervention measures / options, Implementation and Monitoring and Evaluation Frameworks.

4.2 Status Quo Approach

The Status Quo design was based on key engagement principles and followed this analytical approach (Figure 4.1): 1) Identification of who the key players are within and outside the Municipality 2) undertaking an overview of MMM, sector mapping and research exercise, which informs the conceptual approach, 3) analysing the data quantitatively, 4) reaching out to the climate change community (within and outside MMM) and engaging in interviews, 4) requesting sector specific documents from key stakeholders, 5) undertaking an initial capacity building and/or stakeholder engagement workshop and 6) incorporating comments from the initial workshop and finalising the executive summary for decision makers.

Figure 4.1: Status Quo design process

The Mangaung Metropolitan Municipality comprises of a number departments that have policies, plans, frameworks, projects, etc. that are linked to climate change mitigation and/or adaptation. In addition to these departmental documents, the municipality has an Integrated Development Plan (IDP) that guides development and planning within the municipality. In addition to the IDP, separate documents were also obtained from the departments outlining various initiatives undertaken to address climate change within the municipality and are summarised in the Tables 4.1 and 4.2 below.

Table 4.1: MMM departments that provided information for status quo assessments

Department/Sector	Information / Documents Provided	Initiatives currently underway
Planning Department	Integrated Development Plan (IDP) 2014	
Transport	Integrated Public Transport Network (Draft document)	Public transport initiatives to ensure safe, efficient and affordable public transport, towards reshaping of public transport in South Africa and ultimately introducing priority rail corridors and Bus Rapid Transit (BRT) systems in cities.
Human Settlements	Human Settlements Plan Build Environment Performance Plan (BEPP)	Green interventions undertaken on a project basis, e.g. Electricity saving initiatives, insulation, heat pumps, etc.
Centlec SOC Ltd	Policies and/plans documents to be provided	Electricity Distribution, e.*g. 3 Solar Farms operational within the Municipality (Centlec to confirm)*

Engineering and Infrastructure	Guidelines/Standards for provision of services (Red Book) Master Plan (Volumes 1&2): Bulk Storm Water & Roads	
Water and Sanitation	Red Book	1. MMM currently experiencing bulk water shortage, to source from Gariep dam 2. Design of infrastructure takes into account rainfall statistics. 3. Infrastructure is designed to withstand 20yr, 50yr and 100yr floods
Local Economic Development (LED) Department	Economic Development Strategy (2003) Green Economy Framework Energy Efficiency Strategy	Job creation / SMME development Cleaner technologies
Environmental Management	Environmental Management Policy Environmental Management System Environmental Management Plan Urban Open Space Policy	1.Environmental Sustainability 2. Increase the environmental literacy level of stakeholders 3. Reduce the major sources of greenhouse gas emissions and catalysiing the large-scale supply of clean energy 4. Energy saving initiatives
Land Use	Land Use Management Planning Tribunal	
Disaster Management	Disaster Management Plan Mangaung Risk and Vulnerability Assessment Study Report	1.Disaster management plan in place 2.Early warning systems available 3.Disaster Management Centre
Finance	Medium Term Revenue and Expenditure framework (MTREF) 2015/16 – 2017/18	Budgets allocated for developmental and environmental related programs, disaster management, etc.
GIS and Planning	Spatial Development Framework (SDF) - Spatial Maps	1.Supporting an efficient movement system; 2.Supporting sustainable Environmental Management; 3. Initiating and implementing Corridor Development; 4.Managing Urban Growth and densification; 5.Delineating an urban development boundary; and 6.Development of strategically located land.
Architect	Outline of water and electricity saving initiatives	Green building design initiatives currently underway

Waste Management	Waste management initiatives at MMM	1. Construction of Transfer Station in Thaba'Nchu (with a component of waste sorting system to divert waste from the landfill sites 2.Constructions of 3 Buy- Back centres in the 3 regions of MMM 3. Pilot project on separation of waste at source in one suburb. 4.Planning is underway for waste drop-off sites

This data is further supported by information supplied in Annexure 1 (attached)

4.3 Status Quo Vulnerability Assessment

The vulnerability assessment framework applied for this work will consider vulnerability as a function of exposure, sensitivity and adaptive capacity of the population and the sectors affected. These factors assist in the understanding of the municipality's vulnerability context; through the assessment of Mangaung's sensitivity; exposure and estimates of its adaptive capacities to climate variability and change. The Intergovernmental Panel on Climate Change (IPCC 2013) defines adaptive capacity as the ability of a system to adjust to actual or expected climate stresses, or to cope with the consequences of climate change. Sensitivity is the extent at which a system is affected, either negatively or beneficially by climate-related stimuli. Exposure relates to the extent of climate stress upon a particular unit of analysis and may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events.

4.3.1 Social vulnerability

Social vulnerability is influenced by non-climatic factors that play a big role in the ability of communities and population to cope with climate related disasters and extreme events. Factors such as high population densities, poverty, unemployment and high dependency ratios highlight vulnerable populations, while the geographic location of the highly vulnerable population in the flood lines as well as in informal settlements increases their vulnerability to climate change impacts. Non- climatic factors that increase vulnerability in Mangaung are presented in Table 4.2 below.

Table 4.2: Non- climatic factors that increase vulnerability in Mangaung

Poverty	Unemployment	Old and dilapidated houses
Lack of access adequate water and sanitation services	Housing backlog in Mangaung's townships	Informal houses on developed sites and unplanned settlements

4.3.2 Climate hazards for Mangaung

Mangaung is prone to a myriad of extreme climate events because of its geographic location. These events can be classified under the three climate that are plausible to affect South Africa in the future due to climate change; namely extreme temperature, extreme rainfall and extreme weather. Mangaung suffers from all three. Floods and drought are classified under extreme rainfall events; while snow storms, severe thunder storms are classified as extreme weather events while fires and cold spell are classified as extreme temperature events, which include heat waves. The list of climate risks is highlighted below in Table 4.3.

Table 4.3: The list of climate risks

Excessive rainfall and Flooding	Droughts	Strong winds
Fires	Thunderstorms and lightning	Severe Thunderstorms

Floods are the most common with wide ranging impacts on damage to infrastructure, reduced productivity for agriculture which is very important given that almost half of the metropolitan contains rural areas. The changes in temperature which may manifest as heat waves or cold spell are plausible to increase in the metro over time, which likely increase energy may demand for heating and cooling for human comfort. These are but a few of the expected impacts of the climatic hazards in the Metro. Other wide ranging impacts include water insecurity and damage to infrastructure. The Mangaung Metropolitan municipality have enhanced the municipality's capacity to adapt to extreme climate events, by preparing for disaster risk reduction and management.

The listed action below, which are being implemented for disaster reduction reduce the vulnerability to especially extreme weather events are noted:

- Disaster management plan in place
- Early warning systems available
- Disaster Management Centre
- Research input from university and other research institutions

In order to increase the adaptive capacity of the Metro, capacity building in all sectors of government, private sector and as well as in the communities is essential. The identified climate hazards, vulnerable population and sectors will be the focus of the adaptation plan and strategy for the municipality and will be the basis for the work to be done in this project.

As is evident in a number of the above listed projections, there is a risk of drier conditions across the Free State province as a whole on the 40 year time horizon. In contrast, however, historical trends and some downscaled projections suggest that western and southern mountain ranges could experience wetter conditions. This apparent contradiction serves to highlight the complexity of climate drivers and responses, which in turn illustrates the inherent difficulties faced by decision makers when required to plan for climate resilience into the future. The complexity highlights the need for adaptive and flexible responses to climate variability and change that are not focused on fixed timescales or unidirectional change.

4.4 Climate Change Mitigation

There is scarcity of information with respect to greenhouse gas (GHG) emissions in the Mangaung Metropolitan Municipality (MMM) as no complete GHG emissions inventory has been compiled. However, some information is available with respect to energy-related GHG emissions. Grid-supplied electricity is considered to be largest contributor to GHG emissions, followed by petrol and diesel use (SEA, 2015). The residential, commercial and transport sectors emerge as key users of energy that are responsible for the most GHG emissions (Table 4.4). There is little to no information available on GHG emissions related to production and processes in the industrial, agriculture and waste sectors.

Table 4.4: Energy use and related GHG emissions by sector in MMM excluding Eskom distribution data (Adapted from SEA, 2015).

Sector	GJ	tCO_2e
Residential	2 566 386	686 325
Commercial	2 340 899	666 727
Industrial	608 530	149 964
Transport	9 406 084	647 151
Government	192 091	52 474
Total	15 113 990	2 202 641

The MMM faces challenges with respect to the long distances that have to be travelled by people within the city which contributes significantly to petrol and diesel use within the road transport sector (MMM, 2014). The IDP is aligned with the NDP which recognises the need to improve public transport, which could have potential climate change mitigation benefits. The IDP also recognises the need to have dense mixed developments in order for commuters to travel fewer kilometres. The Mangaung Metro Integrated Human Settlements Plan seeks to ensure the development of integrated human settlements and shorter travel distances (MMM, 2014).

The IDP for the MMM emphasises the need for development in the municipality to be aligned with the goals of the NDP. Specifically, a key outcome of the IDP relates to environmental management and climate change with a focus on energy efficiency and clean energy use. It was reported that in 2011, 91% of households were electrified and that 57% of households were using safe/clean energy for their heating needs. As such the IDP highlights the needs for energy savings, by lowering electricity consumption through interventions that would improve energy efficiency and seeking investment in a renewable energy sources (MMM, 2014).

5 Model projections of climate change and extreme weather events impacting on the Free State Province and Mangaung

5.1. Introduction

Climate change is projected to impact drastically in Southern Africa during the 21st century under low mitigation futures (Niang et al., 2014). African temperatures are projected to rise rapidly, at 1.5 to 2 times the global rate of temperature increase (James and Washington, 2013; Engelbrecht et al., 2015). Moreover, the southern African region is projected to become generally drier under enhanced anthropogenic forcing (Christensen et al., 2007; Engelbrecht et al., 2009; James and Washington, 2013; Niang et al., 2014). These changes in the annual and seasonal rainfall patterns will plausibly have a range of impacts in South Africa, including impacts on energy demand (in terms of achieving human comfort within buildings and factories), agriculture (e.g. reductions of yield in the maize crop under higher temperatures and reduced soil moisture), livestock production (e.g. higher cattle mortality as a result of oppressive temperatures) and water security (through reduced rainfall and enhanced evapotranspiration) (Engelbrecht et al., 2015).

However, climate change is not to take place only through changes in average temperature and rainfall patterns, but also through changes in the attributes of extreme weather events. For the Southern African region, generally drier conditions and the more frequent occurrence of dry spells are plausible over most of the interior (Christensen et al., 2007; Engelbrecht et al., 2009). Tropical cyclone tracks are projected to shift northward, bringing more flood events to northern Mozambique and fewer to the Limpopo province in South Africa (Malherbe et al., 2013). Cut-off low related flood events are also projected to occur less frequently over South Africa (e.g. Engelbrecht et al., 2013) in response to a poleward displacement of the westerly wind regime. Intense thunderstorms are plausible to occur more frequently over South Africa in a generally warmer climate (Engelbrecht et al., 2013).

An update on the latest insights and evidence available regarding future changes in climatological averages and extreme events over South Africa is provided, with a focus on changes that are to impact on the Free State and Mangaung. Recent downscalings of global circulation model (GCM) projections of the Coupled Model Intercomparison Project Phase Five (CMIP5) and Assessment Report Five (AR5) of the Intergovernmental Panel on Climate Change (IPCC), obtained at the Council for Scientific and Industrial Research (CSIR) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), are used for this purpose. These downscalings are for the period 1971 to 2100, follow the experimental design recommended by the Coordinated Downscaling Experiment (CORDEX) and have been derived for both low and high mitigation scenarios. The regional climate model used to obtain the downscalings is the conformal-cubic atmospheric model (CCAM) of the CSIRO. In addition, the report also considers evidence on changes in extremes events over southern Africa as presented in Assessment Report Four (AR4) and AR5 of the IPCC (Christensen et al., 2007; Niang et al., 2014) and in the Long Term Adaptation Scenarios Report (LTAS, 2013) of the Department of Environmental Affairs (DEA).

5.2 Experimental design and model verification

Regional climate modelling is used to downscale the projections of CMIP5 GCMs to high resolution over southern Africa. The regional climate model used, CCAM, is a variable-resolution GCM developed by the CSIRO (McGregor 2005; McGregor and Dix 2001, 2008). The model solves the hydrostatic primitive equations using a semi-implicit semi-Lagrangian solution procedure, and includes a comprehensive set of physical parameterizations. The GFDL parameterization for long-wave and shortwave radiation (Schwarzkopf and Fels, 1991) is employed, with interactive cloud distributions determined by the liquid and ice-water scheme of Rotstayn (1997). The model employs a stability-dependent boundary layer scheme based on Monin-Obukhov similarity theory (McGregor et al. 1993). CCAM runs coupled to a dynamic land-surface model CABLE (CSIRO Atmosphere Biosphere Land Exchange model). The cumulus convection scheme uses mass-flux closure, as described by McGregor (2003), and includes both downdrafts and detrainment. CCAM may be employed in quasi-uniform mode or in stretched mode by utilising the Schmidt (1977) transformation.

Six GCM simulations of CMIP5 and AR5 of the IPCC, obtained for the emission scenarios described by Representative Concentration Pathways 4.5 and 8.5 (RCP4.5 and 8.5) were downscaled to 50 km resolution globally. The simulations span the period 1971-2100. RCP4.5 is a high mitigation scenario, whilst RCP8.5 is a low mitigation scenario. The GCMs downscaled are the Australian Community Climate and Earth System Simulator (ACCESS1-0); the Geophysical Fluid Dynamics Laboratory Coupled Model (GFDL-CM3); the National

Centre for Meteorological Research Coupled Global Climate Model, version 5 (CNRM-CM5); the Max Planck Institute Coupled Earth System Model (MPI-ESM-LR) and the Model for Interdisciplinary Research on Climate (MIROC4h). The simulations were performed on supercomputers of the CSIRO (Katzfey et al., 2012) and on the Centre for High Performance Computing (CHPC) of the Meraka Institute of the CSIR in South Africa.

In these simulations CCAM was forced with the bias-corrected daily sea-surface temperatures (SSTs) and sea-ice concentrations of each host model, and with CO2, sulphate and ozone forcing consistent with the RCP4.5 and 8.5 scenarios. The model's ability to realistically simulate present-day southern African climate has been extensively demonstrated (e.g. Engelbrecht et al., 2009; Engelbrecht et al., 2011; Engelbrecht et al., 2013; Malherbe et al., 2013; Winsemius et al., 2014; Engelbrecht et al., 2015). Most current coupled GCMs do not employ flux corrections between atmosphere and ocean, which contributes to the existence of biases in their simulations of present-day SSTs – more than 2 ºC along the West African coast. The bias is computed by subtracting for each month the Reynolds (1988) SST climatology (for 1961-2000) from the corresponding GCM climatology. The bias-correction is applied consistently throughout the simulation. Through this procedure the climatology of the SSTs applied as lower boundary forcing is the same as that of the Reynolds SSTs. However, the intra-annual variability and climate-change signal of the GCM SSTs are preserved (Katzfey et al., 2009).

5.3 Model projections of the changing patterns of extreme events over South Africa under enhanced anthropogenic forcing

In this section the projected changes in a number of climatological variables, including extreme weather-events metrics, are presented. For each of the metrics under consideration, the simulated baseline (climatological) state over South Africa calculated for the period 1971-2000 is shown in Figure 5.1 below (note that the median of the six downscalings is shown in this case). The projected changes in the metric are subsequently shown, for the time-slab 2020-2050 relative to the baseline period 1971-2000, first for RCP8.5 (low mitigation) and then for RCP4.5 (high mitigation). Three figures are presented for each metric for each RCP, for the 10th, 50th (median) and 90th percentiles of the ensemble of projected changes under the RCP. In this way, it is possible to gain some understanding of the uncertainty range that is associated with the projections.

Table 5.1: Relevant climate variables

Variable	Description and/or units
Average temperature	°C
Very hot days	A day when the maximum temperature exceeds 35 °C. Units are number of events per grid point per year.
Heat-wave days	The maximum temperature exceeds the average temperature of the warmest month of the year by 5 °C for at least 3 days.
High fire-danger days	McArthur fire-danger index exceeds a value of 24. Units are number of events per grid point per year.
Rainfall	mm
Extreme rainfall Type I event (also a proxy for	More than 20 mm of rain falling within 24 hrs over an area of 50 x 50 km2. The occurrence of extreme convective

lightning)	rainfall is used as a proxy for the occurrence of storms that produce lightning. Units are number of events per grid point per year.
Dry-spell	Five or more consecutive days without rainfall (units are number of days per grid point per year)

5.3.1 Average temperature

The model-simulated annual average temperatures (°C) are displayed in Figure 5.1 for the baseline period 1971-2000. The coolest conditions occur over the eastern escarpment regions of the domain. The hottest regions are the east coast and the western parts of the domain.

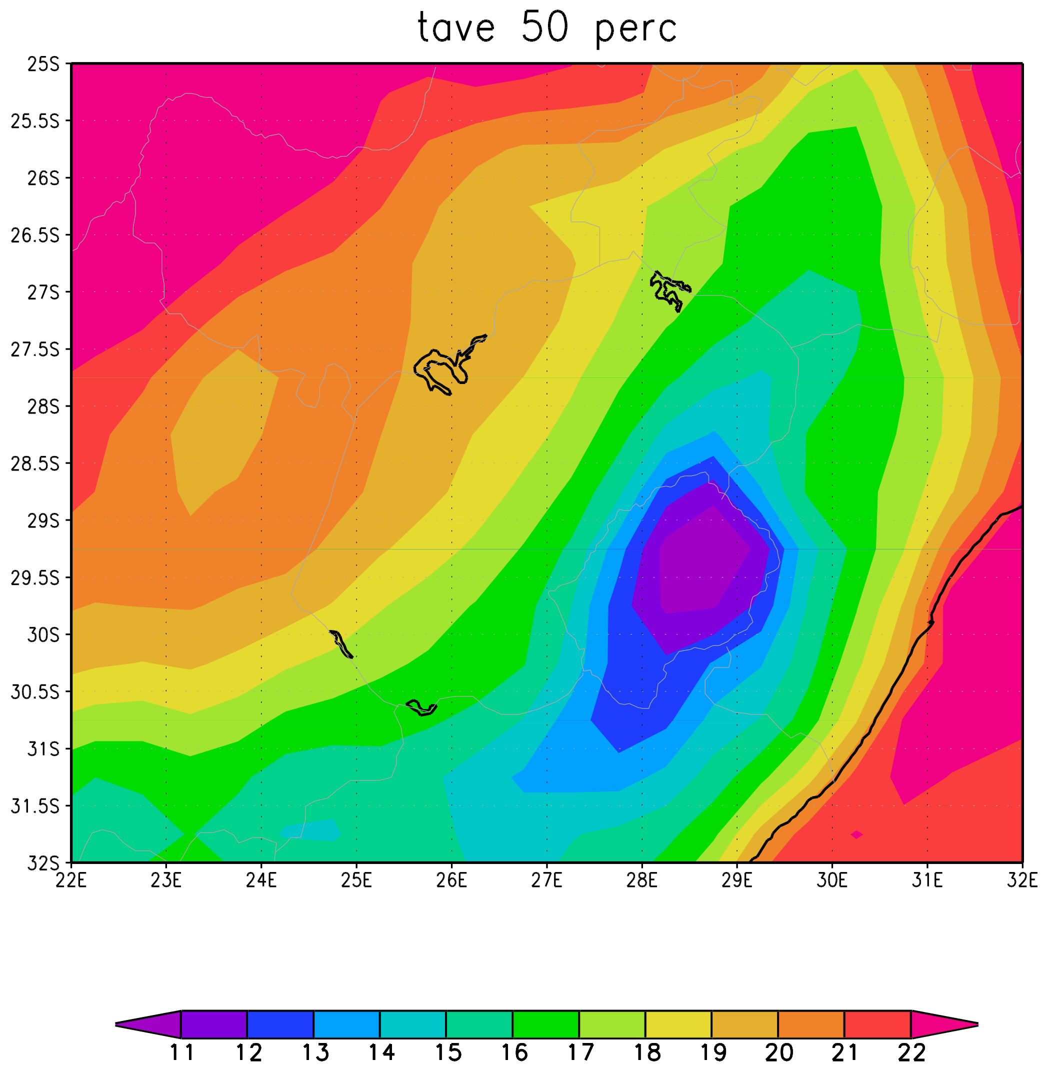


Figure 5.1: CCAM simulated annual average temperature (°C) over central South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.

- Rapid rises in the annual-average near-surface temperatures are projected to occur over southern Africa during the 21st century – temperatures over the South African interior are projected to rise at about 1.5 to 2 times the global rate of temperature increase (Engelbrecht et al., 2015).
- For the period 2020-2050 relative to the period 1971-2000, temperature increases of 1 to 2.5 °C are projected to occur over central South Africa under low mitigation (Figure 5.2).

- Under high mitigation, temperature increases over central South Africa will be somewhat less, but may still reach 2.5 °C over the western part of the domain (Figure 5.2).
- Increasing average temperatures over central South Africa may plausibly increase the household demand for cooling over the coming decades.

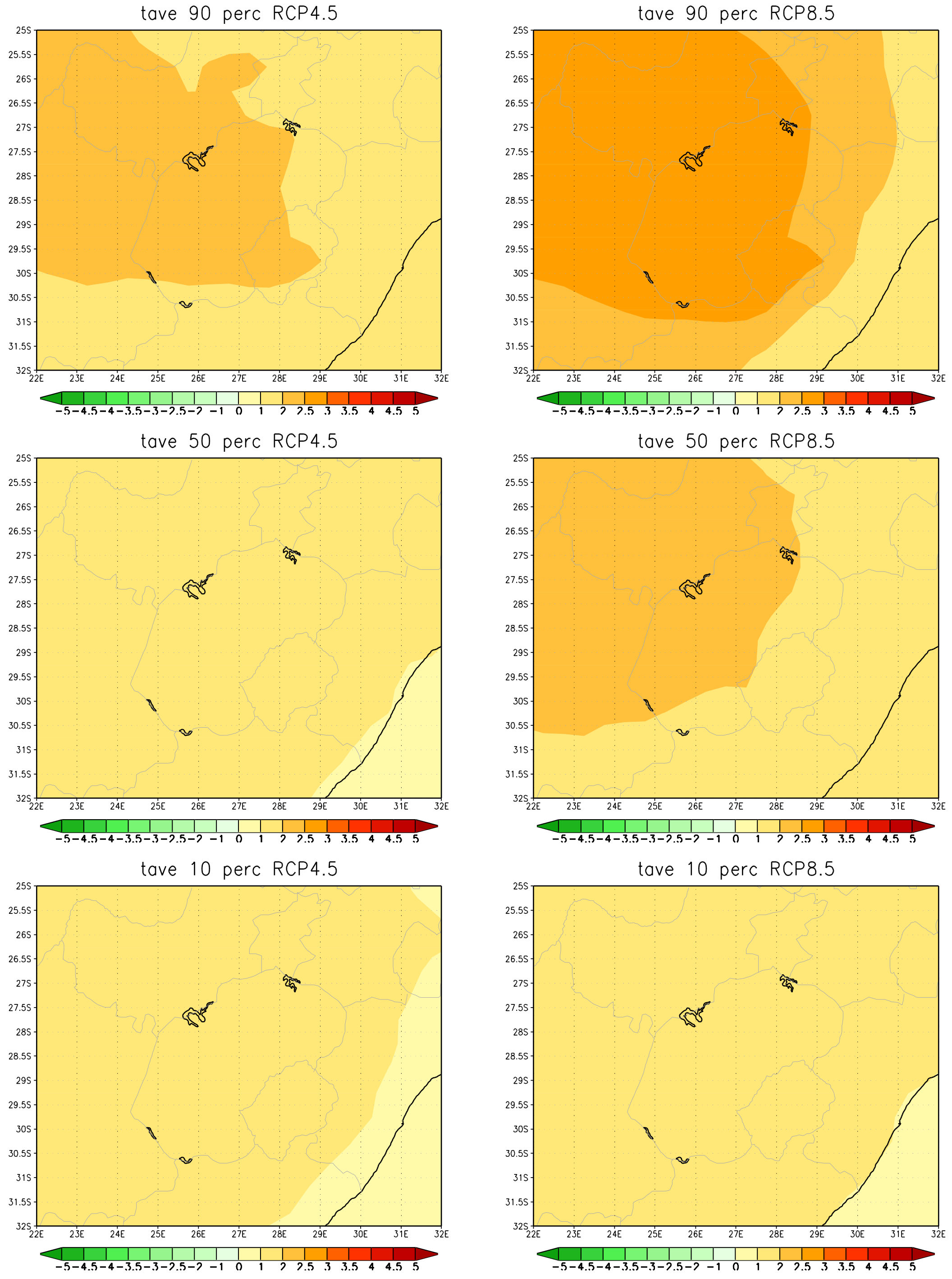


Figure 5.2: CCAM projected change in the annual average temperature (°C) over central South Africa, for the time-slab 2020-2050 relative to 1971-2000. The 10th, 50th and 90th percentiles are shown for the ensemble of downscalings of six GCM projections under RCP4.5 (left) and RCP8.5 (right).

- By the end of the century, temperature increases of 4 to 7 °C are projected to occur over central South Africa under the RCP8.5 scenario (not shown). Such drastic temperature increases would have significant impacts on numerous sectors, including agriculture, water and energy.

5.3.2 Very Hot Days

The model-simulated and bias-corrected annual average number of very hot days (days when the maximum temperature exceeds 35 °C, units are number of days per model grid point) are displayed in Figure 5.3, for the baseline period 1971-2000. Over the western Free State, more than 70 very hot days occur on the average annually.

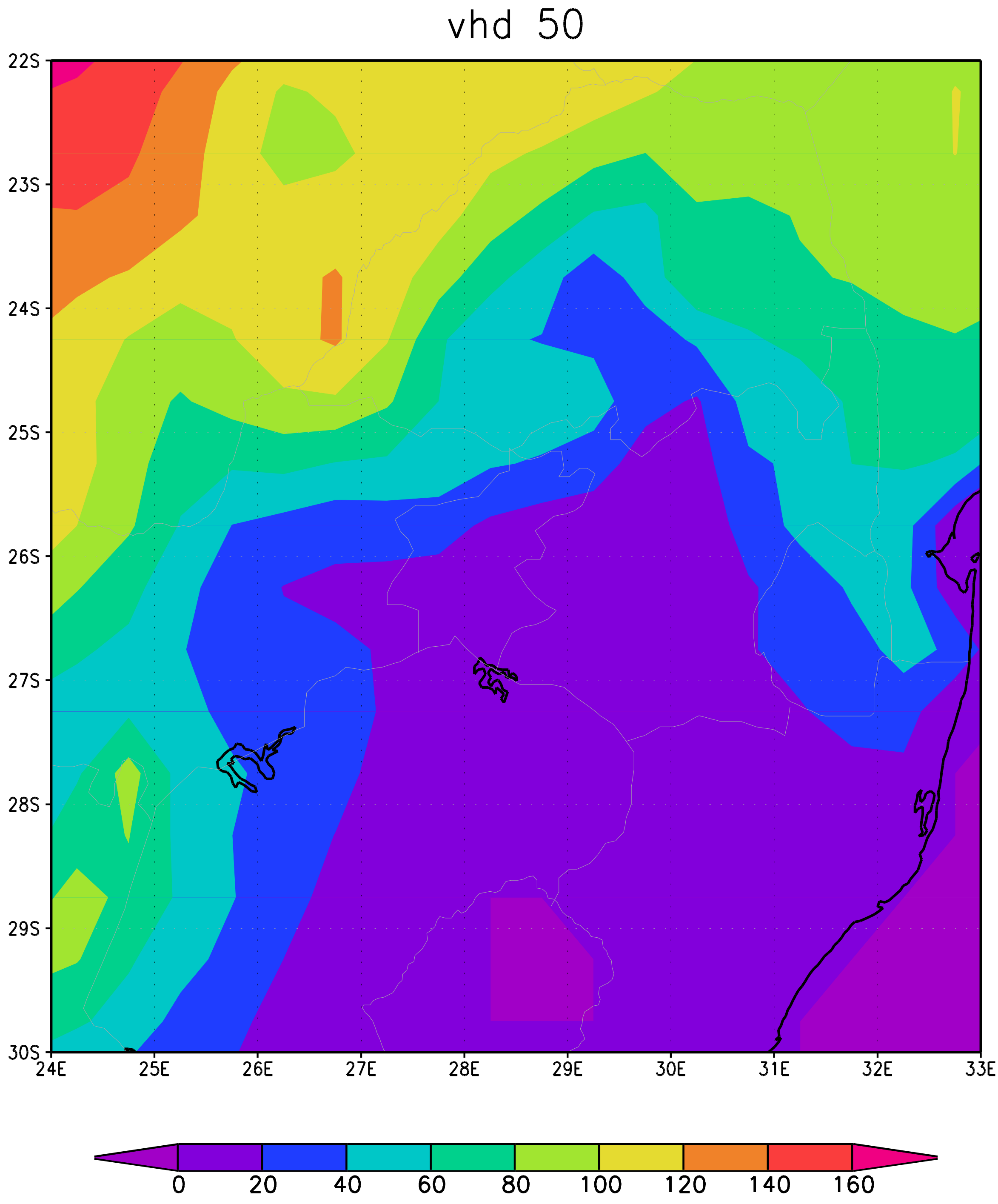


Figure 5.3: CCAM simulated annual average number of very hot days (units are number of days per grid point per year) over central South Africa, for the baseline

period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.

- In association with drastically rising maximum temperatures (Figure 5.4 a to f), the frequency of occurrence of very hot days is also projected to increase drastically under climate change.

- For the period 2020-2050 relative to 1971-1990, under low mitigation, very hot days are projected to increase with as many as 40 days per year in the western part of the domain (Figure 4.4). More modest increases are projected for the eastern parts.

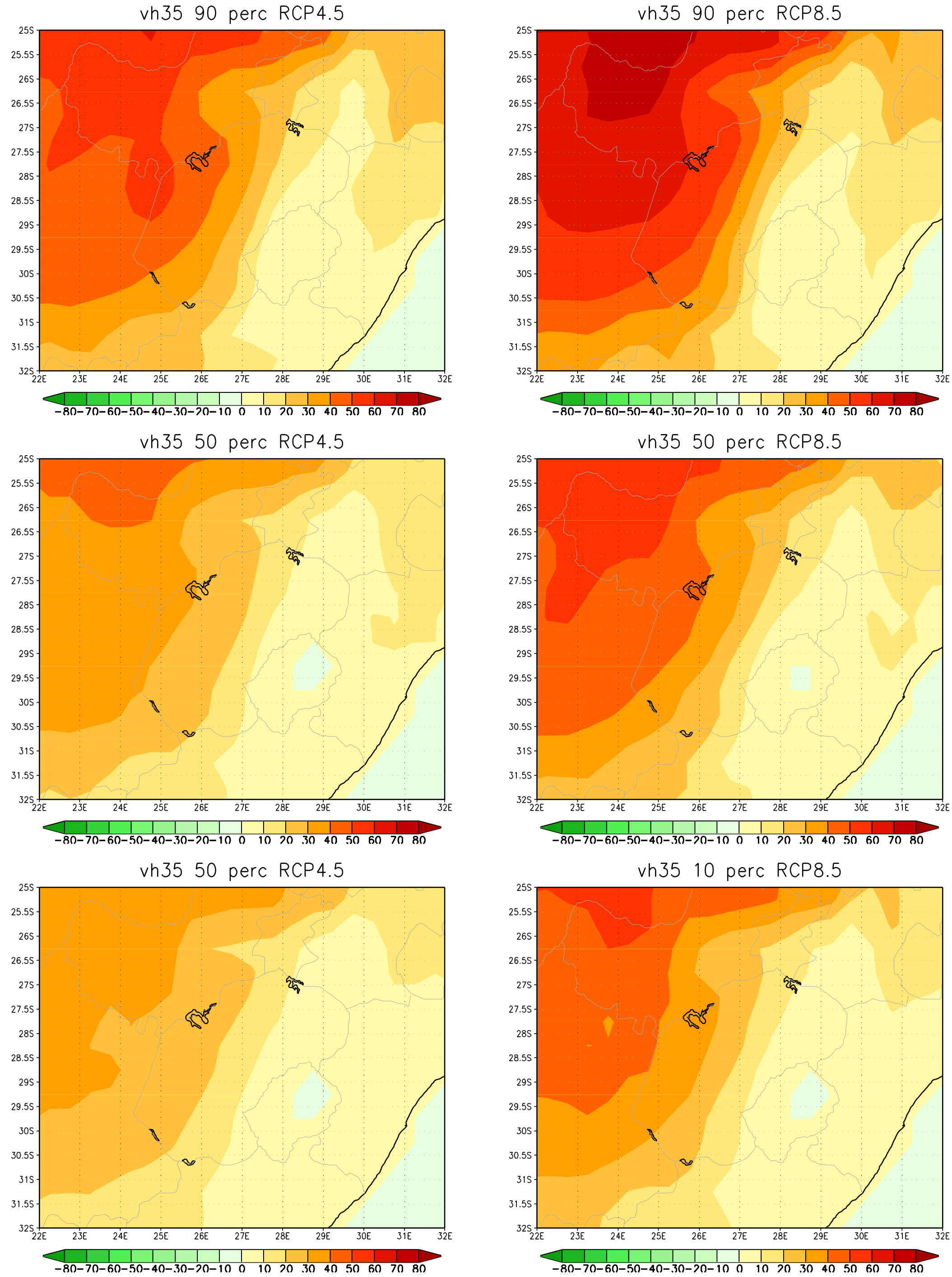


Figure 5.4 a-f: CCAM projected change in the annual average number of very hot days (units are days per grid point per year) over central South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th, 50th and 90th percentiles are shown for the ensemble of downscalings of six GCM projections under RCP4.5 (left) and RCP8.5 (right).

• Even under high mitigation, the increase in the number of very hot days may be as high as 40 days over the western Free State (Figure 5.4).

- Increases in the occurrence of very hot days occur in association with projected changes in the frequency of occurrence of heat-wave days and high fire-danger days (see sections 5.3 and 5.4). These changes may impact on human and animal health through increased heat stress, are likely to impact negatively on crop yield and are conducive to the occurrence of veld and forest fires.

5.3.3 Heat-wave days

The model-simulated annual-average numbers of heat-wave days (units are number of days per model grid point) are displayed in Figure 5.5, for the baseline period 1971-2000. A heat-wave is defined as an event when the maximum temperature at a specific location exceeds the average maximum temperature of the warmest month of the year at that location by 5 °C, for a period of at least three days. To the total number of days occurring within a heat-wave is referred to as "heat-wave days".

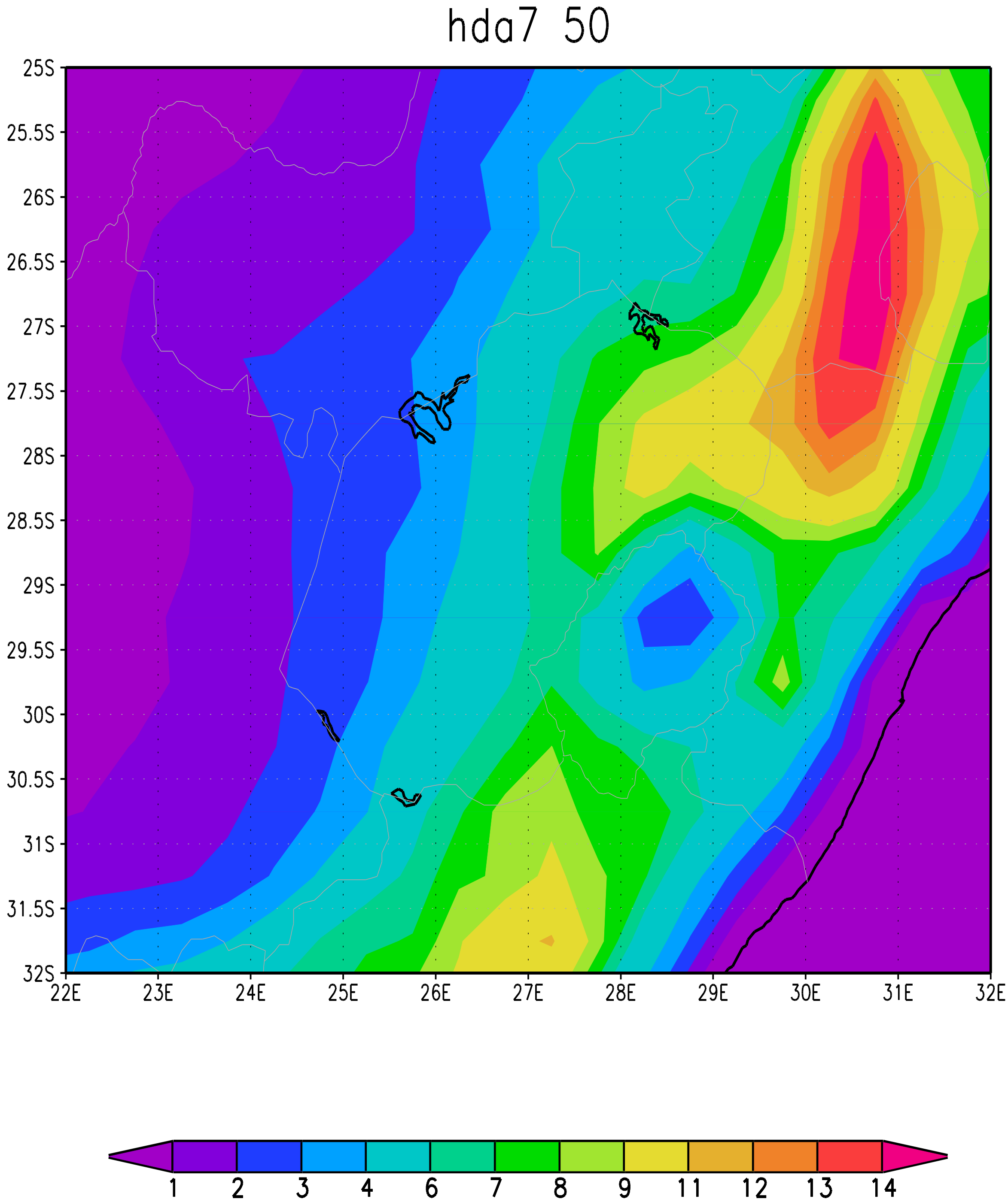


Figure 5.5: CCAM simulated annual average number of heat-wave days (units are number of days per grid point per year) over central South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.

Heat-waves are rare events in terms of southern Africa's present-day climate, with most of central South Africa experiencing less than five of these days per annum.

- In association with drastically rising maximum temperatures (Figure 5.6), the frequency of occurrence of heat-wave days are also projected to increase drastically under climate change.

- For the period 2020-2050 relative to 1971-2000, under low mitigation, heat-wave days are projected to increase with more than 10 days per year over large parts of the Free State (Figure 5.6). More modest increases are projected for the coastal regions.

- Even under high mitigation, the increase in the number of heat-wave days may be 10 or more over the central interior regions (Figure 5.6).

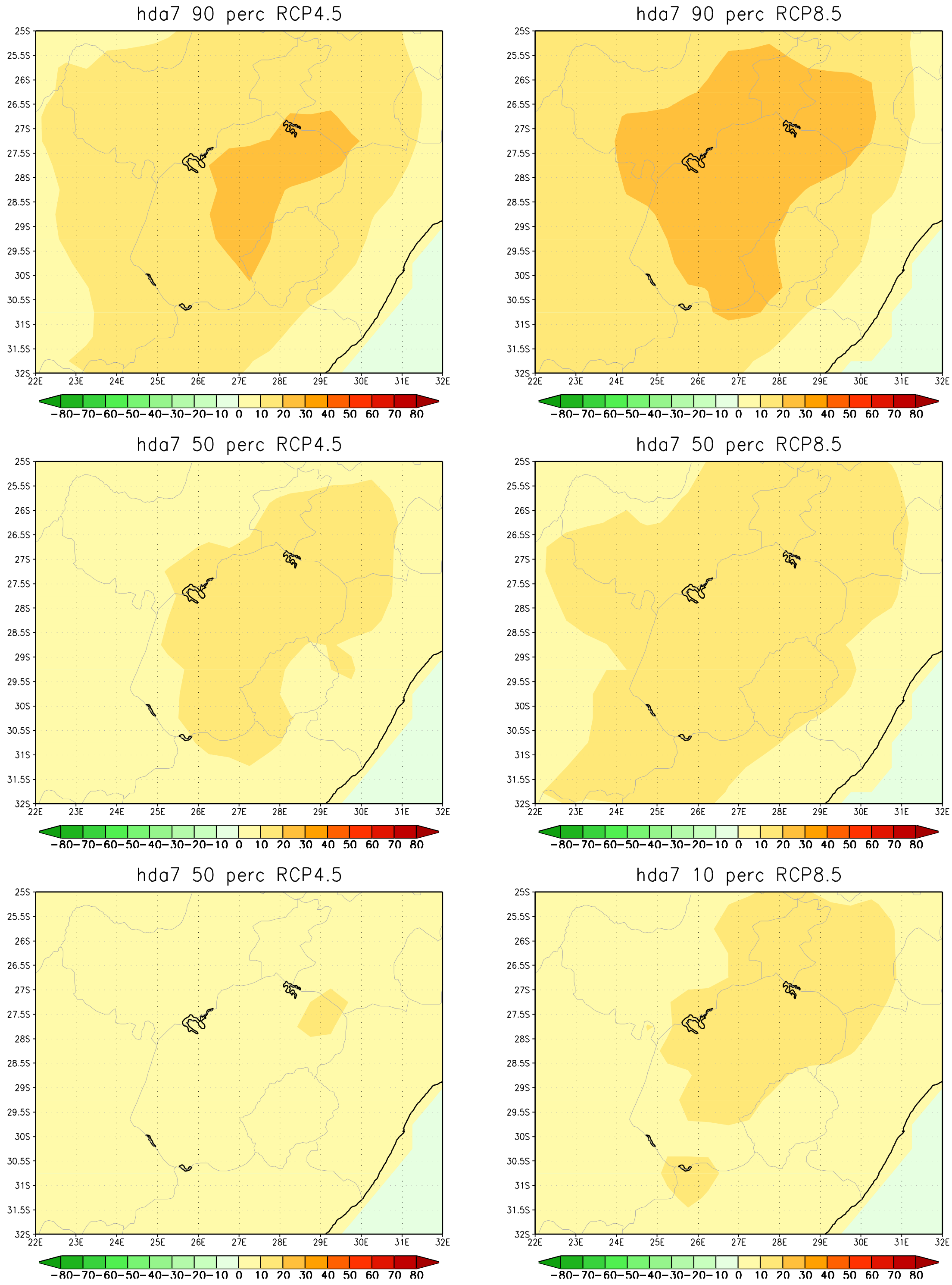


Figure 5.6: CCAM projected change in the annual average number of heat-wave days (units are number of days per grid point per year) over central South Africa, for the time-slab 2020-2050 relative to 1971-2000. The 10th, 50th and 90th percentiles are shown for the ensemble of downscalings of six GCM projections under RCP4.5 (let) and RCP8.5 (right).

• Increases in the occurrence of heat-wave days occur in association with projected changes in the frequency of very hot days and high fire danger days (see section 5.3.4 and 5.3.6). Since heat-wave days are associated with prolonged periods of oppressive temperatures, these changes may impact on human and animal health through increased heat stress, are likely to impact negatively on crop yield and are plausible to be conducive to the occurrence of veld and forest fires.

5.3.4. High fire-danger days

The model-simulated annual average number of high fire-danger days (days when the McArthur Fire Danger Index exceeds a value of 24, units are number of days per model grid point) are displayed in Figure 5.7, for the baseline period 1971-2000. Over much of grasslands of central South Africa more than 20 high fire-danger days occur on the average per year.

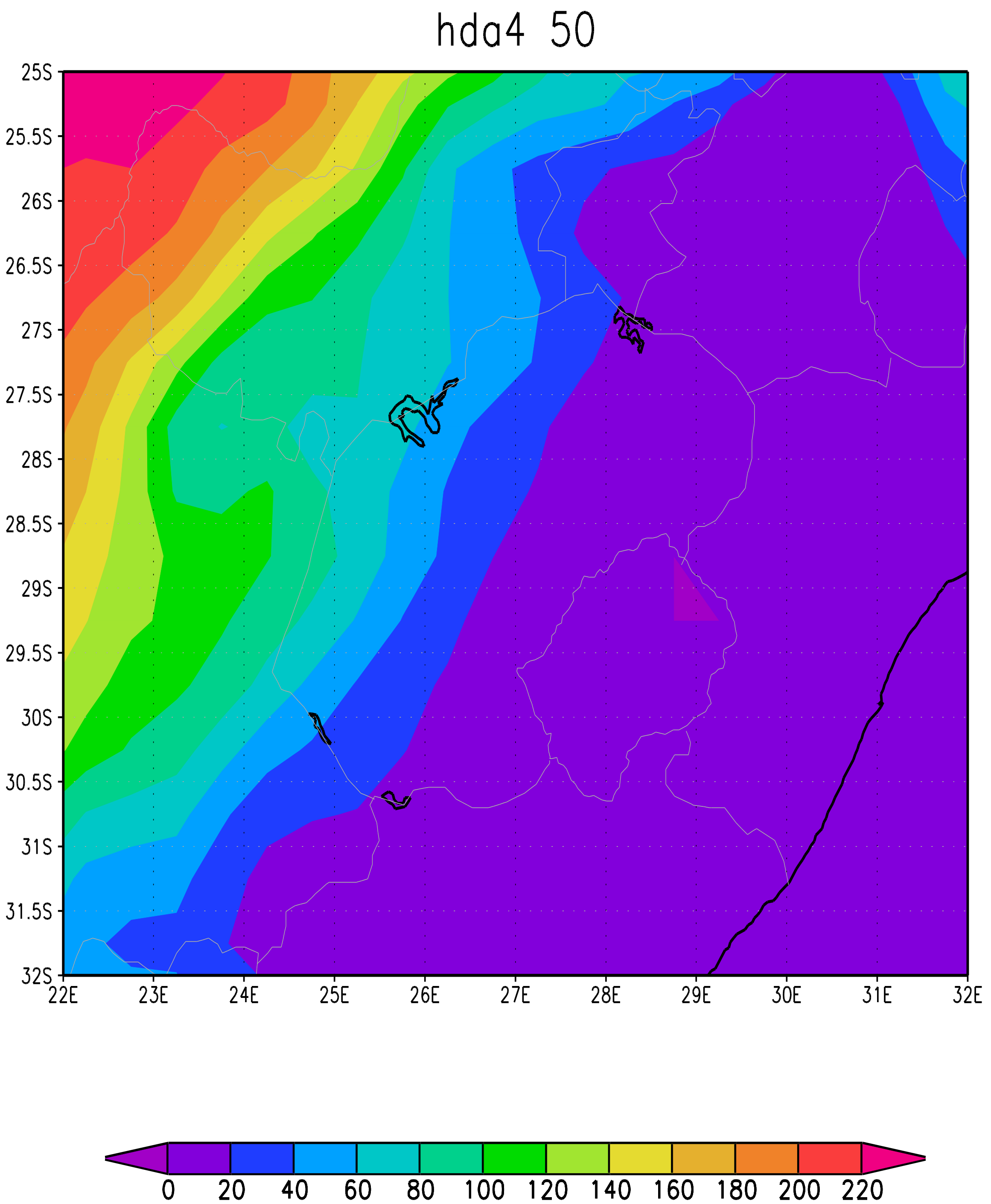


Figure 5.7: CCAM simulated annual average number of high fire-danger days (units are number of days per grid point per year) over central South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.

- In association with drastically rising temperatures (Figure 5.2), the frequency of occurrence of high fire-danger days are also projected to increase drastically under climate change (Figure 5.8).

- For the period 2020-2050 relative to 1971-2000, under low mitigation, high fire-danger days are projected to increase with 20 days per year or more over the Free State grasslands (Figure 5.8).

- Even under high mitigation, the increase in the number of high fire-danger days may be 20 or more over the western interior (Figure 5.8).

- Increases in the occurrence of high fire-danger days occur in association with projected changes in the frequency of occurrence of heat-wave days and high fire danger days (see sections 5.2 and 5.3).

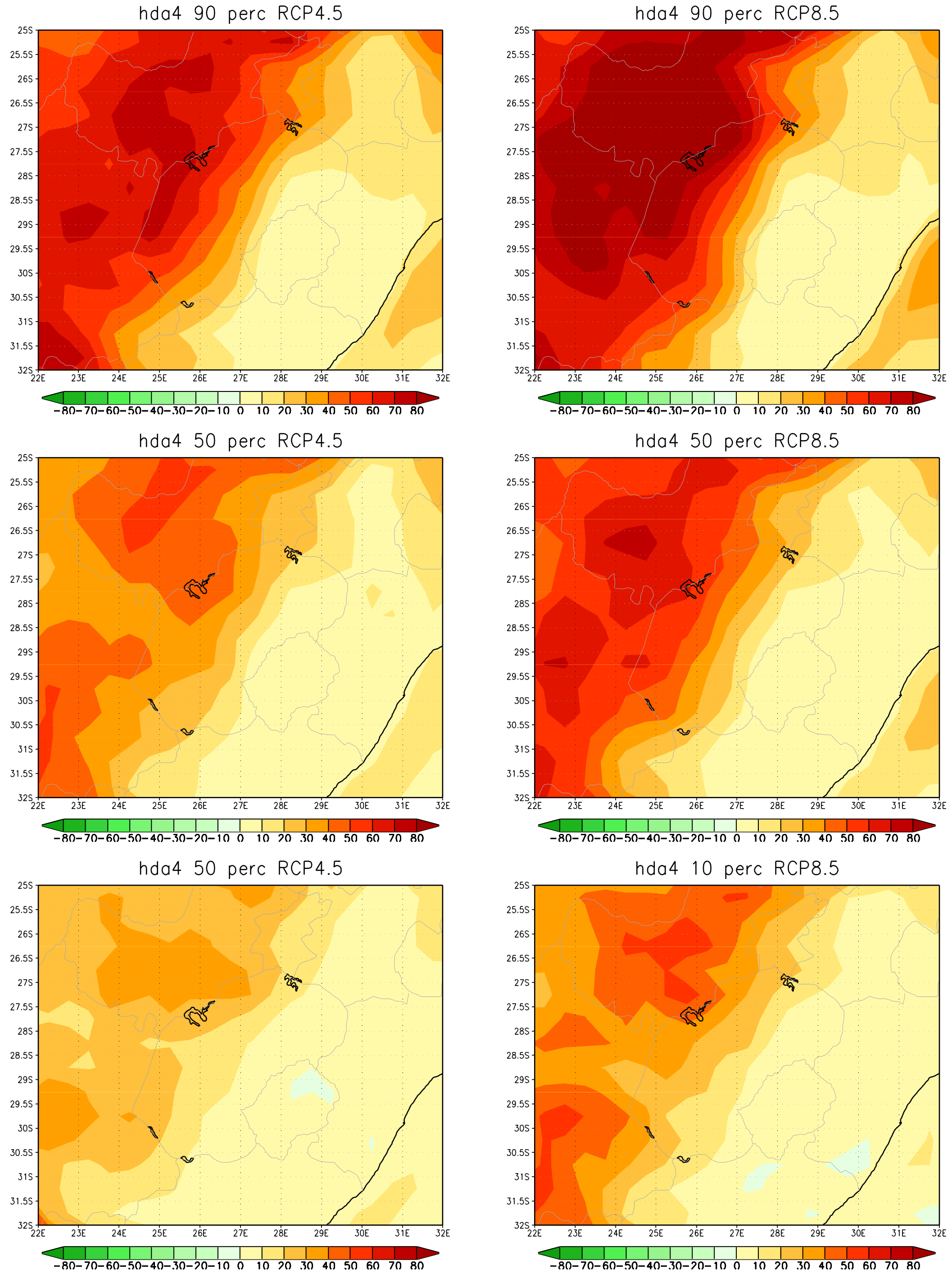


Figure 5.8 a-f: CCAM projected change in the annual average number of high fire-danger days (units are number of days per grid point per year) over central South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th, 50th and 90th percentile are shown for the ensemble of downscalings of six GCM projections under RCP4.5 (left) and RCP8.5 (right).

5.3.5. Rainfall

The model-simulated annual average rainfall totals (mm) are displayed in Figure 5.9, for the baseline period 1971-2000. There is a pronounced west-east rainfall gradient over the country. Over the eastern escarpment and east coast annual rainfall totals exceed 700 mm.

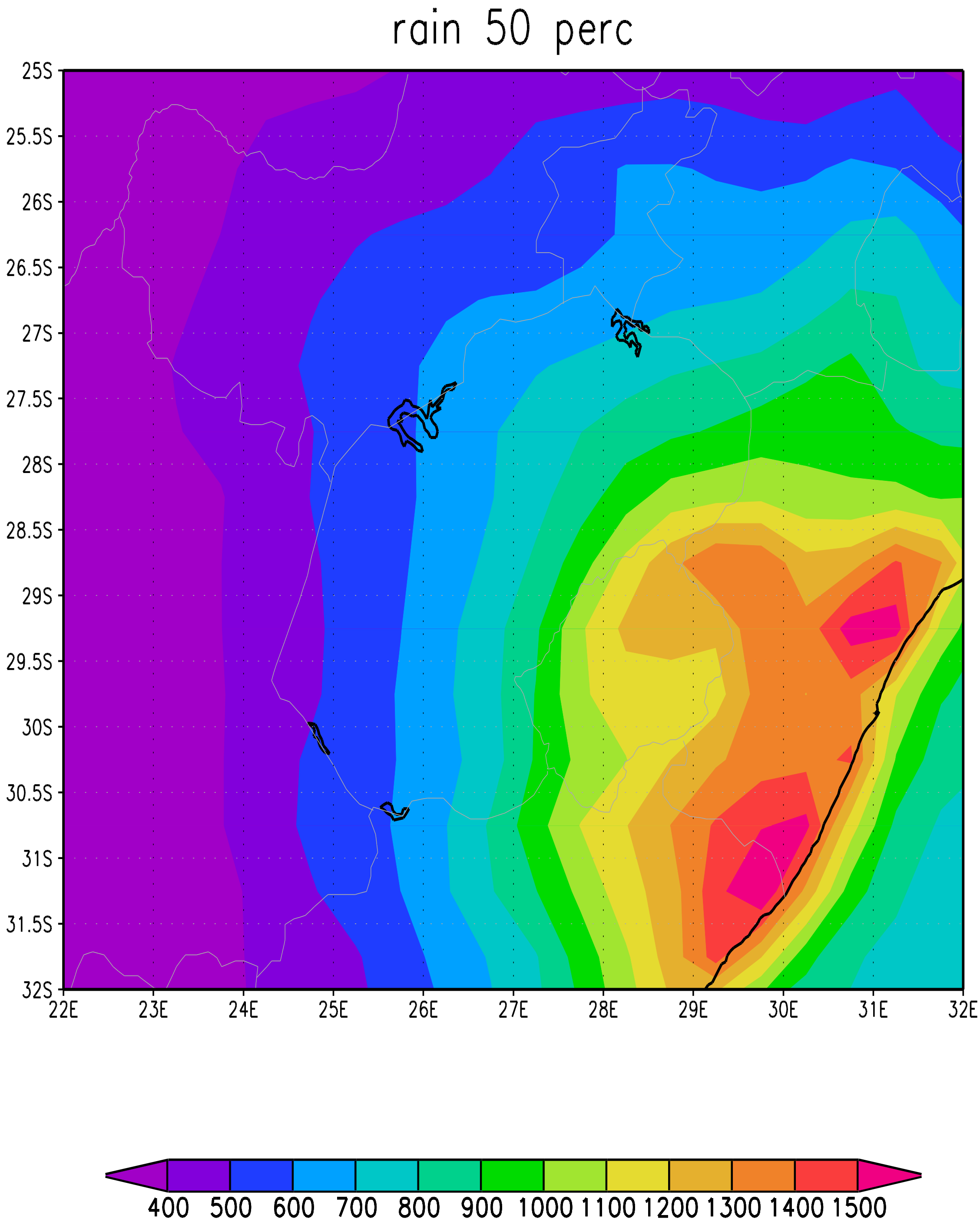


Figure 5.9: CCAM simulated annual average rainfall totals (mm) over central South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.

- A general decrease in rainfall is plausible over southern Africa under enhanced anthropogenic forcing (e.g. Christensen et al., 2007; Engelbrecht et al., 2009).

- For the period 2020-2050 relative to the period 1971-2000, under low mitigation, rainfall is projected to decrease over the eastern Free State by most ensemble members (Figure 5.10). Most ensemble members simultaneously project increases in rainfall over the western Free State.

- The projected changes in rainfall patterns under high mitigation is very similar to the patterns projected under low mitigation (Figure 5.10).

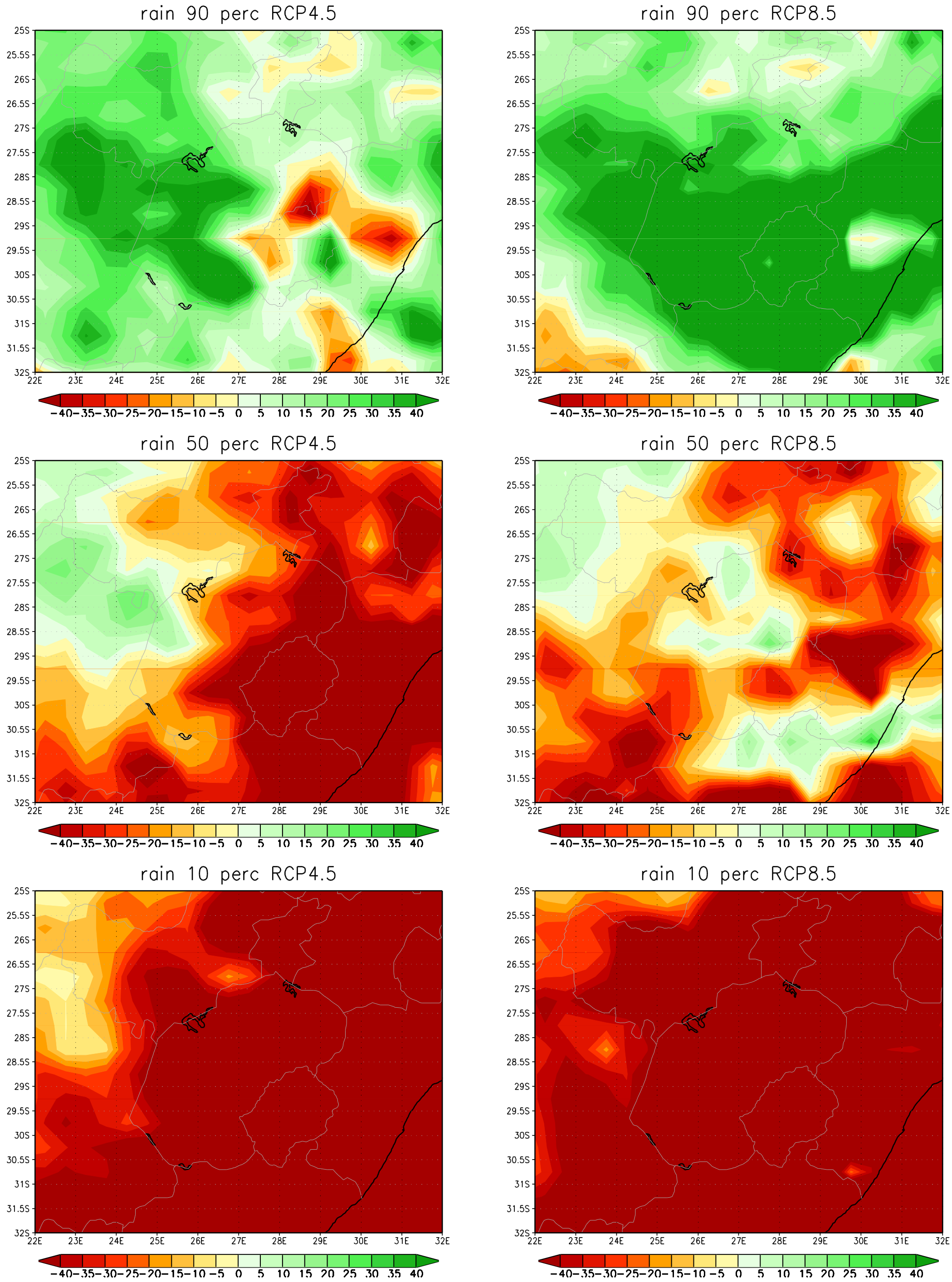


Figure 5.10 a-f: CCAM projected change in the annual average rainfall totals (mm) over central South Africa, for the time-slab 2020-2050 relative to 1971-2000. The 10th, 50th and 90th percentiles are shown for the ensemble of downscalings of six GCM projections under RCP4.5 (left) and RCP8.5 (right).

- The projected changes in rainfall patterns over South Africa in the ensemble of downscalings described here, and more generally in AR4 and AR5 projections, display more uncertainty than in the case of projected changes in temperature. This implies that adaptation policy makers need to take into account a range of different rainfall futures, often of different signal (i.e. drier and wetter) during the decision making process.

5.3.6 Extreme rainfall Type I events (including severe thunderstorms and lightning)

The model-simulated annual average extreme rainfall event frequencies (units are number of events per model grid box per year) are displayed in Figure 5.11, for the baseline period 1971-2000. Here an extreme rainfall event is defined as 20 mm of rain occurring within 24 hours over an area of 50 x 50 km2). Over the east coast and eastern escarpment regions more than 10 extreme rainfall events occur annually, on the average.

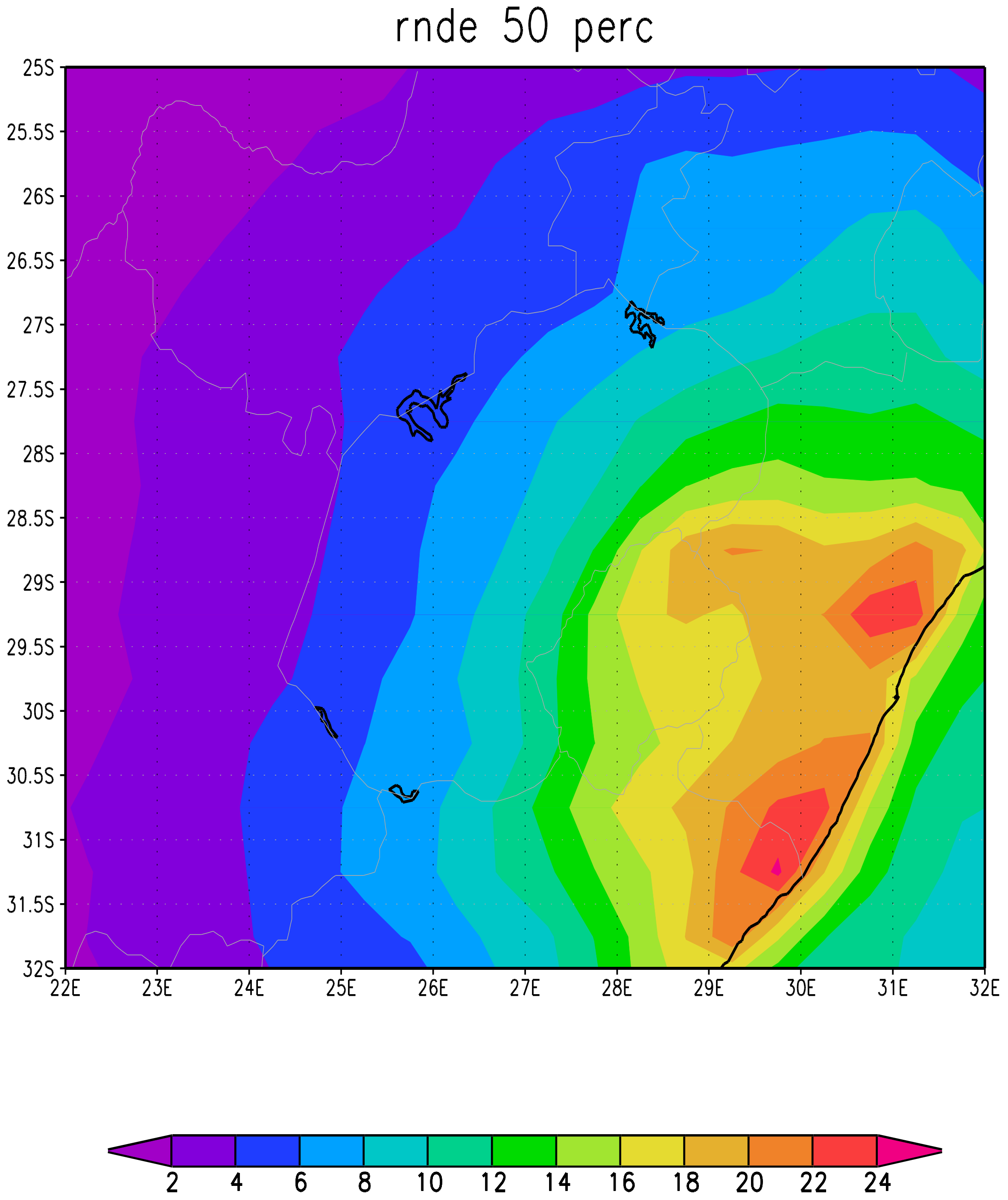


Figure 5.11: CCAM simulated annual average number of extreme rainfall days (units are number of days per grid point per year) over central South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.

• Consistent with the projected decreases in rainfall, extreme rainfall events are projected to decrease in frequency over the Free State under low mitigation, for the period 2020-2050 relative to 1971-2000, by most ensemble members (Figure 5.12). A minority of ensemble members project increases in extreme rainfall events over the Free State (Figure 5.12).

• The projected changes in extreme rainfall events under high mitigation are very similar to the patterns projected under low mitigation (Figure 5.12).

• Extreme rainfall events are mostly caused by intense thunderstorms, which are often also the cause of lightning, hail, damaging winds and flash floods. That is, the climate change projections analysed here are indicative that decreases in these hazardous storms are plausible over most of the Free State, however, a minority of ensemble members are indicative of increases in such events. That is, adaptation policies need to take into account the possibility that extreme rainfall events over the Free State may increase in their frequency of occurrence.

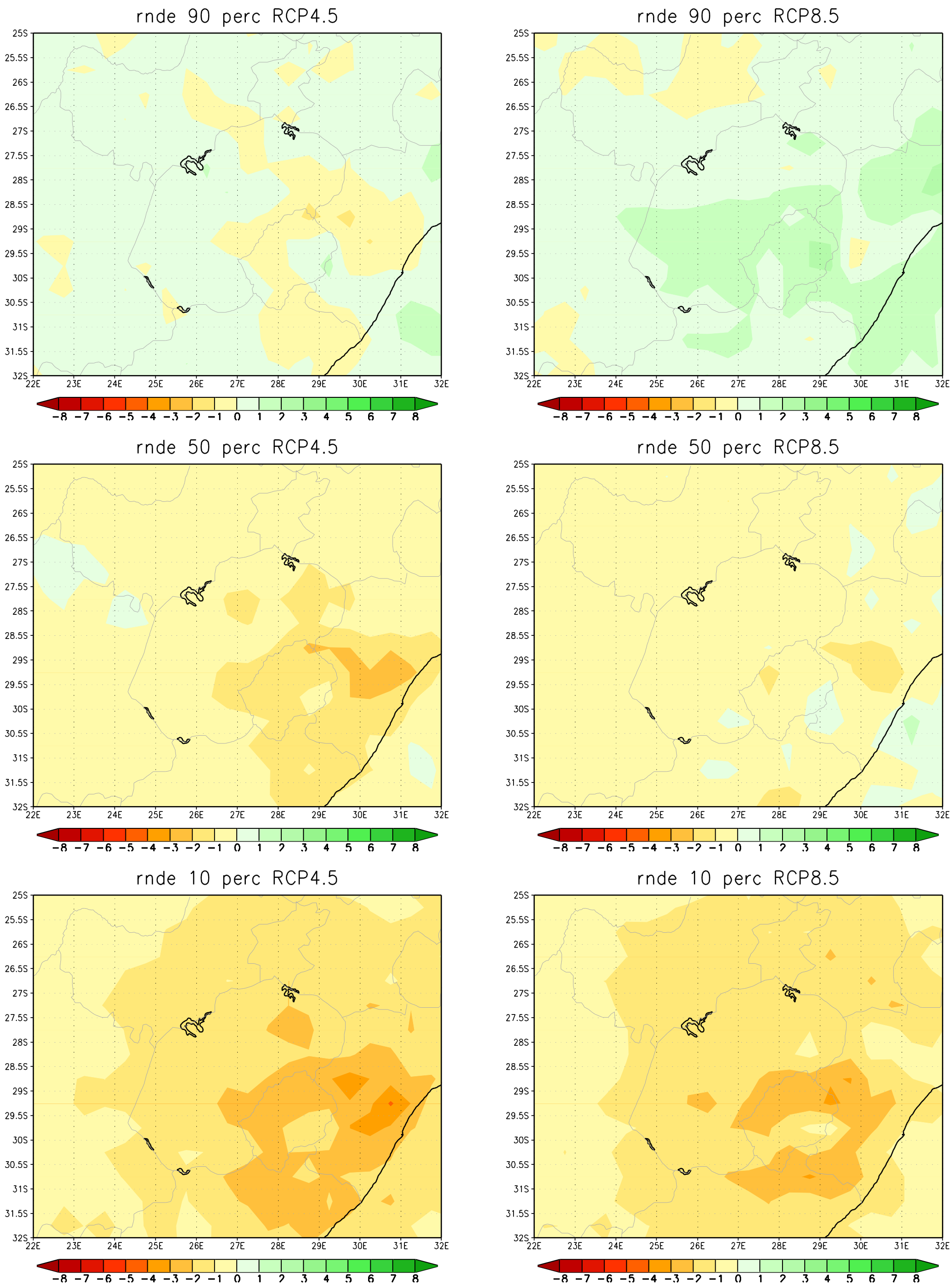


Figure 5.12: CCAM projected change in the annual average number of extreme rainfall days (units are numbers of grid points per year) over central South Africa, for the time-slab 2020-2050 relative to 1971-2000. The 10th, 50th and 90th percentiles are shown for the ensemble of downscalings of six GCM projections under RCP8.5.

5.3.7 Dry spell days

The model-simulated and bias-corrected annual average dry-spell day frequencies (units are number of days per model grid box per year) are displayed in Figure 5.13, for the baseline period 1971-2000. Here a dry spell is defined as a period of five consecutive days without rainfall (or a longer dry period) occurring over an area of 50 x 50 km^2. The days that constitute a dry spell event are termed “dry spell days”. South Africa receives seasonal rainfall over most of the country, implying that most locations experience a dry season exhibiting many dry spell days. The dry spell day gradient over South Africa resembles the rainfall gradient.

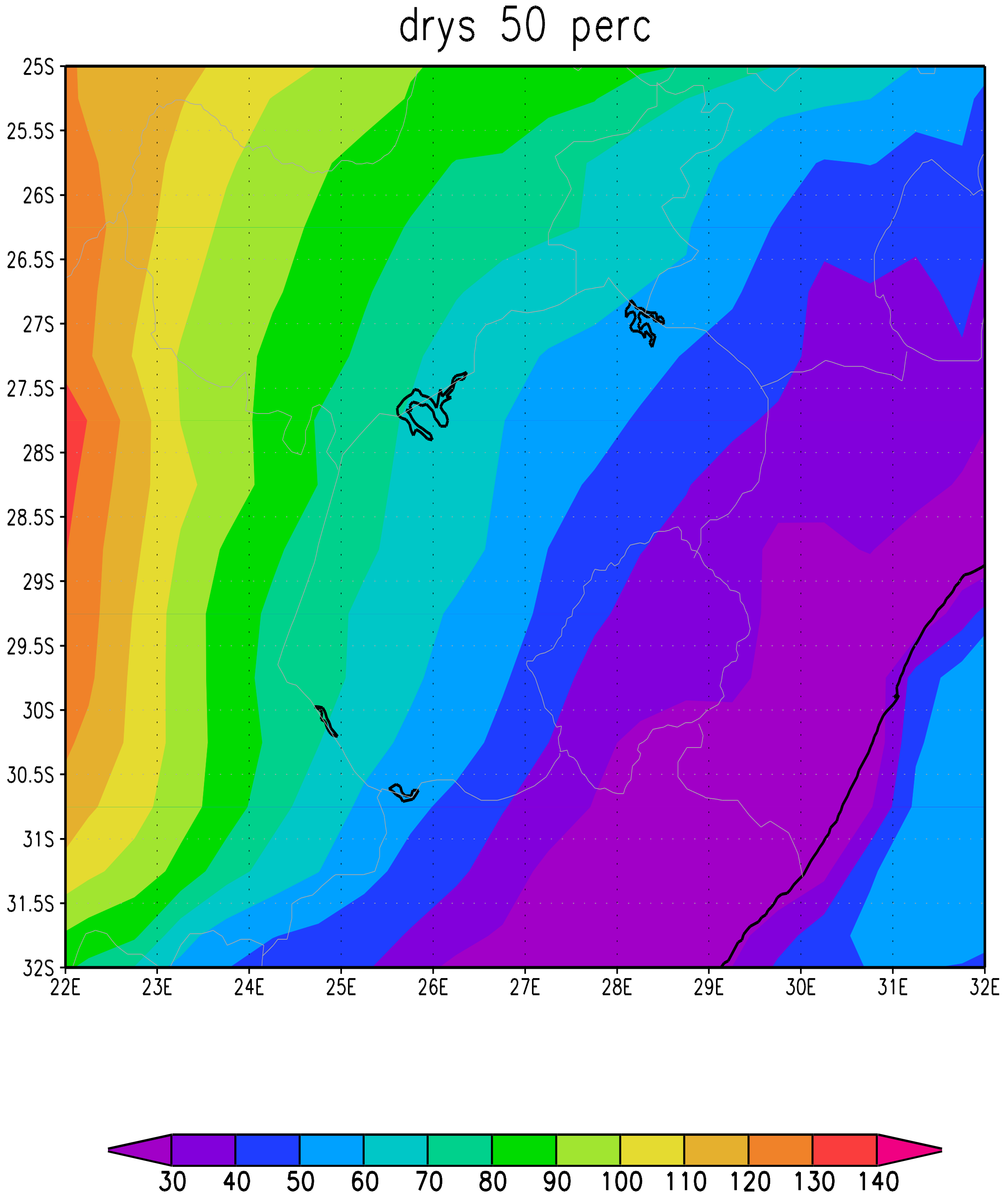


Figure 5.13: CCAM simulated annual average number of dry-spell days (units are number of days per grid point per year) over central South Africa, for the baseline

period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.

- The ensemble of downscalings is robust in projecting an increase in dry spell days over the Free State for the period 2020-2050 relative to 1971-2000, under low mitigation (Figure 4.7.1).
- The projected changes in dry spell day frequencies under high mitigation are very similar to the patterns projected under low mitigation (Figure 5.14).

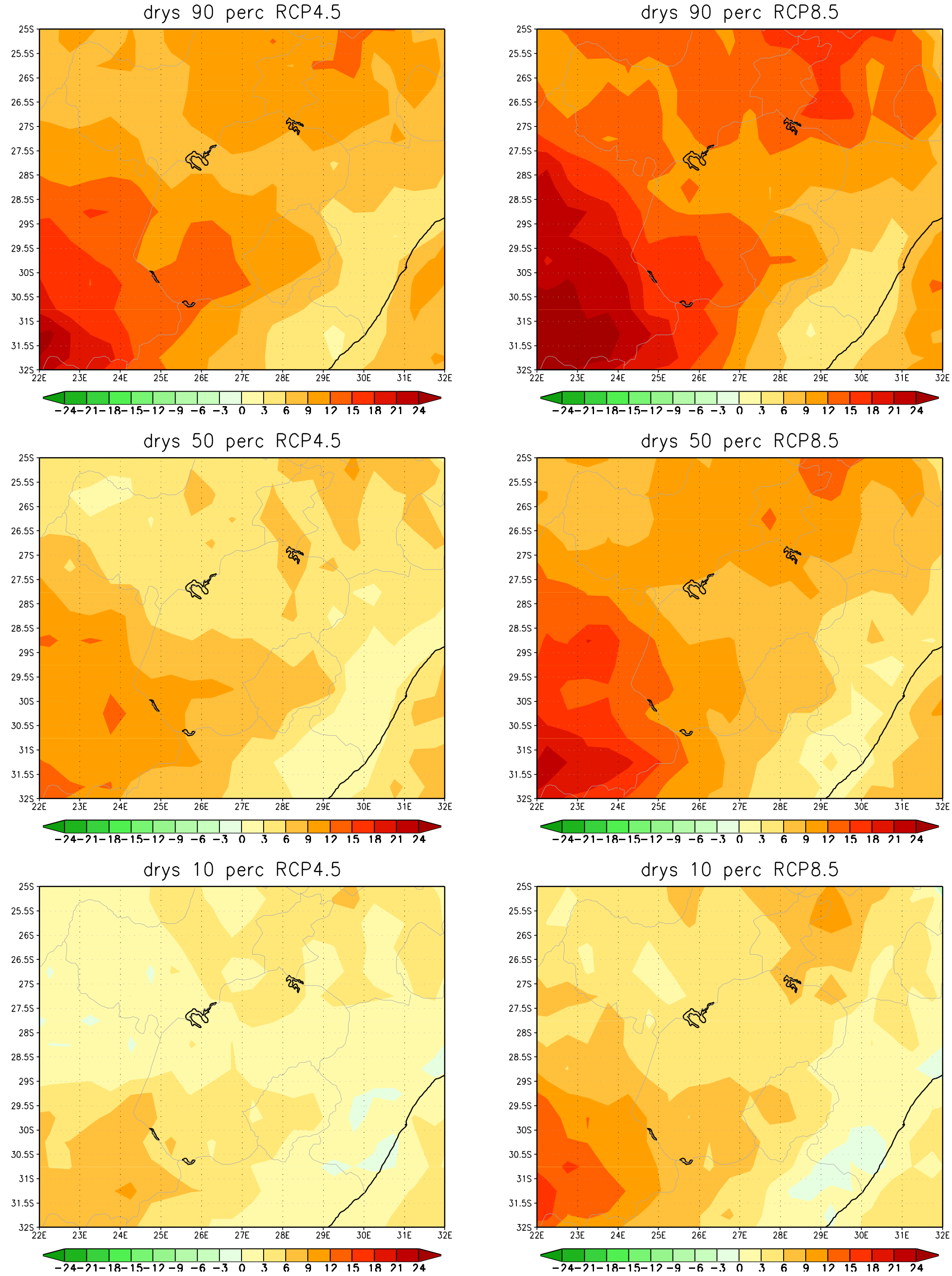


Figure 5.14: CCAM projected change in the annual average number of dry-spell days (units are numbers of grid points per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th, 50th and 90th percentiles are shown for the ensemble of downscalings of six GCM projections under RCP4.5 (left) and RCP8.5 (right).

5.4 Conclusions

This report is based on an ensemble of high-resolution projections of future climate change over Africa, obtained by using the regional climate model CCAM to downscale the output of a number of CMIP5 (AR5) GCMs over Africa. The projections downscaled represent both high (RCP4.5) and low (RCP8.5) mitigation scenarios. CCAM was applied at 50 km resolution globally, and the experimental design of the simulations is consistent with that of CORDEX. The projections obtained are interpreted within the context of the GCM projections described in AR4 and AR5 of the IPCC and the regional projections of LTAS of DEA. The projected changes are presented for the period 2021-2050 relative to the 1971-2000 baseline period.

Under low mitigation, temperatures are projected to rise drastically, by 1-3 °C over the central South African interior for the period 2020-2050 relative to the baseline period. These increases are to be associated with increases in the number of very hot days, heat-wave days and high fire-danger days over South Africa. Key implications of these changes for Mangaung may include an increased risk for veld fires to occur in the grasslands areas. The household demand for energy in summer is also plausible to increase, to satisfy an increased cooling need towards achieving human comfort within buildings. Under high mitigation, the amplitudes of the projected changes in temperature and extreme temperature events are somewhat less, but still significant. The projected changes in rainfall and related extreme events exhibit more uncertainty than the projected temperature changes. A robust signal of increases in dry-spell-day frequencies is evident from the projections.

6 Mangaung Vulnerability Assessment

6.1 Sectoral analysis

In the framework of current and future climate variability and change, this chapter analyses the vulnerability of socio-economic sectors in Mangaung in an attempt to develop a vulnerability and risk profile of the municipality. The analysis includes extreme climate related disaster affecting especially the poor population in the municipality including the profiling of vulnerable population groups and low income groups which reside in areas of environmental risk such as along flood plains and in informal settlements (UNEP, 2011).

6.1.1. Air Quality

The Mangaung Metropolitan Municipality presently has an air quality management plan and there are 3 air quality monitoring stations within the metropolitan municipality namely Bayswater Clinic; Pelonomi Hospital and Kagisanong Community Centre (DEA, 2012a). The pollutants measured by the stations according to DEA (2012b) and DEA (2014) include particles smaller than 10 µm (PM_{10}); particles smaller than 2.5 µm ($PM_{2.5}$); carbon monoxide (CO); sulphur dioxide (SO_2); oxides of nitrogen (NO_x), ozone (O_3) and lead (Pb) (Figure 1 and Table 6.1). It was previously reported in the Free State Air Quality Management Plan (Free State Province, 2009) that 22 exceedances of the national ambient air quality standard of 120 µg/m^3 occurred in 2008. The uncertainty of air quality information from the Mangaung Municipality is high, owing the currency of air quality information being low (DEA, 2012a) and the air quality monitoring stations not being calibrated (DEA, 2014). MMM is currently not reporting ambient air quality data to the South African Air Quality Information System (DEA, 2014).

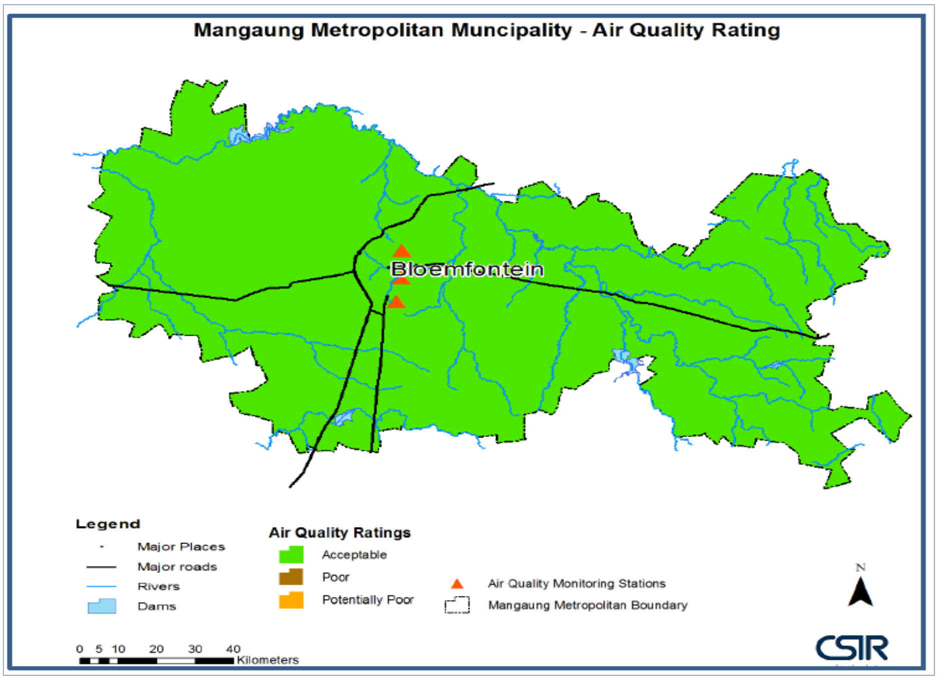


Figure 6.1: Air Quality Rating for Mangaung

Table 6.1: Health effects of air pollutants monitored in MMM

Pollutant	Main Health Effects
PM_{10}	Respiratory and cardiovascular effects1
$PM_{2.5}$	Respiratory and cardiovascular effects
NO_x	Ozone formation; Respiratory effects
O_3	Respiratory effects
SO_2	Acute (short-term) Respiratory effects
CO	Reduction of Oxygen delivery to vital organs
Pb	Organ damage

[1] Exceedances of the national air quality standard of 120 µg/m3 were 22 at Pelonomi Hospital, Bloemfontein in 2008 (Free State Province, 2009)

[2] Low concentrations at air quality monitoring stations in Bloemfontein in 2003 – Bayswater and Long Street (Manguaung Local Muncipality, 2003)

While the linkages between climate change and air pollution have not been extensively studied, but it is expected that climate change, through the alteration of pollutants in ambient air, influenced by weather and anthropogenic emissions may influence respiratory health impacts (DEA, 2013b). Ozone and particulate matter are two pollutants requiring increased focus as they are related to climate change climatic factors, e.g. temperature, precipitation, clouds, atmospheric water vapour, wind speed and wind direction. All of these factors influence the levels of pollution, e.g. high temperatures and humidity could result in more pollutants in the atmosphere while high speed, clouds and precipitation could reduce air pollutants (DEA, 2013b).

6.1.2 Agriculture Sector

A myriad of factors, both climatic and non-climatic affect the agricultural sector in South Africa, with climatic factors being anticipated to be exacerbated by predicted changes in future climate. Climatic factors are essential in the determination of potential agriculture, especially the suitability and the sensitivity of major cereal crops to future changes in climate. This will affect small holder and subsistence farmers more due to their dependence on rain fed agriculture, thus adaptation options for this sector should consider this vulnerability and the risks faced by this vulnerable population.

6.1.2.1 Climate change vulnerability in the agriculture sector

Agriculture has been identified as the biggest consumer of surface water in the country, with at least 60% of the water being used for irrigation as well as a significant amount being sourced from ground water resources. This dependence on water represents an insurmountable amount of vulnerability for all agricultural related activities. This is makes agriculture a key sector for the adaptation interventions including for the water sector, food security and other socio-economic impacts (DEA, 2013).

Rainfall is one of the most important factors in agriculture as it determines the types of agricultural activities and suitability of the type of farming. Rainfall is also the factor to be most affected by climate change, posing a threat to the sector and livelihoods that depend on it. Rainfall further has a direct impact on the dependence of agriculture on water, resulting in a high vulnerability. Approximately 60% of the country's water resources are channelled for irrigation, while all the other activities in support of agriculture consume at least 65% of water. Evaporative losses are a climatic factor influenced by the unreliable rainfall especially in arid and semi-arid conditions (DEA, 2013 – agric). Other climate related conditions that affect agriculture are related to temperature variations and these include heat waves, cold spells and crop evaporation (DEA, 2013 – agric). Rainfall variability further exacerbates agriculture, all affecting crop potential and yield.

6.1.2.2 Non-climatic factors impacting agriculture

While climatic factors are essential in determining the success of agriculture, non-climatic factors are equally as important, in particular the geographic location. Factors such as soil properties are location specific while land degradation is sometimes associated with the apartheid legacy which settled people in areas susceptible to land degradation. The soils in South Africa are thin and are highly susceptible to degradation, with soil organic matter being susceptible to increase in temperature. Climatic elements may result in soil degradation which will negatively affect soil suitability for intensive crop agriculture. On the other hand, socio-economic factors such as population pressure, increasing demand for agricultural, land-use change, unsustainable land uses and poor economic policies result in land degradation, this is exacerbated by bush encroachment and invasive alien plants (DEA, 2013 –agric).

The National Land cover map produced in 2013 highlights the location of the different land cover types in Mangaung, highlighting especially the extent of agricultural land (highlighted as yellow) in the municipality (Figure 6.2).

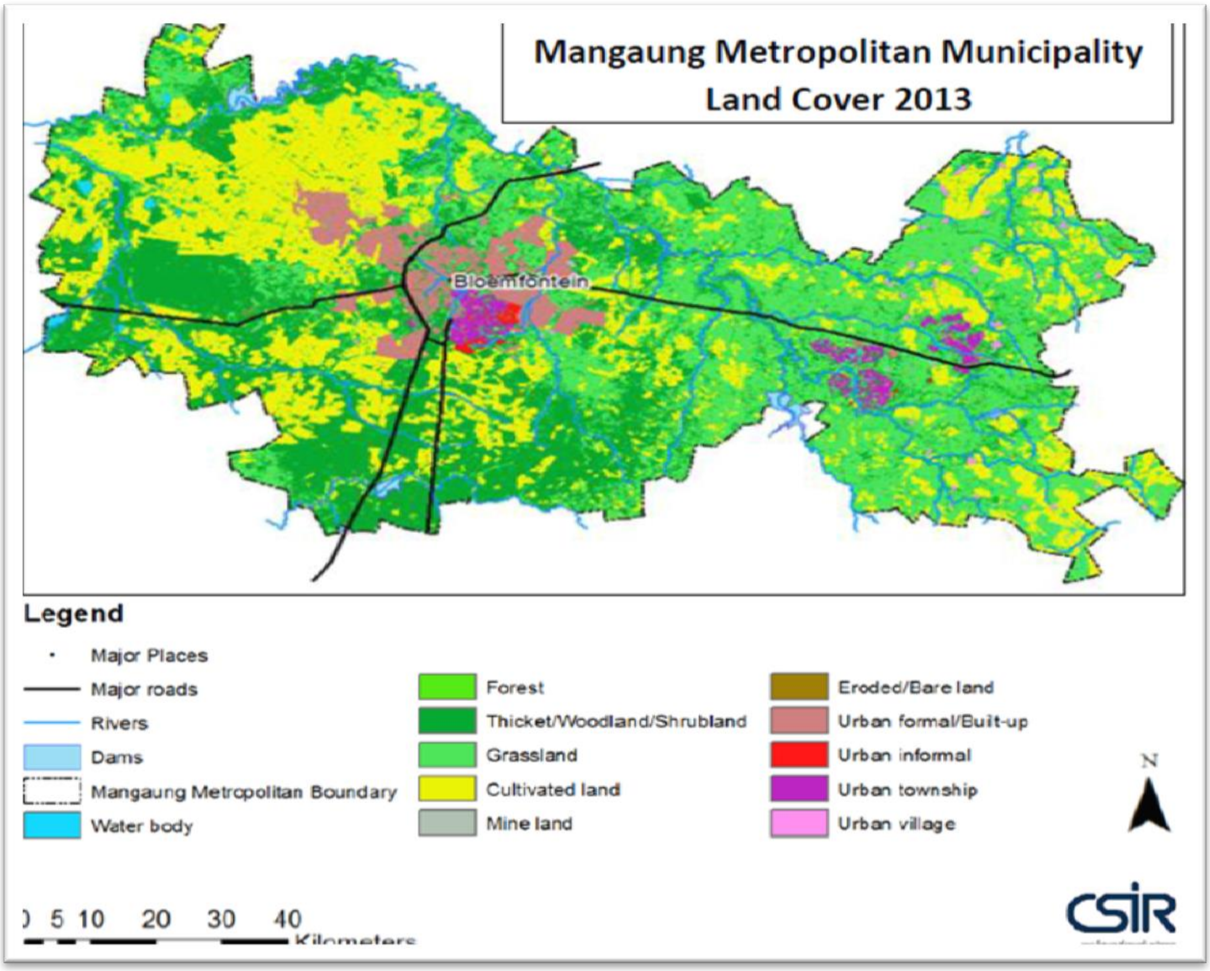


Figure 6.2: Land cover in Mangaung (2013)

6.1.2.3 Agriculture as a Livelihood

The Free State Province is considered to be the bread basket of the country, with both livestock and crop farming taking place in the province. Agriculture in Mangaung is one of the key economic activities with both commercial, small scale and subsistence farming being practised. As a livelihood, an estimated 46 172 households, a percentage of 19,4% of the total households in the municipality depended on agriculture activities in 2011, with a combination of crop farming and livestock. Crop farming is the most dominant in Mangaung, accounting for 67.5% of the agricultural activities, followed by livestock farming, mixed and lastly other types of agriculture (Stats SA, 2011). The agricultural households earned income ranging from R4 801.00 to R38 400, per year, while a less percentage of households did not managed to get an income from agriculture. Only 882 households managed to get an income of above R307 201.00 per year (Stats SA, 2011). Other agricultural activities recorded include poultry, horticulture (mainly vegetables), bee keeping and aquaculture as indicated in Figure 6.3 below. Please note that the red colour represent Mangaung.

Evidence is available that highlights that smallholder and subsistence dryland farmers are more vulnerable to climate change compared to the commercial farmers who depend on large scale irrigation which is in turn is dependent by the availability of rain water. While irrigated agricultural production is probably least vulnerable to climate change, this is premised on the provisional availability of sufficient water supply for irrigation. This is important to note that the adaptation options for agriculture need to take this into consideration.

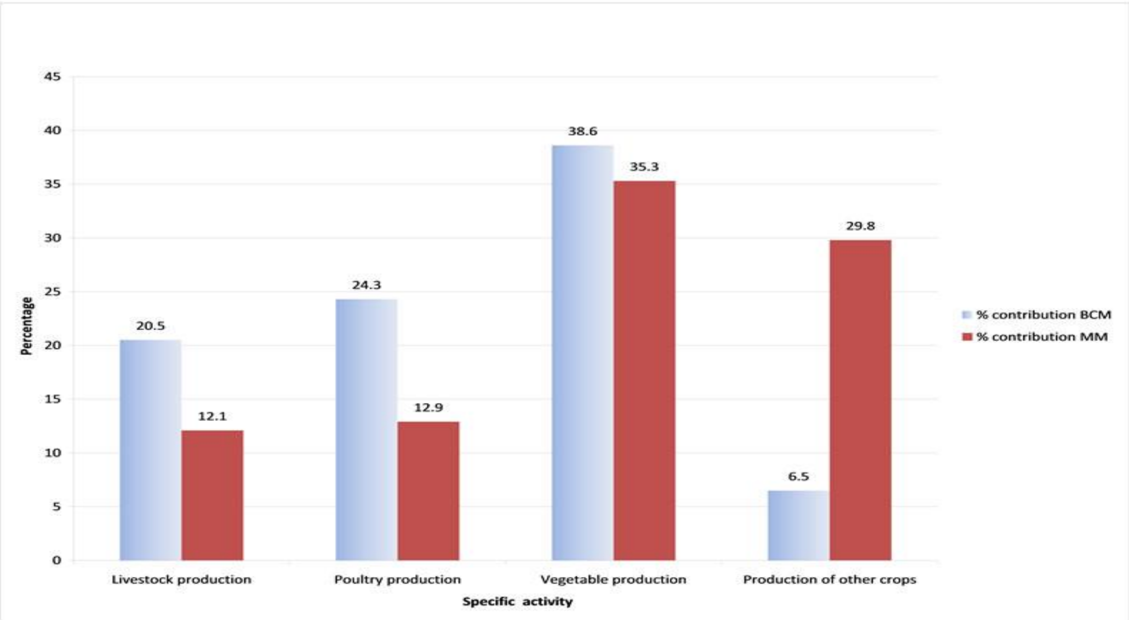


Figure 6.3: Percentage of household agricultural activities

6.1.2.4 Commercial Agriculture in Free State and Mangaung

Agriculture is a critical sector in the province, with at least 14.5% of South Africa's commercial farming taking takes place and is economically important as a provider of food as well as employment. In Mangaung, 22.96% of land is under commercial agriculture; of which 1.4 is under pivot irrigation and 0.02 % is cultivated orchards (DEA, 2014). While agricultural activities in the province are diverse, major crops such as maize, soy beans, wheat, sorghum, sunflowers, potatoes, groundnuts and wool are grown, while horticultural products such as cherries, 90% of which are grown in the Free State, are also key to the sector. Other activities include livestock, dairy farming, game farming, aquaculture and fruit and vegetable production as well as agro-processing (FDC, 2015).

Commercial agriculture in the Free State and in Mangaung is highly dependent on irrigation. It is anticipated that the predicted changes in climate will increase the water demand for irrigation. It is plausible that under a warmer/drier scenario the demand for irrigation will increase by approximately 15 – 30% (DEA, 2013). This will put more pressure on the already strained water resources.

6.1.3 Biodiversity

Mangaung municipality fall under one biome, which covers 100% of the municipality. The grassland which is one of the most threatened biomes in the country. Under the grassland biome, thirteen vegetation types found in the municipality as well as their size are highlighted in Figure 6.4 and Table 6.3.

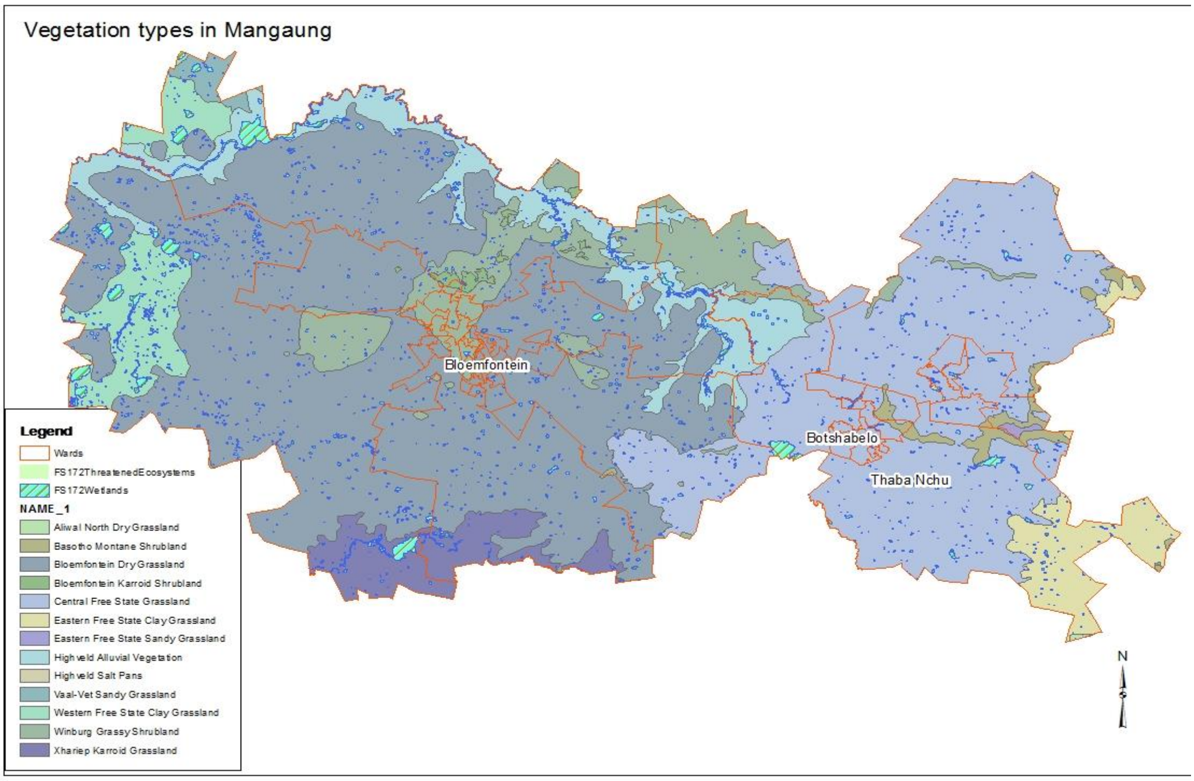


Figure 6.4: Vegetation classes for Mangaung

Table 6.3: Vegetation Types in Mangaung

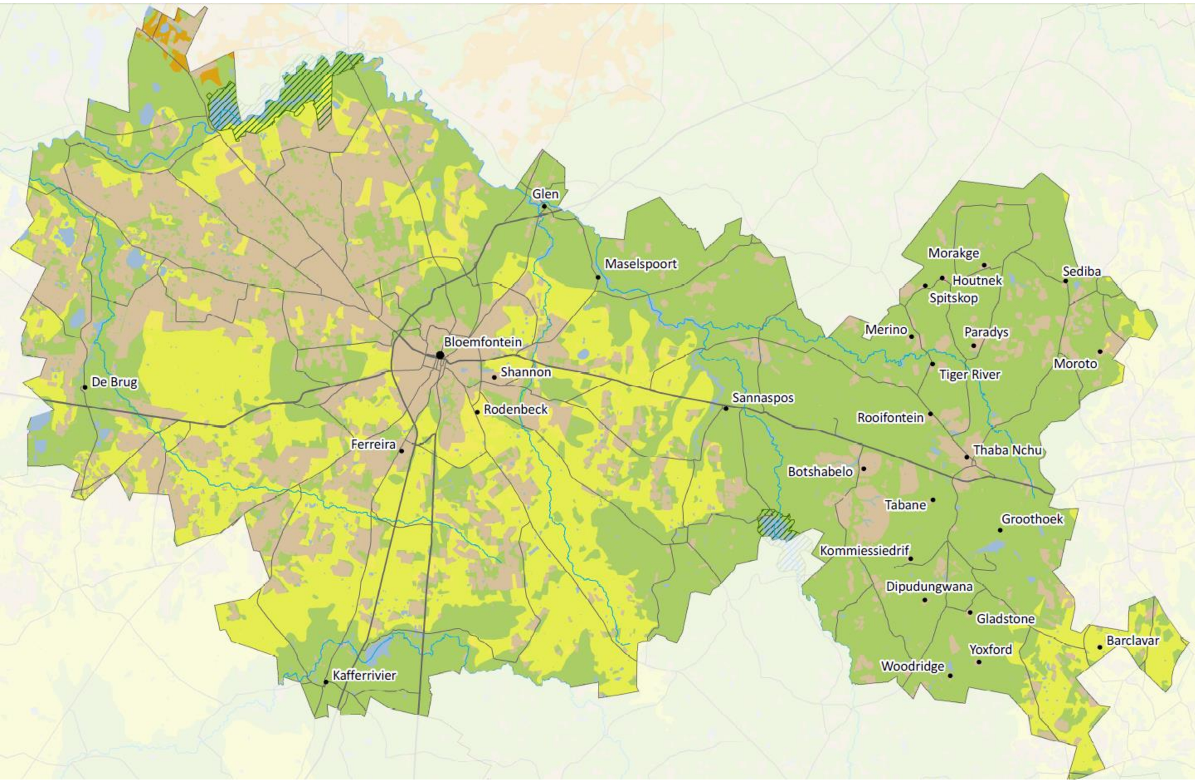
Vegetation Types	Size
Aliwal North Dry Grassland	162.5ha - 0.03%
Basotho Montane Shrubland	6577ha - 1.05%
Bloemfontein Dry Grassland	281715.2ha - 44.83%
Bloemfontein Karroid Shrubland	2002.1ha - 0.32%
Central Free State Grassland	166552ha - 26.5%
Eastern Free State Clay Grassland	539.5ha - 0.09%
Eastern Free State Sandy Grassland	539.5ha - 0.09%
Highveld Alluvial Vegetation	48628.9ha - 7.74%
Highveld Salt Pans	2203.4ha - 0.35%
Vaal-Vet Sandy Grassland	3375.7ha - 0.54%

Western Free State Clay Grassland	27635.1ha - 4.4%
Winburg Grassy Shrubland	46324.5ha - 7.37%
Xhariep Karroid Grassland	23357ha - 3.72%

6.1.3.1 Threatened Terrestrial Ecosystems

Ecosystem threat status highlights the extent to which ecosystems are still intact, or are losing vital aspects of their structure, function and composition upon which their capacity to provide ecosystem services relies on (Driver et al., 2011). Ecosystem threat is classified as critically endangered (CR), endangered (EN), Vulnerable (VU) and less threatened (LT), with CR, EN and VU classified as threatened ecosystems. These are premised on the proportion of individual ecosystems that are in good ecological status, relative to a series of thresholds. The ability to map and classify ecosystems into different ecosystem types is essential in the assessment of threat status and protection levels as well as to monitor trends over time (Driver at al., 2011).

There are five categories of threatened ecosystems, Critically Endangered, Endangered, Vulnerable, Least Vulnerable and areas with no natural habitat. Four of these threatened ecosystems are found in Mangaung with three of these regarded as important, endangered, vulnerable and least vulnerable. The Endangered ecosystem is found in the north west of the municipality, comprising of the Vaal Vet Sandy Grassland covering only 3% of the municipality. The two vulnerable ecosystems are noted as Bloemfontein dry grass, covering 22.7% and the Eastern Free State Clay grassland, occupying only 2.03% of the municipality (see Figure 6.5.).



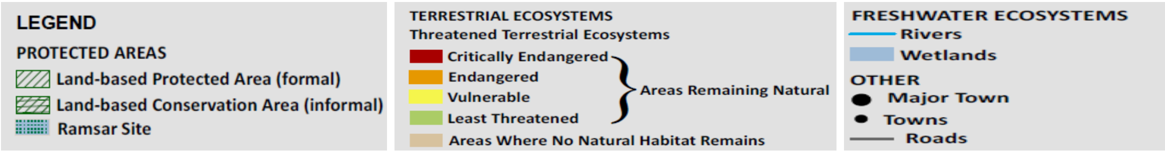


Figure 6.5: Threatened Ecosystems in Mangaung (BGIS, 2013)

As an overview, Mangaung is considered to be a 100% grassland biome. According to the Long Term Adaptation Scenarios (LTAS), and based on the threatened ecosystems status and protection level of each of South Africa's nine biomes, grassland is considered as one of the most vulnerable to land-use change and is rated as a second priority meaning grasslands are endangered but have low protection areas presented.

An assessment of spatial shift of optimum climate conditions for South Africa, under different scenarios, low, medium and high indicate that grasslands are the most vulnerable biome, with large proportion of the biome susceptible to replacement by savannah and forest vegetation (DEA, Biodiversity, 2013).

6.1.3.2 Climate-change induced biodiversity vulnerabilities in South Africa and Mangaung

According to the Long Term Adaptation Scenarios (DEA, 2013a), the grassland biome is highly vulnerable to both land-use and climate change, being ranked the second most vulnerable (endangered), with low protection of this biome nationally. In terms of vulnerability to climate change, the grassland biome is highlighted as a high priority for protection, restoration and research to guarantee adaptation under future climate conditions. Due to the high altitude location of the biome and its susceptibility to warming impacts, substantial change and loss of habitat is projected for the grasslands (DEA, 2013a; Driver et al., 2011). Furthermore, the grassland biome faces threats from the encroachment of tree cover as a result of CO_2 fertilisation and longer growing periods (DEA, 2013a). The savanna biome, conversely, is projected to increase its geographic range, in some areas encroaching and replacing the grassland biome (Driver et al., 2011). This projected increase in woody cover is expected to transfer or change the structures of some areas of the savanna biome towards woodland and forests, including invasion by alien species. The loss of the grassland biome is likely to have adverse impacts on ecosystem goods and services, such as water delivery from the highland catchments and grazing as well as adverse impacts on conservation and ecosystem delivery as well as ecosystem processes such as wild fires.

The grassland biome is an essential ecosystem, providing especially for the regulation of water flow as an ecosystem service. In terms of economic relevance, grassland provide thatching grass, craft work materials and medicinal plants (SANBI, 2005).

6.1.4. Human health

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

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

6.1.4.1 Extreme heat

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

6.1.4.2 Droughts

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

6.1.4.3 Floods

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

6.1.4.4 Climate change and vector-borne diseases

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

Changes in temperature and precipitation directly affect vector borne diseases (VBD) and zoonotic diseases (ZD) through pathogen-host interaction (e.g. VBDs are transmitted by the bites of infected mosquitoes and other insects (vectors), and indirectly through ecosystem changes and species composition. Where mosquitoes are the vectors, temperature plays an important role. The optimum temperature for transmission is an annual average of 22 °C (DEA, 2013b, p25), with the parasite not developing at temperatures below 16 °C and the mosquitoes not surviving temperatures above 40°C. There is an association between availability of water (for breeding) and rainfall and an increase in mosquito population, thus more droughts will have the opposite effect (DEA, 2013b, 2013). However, heavy rainfall may wash breeding sites away, while a little pool of stagnant water after normal rainfall could become a breeding site, thus the association is not linear (Thomson et al., 2005 in DEA, 2013b). The life cycle of pathogens inside vectors is shortened under warmer conditions. (6.4 from Friel et al., 2011), indicates the direct and indirect pathways from climate change to non-communicable diseases (NCDs).

Table 6.4: The direct and indirect impacts of climate change on NCDs (from Friel et al., 2011)

Climate change impacts	Pathway for climate change to NCDs	NCD outcome	Direction of health risk
Direct			
More frequent and increased intensity of heat extremes	Heat stress	Cardio-vascular diseases (CVD)	Increased risk
Increased temperatures and less rain	Higher ground-level O_3 and other air pollutants Increases in airborne pollens and spores	CVD; Respiratory disease	Increased risk
Changes in stratospheric O_3, precipitation and cloud cover	Decreased exposure to solar UVR	Auto-immune diseases Skin cancer	Reduced risk
High winter temperatures		CVD; Respiratory disease	Reduced risk

Extreme weather events (fires, floods, storms)	Structural damage	Injuries	Increased risk
Indirect			
Drought, flooding	Impaired agriculture, reduced flood yields, nutrition insecurity	Poor general health	Increased risk
Extreme weather events (fires, floods, storms)	Trauma	Mental health (post-traumatic stress disorder)	Increased risk
Extreme weather events (fires, floods, storms)	Impaired livelihoods, impoverishment	Mental health (anxiety/depression)	Increased risk

6.1.4.5. Vulnerable populations in the context of climate change

While all populations will be affected by climate change, some are more vulnerable than others , such as the elderly and children (due to their physiological development), people with pre-existing medical conditions and those considered 'special needs populations' such as the physically or mentally challenged (WHO, 2013). Vulnerable population groups have decreased ability to cope with climate change and the socio-economic status of communities is as important as their susceptibility/sensitivity in terms of their coping capacity (WHO, 2013).

High temperatures, as projected with the changes in temperature will impact human well-being by increasing thermal human discomfort for more days than those previously recorded, especially during the summer months. This will consequently increase human thermal discomfort, with severe repercussions for agricultural labour and productivity, in particular those involved in summer and multi-year crops (DEA, 2013). Thermal heat comfort is maintained at a constant body temperature of 36.5°C and 37°C, and thus increases or decreases on this temperature will cause human discomfort. Body temperatures exceeding 40°C will result in blood circulation problems while temperature above 41–42°C could lead into a coma or total collapse can occur (Gomez et al., 2004). Thermal heat comfort can further be compromised by high level of humidity which affects the body's defence mechanisms, leading to heat stroke (Conti et al., 2005). This does not only affect people who work in agriculture but all people who work outdoor since they are affected by the same conditions.

6.1.4.6 Health impacts associated with extreme events for vulnerable populations in the Mangaung Metropolitan Municipality

The vulnerability of the municipality to three climate change aspects was assessed. These aspects were: a gradual change in climate (increase in temperature, decrease in rainfall), extreme precipitation (such as flash floods) and extreme heat events (heat waves)

Factors used in the vulnerability assessment were selected for their potential contribution to human health and well-being. The wards were ranked as high, medium or low and summarised in Table 6.5 below..

Climate events considered	RANKS FOR TWO SCENARIOS					
	Before considering population size of region			After considering population size of region		
	High	Medium	Low	High	Medium	Low
Gradual Climate change	27; 31; 32; 33; 34; 35; 36; 37; 38; 41; 45	1; 2; 3; 4; 5; 6; 7; 8; 10; 11; 12; 13; 15; 16; 17; 18; 28; 29; 30; 39; 40; 42; 43; 49	9; 14; 19; 20; 21; 22; 23; 24; 25; 26; 44; 47; 48	45; 46	12; 18; 27; 34; 37	1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 13; 14; 15; 16; 17; 19; 20; 21; 22; 23; 24; 25; 26; 28; 29; 30; 31; 32; 33; 35; 36; 38; 39; 40; 41; 42; 43; 44; 47; 48; 49
Extreme Precipitation	1; 4; 6; 8; 12; 27; 28; 31; 32; 33; 34; 35; 36; 37; 38; 39; 41; 43; 45; 46	2; 3; 5; 7; 9; 10; 11; 13; 14; 15; 16; 17; 18; 29; 30; 40; 42; 49	19; 20; 21; 22; 23; 24; 25; 26; 44; 47; 48	45; 46	12; 18; 27; 34; 37	1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 13; 14; 15; 16; 17; 19; 20; 21; 22; 23; 24; 25; 26; 28; 29; 30; 31; 32; 33; 35; 36; 38; 39; 40; 41; 42; 43; 44; 47; 48; 49;
Extreme Temperature	27; 45; 46	1; 6; 7; 8; 12; 17; 18; 28; 31; 32; 33; 34; 35; 36; 37; 38; 39; 41; 43	2; 3; 4; 5; 9; 10; 11; 13; 14; 15; 16; 19; 20; 21; 22; 23; 24; 25; 26; 29; 30; 40; 42; 44; 47; 48; 49	45; 46	12; 18; 27	1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 13; 14; 15; 16; 17; 19; 20; 21; 22; 23; 24; 25; 26; 28; 29; 30; 31; 32; 33; 34; 35; 36; 37; 38; 39; 40; 41; 42; 43; 44; 47; 48; 49

6.1.5. Water Resources

6.1.5.1 Surface Water

South Africa generally arid to semi-arid climate rainfall and river flow are often unpredictable and in time and un-evenly distributed in space. The rainfall variability also results in extended period wet and dry periods across the country, exacerbating already stretched surface water resources (DEA (Water), 2013). Demand for water is anticipated to increase with economic growth, increased urbanisation and higher standards of living.

Water resources for the Mangaung consists of a series of dams, rivers, wetlands and groundwater resources. The municipality's water resources straddle between two water management areas, Upper Orange and the Middle Vaal water management areas, with 5 rivers found in the area, the Kaalspruit, Korannasspruit, Modder and Renosterspruit. A total of 2759 wetlands covering 15002ha (2.4%) of the municipality are considered part of the surface water ecosystem (see Figure 6.6).

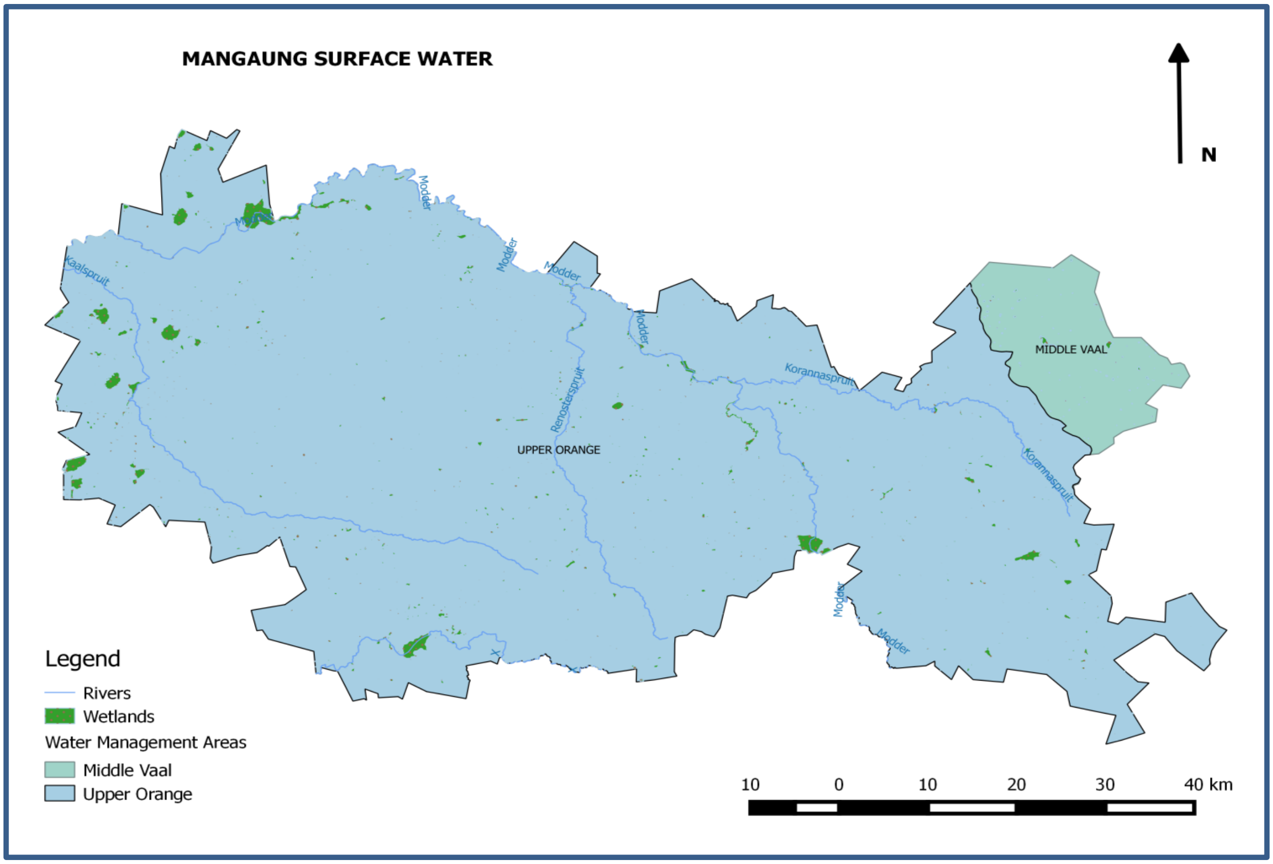


Figure 6.6: Surface Water Catchment areas

Climate change impacts could exacerbate existing water-related challenges while creating new ones as a result of rainfall variability and extreme weather events such as drought and floods, changing rainfall seasonality, and overall warming, resulting in greater losses to the atmosphere. Increasing temperatures will negatively affect water provision, water usage and available capacity. Other factors threatening water resources include alien invasive species, land use change and economic development.

Water and sustainable water provision is a key issue in Mangaung, given that the future projects for rainfall highlight a decrease in rainfall, a critical factor for future planning of Mangaung, making the provision of water a high risk (SACN, 2013).

According to the LTAS water report, the Vaal water management areas which make up part of the Mangaung water supply show that the rainfall will either remain constant or will increase. The mean annual temperatures are also expected to increase, but not much variability will be recorded. However, variability may be influence by the expected increase in flooding events.

6.1.5.2 Ground Water

6.1.5.2a Current system state

The yield and type of an aquifer are important in the effects of climate change studies. An aquifer means a geological formation which has structures or textures that hold water or permit appreciable water movement through them. A fractured aquifer indicates that groundwater is located with fractures in a hard rock formation. An intergranular aquifer indicates groundwater flows in openings and void space between grains or weathered rock. A karst Aquifer indicates an area of limestone or other highly soluble rock, in which the landforms are of dominantly solutional origin and in which the drainage is underground in solutionally enlarged fissures and conduits (caves).

The yield indicates the volume of water that can be abstracted from an aquifer over the long term. The water quality GIS layer indicates the expected groundwater quality of the area. It measures in electrical conductivity (EC), which is a measure of how well a material accommodates the transport of electric charge. The more salts dissolved in the water, the higher the EC value. It is used to estimate the amount of total dissolved salts, or the total amount of dissolved ions in the water.

The ground water vulnerability GIS layer indicates how susceptible the geological formation is from surface based contamination and looks at the following variables.

The DRASTIC method takes into account the following factors:

D	=	depth to groundwater	(5)
R	=	recharge	(4)
A	=	aquifer media	(3)
S	=	soil type	(2)
T	=	topography	(1)
I	=	impact of the vadose zone	(5)

C = conductivity (hydraulic) (3)

6.1.5.2b Potential climate change impacts (the map and content for this section is being finalised)

6.1.6. Human settlements

6.1.6.1 Current system state

Mangaung Metropolitan Municipality has three main urban centres in Bloemfontein, Botshabelo and Thaba Nchu surrounded by vast rural areas. 90.6% of settlements are urban 6.9% tribal and 2.5% farm. There are imbalances between the urban areas of Bloemfontein, Botshabelo and Thaba Nchu and remote rural areas within the metropole as well as the surrounding areas. Bloemfontein was historically a white's only area while Mangaung Township linked to Bloemfontein served as the major settlement area for people of colour. Mangaung township is well serviced and its proximity to the City has attracted more people to come in and increase pressure on basic infrastructure and social services. This has also resulted in an increase in the number of informal settlements within the township. 52% of the population in MMM reside in Bloemfontein with a population density of 90 persons per km².

Botshabelo is the largest township in MMM with 28% of the population living here. The township was spatially designed along the N8, a major route that runs across MMM. This has created a linear urban pattern along the major route. Significant proportion of Botshabelo is under-developed and has limited access to basic services. The township also has challenges with an increasing number of informal settlements and population density of 1396 persons per km².

Thaba-Nchu is a former part of the Bophuthatswana homeland. It has a scattered settlement pattern with 37 villages surrounding the urban core and has a population density of 65 persons per km². The area also consists of large areas of rural settlements on former trusts lands. The MMM is continuing with work to restructure the city post-apartheid as remnants of the past are still evident in some areas. This includes ensuring that people travel shorter distances to their places of work through mixed developments. This is also achieved through consolidation of the City by developing brownfields settlements and infill developments. Currently an estimated 17 000 people commute daily between Botshabelo and Bloemfontein and Thaba Nchu and Bloemfontein.

The map below (Figure 6.7) shows the land cover for MMM and the location of different human settlements in the municipality. Bloemfontein comprises of urban formal built up areas (dark pink colour); informal settlements (red colour) and urban township (purple colour). Botshabelo and Ntaba Nchu on the eastern parts of the map are both urban townships (purple colour) and the land cover is mostly grassland and cultivated land.

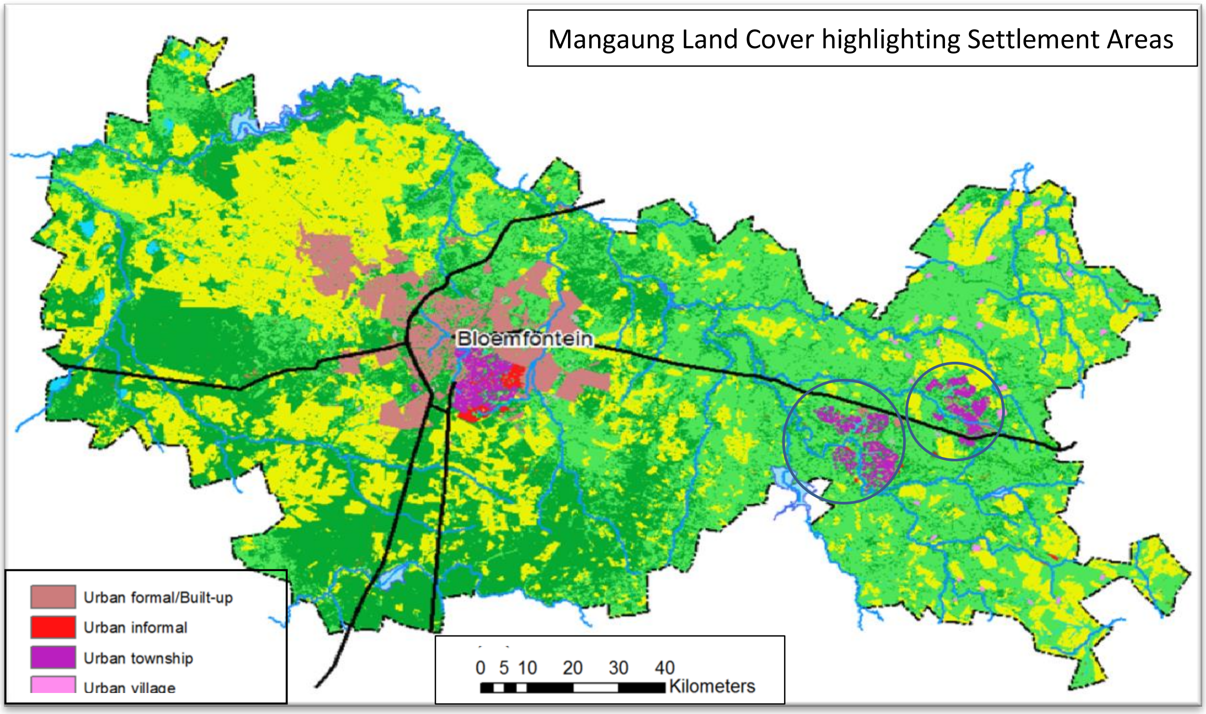


Figure 6.7: Landcover highlighting Settlement Areas

Informal Settlements

Like other municipalities, MMM is also faced with the challenge of informal settlements which are in most instances made of poor material and located in ecologically sensitive areas such as wetlands and flood lines. MMM is currently facing storm water drainage and sanitation problems especially in highly populated areas with fragile ecosystems. The MMM Human Settlements Plan (2013:32) indicates that 40% of main arterial roads and 60% of access streets need upgrading. Progress has been made in providing households with water and as such 92% of households have access to water on their yards while 8% has access to water within a 200m radius as stipulated in the Reconstruction and Development Programme (MMM, 2013). 91,4% of households have access to electricity for lighting (StatsSA, 2011).

6.1.6.2. Potential climate change impacts

Vulnerability of human settlements is influenced by factors such as settlement type i.e. rural/urban/peri-urban or mixed; provision and access to infrastructure and services and spatial and temporal population distribution (DEA, 2014). Specific climate change impacts on human settlements include;

- Heat wave discomfort especially in homes which are not insulated
- Disruptions to water and electricity supply
- Loss and damage to ecological infrastructure which supports livelihoods and economic sectors such as tourism.
- Flooding in homes which can lead to loss and damage to personal assets
- Damage to buildings (roof, doors and windows) especially for low cost houses and informal houses
- Physical seclusion of rural households especially in areas that have poor road infrastructure prone to flooding and erosion. Provision of basic and emergency services is difficult in dispersed and isolated settlements
- Tenure insecurity in communal land and the complexities around land rights and the role of traditional authorities in rural areas

6.1.7 Waste management

6.1.7.1 Current system state

MMM has three large solid waste sites, the largest is the Southern Land fill Site (11 725 hectares) that is located in the south of the city. The Northern Landfill Site is the second largest site (39 hectares) it is in the northern parts of Bloemfontein and the third being Botshabelo Landfill site (24 hectares). The northern and southern solid landfill sites in Bloemfontein receive waste in excess of 16 000 tons per month (Bell Equipment, 2014) however there is no formal waste treatments at all sights with the exception of informal waste recyclers (Mosia, 2014a). The Nthaba Nchu landfill has been closed. The waste facilities have been upgraded to comply with provisions of the Environment Conservation Act (Act No 73 of 1989). This has included rezoning of land utilised for land-filling, access control, computerised weighbridge with control room, area for off-loading by small and private vehicles, offices, ablution facilities for workers, proper fencing to have security and access control and access roads (MMM Human settlements report, 2013:35)

The municipality is involved in solid waste management education and awareness raising in communities. A fully equipped Mobile Environmental Learning Unit funded by Ghent is used for this activity. There are cooperatives engaged in waste recycling e.g. Mphatlalatsane Cooperatives in Thaba Nchu and the municipality assists with training cooperatives in recycling and sorting bins. Waste recyclers in MMM and the Free State generally receive low prices from buyers as compared to other recyclers in areas such as Johannesburg (Mosia, 2014b). There have been challenges with the maintenance of the current operating vehicles responsible for refuse collection and removal e.g. the compaction vehicles. Other challenges include the illegal dumping of waste across the municipality.

6.1.7.2 Potential climate change impacts

Bebb and Kersey (2003) have identified the following as some of the potential impacts of climate change on waste management processes and waste sites;

- Flooding can result in disruption on infrastructure that supports waste management like roads. Excessive rains can also cause damage to waste site facilities such as weighbridges and buildings on the site
- The type and amount of flora and fauna on and around the landfill site.
- Landfill degradation rates are susceptible to changes in rainfall and temperature
- Heat waves, increased number of hot days and temperature increase health risk and discomfort for recyclers and other workers on land fill sites who work in the sun affecting their productivity.
- Health risks from increased pathogen, rodents and pest activity
- Increased unpleasantness of landfill sites as a result of odours, rodents, pests and dust
- Increased risk of slope failure and instability of landfill slopes from drying out of soils on hot days followed by wetting due to heavy rainfall

6.1.8 Industry and commerce

6.1.8.1 Current system state

The Mangaung economy is based mostly on government services and finance. Other economic activities in MMM include trade and transport services while the manufacturing sector has been declining. The development of commerce industry in the municipality has been concentrated in the western areas of Bloemfontein with major office and retail development in the Brandwag area. This development on the western side which is further away from the Central Business District (CBD) has resulted in increased travel distances for people traveling from areas such as Botshabelo and Thaba Nchu. Botshabelo hosts the FDC Industrial Park which is a key node for economic development in the area. The industrial park has 138 warehouses, the Supreme Chickens Abattoir as well as factories involved in the manufacturing of textiles, food processing, electrical enclosures, paraffin stoves and minor engineering services (MMM IDP, 2014/15).

Mining and agricultural activities are reported to be causing pollution in the municipality (MMM IDP, 2014/15). MMM has also experienced an increase in the number of unregistered small business operators or home-industries that conduct business from home raising traffic flow and safety problems. There is inadequate infrastructure to support the area as a competitive business district e.g. road infrastructure and there is a great need to diversify the economy. The informal economy plays a key role in Mangaung and the largest component is the street traders who engage in diverse range of activities. There is a need for policy to address issues of improved productivity in the informal economy.

6.1.8.2 Potential climate change impacts

- Loss of budget and resource allocation for planned activities
- Economic vulnerability to market regulations e.g. carbon tax, emissions policy, policy affecting export prices.
- Increased repair and maintenance costs of infrastructure
- Increased insurance pay-outs and liability costs as assets are exposed to climate risk.
- Increased unemployment

- Business disruption and productivity as operating costs, markets for products and availability of raw materials get affected by changes in climate
- Agriculture sector is sensitive to changes in temperature, precipitation, pests and alien invasive plants.

6.1.9 Transport

6.1.9.1 Current system state

Road Transport is the largest consumer of fuels, with the main sources of energy used in road transport being petrol and diesel. Road transport emissions contribute to poor air quality (particulate matter, oxides of nitrogen and other air pollutants). This sector is seen as being a priority area for expansion of infrastructure to facilitate access to transport services by those living in remote/rural areas.

6.1.9.2 Potential climate change impacts

The immediate threats to transportation operations have implications for industrial and commercial supply chains. For example extreme temperature can have impacts on pavements; railway lines and the mobility of people. Likewise, extreme rainfall can result in increasing road accidents; interruptions to logistic operations and delays to road construction/maintenance. Extreme weather events can also result in the destruction of roads, bridges and railway lines due to floods and storm surges.

6.1.10 Energy

6.1.10.1 Current system state

The main sources of energy used in the MMM include: grid-supplied electricity, petrol and diesel. The combustion of these fossil fuels is a significant source of both indoor and outdoor air pollution. Fossil fuels are also significant contributors to greenhouse gas emissions. Reducing the amount of fossil fuels that are combusted within the municipality would have direct benefits to people that are normally exposed to the pollution, and will also have positive effects for climate change.

In Mangaung significant progress has been made to ensure that households are electrified and that they have access to safe and clean energy sources.

6.1.10.2 Potential climate change impacts

As the municipality largely relies on coal-fired derived electricity, it is vulnerable to the supply and demand challenges facing Eskom. Furthermore, the production, transmission and distribution of electricity to the municipality is likely to be impacted by climate change. For example, Eskom faces challenges with respect to coal that is stored in open stockpiles, which when wet causes delays/problems on electricity generation. Climate change may also impact on water availability, which has impacts on electricity generation, as large amounts of water are needed in cooling towers. The transmission of electricity is also likely to be affected by climate change due to fluctuations of the air temperature.

Within the municipality there is also likely to be increasing energy requirements due to both changing climate and population growth. Temperature changes and extreme weather will change the heating and cooling needs of people. Thus the electricity distribution and transmission needs of the municipality are likely to grow as energy demand increases.

6.2 Social Vulnerability

6.2.1 Introduction

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

6.2.2 Approach

Two methodologies were used to illustrate the vulnerability of communities within the different wards of Mangaung.

- A Social Vulnerability Index (SVI), which was developed by Le Roux et al. in support of national decision-making in South Africa. This index provides a comparison of vulnerability of wards in Mangaung to those in the whole of South Africa (classifying them from the least to the most vulnerable). This index was built for the purpose of developing an appropriate index to measure social vulnerability across South Africa by performing principal component analysis of 14 unique (South African-specific) variables. This index was required by the South African National Disaster Management Centre in terms of the National Disaster Management Framework of 2005 (Le Roux et al., 2015).
- In order to show the drivers of social vulnerability within the Mangaung Metropolitan Municipality, a composite index was derived using the same type of indicators as used by Le Roux et al. The indicators also used the 2011 Census data. Each indicator was looked

at on an individual bases .The dependency indicator were derived by considering the dependency ratio ((<15, >65)/15-65)), with all other indicators using a proportion of the total population in the ward. Indicators were summed and the total used to rank wards from 1-49.

6.2.3 Social Vulnerability in Mangaung

The assessment in Mangaung assisted in quantifying the level of influences for the different factors and how these contributed to vulnerability in the municipality. The following 15 indicators of social vulnerability were considered and are presented in Figure 6.8 below, using a ward level scale:-

- Types of housing (Informal settlements)
- Education (older than 25 years, no education)
- Employment: unemployed
- Household density (> 4 people/room)
- Poverty line (household earning < R400/month)
- Economic dependency (young and old compared to economic active population)
- Physiological vulnerability (young and old)
- Air pollution (fuel use other than electricity)
- Access to water (no piped water)
- Single parents (female-headed households)
- Child-headed households
- Access to transport (no car)
- Access to information (neither radio or cell phone)
- In need of assistance (determined by problems with hearing, mobility, seeing, self-care, speaking)
- Social cohesion (non-South Africans in informal areas for < 2 years)

The 15 variables were collected and ranked to highlight social vulnerability of all the wards in Mangaung, with a ranking of 1 to 49 applied as illustrated in annexure 1 for the ward level ranking. These were further classified into three categories as highlighted below:-

- Highest vulnerability – ranking 1-17 (**orange colour on map**)
- Medium vulnerability – ranking 18 – 34 **(yellow**)
- Lowest vulnerability – ranking 35 – 49 **(green**)

A few social indicators emerge as key drivers of vulnerability in Mangaung, in particular wards. For example, economic dependency[1] increases vulnerability affecting wards 27 to 30 and 31 to 40, and this factor requires substantial investment in health and education to stimulate economic growth and reduce inequality. Physiological factor[2] increase vulnerability affecting wards, 33 – 40

[1] Economic Dependency - Comparison of the population between the economically active population and the young and the old population

[2] Physiological Factors – the population of the young and the old

as well as wards 29 and 41, while access to transport is prominent in wards 35 to 40 as well as wards 27, 41 and 45.

Social Vulnerability comparison between wards in Mangaung

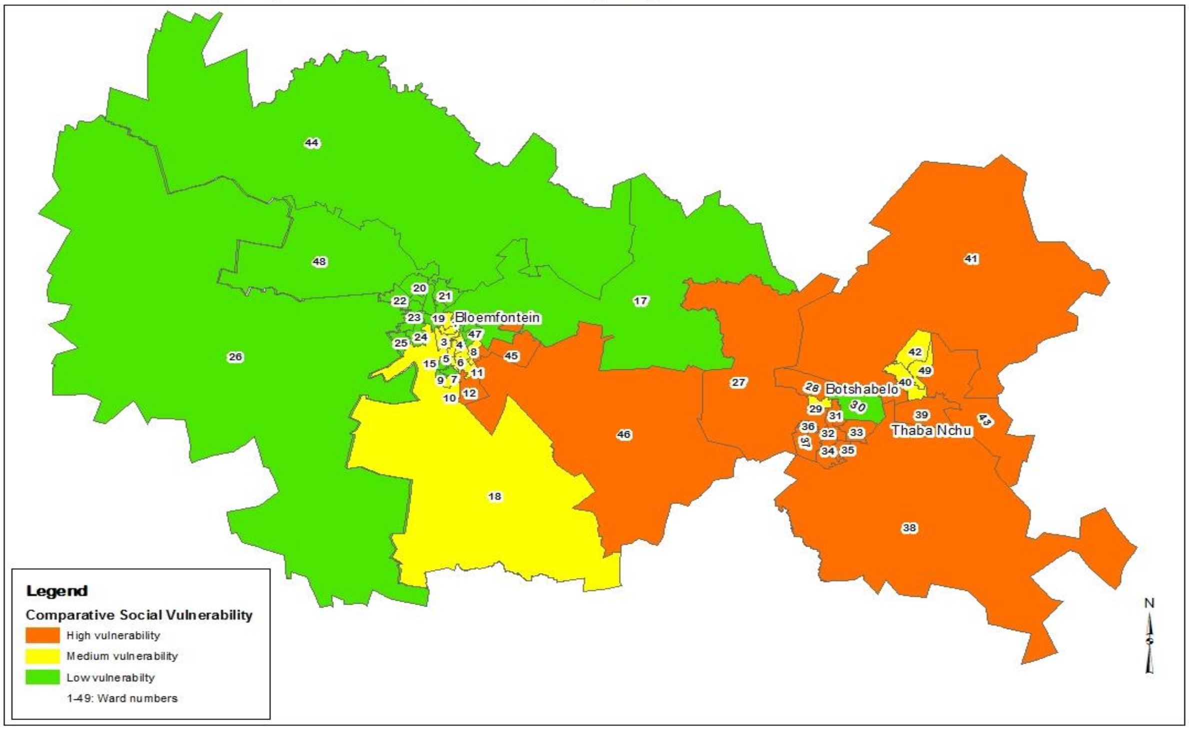


Figure 6.8: Social Vulnerability in Mangaung

6.2.3.1 Wards of High Social Vulnerability

The following wards are highlighted are highly vulnerable: 12, 27, 31 – 34, 36 – 39, 41, 45, 46. The wards are highlighted with the orange colour in the map (Figure 6.8) and are mainly located in the south – eastern corner of the municipality, in and around Botshapelo and Thaba Nchu. These wards are characterised by high economic dependency, poor access to transport, poor access to information and physiological factors. Some and not all are also affected by high unemployment, poverty and access to water. Of these wards, ward 27 emerges as one of the most highly vulnerable, showing high ranking in type of housing (informal settlements), poverty, unemployment, education, access to water and economic dependency.

6.2.3.2 Wards of Medium Vulnerability

The following wards are highlighted as having medium vulnerability: 1, 3 – 4, 6, 8, 10, 15, 18, 29, 40, 42 and 49. This category has the least number of wards, and these are mainly located in the centre of the municipality including Bloemfontein.

6.2.3.3 Wards of Low Vulnerability

The following wards are classified as having low vulnerability: 4, 5, 7, 9, 20 – 26, 44 and 48. These wards are mainly located to the west of the municipality, in the mainly agricultural areas. These wards are characterised by low population or household densities, low economic dependency, low poverty rates and low unemployment, while having better access to transport and information as well as better access to water.

Mapping social vulnerability as well as identifying socio-institutional systems is one of the best ways to understand and respond effectively to climate change. Cross sectoral planning and stakeholder engagement can enhance efforts aimed at climate change mitigation and adaptation while partnerships with private sector, universities, research institutions and as well as international funding agencies cannot be under estimated.

6.2.3.4 Extreme Weather Events

Mangaung Metropolitan Municipality is susceptible to a myriad of extreme climate events and its location on the Highveld makes it vulnerable to particular types of risk which heightens its exposure, and the exposure of its poorer populations. While the determined extreme events are related, i.e. variation in temperature, variation in rainfall and extreme events, Mangaung faces other disasters that are not naturally based. A detailed study on disasters in the metropolitan municipality highlights the types of extreme events associated with hydro-meteorological factors. These were identified through a stakeholder process and the events as well as the areas affected are represented in Table 6.6 below:

Table 6.6. : Types of hazard events and the areas affected in Mangaung Metropolitan Municipality

Hazard	Affected Area
Severe storms	The whole area, Wards 41, 38, 42, 27, 36, 17, 46, 18, 6, 44, Grass Land, Sections F, H, G, J, K N T in Botshabelo,Trust lands, Marago, Mokoena In Thaba Nchu, Mafora, Phase 6 and 9, Caleb Motshabi, Khayelitsha, MK Square, Northern Suburbs of Bloemfontein (Trees)
Floods	Ward 27, Roodewal, Modder River, Klein Modder River, Bloemspruit, Renosterspruit, Bloudam, Tierpoort, Khayelitsha, Canals
Drought	Whole area, Ward 38 and 41, Bloemspruit, Tierpoort, Bainsvlei, Kwaggafontein
Snow	Whole Area
Cold spells	Whole Area

Hydro-meteorological hazards such as floods including flash floods, droughts, thunderstorms, hailstorms, tornados, heat waves and cold spells have a myriad of socio-economic impacts including extensive damage to property, loss of life, injury or other health impacts, loss of livelihoods, social and economic disruption, or environmental damage (MMM, 2013/14). While hydro-meteorological events are the most common, other events caused by extreme temperatures changes do occurs such as veldt fires due to high temperatures.

6.2.3.5 Flooding

Flooding, including flash floods is the most common hazard, affecting most of the municipality, especially those areas with the flood lines of the perennial rivers as highlighted in Figure 6.9. The impacts of the flood would be more severe in areas with informal settlement and in areas with high densities of population. The red areas indicate the areas that are susceptible to flooding and areas that will have an impact on the vulnerable communities (MMM,2013/14).

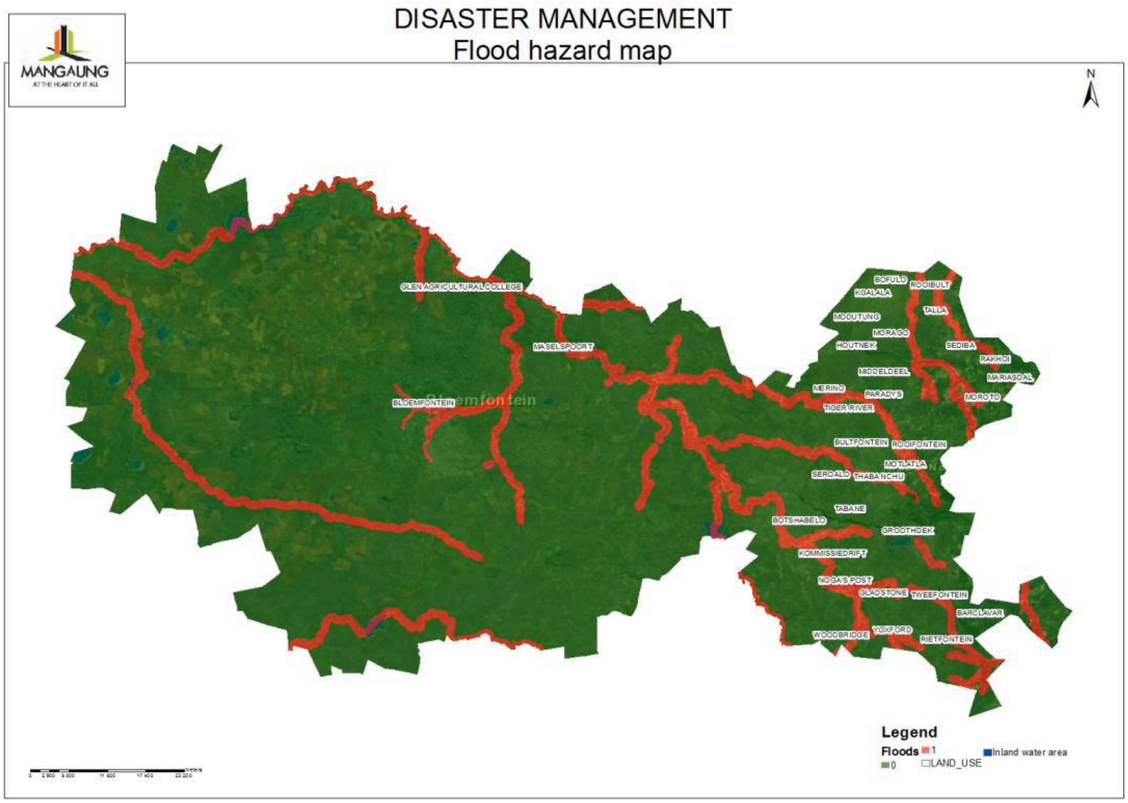


Figure 6.9: Flood Hazard Map for MMM (MMM, 2013/14).

6.2.3.6 Droughts

Drought incidents have been known to affect MMM in the past and are a serious issue given the dependence on the municipality on irrigation for agriculture. Further, water storage capacity in the dams that supply water to Mangaung is a problem, given the issues of dam siltation and ageing infrastructure (MMM, 2013/14). These issues will be exacerbated in a drought year, especially for the population already struggling with access to basic services such as water. For the areas in the municipality affected by drought, see Table 6.6 above.

6.2.3.7 Other Hazards

MMM experiences a myraids hazards over and above the ones mentioned above and these include (Figure 6.10):

- Strong Winds
- Severe thunder storms
- Thunderstorms and Lightening
- Veld Fires

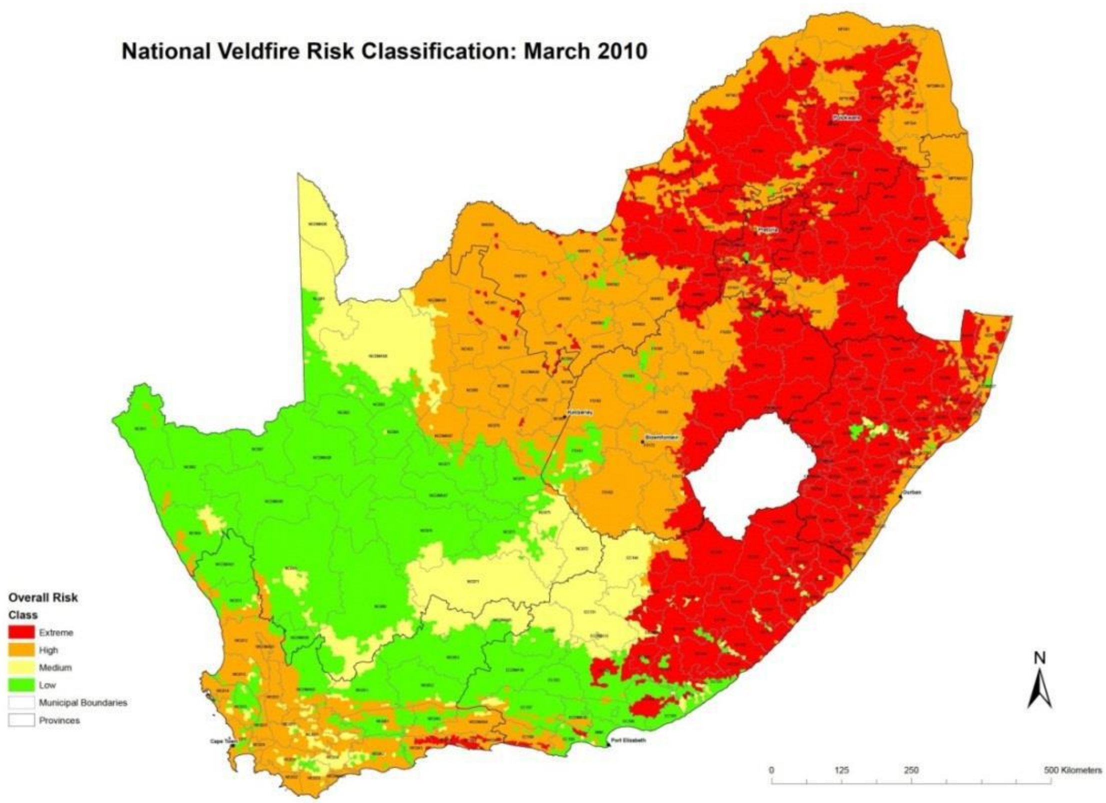


Figure 6.10: National Veld Fire Classification – indicting an extremely and high classification for Mangaung.

6.2.3.8 Vulnerability Risk Profile

The vulnerability profile for Mangaung is premised on the ability of the population to cope or adapt to climate related natural disaster as indicated by the importance of social vulnerability in the ability of people of communities to respond to climate change. The map in Figure 6.11 ANNEXURE 1 indicates the overall vulnerability profile with the green areas indicating areas of low vulnerability, and the red areas highlighting areas of high to very high vulnerability. It is important to note that the areas of high social vulnerability, especially around the urban settlements of Bloemfontein, Botshabelo and Thaba Nchu are regarded as the areas of high vulnerability to disasters. Thus, adaptation option or plans for the areas of high vulnerability within Mangaung will benefit the municipality in addressing the inequalities of the past, and service delivery which will go a long way in reducing the social vulnerability and increasing the resilience of the municipality to climate change.

6.2.4 Conclusion

This chapter has attempted to highlight the vulnerability of both economic and social sectors in the municipality to climate change, both the current climate and the projected climates based on the climate change projections provided. The chapter has also attempted to highlight the vulnerable population in the municipality especially considering the health of the population groups.

7 Responding to Climate Change Adaptation Risk in Mangaung

7.1 Climate Change Adaptation

Climate change adaptation refers to "*adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change*" (UNFCC, 2014). The following section of the Strategy looks at the current adaptive capacity, possible adaptation options that can help build the MMM's resilience to climate change. These will change the future profile of the Municipality's risks addressed and ideally shift the risk to a tolerable level, rather than critical. Therefore a subsequent risk and vulnerability assessment based on agreed adaptation measures will ensure currency of priorities for concern and action. The climate and vulnerability assessment above identified the following as climate change risks for Mangaung:

7.1.1 Climate change risks for Mangaung Metropolitan Municipality

- Loss of livelihoods (rural and urban) and income, water insecurity, reduced agricultural productivity as a result of reduced rainfall and increased temperature
- Loss of grassland ecological infrastructure goods and services that support livelihoods
- Potential increase in disease and disruption of livelihoods due to floods especially for people residing in flood line zones
- Serious damage and collapse of infrastructure networks and critical services such as water supply as well as access and provision of emergency services
- Potential loss of life, discomfort and disease resulting from extreme heat as well as increase in the number of hot days. Persons at risk include vulnerable urban populations and those who work outside, e,g. in the farms and road maintenance in both rural and urban areas.
- Increased food insecurity and the breakdown of food production and supply systems due to increased temperatures, drought, flooding, rainfall variability and other extreme weather events.

7.2 MMM Adaptive capacity

Adaptive capacity generally refers to the ability of a system to change or modify its composition or actions to reduce potential damage or cope with the consequences of shock or stress (climate variability and extremes) while also taking advantage of opportunities that come with this change (Füssel and Klein, 2006). This requires that individuals, communities and societies are actively involved in the processes of change through changes in behaviour, technologies and resources (Pettengell, 2010). Capacity to adapt is dynamic and is influenced by factors such as,

- income
- availability of natural resources
- social and institutional networks

- education and training of human capital
- level of human development
- access to and understanding of technology
- terms of trade and international finance
- political will of governments (UNEP, 2011: 48)

7.3 Adapting to climate change

Adapting to climate change is a process that requires observation of climate; assessment of climate impacts and vulnerability; planning; implementation of actions; as well as monitoring and evaluation of these actions (UNFCCC, 2014). This adaptation strategy represents the MMM's commitment to climate change adaptation and is also based on the climate change projections (Chapter 5) and identified vulnerabilities (Chapter 6) presented in this strategy report.

Adapting to climate change requires both human and natural systems to adjust to actual or expected changes in climate and associated effects and build resilience through better decisions about managing our built and natural environment and taking advantage of opportunities (UNFCCC, 2014). It requires an understanding of and planning for the current risks and vulnerability as well as the projected changes/ risks in the future. Developing sustainable adaptation options also relies on information of past events, their effects and measures put in place to respond which illustrates a systems adaptive capacity.

The project was done in partnership and with input from the various municipal departments and structures through stakeholder workshops and published reports. A stakeholder workshop with stakeholders from Mangaung identified the adaptation outcomes for MMM and these are,

- *Behavioural change and an active citizenry that makes informed decisions in climate change response activities*
- *A society and economy that takes advantage of the opportunities that emerge as a result of climate change and variability while also being resilient to the adverse effects*
- *Advancement in green economy activities to conserve the natural environment whilst also reducing poverty and unemployment*

7.4 Adaptation options and climate change focus areas for Mangaung

Table 7 below provides an overview of the current and possible future adaptation options to climate change risks identified above for the different sectors in Mangaung. It also includes the Metropolitan's adaptive capacity as well challenges that may constrain adaptation

Table 7: Adaptation options and priority areas for adaptation

Sector	Adaptation options	Priority areas
Agriculture	• Promote investment in community food production- including urban gardens that	• Climate smart agriculture

	promote environmental conservation practices • More efficient management of applications of nitrogen fertilizer and manure in agricultural areas. • Early warning system to inform farmers and communities of impending disasters such as hailstorm, floods and droughts • Implement integrated agro-forestry systems that combine crops, grazing lands and trees in ecologically sustainable ways • Conservation agriculture to improve soil organic matter management with permanent organic soil cover, minimum mechanical soil disturbance and crop rotation • Rainwater harvesting • Organic and precision farming • Protection of fresh water habitats and resources • Diversifying in food crops to allow for systems to be resilient in the event of a disaster that affect a particular food crop e.g. maize	• Promote agro-forestry systems • Minimize pollution of water sources by fertilisers
Energy	• Assessing and investing in renewable energy for cooking, heating and lighting e.g. biogas and solar • Add thermal heating to low cost houses • Smart meters to encourage users to manage electricity well • Community awareness programmes on energy conservation and alternative energy sources • Improve material used for solar water geysers • Efficient appliance programmes (kettles, energy saving lights) to reduce use of non-renewable energy • Climate change presents opportunities for investors and financial institutions to invest in areas such as renewable energy and energy efficiency • New job opportunities in renewable energy, flood management, geo-engineering, disease control and	• Assess the potential of creating jobs through waste to energy projects for both municipal and private waste systems • Investing in solar energy and other renewables for heating and lighting at different scales • Explore job opportunities that come with transitioning to a green economy and climate resilience • Raise awareness on energy saving

	insurance.	
Transport	• Provide the public with affordable, comfortable, safe and reliable public transport • Provide public with facilities for low carbon transport systems such as cycling lanes, which will encourage eco-mobility and also has health benefits. • Upgrade and maintain transport infrastructure including bridges and unpaved roads • Invest in green transportation and logistics technology that facilitates mitigation and adaptation • Use durable material for construction of roads • Upgrade storm water and waste water drainage systems • Mixed urban development that would reduce the distance that people travel to work	• Provide infrastructure for public transport and low carbon transport systems • Awareness raising campaigns to promote the use of public transport and low carbon transport systems • Assessing other alternative transport fuel sources e.g. biofuels
Water	• Early warning system to inform people of upcoming climate extremes • Farmers need to increase water storage capacity in drier periods • Wetland rehabilitation and management • Removal of alien plants and replacing them with indigenous plants • Improve coordination between sector departments particularly when developing sector specific adaptation responses • Community awareness raising campaigns on climate change, water conservation and adaptation • Upgrading infrastructure to monitor and curb water losses due to leakages • Retaining of storm water through rain water tanks, penetrable pavements and green roofs. Harvested water can be for household and agricultural use	• Vulnerability mapping or rivers that supply water to MMM and considering ecosystem based risk reduction • Integrated management of water with other sector departments • Clearing alien invasive species • Water conservation-curbing leakages, rain water harvesting and reusing grey water • Community awareness raising to save water

	• Make use of waste water or water from sewage treatment • Water restrictions for some activities • Water pressure management- reduce water lost through leakages by decreasing the amount of water in pipes during off peak times • Increase adaptive capacity of institutions responsible for water management and governance	
Biodiversity and Ecological infrastructure	• Vulnerability assessment and mapping of vulnerable ecosystems including wetlands, floodplains and grasslands • Monitoring and evaluation of greenhouse gas emissions • Early warning system • Wetland rehabilitation and management • Removal of alien plants and replacing them with indigenous plants • Build capacity within communities to engage in green jobs • Protect fresh water habitats and resources to promote growth of marines species • Rebuilding over exploited fish resources and affected ecosystems • Raise awareness on ecosystem based adaptation and how they can be involved	• Biodiversity stewardship programmes to help communities to understand the link between biodiversity and ecosystem services in their area • Community based adaptation projects that protect and restore grasslands • Protect grasslands from land use change • Mainstreaming conservation of ecological infrastructure to support poverty alleviation, rural development , job creation and conservation of threatened ecosystems
Human settlements	• Risk and vulnerability assessments and mapping of vulnerable social groups, regions and economic sectors • Monitoring and evaluation of climate change activities hazard trends location, frequency and magnitude • Ensuring climate change projects do not get pushed from the agenda by more pressing developmental issues • Promote mixed land use developments • Restrict development within flood lines	• Integrate climate change in the provision of basic services • Mapping and monitoring of vulnerable settlements Mixed land use developments to curb urban sprawl and cut

	• Curtail urban sprawl to avoid uneconomic spread of development which will be difficult to provide with basic services • Increase resources (health supplies, food supplies and human resources) for emergencies • Early warning system to inform municipalities of impending climate extremes • Improve coordination between sector departments particularly when developing sector specific adaptation responses • Awareness raising in communities on climate change risk and respond strategies (including resources available) • Training of community volunteers to assist in the event of a disaster • Provide adequate basic services for the poor and marginalized members of the society • Increase public-private partnership to develop and implement adaptation projects • Upgrading, de-densification and relocation of informal settlement infrastructure in areas that are vulnerable to flooding and fires Improve the quality of building material used for building low cost houses so that its durable	down travel distances for communities in Thaba Nchu and Botshabelo • Improving public-private partnerships to increase the resilience of communities • Mainstreaming climate change into municipal spatial planning processes
Infrastructure Development	• Mapping of vulnerable areas • Upgrade and maintain storm water in all regions to keep them clear of any sand and rubbish • Ensure adequate budget for maintenance of infrastructure • Upgrade sanitation systems to curb seepage of sewage into underground water and the spread of disease • Promote recycling of waste • Maintain waste management facilities and equipment	• Promote activities in waste recycling /management that support livelihoods • Waste characterisation for MMM • Identification of critical infrastructure hot spots • Maintenance of infrastructure
Social, health and community	• Upgrade sanitation systems to curb seepage of sewage into underground water and the spread of disease • Increase resources (health supplies, food supplies and human resources) for	• Keep track of health trends related to climate in MMM • Invest in research to get a better

	emergencies such as floods and hailstorms • Awareness raising and training communities on fire fighting and fire rescue skills • Multidisciplinary ecosystem-based studies to identify hosts, vectors, and pathogens with the greatest potential to affect human populations under climate change scenarios in MMM. • Keep records and monitor health data • Monitoring air quality • Increase investment in research on the impacts of climate change on diseases and human health • Community outreach programme on health risks of increasing temperature and other climatic variables	understanding of local specific changes in climate and their impacts on health, air quality, disease vectors water and food security

8 Climate Change Mitigation

8.1 Introduction

Climate change mitigation requires the implementation of policies to reduce the emissions of greenhouse gases (GHGs) and the enhancement of carbon sinks. South Africa has recognised that it is important for the country, as a responsible global good citizen to participate in efforts to address climate change (RSA, 2015). The National Development Plan (NDP) for South Africa acknowledges that in the long-term the country should be able to manage its transition to a low-carbon economy without negative consequences for economic growth (RSA, 2011a). The IDP for the MMM emphasises the need for development in the municipality to be aligned with the goals of the NDP, that seeks to ensure that the planned development trajectory takes cognisance of GHG emissions.

The climate change strategy of the municipality will provide the overarching approach that should be taken towards reducing GHG emissions that will support national and provincial goals for mitigation and developmental growth. This strategy will enable, in the long-term, the development of appropriate sector based interventions that allow for optimal use of financial incentives/markets and maximize opportunities to achieve synergies with adaptation interventions.

In order to identify which climate change mitigation measures are likely to contribute significantly to the country's GHG emissions reduction plans, South Africa has undertaken a mitigation potential analysis (MPA) of the key GHG emission sectors (DEA, 2014). The MPA updated the previous long-term mitigation analysis for the country (Winkler, 2007) and the previous national GHG emissions inventory (DEAT, 2009). The study included an analysis of long-term growth in GHG emissions in relation to the long-term economic growth of the country as well as the socio-economic and environmental impacts of mitigation options through scenario analysis. Specifically, a bottom up assessment of mitigation options in the energy, transport, industry, and waste and Agriculture, Forestry and Other Land Uses (AFOLU) sectors was undertaken to devise the best scenarios to optimise South Africa's capacity to reduce GHG emissions (DEA, 2014). The energy sector was found to be the largest contributor to total GHG emissions in the country and has the greatest potential for abatement. Specifically, the electricity and heat production, residential and road transport sub-sectors were found to have the most significant potential for GHG abatement in the short-to-medium term in SA. The Industrial, Waste and AFOLU sectors were identified as having lower mitigation potential.

8.2 Approach to Mitigation Activities

Owing to MMM not having an inventory of energy demand and carbon dioxide emissions in place, the information collected from status quo analysis was used as a starting point for prioritising greenhouse gas mitigation measures. Therefore, mitigation interventions were identified to "*push-start*" a coordinated and scaled process of climate change mitigation in the short- to medium-to-long term.

8.3 Modelling the MMM Emissions Trajectory

At a national level the GHG emissions trajectory range has been modelled and agreed to, in terms of South Africa emissions should peak in the period from 2020 to 2025, remain stable for around a decade, and decline thereafter in absolute terms. In order for the MMM to support the achievement of this national trajectory, its energy and GHG emission reduction targets need to be aligned with the national trajectory and its short, medium and long-term actions designed to contribute towards this trajectory. As a first step, work is required to quantify the impacts of existing projects in order to determine how best to support the achievement of targets in the MMM context.

A long-term energy and CO_2 modelling exercise for the MMM need to be undertaken in order to determine the energy and emissions trajectory for the province. This modelling exercise will include a number of different scenarios around the implementation of demand-side and supply-side programmes / interventions in order to determine the type and scale of interventions required by MMM and its stakeholders.

8.4 Energy use and energy efficiency in Mangaung

A key outcome of the IDP relates to environmental management and climate change with a focus on energy efficiency and clean energy use. In Mangaung, grid-supplied electricity is considered to be the largest contributor to GHG emissions, followed by petrol and diesel use (SEA, 2015). The residential, commercial and transport sectors emerge as key users of energy that are responsible for most of the GHG emissions in Mangaung (Table 8.1).

Table 8.1: Energy use and related GHG emissions by sector in MMM excluding ESKOM distribution data (Adapted from, SEA, 2015).

Sector	GJ	tCO_{2e}
Residential	2 566 386	686 325
Commercial	2 340 899	666 727
Industrial	608 530	149 964
Transport	9 406 084	647 151
Government	192 091	52 474
Total	**15 113 990**	**2 202 641**

It was reported that in 2011, 91% of households were electrified and that 57% of households were using safe/clean energy for their heating needs. As such the IDP highlights the needs for energy savings, by lowering electricity consumption through interventions that would improve energy efficiency and seek investment in renewable energy sources (MMM, 2014).

The MMM also faces challenges with respect to the long distances that have to be travelled by people within the city, which contributes significantly to petrol and diesel use within the road transport sector. In terms of the IDP there is alignment with the NDP which recognises the need to improve public transport, which could have potential climate change mitigation benefits. The IDP also recognizes the need to have dense mixed developments in order for commuters to travel fewer kilometres. The Mangaung Metro Integrated Human Settlements Plan seeks to ensure the development of integrated human settlements and shortened travel distances (MMM, 2014).

8.5 Municipal operations

Municipal owned and operated facilities present opportunities to reduce energy consumption through the implementation of energy efficiency measures. The Local Government Energy Efficiency and Renewable Energy Strategy (SALGA, 2014) identifies municipal 'own' energy as a key priority area, with a goal that municipalities should be able to manage energy consumption in their facilities and convert local waste to energy where possible. The strategies suggested by SALGA, (2014) to achieve this goal, include implementing building and lighting efficiency, developing an efficient vehicle fleet and supporting waste reduction and waste to energy development.

The analysis of potential energy efficiency measures and cost savings for the municipality is presented in Table 8.2.

Table 8.2: Energy efficiency and cost savings for MMM (SACN, 2014)

Sector	Baseline Energy Consumption (GJ/a)	EE measure penetration (%)	Potential Electricity Savings (MWh/a)	Potential Energy Savings (GJ/a)	Carbon emissions reduction (tCO2e/a)	Financial Saving (ZAR)
Buildings & Facilities	92,710	10%	4,112	14,803	4,325	2,261,429
Street lighting	142,165	20%	No data	-	No data	No data
Traffic lighting	No data	No data	No data	-	No data	No data
Bulk water supply & wastewater treatment	36,473	0%	26,139	94,100	26,923	14,376,440
Petrol (l)	30,780	0%	288,000	9,850	1,693	7,751,040
Diesel (l)	45,720	0%	384,000	14,630		

8.6 Mitigation Potential in the MMM

The majority of the MMM's emissions arise from energy generation (electricity and liquid fuels) and use (industry and transport), and mitigation actions therefore need to focus on these areas. The main opportunities for mitigation include energy efficiency, demand-side management and moving to a less emissions-intensive energy mix. The consequent economic benefits include improved efficiency and competitiveness as well as incentivising economic growth in sectors with lower energy intensities. MMM need to also investigate the Carbon Budget approach that is being used at a national level to determine how this can be supported in MMM. The Carbon Budget approach will identify an optimal combination of mitigation actions at the least cost to- and with the most sustainable developments benefits for the relevant sector and national economy to enable and support the achievement of the desired emission reduction outcomes consistent with the benchmark National GHG Emissions Trajectory range.

Policy decisions on new infrastructure investments must consider climate change impacts to avoid the lock-in of emissions-intensive technologies into the future. However, in the short-term, due to the age of existing infrastructure and the planning around new infrastructure, the most promising mitigation options are primarily energy efficiency and demand-side management, coupled with increasing investment in a renewable energy programme in the electricity sector. A mix of economic instruments, including market-based instruments such as carbon taxes and emissions trading schemes, and incentives, complemented by appropriate regulatory policy measures, are essential for driving and facilitating mitigation efforts across a wide range of key economic sectors. Although these will be implemented at a national level, MMM need to understand the implications of these in order to ensure their implementation benefits rather than negatively impacting on its businesses and residents.

In the short/medium term, the mitigation options that will present the biggest mitigation potential for the MMM are:

- Significant upscaling of energy efficiency application, especially industrial energy efficiency and energy efficiency in public, commercial and residential buildings and in transport;
- Promoting smart-mobility / transport-related interventions including transport modal shifts (road to rail, private to public transport, non-motorised transport (active mobility)), switches to alternative vehicles (electric and hybrid vehicles) and lower-carbon fuels and the promotion of telecommuting / flexible working;
- Supporting the implementation of programmes that can transition society and the economy to more sustainable consumption and production patterns, including the development of more sustainable communities; and
- Promoting renewable energy in the form of both small-scale embedded generation as well as large scale renewable energy facilities.

Long-term planning, information on the outcomes of mitigation options, technology development and other new information, may identify additional mitigation actions in due course, such as:

- The socio-economic benefits of the mitigation activities include:
- Reducing fuel costs to households and business;

- Improving the competitiveness of businesses;
- Job creation opportunities with the development of new economic sectors;
- Local business development;
- Improved air quality (with positive health impacts);
- Reducing the negative impact of large carbon footprints, particularly for export products;
- Reducing stress on energy needs of the province and thereby increasing energy security.

8.7 Development of a framework for mitigation

The municipality's reliance on fossil fuel derived energy presents many options for mitigation that include:

- Implementation of energy efficiency measures within the commercial, residential and transport sectors
- Energy efficiency measures within municipal operations
- Diversification of energy sources (such as solar PV)

There are likely to be socio-economic benefits derived from the implementation of such mitigation measures that will help support adaptation in the municipality by improving socio-economic conditions. This will include:

- A reduction in fossil fuel consumption by motor vehicles and in homes will result in improved air quality in the municipality
- Implementing energy-efficiency measures within households, industry, transport and municipal operations will result in energy and cost-savings
- Increased use of renewable energy will help the municipality to become more energy self-reliant and thus energy secure
- Use of financial incentives aimed at supporting mitigation will support the adoption of improved technologies that could boost the economy

The development of future plans and programmes will need to take into consideration these opportunities for climate change mitigation. In order to benefit from economic mechanisms and initiatives centred around GHG mitigation, there is a need for a GHG emissions reporting system to be developed for the municipality. This will allow the municipality to develop a robust baseline of emissions and develop projections of where significant emission reductions are possible, to focus investment opportunities. Specifically, such information will allow for the identification of mitigation projects and position the MMM to finance, implement, monitor and evaluate the progress of emission reduction interventions.

The key short-term goals per sector are described in Table 8.3 in ANNEXURE 1. ***An important first step toward effective mitigation in the MMM is establishing the GHG emissions baseline and mitigation potential of different interventions per sector. This initiative will be***

supported by a GHG emissions framework/system for data collection that aligns with provincial and national GHG reporting processes. The framework will thus seek to draw information for other key sectors from other databases such as the National Atmospheric Emissions System (NAEIS) and the South African Waste Information System (SAWIS). Numerous formalised institutional and data sharing arrangements need to be established with provincial or national departments for data collection, research and development into mitigation options and technology transfer, capacity building and assigning roles and responsibilities for financing and implementing projects and programmes.The proposed climate change interventions / options that are focused on Adaptation are presented in Table 8.5.

Table 8.5: Proposed Mitigation Interventions / Options / Programmes for MMM

Sector	Proposed Mitigation Programme/Interventions/Projects	Details of the proposed Intervention / Programme
Energy	Renewable Energy	Build Solar parks that will feed electricity to the National Grid
		Introduce the use of Solar in residential areas and industry
	Energy Efficiency	Refurbish MMM buildings (Government buildings hospitals, clinics and schools with EE equipment)
		Refurbish street lights with CFLs/LED lights
		Encourage energy efficiency by industry processes
Water	Rain Water harvesting by residential areas and businesses	Encourage rain water harvesting by installing rain water harvesting tanks in residential areas
	Encourage Efficient water use –	Fix leaking water infrastructure
	Alien plant species removal	Remove alien plant species to reduce water usage
Human Settlements	Insulate RDP houses	To reduce heating and air conditioning need for human comfort
	Renewable Energy	Install Solar Water Heaters or heat pumps in Residential areas (existing and new houses and RDP houses)
	Energy Efficiency	Refurbish residential areas with CFLs/LED Lighting
	Rain water harvesting	Install rain water harvesting tanks in residential areas
Agriculture	Smart Agriculture	Encourage and support vegetable gardens in residential areas

Sector	Proposed Mitigation Programme/Interventions/Projects	Details of the proposed Intervention / Programme
		Encourage organic farming (Introduce vermiculture – organic manure)
Transport	Public Transport – Bus rapid Transport system (e.g. Reya Vaya)	Introduce buses
	Introduce bicycle lanes	Encourage bicycle
	Introduce Electric Vehicles	Introduce Nisaan Leaf electric vehicles to be used by Municipality officials; that are charged by Renewable energy (Similar to DEA vehicles)
Waste Management	Waste to Energy	Convert Landfill gas to electricity /gas
		Use wastes to generate biodiesel for MMM bus fleet and Biogas (Biofuels)
	Recycling	Recycling
		Separation at Source
		Introduce Manufacturing Plant industries using Recycled material, to create jobs
Biodiversity	Plant indigenous trees to act as carbon emissions sinks	Remove invasive alien plant species and plant indigenous plants
	Protect parks and open spaces to maintain their role as carbon sinks	e.g. MOSS study
Commercial and Industry	Energy Efficiency	Encourage and incentivise EE initiatives by industries
Climate Change Awareness Campaigns	Conduct community and business awareness campaigns to encourage behavioural change	
Other Programme/Project	Develop a Greenhouse gas inventory for MMM	This will provide the baseline of current GHG emissions levels for MMM and will be used in monitoring projects implementation progress

The socio-economic benefits of the mitigation activities include:

- Reducing fuel costs to households and business;
- Improving the competitiveness of businesses;
- Job creation opportunities with the development of new manufacturing and economic sectors;

- Local business development;
- Improved air quality (with positive health impacts);
- Reducing the negative impact of large carbon footprints, particularly for export products;
- Reducing stress on energy needs of the municipality and thereby increasing energy security.

9 Stakeholder Engagement and Capacity Building

As a critical and vital aspect to the development of a sound and robust climate change strategy for MMM, stakeholders both from the Municipality (different departments), civil society, industry / business were gathered for three (3) engagement and capacity building workshops that took place on the 10th September 2015, 08 October 2015 and 29th October 2015 at Indaba auditorium (Bram Fischer Building – MMM) to be introduced to the study, empowered, capacitated, create a network of climate change community and finally, contribute to the development of the work.

Interesting discussions ensued and deliberations were mainly focused on green initiatives in their departments / sectors, and the following three Tables, Table 9.1, 9.2 and 9.3 summarise inputs from Stakeholders based on questions posed to them. Contributions to the discussions were captured and are presented below:

Table 9.1: Capacity Building Workshop 1

Stakeholder and Capacity Building Workshop #1 – 10 September 2015		
Question 1: What are the critical elements that need to be considered in the Development of the MMM Climate Change Strategy?		
Group 1	Group 2	Group 3
• Funding/Investment (who?/how?/when?/what?) • Community initiatives • Involvement of all Stakeholders (Social Cohesion/Community involvement) • Sustainable management of resources (e.g. Water Harvesting) • Vulnerability – Risk Assessments • Priority Areas • Early warning Systems • Allocation of resources • GHG (CO2e) Emissions levels for	• Proper Economic Policy- raw materials extraction • Water quality – Mines and Construction • Relevant stakeholders – Ward level • Religious Institutions – expanding knowledge to communities • International NGOs • Manufacturing Sector • Capacity building • Zero Waste – manufacturing of climate smart technology • Education system – implement in the	• Inclusivity (e.g. civil society, government collaborations) • Geographic Area • Coordination • Education and Behavioural Change • Socioeconomic factors to be considered • Ownership and accountability • Funding for Research and Green Technology • Capacity Building

MMM • Agro-ecology (Types of mitigation) • All contributing factor/sources of GHG should be holistically addressed	curriculum system • Trade Unions – include them in campaigns and climate change framework • Funding – MMM strategy to include funding • Early warning systems – communicate at grass roots level, register on database • Social Media • Attitude – youth adoption of climate change	
Question 2: What are the key climate related issues/problems/impacts facing your Department/Sector?		
Group 1	Group 2	Group 3
1. Water Quality and availability Rainfall Patterns Borehole Underground water Alien Vegetation Drought/Depletion of water Reserves and Storage Gariep (History thereof) 2. Lack of Legislation Bylaws enforcement (Biofuel Project) Compliance Monitoring Development around the MOSS area 3. Food security - Prices escalating - Food solidarity economy - Food Shortage reserves 4. Job creation and losses 5. Health related issues/impacts 6. Carbon Tax and Environmental Levy– revenue ring-fenced for environmental projects and climate change	1. Tsholo – Dept of Agric Drought, Fire outbrakes, floods Rollout for farmers (Disastermanagement), working for fires 2. Matshego- Dept of Police, Roads and Transport Heat waves for people fixing the roads Invisible wetlands making planning difficult Material used to be taken in to account 3. Bhekiwe- Dept of Planning Squatter camps, floodlines invasion, heavy rainfall 4. Tumelo – EAP EIAs Proposed sites are not suitable and no alternatives 5. Motsi – BUM, 1Million Jobs Campaign Govt policy People's livelihood Water shortage Land infertile and not enough for farming Transport Mode e.g. Reya	1. Capacity Building - . Human resources, financial, climate change knowledge 2. Implementation strategy – (planning, implementation, monitoring and control) to include implementation of EIA recommendations by DEA 3. Monitoring and Evaluation 4. SMME support (advisory and mentoring)

	Vaya, revive railway Retrofit of houses including quality of material Manufacturing locally – to create job opportunities	
Question 3: What measures/plans do you have in place to cope/deal/respond to the above climate change related issues/damages?		
Group 1	Group 2	Group 3
1. Transport - Road to rail - Freight Emissions Reductions - Planning and spatial development 2. Renewable Energy Resources - - Solar Energy farms currently in the free State - Roof-top solar panels for houses (for new housing developments) - Solar panel manufacturing (creating employment) 3. Awareness campaigns - Community and children education - Social awareness using volunteer organisation e.g. NGOs 4. Waste Management - Converting waste to electricity - Recycling – reducing poverty by creating job in the recycling sectors Job creation – green jobs initiative 5. Food Solidarity Economy - Agro-ecology - Establishment of cooperatives - Access to local markets 6. Introduce organic farming - Use of Eco-friendly products - Whole value chain 7. Waste hierarchy 8. Monitoring and Evaluation	1. Capacity Building 2. In implementation there is also a need to prioritise projects 3. Sustainability including rehabilitation of degraded sites – e.g. mine quarries 4. Stakeholder involvement – land developers, municipalities, private sector 5. Zero waste programmes – for job creation 6. Awareness	1. Collection of waste – buy back centre – reduces waste to landfill site and creates jobs 2. Environmental Regulation – EIA 3. Advisory Services and environmental project management, e.g. construction 4. Awareness , e.g. Health Education 5. Public Cleansing, e.g. cleaning dumps 6. Organic or biodegradable products 7. Water purification for reuse

- Accountability and transparency - Access to information - Access to land for agrarian purposes

Table 9.2: Capacity Building Workshop 2

Stakeholder Engagement and Capacity Building Workshop #2 – 8th October 2015		
Question 1: What do you expect to change in your communities when you implement climate change adaptation (what problems do you expect climate change adaptation to solve?)		
Group 1	Group 2	Group 3
1. Mindset/Behavioural change 2. Poverty eradication 3. Economic vibrant Development 4. Plough Greens, e.g. Plant tree to avoid soil erosion	1. Minimising the impacts of floods – remove people from flood lines and wetlands 2. Disaster Management measures should be in place – Evacuation Procedures (Spaces) - Identify other areas that might experience disasters 3. 3. Job Creation – Green Economy - Waste; Energy; Agriculture 4. 4. Minimise the impacts of droughts 5. 5. Awareness – informed communities 6. 6. Climate Smart Agriculture 7. 7. Water Harvesting, Grey Water, 8. 8. Pesticides Regulation	1. Renewable Energy Programs 2. Cleaner Air Quality 3. Recycling: Domestic Household 4. Healthier Society 5. Collaboration Between various sectors 6. Promotion of public transportation (Reya Vaya buses @ City of JoBurg) 7. Generation (Kids) that is environmentally cautious 8. Better protection of animals 9. Flooding; Fires; Droughts
Question 2: What other stakeholders should be included in climate change adaptation and mitigation. What is their role?		
Group 1	Group 2	Group 3
1. Schools/ECD/SGB Role: Awareness 2. Disabled groups	1. All Govt Departments 2. NGOs 3. Community Based	1. Business Forums 2. Role: Educate employees about

Role: To develop Climate change information in Sign language 3. Faith Based Groups Role: Awareness 4. Civil Society Role: Identify community based organisations 5. Military Veterans Role: Provide local wisdom 6. Water and Sanitation Department Role: to provide water wise information	Organisations 4. Botshabelo Unemployment Movement 5. Botshabelo Procedures Forum 6. Right to Food 7. Sovereignty Food Cooperatives 8. Academic Institutions 9. SRCs 10. SMMEs	climate change, including materials, PPE, Transportation, speed up the process 2. Political Leaders 3. Education Sector 3. Role: Raising awareness, Research 4. Community 5. Religious Leaders 4. Role: Raising awareness, need to adapt 6. CPF (on behalf of SAPS) 5. Role: Disaster Management

Table 9.3: Capacity Building Workshop 3

Stakeholder Engagement and Capacity Building Workshop #2 – 29th October 2015	
Shortcomings not presented in the draft strategy?	
Group 1	Group 2
• **Commitment and implementation of the strategy** • **We need to cover more energy generating sources and energy industry sector such as electricity, gas, petrol** • **Even if CBOs, NGOs/SMMEs ; roles need to be specified for all role players to ensure that all members take full responsibility for roll out of the implementation plan.** • **Technology transfer is not clear** • **Negotiation position for Mangaung at COP 21 in Paris to be explained** • **Recommendation is to promote the use of organic fertilisers. For e.g. use of kraal manure instead of fertilisers to create healthy soil** **Awareness and outreach campaigns are**	• Practical implementations. E.g. CO_2 emissions – How? • Traffic Department with synchronised traffic lights • Environmental Management to be used as a guideline • Goal and timeframes, i.e. Monitoring and Evaluation • Who? i.e. Roles and Responsibilities Identify roles internally, Potential Projects, Law Enforcement, Finance/Budget

required.	
What are the critical success factors that need to be considered in the Climate Change Strategy Development?	
Group 1	Group 2
• **Mangaung Municipality need to build on existing initiatives within communities that are run by CBOs and NGOs, Faith based groups, etc.** • **Focus on educational systems, considering introducing climate change topics into the school curriculum.** • **Mangaung Municipality must roll out climate related projects such as Renewable energy e.g. Solar to reduce Carbon emissions.** • **Encourage SMMEs in RE and Energy Efficient technologies equipment manufacturing to create job opportunities for the unemployed in the municipality, especially women and the youth; as well ensuring skills development in this area.** • **Municipality must include the reduction of carbon emissions when procuring goods and services from service providers.** • **Communities need to be educated about the importance of protecting the environment and storm water drainage systems – to ensure that they do not block them with wastes that can lead to flooding during heavy rainfall events.** • **Highlight pedestrian walkways as well as cycling lanes** **Development and change cannot be forced. Participatory model is required to get community buy in to ensure their full participation in the implementation of the strategy.**	• Education: Media, expectancy of society • Public participation • Capacitating officials • Global funding • Skill development – job creation • Intergovernmental relationships - PPP

Notably, Responses to the above questions were diverse, very interesting and vital for the comprehensive development and delivery of MMM adaptation and mitigation response strategy.

10 Strategy Implementation Framework

It is anticipated that the MMM will develop an implementation framework in consultation with all relevant stakeholders from the municipality and those also identified in table 6.5 below to ensure the strategy is implemented effectively. The implementation framework is made up of different components that have also been used in the Western Cape Climate Change Response Strategy (Western Cape Government, 2014) and are discussed below.

10.1 Institutional structure

The MMM needs to identify and put in place structures and working groups to facilitate climate change response in the municipality. These institutional structures need to have specific roles and responsibilities outlined in order to achieve set goals on climate change adaptation and mitigation. This should be done at various levels and with different role players and this can include;

- An institutional structure responsible for planning, prioritising, implementation as well as monitoring and evaluation of the municipality's response activities
- Keeping a database of current climate change response activities undertaken by different stakeholders and their objectives and anticipated outcomes
- Partnerships with other stakeholders who have vested interest in climate change response locally and internationally.
- Establishing partnerships with specialists and researchers in the field of climate change to stay abreast of new science and technology

Local governments need to have an understanding on climate change effects; mitigation and adaptation so that they can mainstream climate change into their strategic and corporate processes and actions achieve the ultimate goal of sustainable development.

10.2 Partnerships for integrated response

Climate change response requires collaboration between stakeholders to avoid duplication of efforts and wasting resources. Partnerships also allow for stakeholders to share resources and lessons learnt so as to maximise the effectiveness of climate change mitigation and adaptation activities. The municipality would need to lead some of these activities while in some instances it would have to facilitate and support other role players who can be in private or civic sector. Possible partners in Mangaung include;

- Government stakeholders from other neighbouring local and district municipalities; Free State Provincial government as well as the national government

- University of the Free State as well as other tertiary institutions
- Funding institutions, research institutions and project implementers in South Africa and internationally
- Private companies
- NGO's and Community Bases Organisations

In a stakeholder workshop participants identified stakeholders who can partner with MMM and the role they could play in climate change adaptation is presented in Table 6.5 below. This is however not a comprehensive list of the stakeholders and the role that they can play. This still needs to be fleshed out as specific programmes and actions are undertaken within the municipality.

10.3 Resource and finance mobilisation

Climate change response is expensive and in many developing countries such as South Africa the need is high and direct government funding is limited by other pressing development needs such as the provision of basic services. There is a need for funders at different spatial scales to shift current and projected "*business-as-usual*" investments, and mobilize resources at the scale required. However for municipalities to access this funding they need to have an understanding of their climate response needs and which funding institutions to approach for funding. They also need to have a solid business case which can be financed through grants, concessionary finance, risk insurance, specialised environmental funds and new capital market innovations for example green and climate bonds (Western Cape Government, 2014:40). The Municipality will also need to create an enabling environment so that these resources can be utilised effectively without succumbing to the institutional barriers.

The municipality needs to continuously seek and maintain the financial resources for climate change mitigation and adaptation so that they are for a long term as the benefits of these activities often take long to be realised. For example the benefit of reducing carbon dioxide emissions now may only be realised decades to come. MMM needs to promote partnerships between multiple stakeholders (e.g. industry, NGO's local government and research institutions in the climate response projects so as to promote sharing of resources as well as skills and capacity building.

10.4 Programme- based approach

Sector departments are responsible for undertaking programmes to integrate mitigation and adaptation activities for their sector. This should be done in consultation with other sector departments and not in isolation as some of these activities overlap. For example promoting investment in community food production and urban gardens requires partnership between the agriculture and social and community development sectors.

10.5 Climate change adaptation and Mitigation: role players

Climate change adaptation is a multilevel governance challenge because its impacts cut across different government levels, sectors and social groups (Bauer and Steurer, 2014). Responding to these impacts also requires collaboration between these different groups. The Disaster Management Act (Act no 57 of 2002) makes provision for “an integrated and coordinated disaster management policy that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post disaster recovery” at various levels of government. Climate change has an impact on every sector and department in Mangaung. Adaptation efforts are only effective if there is real commitment to collaborate from stakeholders both within Mangaung and external. This requires effective communication and coordination among the different role-players. In doing so, it will be important for departments to understand their respective roles and how they interface with that of other stakeholders. Assessing the linkages between stakeholders (Table 10.1) is important as it will help to identify synergies between them and identify ways in which strategies should be aligned and implemented across institutional boundaries.

Table 10.1: Stakeholders that can contribute to climate change response and their roles

Stakeholder group	Role
Community based organisation e.g. Botshabelo Producers Forum, Right to food campaign	• Awareness raising in communities, • Develop adaptation and mitigation projects to improve livelihoods and food security • Enhance community’s adaptive capacity
Small, Medium and Micro-sized Enterprises (SMMEs)	• Contribute to adaptation and mitigation through green economy projects and creating green jobs
Community Policing Forum	• Assist with disaster management
Civil Society	• Assist with adaptation and mitigation implementation projects at local level. • Identify members of the community who need special assistance
Schools; Early Child Development Centres; School Governing Body, Tertiary institutions	• Raise awareness with the children. • Tertiary institutions can conduct research to understand as well as find solutions for local climate change and development challenges
Disabled groups	• Develop climate change information to cater for disabled persons needs
Faith Based Groups	• Climate change awareness raising with in community
Military Veterans	• Use their experience to assist with disaster preparedness and recovery
Business Forums	• Provide resources to support climate change response projects and improve livelihoods • Apply low carbon and resource efficiency in their operations • Raise climate change awareness amongst employees; • Improve working conditions of employees who have to

	work in harsh climatic conditions
Political Leaders	• Awareness raising and support implementation of climate response projects
Community	• Engage in climate response projects such as energy saving, water conservation and recycling of waste • Volunteers for disaster response

Adapting to climate change is not an easy task (WIREs, 2014), one of the challenges is the fact that adaptation is a process that has no clear benchmark to show when an adaptation project or programme is successful. Therefore proxy indicators that relate to overall achievement of societal goals are used (Bours, *et.al*, 2014). Measuring the impact of an adaptation project or programme is difficult task as this may take many years to be realised. With this understanding adaptation therefore needs to be viewed as a dynamic process that is informed by feedback from a M&E hence process indicators would need to be used to measure progress even though cannot be determined at that time (Bours, *et.al*., 2014:3). The next section of the strategy document presents the Monitoring and Evaluation system proposed as an internal management tool to provide information on the progress being made in implementing climate response activities.

11 Monitoring and Evaluation

Monitoring and evaluation of climate change response efforts has recently gained momentum in development projects which include work by the Deutsche Gesellschaftfür Internationale Zusammenarbeit (GIZ). Monitoring can be described as the continuous process of collecting information on the progress being made towards attaining specific goals and objectives set e.g. reduce carbon emissions by a certain percentage. Evaluation on the other hand is the periodic assessment of either ongoing or completed activities to determine the extent to which the stated goals and/or objectives are being realised contributing to subsequent planning and decision making process. Some of this work stems from the Cancún Adaptation Framework (2010) under the UNFCCC which promotes developing countries to adopt National Adaptation Plans to reduce their vulnerability, build adaptive capacity and mainstream adaptation into all sector specific planning and general development planning (GIZ, 2013).

This section of the report seeks to provide guidance on the monitoring and evaluation system that can be used by the Mangaung to perform periodic reviews to track

- Monitoring implementation of adaptation and mitigation projects- who, when (frequency of reporting) and reporting mechanism
- Monitoring of climate change projections and impacts on the municipality

As climate response activities are implemented the municipality would need to look for the following as part of M&E;

- Assess the activities that were planned that did or did not get implemented

- Evaluate the similarity between what was supposed to be implemented and what was implemented
- Analyse how appropriate and close to the plan were the costs, time and staff capacity and capability, financial resources etc.
- Evaluate the unanticipated (unintended) outputs or outcomes emerged from the implementation phase

Research has the ability to bring the best available knowledge to address some of the current and future wicked problems. This is however a continuous process whereby new information is created regularly to better understand phenomenon and new ways of doing things are also developed in that process. Climate change projections are one such phenomenon that is updated regularly as new information and knowledge becomes available. As such there is need to also monitor and evaluate the projected changes for Mangaung i.e. assess the patterns in the frequency and severity of extreme weather events and any changes in the communities or sectors at risk.

12 Conclusion

The percentage of global governments' Gross Domestic Product (GDP) being consumed by recovering from climate related disaster could, according to the Stern Review (2006), increase to between 5% and 20% by 2100[3]. Against the backdrop of the socio-economic challenges faced by the country, the Free State province and the Mangaung Metropolitan Municipality, such increased disaster recovery costs pose a significant risk to the achievement of MMM's growth and development goals (including those related to job creation). Short, medium and long term adaptation interventions designed to ensure that MMM does not compromise its growth and development strategy are, therefore, critical to ensuring reduced vulnerability to the impacts of climate variability and climate change across the municipality.

Cross-cutting programmes include governance / communication, awareness raising, capacity building and education; financial models and mechanisms; and job creation. The strategy will be executed through an implementation framework which will include an institutional framework for both internal and external stakeholders, with a strong emphasis on a monitoring and evaluation (M&E) system that will be developed to track progress on the transition to a low carbon and climate resilient municipality. The M&E system will:

- provide a clear picture of the various climate change mitigation and adaptation responses
- assess the effectiveness of the response measures,
- measure the effectiveness and level of co-ordination of climate change responses across MMM, and
- enable efficient participation and reporting into provincial and national climate change commitments and responses.

[3] Stern Review: The Economics of Climate Change – a leading international assessment of the effects of climate change, 2006

Resource mobilisation needs to be informed by the mainstreaming of planning and decision-making of government, the private sector and civil society. This can be achieved by creating an enabling environment for climate resilient development, by promoting the green economy and consolidating and extending existing initiatives towards a climate resilient economy.

While climate change will pose significant challenges to government and civil society into the future, the Mangaung Metropolitan Municipality Climate Change Response Strategy will create an enabling framework through which significant new and emerging opportunities related to developing a low carbon and climate resilient MMM can be realised.

The Strategy has identified a number of actions to achieve climate protection. However, priority actions required to synergise the implementation of climate protection interventions in MMM will need to be determined by the committee comprising of Municipal Stakeholders and including SALGA Free State. The actions prioritised will provide the impetus to integrate the IDP and cascade the implementation of various interventions. It should be noted that the responsible departments within the municipalities will need to develop comprehensive projects and plans with requisite budgets to undertake the implementation of projects.