Vulnerability and resilience in the Mopani district municipality in a changing climate

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PREFACE

The aim of the research was to assess climate change and the existing socio-economic vulnerabilities and resilience in the local communities within the Mopani District Municipality (MDM) in the Limpopo province (Mopani District Municipality Integrated Development Plan (MDM IDP), 2016/17). Eighty one percent (81%) of communities of MDM occupy rural areas, 14% urban areas and 5% occupy the farms (MDM IDP, 2016/17). Environmental conservation and tourism attractions, heritage sites, mining industries and the presence of Mopani worms and Marula fruits contribute to economic development in the communities of MDM (MDM IDP, 2016/17).

In the rural areas of MDM, communities are living under poverty conditions as results of high unemployment rate, low level of education, and generally low life expectancy. Lack of basic services in the rural communities of MDM further contributes to the high level of poverty conditions as compared to urban areas (MDM IDP, 2016/17).

The research was presented in Applied Centre for Climate & Earth System Sciences (ACCESS) and South African Society for Atmospheric Sciences (SASAS) (Poster) 31st Annual conference and 2nd National Conference on Global change conferences (Poster). The research won the best poster awards in 2014 at the 2nd National Conference on Global change conferences.

The research performed effectively provided a risk and vulnerability analysis of present-day and future impacts of climate change and variability on the MDM (IPCC, 2007). As such, the work is of value to the Department of Rural Development and Land Reform from the perspective of formulating suitable adaptation strategies for the district (DRDLR, 2013). Similarly, the research points out a number of pronounced risks that climate change poses to agriculture in the district and emphasises the need for the Department of Agriculture, Forestry and Fisheries to respond to these risks through the formulation of timeous and suitable adaptation strategies (MDM IDP, 2016/17).

ACKNOWLEDGEMENT

First and foremost I would like to thank GOD for giving me the opportunity and strength to undertake this research.

I wish to express my sincere gratitude to my Mom (Vho_Ivy) for taking care of my girls (Nyiko, Tinyiko & Nyikiwe) during my studies and for being the source of my inspiration and strength together with Dad (the late Muzila Khwashaba). Your support and guidance brought me to where I'm today.

GrandMom (Vho-Nyawa), my uncle (The late Vho-Fistos), Phathu, Mbula, Una, the late Pfadzi, my husband Gift, Vho-Anna and Ndivhu, Thanyi and Charity thank you for all your support and words of encouragement.

I would like to express the deepest appreciation to my supervisors, Prof FA Engelbrecht, Dr. R Burger, Prof D Van Niekerk and additionally Koos and Dr. M Bopape for all your contributions towards the success of this research.

Special thanks to the Applied Center for Climate and Earth System Studies (ACCESS) for funding the research through the Master's degree.

ABSTRACT

The overall aim of this study is to identify how climate change may impact on the Mopani district municipality (MDM) in Limpopo province of South Africa, towards the formulation of suitable adaptation strategies. This implies the projection of future risks and vulnerabilities of the MDM and its rural communities under climate change, and a need to understand the resilience of these communities, and how it can be strengthened. Eighty-one percent (81%) of the communities of MDM are rural in nature, 14% are urban and 5% are farms according to MDM IDP for 2016/17 and the reviewed MDM IDP, 2017/18 indicated that there are 16 urban areas which includes towns and townships, 354 villages; moreover, due to the high poverty and low educational level rural communities of MDM are limited to economic development and to the outside market in terms of job opportunities.

Based on the above mentioned challenges, MDM rural communities there is a high possibility of being vulnerable to impact of climate change. A projection of the future changes of climate in the MDM was generated using a regional model in South Africa. These detailed projections are interpreted within the larger set of global climate model projections for north-eastern South Africa, as described in Assessment Report Five of the Intergovernmental Panel on Climate change.

Results show drastic increases in temperature and extreme temperature events in the Limpopo province including the MDM under low mitigation climate change futures, already in the near-future period of 2030-2050. In particular, drastic increases in the frequency of occurrence of extreme temperatures (e.g. number of heat-wave and high-fire danger days) are likely to occur in the MDM, whilst seasons of drought will also plausibly occur more often. Such changes will impact on human health, livestock production, and agriculture in the MDM over the next few decades. Given that MDM rural communities living conditions are not sufficient in terms of services that are rendered to them by the government such as the provision of water for domestic use and sanitation in terms of safe and reliable toilet facilities and dumping sites, electricity for lightning and cooking, health services and facilities, roads, bridges and housing infrastructures, it may be concluded that vulnerability to the above mentioned climate stressors is high.

The methodology for assessing climate change vulnerability was based on the UNDP approach, where climate change vulnerability is represented as an outcome of the interrelationships between hazard exposure, sensitivity and adaptive capacity The interaction between hazard exposure, based on observed climate data (present-day) and climate change projections (future), and sensitivity, based on an analysis of bio-physical characteristics, can be understood as encompassing the risks posed by present-day climate variability and future climate change.

Aspects that contribute towards the resilience of communities in the MDM to climate risks was assessed based on the status of the available financial and human resources, provision of basic services (e.g. infrastructure) that is readily available to rural comunities to respond to the occurance of disaster risks associated with climate change

Moreover, existing socio-economic vulnerabilities in the Mopani District Municipality will worsen under climate change as the majority of rural communities are reliant on subsistence agriculture and natural resources to supplement government grants (implying vulnerabilities in terms of food security in a climate that becomes more variable and extreme).

Key Words: Climate Change; Vulnerability; Resilience; Limpopo Province; Mopani District Municipality

DEDICATION

I dedicate this dissertation to my late Dad (Vho-Muzila), my younger sister Pfadzani, my uncle (Vho-Fistos) and my Aunt (Vho-Nyawa)

MAY THEIR SOULS REST IN PEACE

GLOSSARY

CBDRM - COMMUNITY BASED DISASTER RISK MANAGEMENT

CCAM - CONFORMAL-CUBIC ATMOSPHERIC MODEL

CORDEX - COORDINATED REGIONAL DOWNSCALING EXPERIMENT

CRDP - COMPREHENSIVE RURAL DEVELOPMENT PLAN

CSIR - COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION

CSIRO - COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION

CSAG - CLIMATE SYSTEMS ANALYSIS GROUP

CoGHSTA - DEPARTMENT OF CORPORATIVE GOVERNANCE HUMAN SETTLEMENTS AND TRADITIONAL AFFAIRS

DEAT - DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM

DRDLR - DEPARTMENT OF RURAL DEVELOPMENT AND LAND REFORM

DST - DEPARTMENT OF SCIENCE AND TECHNOLOGY

EHP - ENVIRONMENTAL HEALTH PERSPECTIVE

FAO - FOOD AND AGRICULTURE ORGANISATION

IFRC INTERNATIONAL FEDERATION OF RED CROSS AND RED CRESCENT SOCIETIES

IPCC - INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

IFPRI - INTERNATIONAL FOOD POLICY AND RESEARCH INSTITUTE

IISD - INTERNATIONAL INSTITUTE FOR SUSTAINABLE DEVELOPMENT

IDP - INTEGRATED DEVELOPMENT PLAN

UNEP UNITED NATIONS ENVIRONMENT PROGRAMME

UNICEF UNITED NATIONS INTERNATIONAL CHILDREN’S FUND

UNISDR UNITED NATIONS OFFICE FOR DISASTER RISK REDUCTION

UNDP UNITED NATIONS DEVELOPMENT PROGRAMME

NASA - NATIONAL AERONAUTICS AND SPACE

NDMC - NATIONAL DISASTER MANAGEMENT CENTER

RDP - RECONSTRUCTION AND DEVELOPMENT PROGRAMME

SANBI - SOUTH AFRICAN NATIONAL BOTANICAL INSTITUTE

LTAS - LONG TERM ADAPTATION SCENARIO FLAGSHIP RESEARCH PROJECT

LRTS - LIMPOPO RURAL TRANSPORT STRATEGY

UNFCCC - UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

UNISDR - UNITED NATIONS OFFICE OF DISASTER RISK REDUCTION

UNEP - UNITED NATIONS ENVIRONMENT PROGRAMME

USAID - UNITED STATE AGENCY INTERNATIONAL DEVELOPMENT

UNDP - UNITED NATIONS DEVELOPMENT PROGRAMME

WMO - WORLD METEOROLOGICAL ORGANISATION

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CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1. Rationale of the project

It is crucial for every country around the world to take into account social and economic development to improve or enhance socio-economic conditions in the communities. In South Africa's rural areas, development is undertaken with the main purpose of improving the lives of the poor (*The reconstruction and development Programme (RDP) - the O'Malley archives, 1994).* One of the functions of Department of Rural Development and Land Reform DRDLR is to develop and execute the Comprehensive Rural Development Plan (CRDP), linking to the Land and Agrarian Reform and food security (DRDLR, 2014). South Africa as a country is faced with a challenge that may affect sustainable development amongst other including rural communities dealing with the existing socio-economic vulnerabilities and resilience in the rural communities and climate change in relation to socio-economic development in the rural communities. The research focused on the risks and vulnerabilities that might have resulted from the changes in climate change affecting rural development in the Mopani District Municipality (MDM) in the Limpopo Province. The occurrence of disaster risks and unpredictable weather events impacted on the infrastructures, water, and food production, human and animal health. Rural people's livelihoods have a relatively large dependence on the natural environment, compared to urban people (FAO, 2002). The natural environment has the ability in determining areas that are suited for agricultural potential, settlement patterns, and type of climatic conditions in that area. These conditions, further influence the type of social and economic development activities that take place in that specific area. It is therefore important to obtain an understanding into the plausible impacts of future climate change on South Africa's rural communities, towards the timeous formulation of adaptation strategies. Within this context, it may be noted that much of southern Africa region consists of semi-arid climatic conditions that experience very high climate variability and it is therefore vulnerable to climate change. That is, should the warm and dry areas of southern Africa become warmer and drier as indeed seems plausible (Engelbrecht *et al*., 2015), adaptation options would be limited. This scenario would be further complicated by the high level of poverty in most rural areas that drives the associated low adaptive capacity under climate change (Davis, 2011).

It is against this larger regional background of climate change and rural poverty that the risks climate change poses to the MDM should be considered. Environmental conservation and tourism attractions, heritage areas, mining industries and the presence of Mopani worms and Marula fruits contribute to economic development in the communities of MDM (MDM IDP, 2016/17). MDM is characterised by high level of poverty and low human development potential that has resulted from low levels of education and a high unemployment rate. There are difficulties in accessing some areas in the rural communities of MDM due to the nature of the landscape, gravel roads that are not in good conditions and not well maintained, and settlement patterns that are very scattered. MDM is also characterized by low rainfall, except along the escarpment areas. As a result, local municipalities such as the Greater Giyani Local Municipality and Ba-Phalaborwa Local Municipality do not have many water sources and that can have an effect on rural communities experiencing shortages of water and experiencing disaster risks (e.g. drought conditions) (MDM IDP, 2016/17).

MDM lacks adequate basic services such as proper sanitation and infrastructure, which poses threats to the environment and humans within the district (MDM IDP, 2016/17). In particular, rural communities in the MDM are characterized by inadequate basic services to sustain their everyday lives. The Maruleng and Greater Letaba local municipalities have more than 50% pit latrines without ventilation, whereas the Greater Giyani and Greater Tzaneen local municipalities show more than 40% of pit latrines without ventilation (StatsSA, 2011). Consequently, a total of four local municipalities in the MDM show more than 50% of own refuse dump.

Moreover, many people in these communities depend on subsistence farming which is affected by rainfall for yield. A total of about 35 000 households (StatsSA, 2011) in the MDM primarily depend on different crops as one of their agricultural practices and these contribute negatively towards the impact of climate risks as it drives the rural communities to higher risks of being more vulnerable. Rural communities that rely on the state of the environment feel more effect of the changes in climate, as rainfall is unpredictable at times and also unpredictable occurrence of disaster risks such as drought conditions affect them negatively when it comes to the availability of natural resources from the environment (De Beer, 2005). Livestock feed also depend on rainfall, a total of about 45 000 households (StatsSA, 2011) in the MDM depend on livestock farming. About 2 500 households (StatsSA, 2011) produce fodder for grazing in the MDM.

Lack of financial stability has a negative impact on the livelihoods of local residents as during disaster risks and climate change they are unable to respond to the impact caused by climate change (e.g. seeking credits or loan, loss of crops, and so forth (Mitchell, et, al., 2008). The MDM is characterised by high unemployment and low literacy rates, which renders the region highly susceptible to climate change. During drought conditions, rural communities will be limited to financial credit and are less able to respond to financial shocks such as the death of a breadwinner, or loss of crops (MDM IDP, 2016/17). The unemployment rate is less than 40% in Maruleng, Greater Tzaneen and the Ba-Phalaborwa local municipalities.

In order for the rural communities to have sustainable agricultural practices, they need to have enough land for economic development so that it would be easier to raise capital or invest for financial development and stability (DRDLR, 2013). According to the (MDM IDP, 2016/17), 190 land claims are currently in process, with 146 of these yet to be validated. Delay in settling registered land claims is having a negative challenge and restricts the utilization of land for agricultural purposes and rural development.

It is important for rural communities to have proper health services and facilities as climate change impacts could worsen those community members whose systems are already weak due to poor nutrition or illness such as HIV in some instances and that could result in them to be less resilient to environmental stresses such as cholera and malaria (EPA, 2016). Infrastructure (housing, clinics, schools, roads, and telecommunications) is also crucial in the rural communities during shocks and stresses associated with an increase of droughts, extreme cold and hot temperatures, floods, veld fires, and heat waves. In the rural communities of MDM there are not enough health facilities that are able to cater for all communities and in addition to not having enough health facilities, access to the rural communities are mostly accessed by dirt roads or even footpaths and these roads are vulnerable to degradation during rains, which may result in the difficulties in providing disaster relief services to those rural communities. Due to the nature of settlement patterns and landscape of MDM rural communities, it becomes challenging to the government to provide required health services and facilities to all communities around the district (Mopani IDP, 2016/17).

Proper shelter is also important in the rural communities so that people in rural communities are able to be housed in safe buildings to prevent the impacts of disaster risks (e.g. violent storms or floods) (DRDLR, 2013).

1.2. Justification

The government of South Africa's main operational strategy is the National Development Plan (NDP) with its main goal focused on reducing inequality amongst the people of South Africa, thereby ensuring that the level of poverty is reduced in the rural communities and to all the people of South Africa at large. In order for the NDP to achieve its vision, programmes that focus on the livelihoods of rural communities through the provision of basic services (e.g. water, electricity, and sanitation), infrastructures (e.g. houses, clinics, schools, roads) and the creation of employment amongst others. The government of South Africa operates through the three spheres that include the National, Provincial and the Local government (e.g. district and local municipalities). The local municipalities render services to the people of South Africa including the rural communities. All the plans of the spheres of government should implement programs that will aid in the success of achieving the goals of the NDP. In the local government, the overall strategic plan is the Integrated Development Plans (IDPs) of which all the social and economic development plans are included and should improve and provide spatial planning, infrastructure, and basic services to the local communities they serve. MDM is a typical example of a district that is the focus of the NDP in terms of the development of its economy and the skill level of its people.

All government sectors (national, provincial and local) including the DRDLR are required to contribute to the implementation of the NDP, and also to identify any obstacles that may occur for the sector to achieve the overarching goal of the NDP. Due to its impacts, climate change poses a threat to reaching the goals of the NDP (DRDLR, 2013). In responding to climate change, capital that is needed for growth of the country or of the rural communities may be utilised for climate change interventions for example, water shortages to sustain agricultural activities, water for human consumptions to sustain their health and so forth (DRDLR, 2013). Climate change threatens the state resources that are planned for economic development of the country (Girma, 2015).

DRDLR provide functions on presidential outcome seven (7) which stipulates building vibrant, equitable and sustainable rural communities by providing safety and security for communities in those specific areas. In order to achieve the goals of outcome seven (7), programmes such as CRDP which provides job creation in order to eliminate poverty are implemented in the rural communities (DRDLR. 2016). DRDLR developed Rural Human Settlements sector plan for climate change adaptation on a national level in terms of output two (2) that focused on greenhouse gas emissions reduction, changes in climate and its effect through the improvement of atmospheric air quality and outcome 10 focusing on protecting environmental and natural resources for sustainable development.

The research described here, therefore, relates to outcome seven of the DRDLR. This study is aimed to identify potential climate impacts in the Mopani District Municipality (MDM) and to project risks under low mitigation futures (e.g. extreme temperatures, extreme rainfall, droughts and high fire danger days). These potential changes in the climate of the MDM are subsequently interpreted within the context of the specific vulnerabilities and exposure of the MDM, towards the development of rural communities' adaptation options.

It is therefore important to evaluate vulnerabilities and exposure in relation to climate change. Evaluation of the current exposure to the hazards and sensitivity has been done with respect to environmental risks on the rural communities in the MDM. The research focused on the impacts on the key sectors of economic rural development such as agriculture (food security), water, rural livelihoods, and infrastructures (roads). This research is aimed at contributing to long and short term planning for the MDM, including decision making with regards to financial and economic development planning and to assign responsibilities to different role players and also to promote disaster risk management, reduction and response.

1.3. Aims and objectives

The overall aim of this research is to identify climate change on the MDM, towards the formulation of suitable adaptation strategies. This implies the projection of future risks and vulnerabilities of the MDM and its rural communities under climate change, and a need to understand the resilience of these communities, and how it can be strengthened.

More specifically, the objectives of this study are:

- To analyse a robust set of projections of future climate change over the MDM, towards quantifying plausible future changes in temperature, precipitation, and extreme weather events.
- To assess the potential impact of future changes in climate on the environment and biophysical systems of the MDM.
- To assess how climate change may impact directly on rural communities and social systems (human systems, i.e. livelihoods and infrastructures) in the MDM.
- To assess climate change adaptation options for rural communities in the MDM.

1.4. Study Design

The study covers the five local municipalities in the MDM, which are: Ba-Phalaborwa, Greater Giyani, Greater Letaba, Maruleng and Greater Tzaneen (*Geographical map of MDM is shown in Chapter 3 (Figure 12) of this dissertation*). The main purpose of the work is to analyse plausible projections of future climate change over the MDM and its constituent municipalities, towards understanding the risks and vulnerabilities that climate change poses to the rural communities in these regions. From the risk and vulnerability analysis, the study then proceeds to formulate suitable adaptation options for the MDM.

The study commences with identifying those climate-related risks that impacted the MDM and the larger Limpopo Province over the last five decades (1971-2000). With climate-related disasters are meant: high-impact disaster risks such as extreme temperatures (heat waves), extreme rainfall (floods), droughts and high fire danger days. The types of disaster risks that are relevant to Limpopo Province under present-day climate were identified by considering peer-reviewed literature on this topic (including the publications of the South African Risk and Vulnerability Atlas (DST) and the Long Term Adaptation Scenarios project-reports (DEA), and various disaster management and development related publications). Additionally, newsletters from the Corporate Governments and Traditional Advice (COGTA) were scrutinised as an inventory of high-impact weather events that have affected the Limpopo Province. Finally, the archives of newspapers (including News24) have been used as a further investigation into climate-related disasters relevant to the province.

Following this qualitative identification of extreme weather events relevant to the Limpopo Province, the subsequent stage was to measure their present-day recurrence of event over the area. Given the complete lack of gridded observational data sets of daily weather over the Limpopo province, this step of the research was performed using high-resolution regional climate model simulations of Limpopo's climate. This analysis has been conducted on both a seasonal and annual basis. Maps displaying this information have been generated within a GIS environment. For example, model simulations of the present-day average maximum temperature in summer and the associated average number of heat-waves were considered. As far as possible, these simulations were verified against observational data sets of the Climatic Research Unit (CRU), although the monthly-averaged nature of the CRU data allows only the verification of the model simulations of monthly average of variables such as temperature, humidity and rainfall, and not the verification of how the model simulates daily circulation statistics. In addition to the spatial maps of present-day frequencies of high-impact weather events, a trend analysis was done for each type of event, to determine whether anthropogenic forcing has over the last five decades (1971-2000) caused any significant changes in extreme event occurrence over the Limpopo Province and the MDM. This was feasible for those variables for which time-series data of annual and seasonal frequencies of events that were available, and for which a linear trend analysis was subsequently performed.

The next step in the procedure is to analyse projections of future changes in climate over the Limpopo province and the MDM, once again through the application of high-resolution regional climate modelling of particular interest was CCAM high-resolution projections of future changes in climate over the Limpopo province, as performed at the CSIR as part of the Coordinated Regional Downscaling Experiment (CORDEX). Spatial maps showing the future changes in climate in terms of frequency and magnitude of high-impact disaster risks was constructed in GIS. The analysis of projected changes was performed for various future time-slabs (e.g. 2030-2050). The analyses were performed for both low mitigation (high emissions) and high mitigation (low emission) futures.

The methodology for assessing climate change vulnerability was based on the UNDP approach, where climate change vulnerability is represented as an outcome of the interrelationships between hazard exposure, sensitivity and adaptive capacity (Figure 1). The interaction between hazard exposure, based on observed climate data (present-day) and climate change projections (future), and sensitivity, based on an analysis of bio-physical characteristics, can be understood as encompassing the risks posed by present-day climate variability and future climate change. The vulnerability is therefore determined by the extent to which these risks are mitigated or exacerbated by the presence or absence of adaptive capacity.

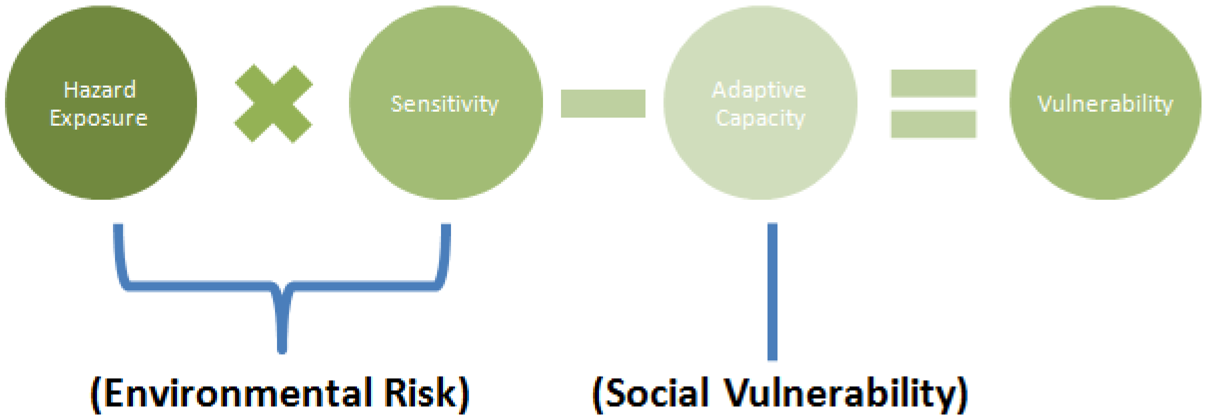


Figure 1: UNDP vulnerabilty assessment approach
Source: UNDP, 2015

Based on the analysis of the present-day frequency of occurrence and intensity of disaster risks over the Limpopo province, it was subsequently possible to determine hazard exposure to climate change. The period of analysis was 1970-2000 for present-day climate and 2030-2050 for future-climate. Maps were constructed for identified hazards using GIS technology in terms of the spatial distribution and frequency of occurrence of the hazards over Limpopo for both present-day and future climate.

The specific climate sensitivities of the MDM have been identified through a literature review and from the analysis of spatial maps using GIS technology to display the biodiversity, ecosystem health, and land cover, distribution of invasive alien species, conservation areas, carbon sequestration, rivers and degraded areas around the district. The state of the ecological ecosystem was also observed by the researcher during five (5) field visits as another form of a data collection tool with a specific focus on observing the status of grazing areas, crops and water sources in the rural communities in the MDM.

Aspects that contribute towards the resilience of communities in the MDM to climate risks was assessed based on the status of the available financial and human resources, provision of basic services (e.g infrastructure) that is readily available to rural comunities to respond to the occurance of disaster risks associated with climate change. Census 2001 and 2011 was used to analyse the changes in basic services for the past 10 years. In addition to that five (5) focus group discussions were used to get information about the livelihoods of rural communities in the MDM, as well as the perception of the communities of how climate change impacts on these livelihoods. Rural community members involved in the focus group discussions were a group of household's members which included young unemployed youth from the age of 18 to the head of the house of ages that ranges from 30 years to 65 years. This first group consisted of a total of 16 participants. The second focus group considered was constituted of women between the ages of 25 and 40 years, who work on a farm. This group consisted of 20 participants. The third focus group was also consisting of women only due to the fact that 60% of unemployed people in the district are women (MDM IDP, 2017/18). Their subsistence depends on selling vegetables and fruits in the market. This group had 10 participants between the ages of 30 and 65. The fourth focus group consisted of both males and females between the ages of 26 and 55 that are involved in the government programmes in the rural communities. This group consisted of 25 participants. The last focus group consisted of professionals who are involved in agriculture and this group had 10 participants. The most important focus in the group discussion was the status of their everyday lives with respect to their social and economic issues and their perception of climate change in their rural communities and how climate change is affecting their livelihoods and their coping capacity. Discussion questions were focussed on the current status of education, employment and signs of climate change in their local communities taking into consideration the changes in the precipitation, temperature trends, yields of water sources, and the performance of crops, animals, and general ecosystems. However, the local knowledge from focus groups alone was not sufficient to gain an understanding of vulnerabilities, resilience and climate change impacts that affect the socio-ecological systems and rural communities in the MDM, in addition to that historical records, census data, and GIS technology had to be used for further analysis.

An overview of social vulnerability indicators that have been considered in this research has been adopted from DRDLR 2013 as indicated below in Figure 2. The net result of the literature review of resilience and sensitivities, spatial analysis of environmental health and vulnerabilities, and focus group interviews were used in combination to build a holistic picture of the vulnerabilities and resilience of the MDM rural communities to present-day climate variability. This provided a baseline from where to project future vulnerabilities and reduced resilience under climate change. These projections were subsequently analysed to formulate suitable adaptation options for the MDM.

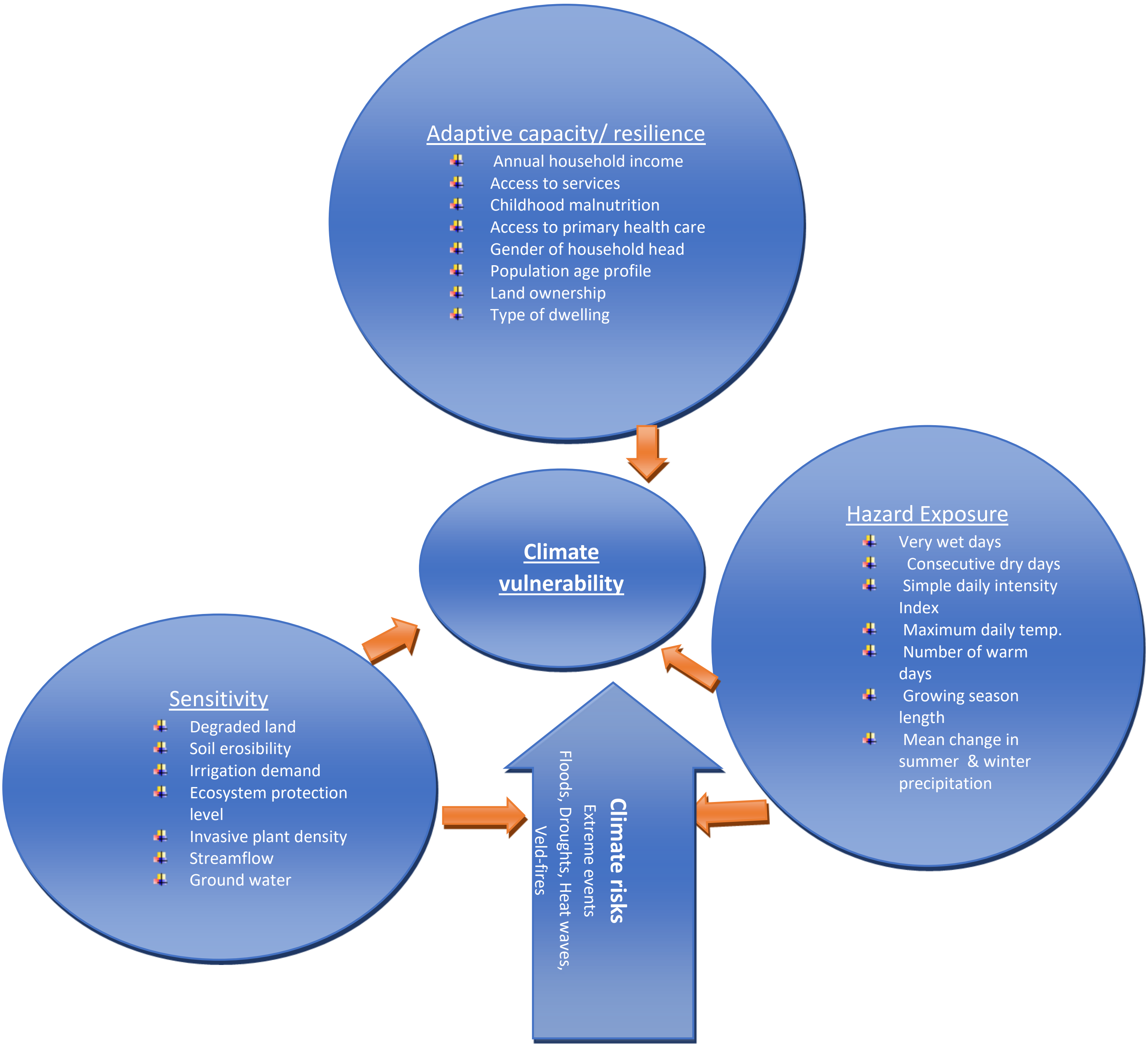


Figure 2: An overview of social vulnerability

Source: DRDLR, 2013

To achieve the objectives as set out earlier in this chapter, Chapter 2 will highlight the existing literature review of natural hazards, climate change, vulnerabilities and resilience on a global, national and local scale.

CHAPTER 2: LITERATURE REVIEW

2.1. Natural hazards

The world involved numerous natural hazards that influence the living states of people and the condition of the earth in particular the natural environment. The status of the common habitat is ingenuity bringing about various changes that are once in a while erratic. The capricious extraordinary changes of the normal state result in unpredicted natural hazards causes environmental, social and economic disruptions and destructions of living and environmental conditions of rural communities (UNISDR, 2009; IPCC, 2012; Brooks, 2003). The effect and impacts of outrageous changes and event of components in the physical condition that adversely influence human causing hurt as an aftereffects of quick or moderate beginning occasions which can either be climatological (i.e. drought, wild fires - forest and land fires), Geophysical (i.e. earthquakes-ash fall, ground movement, lava flow, rock fall and tsunami), Hydrological (i.e. floods-flash floods, landslide and riverine flood), Meteorological (i.e. storms-convective storms and tropical cyclone, extreme temperatures - cold wave, heat wave and severe winter) are referred to as natural hazards. The magnitude or intensity, frequency, duration, and the extent of natural hazards varies in relation to the geographical location of that specific area (IPCC, 2007).

The extent of the impact of the natural hazards can also be exacerbated by man-made hazards occuring in their geographical areas or settlements. For example the occurence of land and environmental degradations, air and water pollutions that have a major impact in driving the extreme changes in the state of the natural environment resulting in temperature and precipitation extreme events (Tsultrim, 2012; Novelo-Casanova, 2011). The effects of natural hazards on humans are called natural disasters. The occurrence of natural hazards and disasters can be quick, can be in a large-scale and violent and can be continuous in a long-term (Pawson, 2011). Quick and large scale events result in huge damage and destruction (e.g.Tornadoes, severe storms, and thunderstoms). Countinous long term disasters take a long time while severly impacting on the environment and human livelihood affecting health, economic (i.e agricultural production) and social issues(e.g drought).

Natural disasters affects communities, countries and continents around the world. Centre for Research on the Epidemiology of Disasters (CRED) in 1988 created an International disasters database (EM-DAT) which sourced its data from various sources such as UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies. The scope or coverage of EM-DAT includes the occurrence and effects of over 22,000 mass disasters in the world from 1900 to the present day. EM-DAT has been supported by the World Health Organisation (WHO) and the Belgian Government.

Below graphs (1-5) and table (1&2) indicates all disasters that occurred from 1950-2014 in the Continent, South Africa as a country and in the Limpopo province. Based on the data acquired from *EM-DAT (The International disasters database, 2017),* Figure 3 below show trends of disasters in all continents from the year 1950 to 2014 where natural disasters are increasing through the years. In 2000 the graph indicates that it is the year that all the continents experienced their highest level of disasters and from the year 2000 the disasters were not in a consistent motion meaning that in some years disasters would decrease and the following may increase again. Thus, the trends of disasters in all continents have been decreasing from 2000 till now. The Figure 3 indicated that with the african countries or with Africa as a contintent the disasters have been increasing from the year 1950 till the year 2006 and from there they started decreasing. As for America disasters have been increasing from 1950 and between the year 1986 to 1998 there has been inconsitency on the trends of these disasters. The Asian continent is showing the trends of increases in disaters from 1950 till now. The Europe continent seemed to be on an equillibrium from the year 1950 to 1978, but from there they started increasing until today even though there is incosistency. The continent of Oceania have not experienced any natural disasters from the year 1950 to 1964 and started experiencing these disasters from 1966 and have been increasing from then to date.

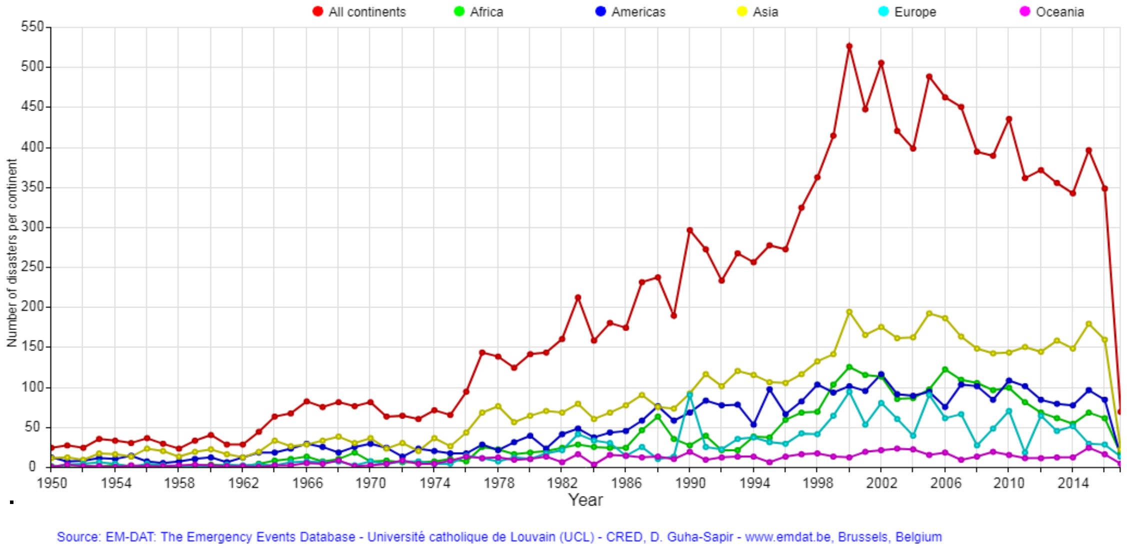


Figure 3: Total number of natural hazards recorded from 1950-2014

Source: EM-DAT.bet (The International disasters database), 2017)

Based on the data obtained from *EM-DAT.bet (The International disasters database), 2017), 2017,* Figure 4 below shows the occurrence of natural events as per type of the natural disasters From the year 1950 - 2000 mark the years that all of these disasters occurred at most and from there, their occurrence started decreasing. Biological disasters started occurring from the year 1964 and their trends have been increasing from there till the year 2000 which marks their highest levels but from there, they started decreasing till to date. Climatological events have been increasing from they year 1950 to date. Geophysical events have also been increasing from the year 1950 - 2004 and then they started decreasing till to date. Likewise, hydrological disasters have been increasing to date. Meteorological events have been increasing from the year 1950 – 2004 and after that started decreasing till to date.

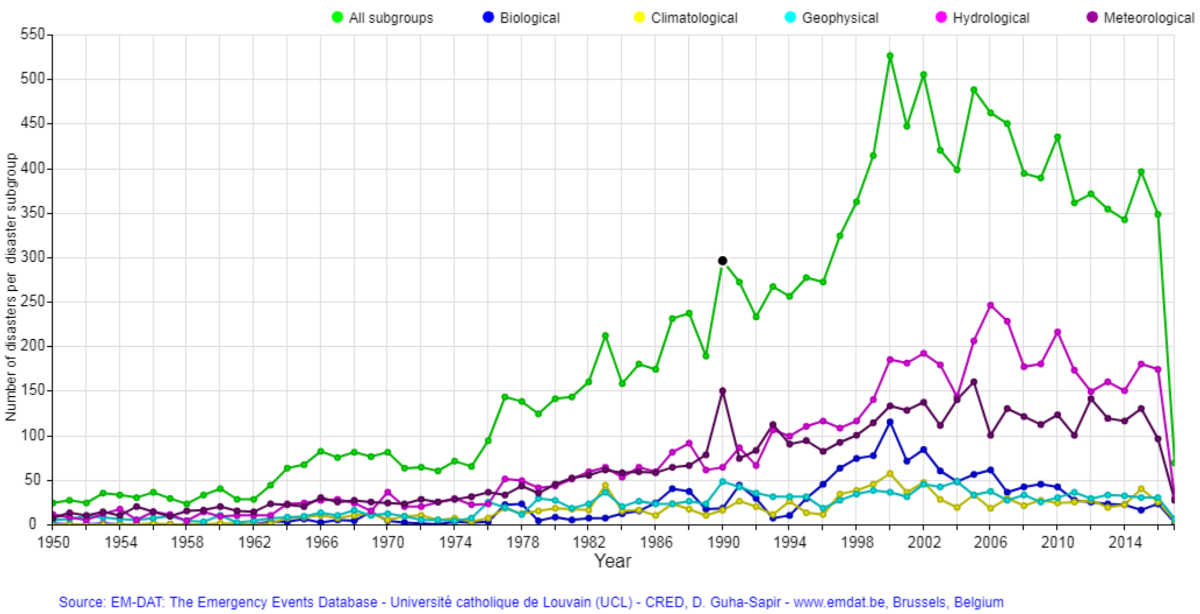


Figure 4: **Occurrence of natural events per type of disaster from 1950-2014**
Source: EM-DAT.bet (The International disasters database), 2017)

Based on the data obtained from *EM-DAT.bet (The International disasters database), 2017).* Figure 5 shows the occurrence of earthquakes as disastrous events that have been increasing from the year 1950 - 2004 and from there the events started decreasing around the continents. Floods seem to be the most occurring disaster from the year 1950 increasing through the years until reaching the highest level in 2006 of which thereafter started decreasing till to date. Storm events occurred from 1950 - 1990 and started decreasing thereafter. Drought events occurred from 1950 but showing lower level of occurrence even though throughout the years it showing slight increase until 1995 where it started rising from 19 – 20 drought occurrence events and continue to increase till to date. Epidemic disasters occurred from the year 1950 and showing an increase through the years until reaching the highest level between 1994-2002 and started decreasing thereafter till to date. Other types of disasters also occurred from 1950 as recorded in the *EM-DAT.bet (The International disasters database), 2017)* and shown from figure 4.

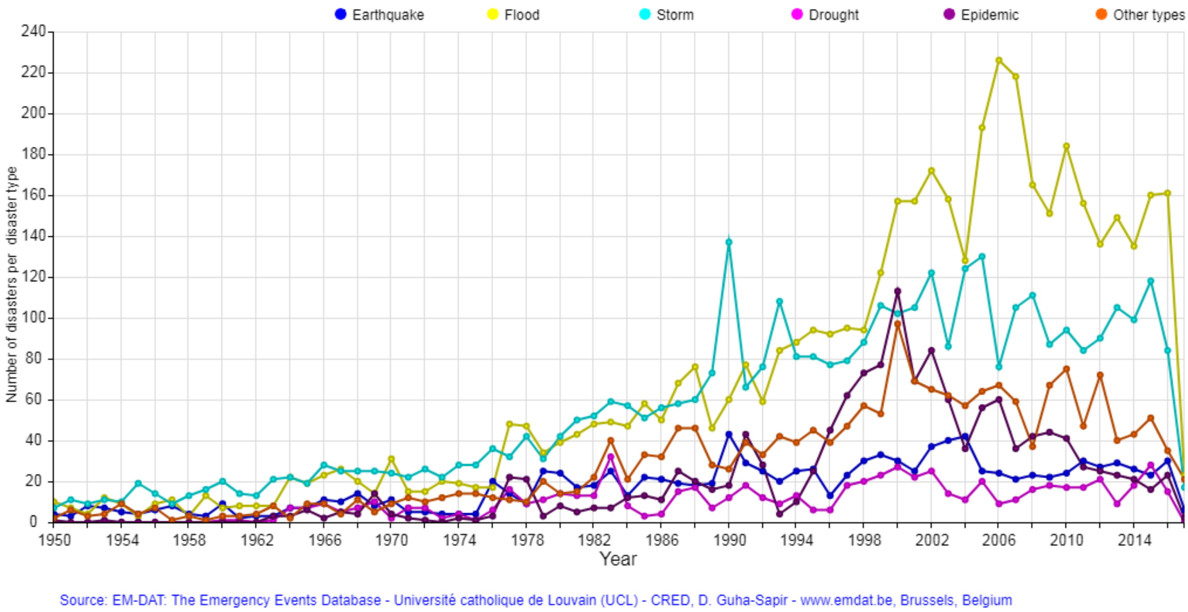


Figure 5: Occurrence of natural hazards in the five continents
Source: EM-DAT.bet (The International disasters database), 2017)

According to the information recorded from *EM-DAT.bet (The International disasters database, 2017) - Universite catholique de Louvain (UCL), (2017)* the South Africa as a country experienced natural hazards in the following years

Table 1: ***Natural hazards experienced in South Africa***

Climatological hazards	**Geophysical hazards**	**Meteorological hazards**	**Hydrological hazards**	**Biological hazards**
Drought *1964*, *1980*, *1982*, *1986*, *1988*, *1991*, *1995*, *2004*, and *2015*	**Earthquakes** *1920*, *1969*, *1982*, *1987*, *1988*, *1990*, *1997*, *2005*, *2014*	**Extreme temperatures** *1996*, *2007*, *2016*	**Floods** *1959*, *1968*, *1974*, *1977*, *1978*, *1981*, *1987*, *1988*, *1993*, *1994*, *1995*, *1996*, *1997*, *1999*, *2000*, *2001*, *2002*, *2003*, *2004*, *2006*, *2007*,	**Epidemic** *2000*, *2002*, *2003*, *2004*, *2008*

			2008, 2009, 2011, 2012, 2014, 2016	
Wildfires *1991, 1998, 1999, 2000, 2001, 2002,2007, 2008*		**Storm** *1952, 1983, 1984, 1990,1993,1994,1998, 1999, 2000, 2001, 2002, 2003, 2008, 2009, 2010, 2011, 2012, 2013, 2017*	**Landslide** *1996*	

According to the information recorded from *EM-DAT.bet (The International disasters database), 2017)- Universite catholique de Louvain (UCL),*The Limpopo province experienced natural hazards in the following years.

Table 2: Natural Hazards experienced in Limpopo Province

Climatological hazards	**Meteorological hazards**	**Hydrological hazards**	**Biological hazards**
Drought *1986, 1988, 1991-1992, 2004, 2015-2017* Drought that occurred in 1986 affected the Lebowa	**Extreme temperatures** *1996, 2007, 2016* **Storm** *2002, 2010-2011, 2012* 2002 convective storm affected most parts of Limpopo province	**Floods** *1978, 2001, 2011, 2014* 2001 flash floods affected Greater Tubatse in Sekhukhune district municipality in Limpopo province	**Epidemic-bacterial diseases** *2008-2009* affecting Vhembe district municipality in Limpopo

and Venda former homeland 1988 drought affected all former homelands areas.	2012 tropical cyclone storm affected most parts of Limpopo	2011 Riverine floods affected Mopani, Vhembe, Sekhukhune and Waterberg district municipality	province
Wildfires *1986, 1988, 2001, 2007* 2001 land fire affected Mopani and Vhembe district municipalities 2007 forest fires affected most parts of Limpopo province			

2.2. Climate variability

The atmosphere shows various methods of fluctuation globally and hemispheric flow at intra-seasonal (of the request of 1 or 2 months) and inter-annual (year to-year) timescales and that additionally brings about atmosphere inconstancy in terms of climate variability (Dickinson, 2000). Climate variability occurs when a climatic condition goes beyond individual weather events on spatial and temporal scales (NOAA, 2016). Figure 6 (a-c) describes the changes in climate variability and extremes that have resulted from the occurrence of natural hazards. Figure 6 (a) indicates the change in direction of the whole distribution to warmer climate conditions that depicts a change in the mean where more hot weather conditions are expected together with less cold weather conditions. Figure 6 (b) indicates the likelihood of temperature distribution preserving mean value while increasing in the variance of distribution and thus the temperature does not change on average, but the expectations for the weather conditions in the future will change to be hotter and colder weather conditions. Figure 6 (c) indicates temperature probability distribution where it preserves its mean and in this instance, variability emerges through a change in asymmetric approaching the hotter part of the distribution and this resulted in the near constant cold weather conditions, while increasing to hot weather conditions.

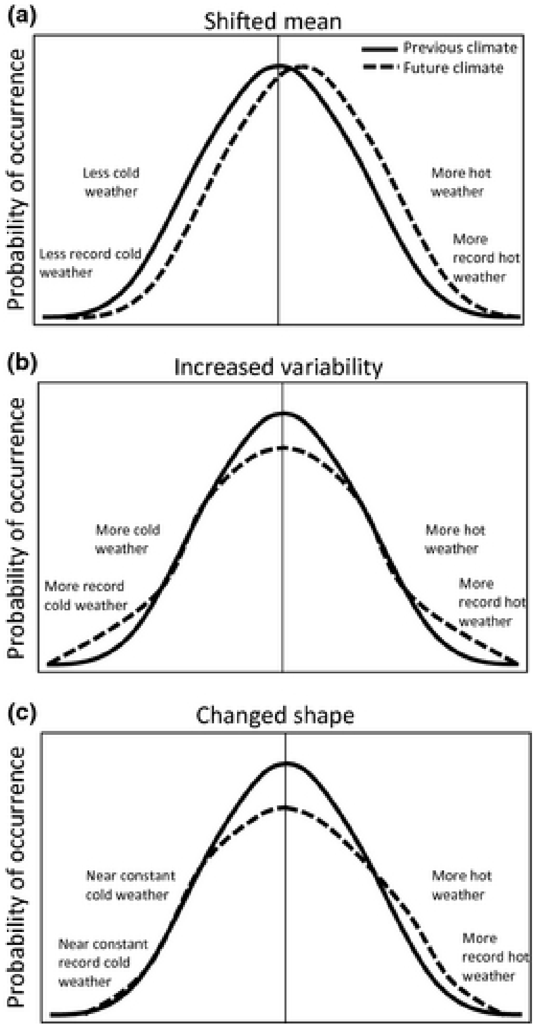


Figure 6 (a-c): Changes of climate variability and extremes

Source: IPCC (2012).

The continent of Africa in the Southern Africa region is considered to be semi-arid where the extreme temperature events that results in conditions such as drought occurs being influenced by high intra-seasonal and inter-annual rainfall variability (Nicholson, 2016).Due to Southern Africa geographical location in the sub-tropics, the region has a potential of being affected by the tropical and temperate latitude circulation systems as well as high pressure systems that might be semi-permanent (Nicholson *et al*., 2016).

The amount and distribution of precipitation are the most essential variables to consider when analysing precipitation in the southern Africa region. Climate variability in Southern Africa region has been recorded since the year 1800 and oscillations such as quasi-biennial oscillation (QBO) and El Niño Southern Oscillation (ENSO) has been identified (Garfinkel *et al*., 2007).The Southern Africa region other climate variability that results in wet and dry spells include changes in macropressure over the interior and adjacent oceans (Cook et, al., 2004).

ENSO influences temperature and precipitation because of its ability to change the global atmospheric circulation and its occurrence can be anticipated occasionally. El Niño came about because of the warming of the ocean surface or above-average sea-surface temperatures (SST), in the central and eastern tropical Pacific Ocean. Amid El Niño occasions easterly breezes which for the most part blow from the heading of east towards the west along the equator ends up powerless and alter the course in a few occurrences blowing to different bearings from west to east (i.e. westerly breezes) (Mason, 2001)

La Niña came about because of the cooling of the sea surface, or below normal ocean surface temperatures (SST), in the central and eastern tropical Pacific Ocean. During La Niña events over Indonesia, precipitation tends to increase while precipitation diminishes over the central and eastern tropical Pacific Ocean. The ordinary easterly breezes along the equator turn out to be much more grounded. When all is said in done, the cooler the sea temperature inconsistencies, the more grounded the La Niña (and the other way around) (Davis, 2011).

The South-Eastern region of Southern Africa is highly influenced by El-Nino conditions where in 1982/83 the region experienced below average rainfall caused by El Niño conditions and resulted in the occurrence of drought (Davis, 2011).During El Niño conditions, wind, ocean temperatures, cloud and rainfall patterns all change. El Niño conditions occur every two to seven years and lasts for nine to twelve months and in some instances can reach up to two years). South Africa experienced strong El Niño events in 1997/98. During El Niño events global temperatures can rise, by up to about 0.3°C. The impact of El Niño includes South American rainfall, droughts in Africa and Indonesia and also promotes fires and modulates the strength of tropical storms (IPCC, 2007).

The climate of Southern Africa exhibits a large degree of natural variability (Tyson et al., 2002). More specifically, the MDM is located in the Limpopo Province which has a highly variable climate and frequently experiences the impacts of droughts and floods (Malherbe et al., 2012; 2014).

Climate variability changes based on the frequentness, magnitude, the extent of geographical location and the duration spent during those changes and that condition describe the process of climate change, which will be discussed in the following section (IPCC, 2012).

2.3. Climate change

Climate change has become the main focus area for many scientists, organisations and government institutions due to its global impact on the environment and world economy (World-nuclear, 2015). Researchers and policy makers established climate change related frameworks, forums and other bodies that focused on the change in climate. The United Nations Framework Convention on Climate Change (UNFCC) (1992) was formed in 1992 and followed by Kyoto Protocol (1997). The International Panel on Climate Change (IPCC), Fourth Assessment Report (AR4).(2007) indicated that a trend of natural variability changes over time due to human activities result in climate change conditions. The Fifth Assessment Report (AR5) provided extensive summaries of scientific information of climate change and plausible projections for the future (AR4, 2007; AR5, 2014). Climate change has an effect on water, agriculture, health, biodiversity and environmental sectors (Molnar, (2010); DEAT, (2012); Haines *et al.,* (2005); Bush *et al.,* (2011); Roser-Renouf *et al.,* (2016); UNEP, (2013). AR4 and AR5 of the IPCC have firmly established that climate change is the result of increasing human activities that contribute to the increase of atmospheric carbon dioxide.

From an international perspective, climate change has an impact on a global level resulting in the increase of sea levels and a decrease in agricultural products, while increasing the occurrence of extreme weather events (IPCC, 2007).

South Africa as a country should ensure that disaster risk reduction as stipulated in Hyogo framework and Sendai framework is considered in planning for climate change adaptation strategies as it integrates changes in climate and reducing disaster risks addressing the changes of hydro meteorological patterns and to ensure that all spheres of government play a role in reducing disaster risks and also engage or form collaborations with other relevant stakeholders by sharing responsibilities. The risks reduction should put emphasis on the livelihood of rural communities, social, economic, cultural and environmental assets (UNISDR, 2016).

Climate models aid in predicting and assessing current and future climatic conditions. A different climate model indicates that climate change is causing and will lead to the increased occurrence of extreme weather events. This may be due to a warmer atmosphere having available larger amounts of energy to generate intense weather systems and a warmer atmosphere having ability to carry more moisture, which favors the release of latent heat in tropical storms and increased amounts of precipitation. It is natural to expect increasing extreme temperatures and precipitation associated with increasing occurrence of weather related disasters, it therefore important to assess different climate models and their capabilities in future climate change predictions and projections.

2.3.1. Climate models

The future projections of climate change have been done by different researchers using different climate models (IPCC, 2007). The main aim of different researches from different researchers is to predict the future climate changes that will have an impact on the livelihood of rural communities as well as the world at large and this future predictions aid in policy and decision making.

Different models are having different capabilities in projecting future climate. Global Climate Models (GCMs) have the ability to assess previously occurred disaster risks or changes and also in projecting future change. They are based on models which represent interactions between land surface, atmosphere, and the ocean. Monthly mean precipitation and temperatures variables can be simulated using GCMs, but GCMs has no ability to simulate daily frequency or diurnal cycle of precipitation. GCMs are unable to capture important features of the regional climate (Davis, 2011). GCMs' resolutions are typically in the order of 100 x 100 km^2 or lower.

The Division of Atmospheric Research Limited Area Model (DARLAM) and the Conformal-Cubic Atmospheric Model (CCAM) of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) have been applied extensively to obtain projections of future climate change over southern and tropical Africa. The CCAM has the ability to project future climate change and forecasting of seasonal and short time scales in the Southern region of the African continent. It also has the ability to simulate present day climatic conditions from global simulation perspective at a lower horizontal resolution and at ultra-high (1km) resolution (Engelbrecht *et al*., 2002; Engelbrecht *et al*., 2005; Engelbrecht *et al*., 2009).

Dynamic Regional Climate Models (RCMs) have the ability to operate on a higher resolution on a specific area and are forced at their lateral boundaries (in the case of limited-area models) or in the far-field (in the case of variable-resolution global models) by the output of a CGCM. RCMs are atmosphere-only models that are also forced at their lowest boundaries by the sea-surface temperature (SST) and sea-ice simulations of a CGCM, and by static descriptions of the land-surface. Present-day computing power allows RCMs to be applied at the continental scale at resolutions of about 50 km, and at even higher resolutions when applied over sub-continental or smaller regions (Engelbrecht *et al*., 2011). Climate models predicted the change in climate conditions globally and it is important to assess the observed trends on climate change on a global and local scale.

2.3.2. Observed trends of climate change

Many scientists, engineers, and researchers around the world wrote many reports based on the evidence from observations obtained atmospheric and surface systems (WMO,2017). Observations indicated that planet earth is warming and human activities are accelerating and driving the changes in global climatic conditions and that has been observed in the agricultural sector where planting seasons have shifted due to the dependence in the rainy seasons influenced by the occurrence of extreme temperatures and heavy rainfall that comes late in the planting seasons (Kassie *et.al*.,2017).

In Figure 7 an increase of 0.8°C (1.5°F) from the year 1880 to 2012 can be observed. Temperatures above the long-term average are indicated by the red lines in the figure and temperatures below the long-term average are indicated by the blue lines in the figure. The concentration of atmospheric carbon dioxide (parts per million (ppm)) is indicated by the black line in the figure. However, there are variations in temperature analysis as years differs where some years shows increasing temperature and some years shows decreasing temperatures. Thus some year will show greater changes than the others and some will show lower changes than the others. The fluctuations of temperatures on a yearly base might be because of the natural effect of climate variabilities such as El Niño and La Niña and in some cases volcanic activities.

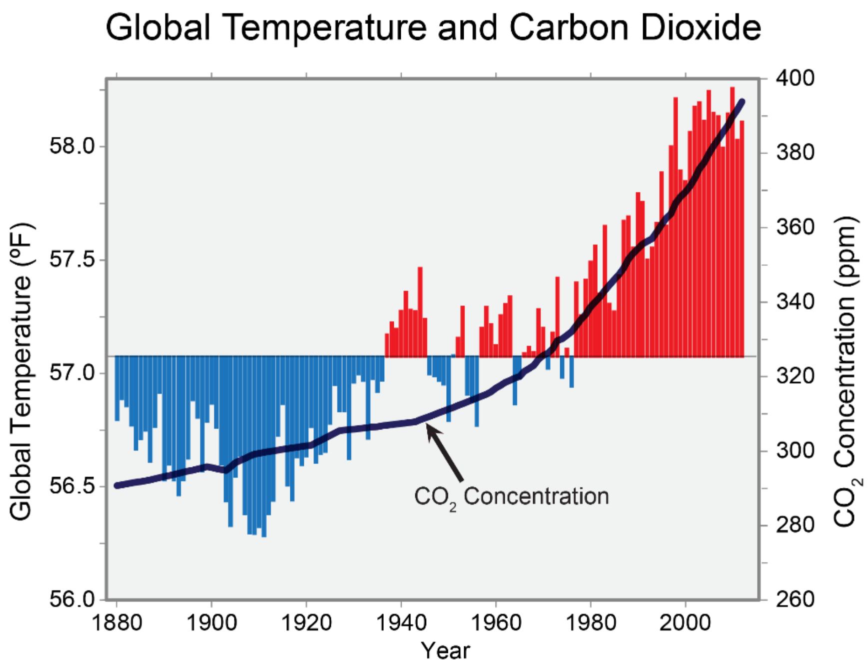


Figure 7: Global Carbon dioxide concentration and temperatures

Source: Simpson *et al., (2009).*

Climate change around the globe is believed to be driven by the warming conditions from the atmosphere however, natural factors such as solar forcing and volcanoes in the past five decades are believed to have contributed to slight cooling around the globe (US EPA, 2017). Figure 8 below, indicates observed global average changes in a black line and variability influenced by human factors (Davis, 2011; Carbon Brief, 2017). Model simulations representing changes influenced by the natural factors are shown by the green line and human factors are shown by the blue line in the figure. It is therefore important when doing an analysis of climate change to consider both the natural and human factors.

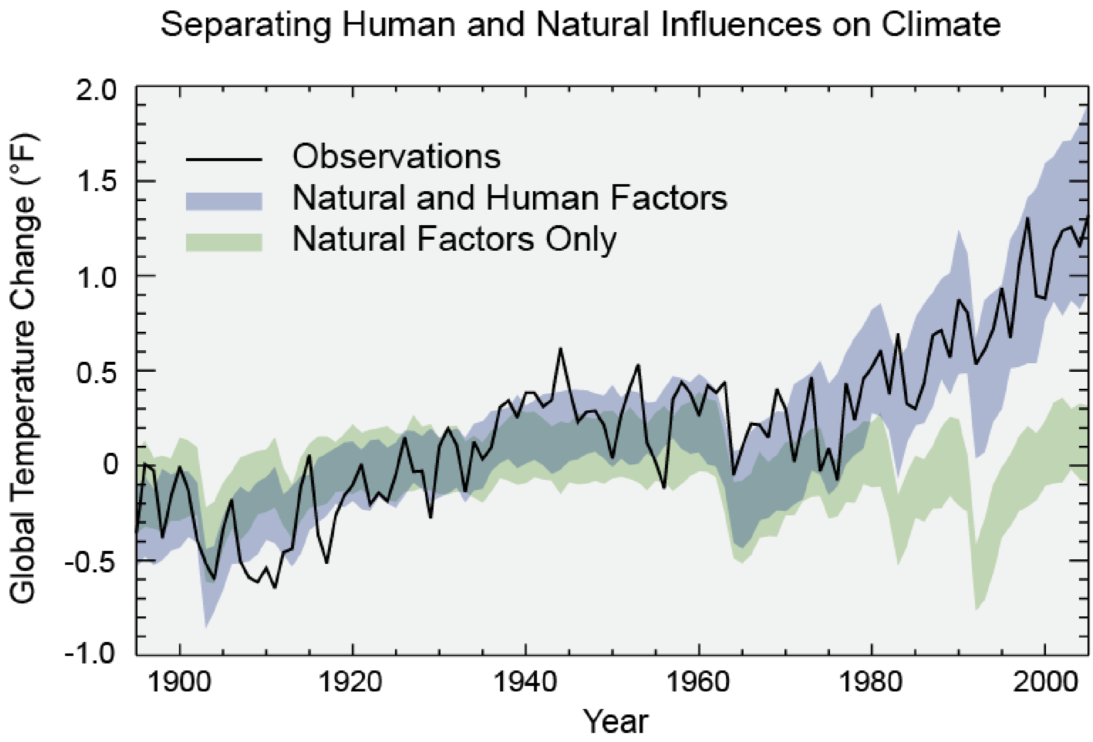


Figure 8: Human and natural factors on the global temperatures

Source: Huber and Knutti (2011).

It is of the utmost importance to assess the change of climate in South Africa by taking into consideration the past year's climate trends in relation to temperature and rainfall. The trends can be assessed based on the observations done on temperatures and rainfall using information gathered from different weather stations and historical records. With this baseline understanding of changes that have occurred to date, model projections of future climate change can be considered.

2.3.3. Temperature

In South Africa, there are numerous temperature reports that have been finished by various specialists and demonstrated distinctive discoveries. From previous years (between 1940 and 1989) South Africa's maximum temperatures have been reported as decreasing, while the minimum temperatures have been seen as increasing and this has been observed from the month of September to November which is a spring season and reversed in the autum month from March to May (Muhlenbruch, 1992). However, observations from the year 1951 to 1991 has indicated increasing minimum and maximum temperatures and decreasing diurnal temperatures around the country (Karl *et al*., 1993). For the past years from 1885 to 1915 and 1915 to 1945, Jones (1994) indicated consecutive cooling and warming conditions and he also indicated that for the past years from 1945 to 1970 thare has been a slight cooling. He added that from 1970 to 1990 there have been rapid warming conditions in South Africa. Morover, from the past years from 1960 to 1990, an increase of 0.11ºC temperatures in maximum and 0.12ºC temperatures on average have been observed (NASA, 2016). The changes in temperatures has been observed in the rural communities and urban areas of South Africa.

The average temperatures in South Africa have increased by 8.48ºC from 1991 to 2003 compared to an increase of 18.18ºC from 1960 to 1990. From the year 1991 to 2003 temperature increase on average was 0.09ºC and from the year 1960 to 1990 was 0.11ºC (Kruger and Shongwe, 2004). The Limpopo Province has experienced an increase in temperature from 1960 to 2003 as observed from three weather stations in Bela Bela, Polokwane, and Musina.

2.3.4. Rainfall

A change in rainfall varies according to different places from year to year in South Africa. Inter-annual rainfall variability in Southern Africa has been observed to have increased from the late 1960s and this has intensified the occurance of drought conditions in the country.

South Africa as a country has experienced extreme temperatures in terms of extereme dry years which has resulted in drought conditions and extreme wet years which has resulting in flood conditions. An example of these conditions can be seen by the occurence of tropical cyclone Eline in the year 2000. Eline's effect was felt during widespread flooding in southern and central Mozambique, eastern Zimbabwe and parts of South Africa and Botswana. In the years 1982 to 1983, 1986 to 1987 and 1991 to 1992 El -Niño events brought severe drought that impacted the agricultural sector, decreasing in crop and livestock production in many parts of South Africa (Davis, 2011, Maponya *et al*., 2012).

Authentic precipitation reports as estimated from 138 South Africa climate stations from 1910 to 2004, demonstrated that there is no substantial evidence of changes in the precipitation distribution from the previous years. Despite the fact that in some different areas there are sure qualities that demonstrate the adjustments in precipitation and has been seen by the sign of increasing and decreasing of annual precipitation. The country encountered the longest yearly drought which has been demonstrated by more outrageous dry seasons.Some of the seasons experienced wet conditions showed by the longest yearly wet spells while expanding the measure of every day precipitation (Kruger, 2006).

South Africa Long Term Adaptation Strategy (LTAS) report has indicated a high inter-annual variability, showing the amplitude of about 300mm as compared with the national average of rainfall in South Africa. Based on the LTAS report it has been indicated that South Africa in the 1970s, 1980s and the mid 1990s, the country experienced above average amount of rainfall and in the 1960s and early 2000s and near 2010 the country experience below average amount of rainfall. Marginal reduction of rainfall has also been observed during autumn season in South Africa (DEA, 2013).

The Limpopo province experience annual rainfall of less than 500mm in most parts of the province as influenced by its semi-arid climatic conditions, while the southern part and along the eastern escarpment of the province experience high annual rainfall from 400 to 700mm (LDA, 2015; Mzezewa *et,al*.,2010).

The Limpopo province observed rainfall trends from 1993 to 2015 indicating inter-annual variations over the province as observed from Subtropical, Eastern, lowveld and escapment weather stations based in Lephalale, Mokapane, Tzaneen, and Phalaborwa (DEA, 2012)).

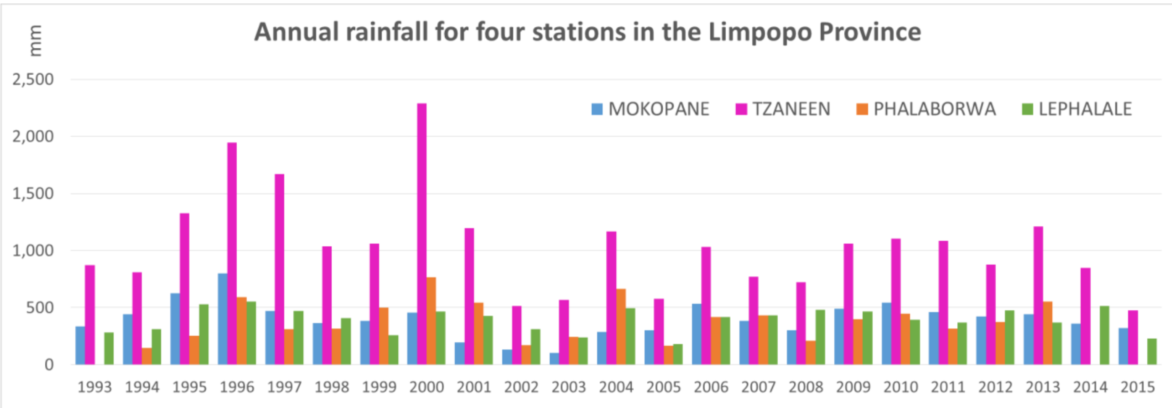


Figure 9: **Limpopo annual rainfall based in 4 weather stations from 1993-2015**
Source: DEA, (2012)

2.4. Climate change predictions

Global and regional circulation models may be used to project the future climate, globally and regionally. The Long Term Adaptation Scenario Flagship Research Project (LTAS) of the Department of Environmental Affairs (DEA) in South Africa projected the regional future climate change predictions in South Africa. These projections were based on the dynamic downscaling of global climate models using a regional climate model, the Conformal-Cubic Atmospheric Model (CCAM) (Engelbrecht *et al*., 2011), and on a Statistical Downscaling methodology (Hewitson and Crane, 2006).

The CCAM projections were performed at the Council for Scientific and Industrial Research Organization (CSIR) and the Commonwealth Scientific and Industrial Research Organization (CSIRO). The statistical downscaling was performed by the Climate Systems Analysis Group (CSAG) of the University of Cape Town (UCT), these scenarios have been generated for a high mitigation scenario. The A2 scenario (also known as the "business as usual" scenario) was constructed in the year 2000 as part of AR4 of the IPCC. It is a negative (high emissions/ low mitigation scenario), however, every year since 2000 greenhouse gas concentrations were increasing at a faster rate than predicted by the A2 scenario. In AR5 of the IPCC, an even more negative scenario (RCP8.5) has received a great deal of attention, as this is the pathway the world is currently on (Figure 10).

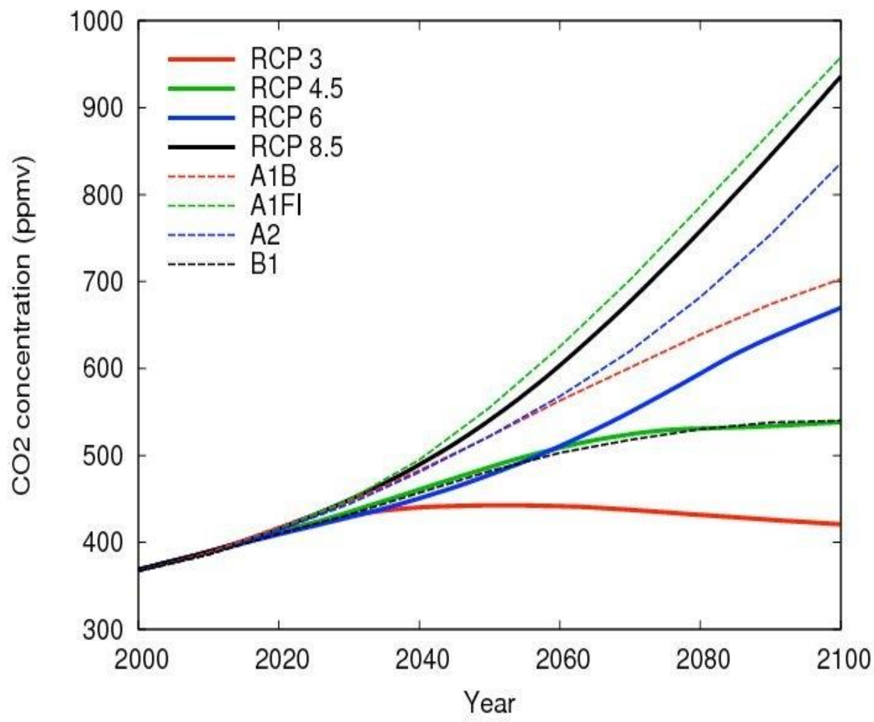


Figure 10: Representative concentration pathway

*Source: (*Jub *et.al., 2016)*

According to LTAS (2013) South Africa's climate future projections were performed at a national level indicating different degrees of climate change conditions. Different climate change conditions identified as the warmer and wetter climate conditions with high frequency of extreme precipitation at <3°C above the year 1961 to 2000; warmer and wetter conditions with warmer and drier conditions increasing in the frequency of drought conditions and somewhat greater frequency of extreme rainfall events at <3°C above the year 1961 to 2000; warmer and wetter climate conditions warmer and drier climate conditions increasing in the frequency of drought conditions and indicating hotter and wetter climate with high frequency of precipitation at >3°C above the year 1961 to 2000; and lastly hotter and drier climate conditions substantially increasing the frequency of drought conditions while showing high frequency of extreme precipitation at 3°C above 1961 to 2000.

In South Africa future projections of different climatic zones has been identified using statistical and dynamic downscaling of climate projections for rainfall and temperatures and the numbers indicated in Table 1 are from CCAM model projections.

Table 3*: Projected changes in the Limpopo climate zone*

Source: LTAS Phase 1, Technical Report (no. 1 of 6),(2013)

Zone 1 (Limpopo)	Near term (2015 – 2035)	Mid-term (2040 – 2060)	Long term (2080 – 2100)
Temperature	Mostly within the range of current variability, but showing an annual anomaly (increase) of about 2 °C towards the end of the period under RCP8.5	Average annual increases of between 2 and 4 °C	4 – 7°C average annual increase in temperature under RCP8.5, substantially exceeding historical variability. 2 to 3 °C under RCP4.5
Rainfall	Increased drying under both the RCP 4.5 and RCP8.5 scenarios but still within the range of current climate variability.	Increased drying under the RCP 4.5 and RCP8.5 scenarios strengthening over time, but within the range of current climate variability.	Increased drying under RCP 4.5 and RCP8.5 scenarios strengthening over time, outside of the range of historical climate variability.

Figure 11, indicates climate variability and change in the Limpopo province where the year 1961 to 1970 is indicating high rainfall of 300mm more than the average and 1.8°C cooler temperatures. Some years are wet and warm and some years are wet and cool. As we move over time towards the year 2040 to 2080 the climate is becoming dryer and warmer and at the end of the century, the Limpopo province will be significantly dryer.

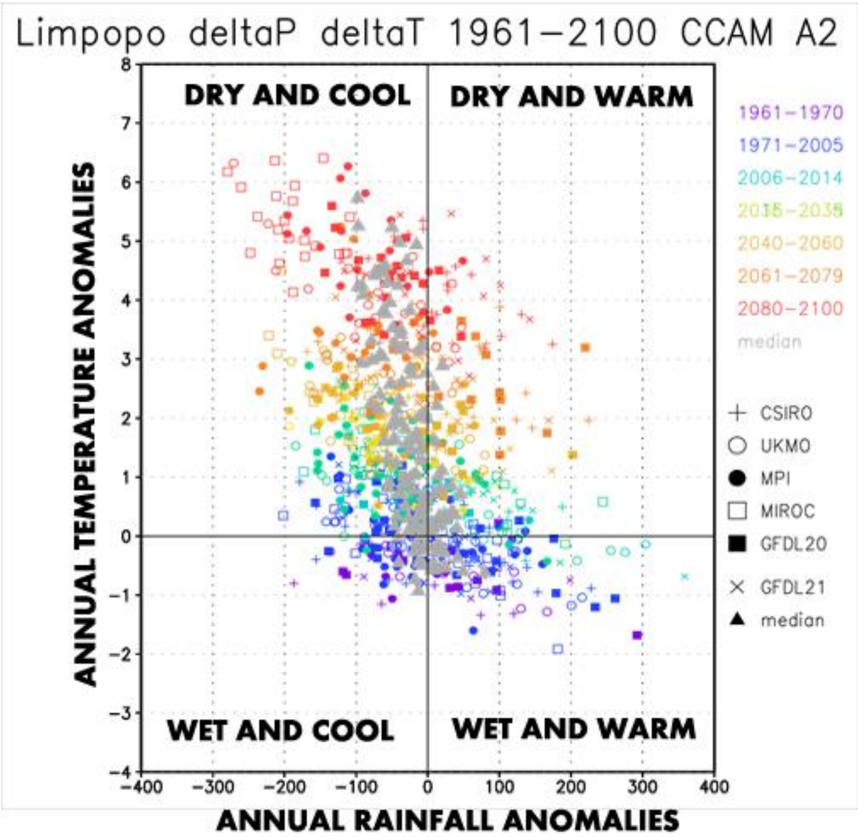


Figure 11: Projected changes in temperature and rainfall over Limpopo province

Source: (LTAS Phase 1, Technical Report (no. 1 of 6),(2013))

The uncertainty of plausible future climate change projections may be determined by the diversity and rapid changes of rural community's vulnerabilities and the random occurrence of extreme events. However, the existing historical information plays a major role in identifying extreme events that happened in the past and their related impacts and therefore it is important to take account the observed climate change trends and plausible future climate change projections for future planning.

2.5. Climate Change Vulnerability in rural communities

Understanding the role of climate change vulnerability and resilience between the ecosystem and the rural communities is important in climate change response in terms of systems and actors to change. The ecosystem and rural communities are expected to respond to disasters that have occurred unpredictably as a result of natural or man-made causes affecting social, economic and environmental disruptions and destructions, and in some instances the communities might not have required or enough resources to cope and respond to the impact (National Disaster Management Framework (NDMF) of 2005, IPCC, 2013, UNISDR, 2007). Natural or human made caused events results in disasters which may have been influenced by the occurrence of hazards, state of social and economic vulnerability and ineffective risks reduction measures.

Most research studies put their main emphasis on vulnerability assessment focusing on the social or ecological systems that result in the gap in evaluating linkages between social systems and ecosystem that may play a major role in climate change vulnerability assessment (Ericksen, 2008). Vulnerability is defined as the conditions that cause rural communities, ecosystems or any social or economic asset to be susceptible to destructions caused by the effects of a hazard (UNISDR, 2009).

According to the South Africa National Disaster Management Framework of (2005), hereafter will be referred to as NDMF (2005) defines vulnerability as the degree that rural communities as per household individual members or a group, geographical area, social and economic development areas are highly impacted by the occurrence of a hazard. The state and conditions of vulnerability and susceptibility to the effect of hazards in the rural communities are determined by the physical, social, economic and environmental factors. Thus some studies define vulnerability to climate change on geophysical, biological and socio-economic systems considering the degree in which they are susceptible and the ability to respond to the effect the changes in climate in terms of their coping capacity (IPCC, 2015; NDFM, 2005). It is therefore important for vulnerability to be considered in disaster risk reductions with the main focus on rural communities' livelihoods and agricultural practices in terms of food security. By considering vulnerability in disaster risk reduction will also add more value in approaching climate change in terms of rural communities' exposure, sensitivity, coping and adaptive capacity (Fortini *et al.,*2017). Hazard, vulnerability and coping capacity represent the disaster risk process (Alexander, 2012).

Vulnerability can be led by many factors such as increasing population growth, improper and insufficient planning by all spheres of government. Population growth can be influenced by immigration from neighbouring countries and this further lead to overutilization of ecosystem resources by the rural communities resulting in environmental degradation, application of poor buildings architecture, low educational level and high level of poverty (Philip, *et al.,* 2004).

Singh *et al.,* (2014) indicated that climate change vulnerability focuses on social inequalities such as the response of different social groups on a specific impact of hazards and their ability to cope and recover form hazards impacts and the dynamics that occurred affecting social issues (e.g. gender , class, race, culture, nationality, age amongst others). Social class in the rural communities determine the status of rural communities in terms of the type and stability of employment, level of education, the type of infrastructures (e.g. houses), health services amongst other factors that influence economic and social losses during the occurrence of hazards or disaster risks (Singh *et al.,* 2014). In the rural communities where there are different races and ethnicity groups, vulnerability is driven by limitations in the access to resources considering the language, culture and educational level (Emrich and Cutter, 2011). Climate change vulnerability in the rural communities is measured based on identified vulnerable systems associated with sensitivities systems (e.g. ecosystem) that serves on water and food supply, infrastructure and health (Emrich and Cutter, 2011).

IPCC (2015), argued that potential impacts of climate change can be measured using quantitative, quantified and qualitative methods. Climate change potential impacts can be measured in terms of financial impacts where factors such as income or revenue losses to farmers for instance during drought conditions, costs that may be acquired when the rural communities are trying to adapt to climate change impacts. Potential impacts can also be measured by determining the number of rural communities that have been affected through for instance, their agricultural products and that further affect their food security, water scarcity, loss of lives through diseases and migration from one place to another. All this can be measured by applying the quantitative methods of measuring climate change impacts. The potential of climate change can also be measured using the quantified methods which focuses on biophysical conditions considering aspects such as changes in agricultural production and the rate of species extinction. Potential impacts can also be measured using the qualitative method on the base of social preferences in relation to the loss of identity culturally and on a national scale in terms of heritage sites and biodiversity amongst others.

As Emrich and Cutter (2011) indicated, climate change vulnerabilities are measured in terms of magnitude and timing amongst other things, in that regard the measurements can be done in consideration of geological, hydrological, meteorological and biological hazards caused by natural and human processes. Hazards potential impacts include causing destructions to properties, environmental, social and economic aspects as well as the loss of human and animal lives (UNISDR, 2009; IPCC, 2012; Brooks, 2003). Wisner *et al.,* (2003) discussed that the vulnerability in the rural communities of a certain type determines the magnitude and time frame in that specific area. Due to variations in communities, the possibility of reacting differently to disaster risks is high due to different coping mechanisms and different socio-economic and cultural values (Wisner *et al*., 2003). The impact of hazards affects different rural communities differently on different time frames and magnitude. Under such conditions, different rural communities will react differently to disaster risks and the coping mechanisms will highly differ due to different socio-economic and cultural values (Wisner *et al.,* 2003). Rural communities which are comprised of more poor community members are considered to be at high risk in disaster risks more as compared to more developed communities with coping mechanisms such as social, economic, physical, political or environmental capital (WWF, 2017).

In responding to disaster risks and climate change vulnerability impacts, it is important to take into consideration timing. Timing considers the rate at which disaster risks or climate change impacts occur. Severe thunderstorms may occur suddenly and unexpectedly resulting in the severe damage to infrastructures in the rural communities in a very short period of time. Extreme events such as heat waves and drought impacts may occur gradually over time and in such events, resource allocation may become a concern due to underestimating the magnitude that has affected rural communities. Assessing uncertainty of climate change by taking into account the likelihood and confidence in relation to the occurrence of the impact is important. Likelihood shows the possibility of the impacts that has occurred or is expected to occur in future and confidence indicates that the predicted impacts are correct (IPCC, 2016) Disaster impact is considered a key impact when it shows a higher probability of occurrence and the higher its risk (Alexander, 2012).

IPCC (2015), further argued that if the impact in a particular area becomes harmful or dangerous to the rural communities and need to be monitored and managed as the key impact if it continues to occur and reaches and irreversible state. For instance, drought conditions can result in close to permanent damage where the condition cannot be restored leading to changes in the social and ecological system to another land use.

It is of the utmost importance for rural communities to adapt to impacts of changes in climate. If rural communities are unable to adapt to changes in the impacts of climate therefore those impacts are considered a key vulnerability. It is therefore important in rural communities adaptation strategies and assessments to take into consideration the availability of required financial and human resources, training and capacity building, knowledge transfer, development and implementation plans, and adaptation strategies compatibility with individuals in the rural communities and their cultural preferences (Phiri, 2014).

2.6. Climate Change Resilience in rural communities

Recent studies indicated that climate change will impact on the geophysical systems, biological systems and socio-economic systems that will lead to the changes in their original state (IPCC, 2007; Ciscar *et al*., 2010). Resilience plays a role in the understanding of response to systems and actors to change. Changes that have occurred over rapidly and relatively long multi-decadal periods while exceeding the key thresholds may come as a shock and surprise to social or ecological systems (Ciscar *et al.*, 2010).

The World Disaster report of 2015, defined rural community's resilience as a set of characteristics, future goals, existing resilience capacity, current and future vulnerabilities and their own tolerance for disruption. It is therefore important when assessing rural community's climate change resilience to take into account the local knowledge and abilities as it plays an important role in finding unique solutions that reduce underlying risks because of their understanding of local contexts of aspects such as weather patterns and vulnerabilities. Local communities and knowledge further aid in playing a vital role in addressing future disaster risks and threats (IFRC, 2016).

A debate between adaptive capacity and resilience is found amongst so many researchers. Some researchers refer adaptive capacity as resilience (Nyamwanza ,2012). After the occurrence of disaster risks, rural communities and ecological systems are supposed to cope and recover from the effects of those risks and the ability to cope and recover while retaining and maintaining the original state of the environment while preserving the original functions and structures is regarded as the community that is being resilient towards disaster risks impacts (Ching, 2016). Rural communities, if they are resilient towards the occurrence of disaster risks, have the capability to learn from previous disaster experiences and are able to plan for the future and improving disaster risk reduction measures.

The state of environmental conditions, the manner in which people manages and maintains the natural systems and the state of demographic and societal conditions characterise the resilience process (NCCARF, 2016). Resilience has two dimensions which indicate resilience of agents or actors including people, social organizations, individuals, households, community organizations, spheres of government amongst others and resilience of ecosystems, infrastructures, institutions and knowledge that play a role in the support of rural communities (Krishnaswamy *et al.,* 2012; IFRC, 2016).

Miller (2010) reported that to assess climate change resilience and rural communities, it is important to consider the interaction between long term changes and factors that drives climate change and in some instances rapid changes in the occurrence of disaster risks such as unexpected flooding, a change in the leadership structures such as political structures causing economic crisis. In his report Miller (2010) indicated that rural communities interact and depend on the ecosystem in their everyday lives thereby utilising ecosystem resources (e.g. water for drinking, cooking, and agricultural productions such as cash crops, livestock, and so forth). Miller (2010) further indicated that most rural communities consider agriculture as an important economic development resource, and the quality of agricultural production, water sources are influenced, the climatic conditions on a local scale and atmospheric CO_2. Agricultural activities occupy and utilise most parts of the rural land and water sources, playing an important economic role in many rural communities (Ciscar *et al.,* 2011). Climate change resilience between rural communities and the ecosystem should be sustained by maintaining diversity and redundancy that will promote different components to play a role in the sustainability of the interaction between the ecosystem and the rural communities (Ciscar *et al.,* 2011).

The interaction between the social-ecological systems and rural communities can be strengthened and maintained by managing connectivity between the ecosystem and the rural communities. Strengthening and maintaining the interaction between the ecosystem and the rural communities play a major role during disaster events in terms of ensuring that e both rural communities and the ecosystem recover quickly. In cases where the ecosystem and the rural communities are not well connected these may lead to the rapid spread of disturbances or increase in the hazard across the entire system and results in all the systems highly impacted (Simonsen *et al*., 2016; Ingram *et al.,* 2012). There are cases and conditions where disaster risk reduction is not sufficient enough, as an example, where natural environmental systems become own major drivers of disaster risks. For example, already degraded ecosystem or the environment in other instances worsen the effect of natural hazards, by destroying physical processes that affect the extent, frequency and the period of hazards (Kamble *et al*., 2013).

Managing slowly changing variables that may negatively impact the ecosystem is also important. For example, managing feedbacks such as chemicals that can contaminate groundwater and affect the quality of the water, managing social domains, legal systems, values and traditions of the rural communities (agricultural practices in the application of fertilisers may result in phosphorus and nitrogen levels in the water that eventually exceeds the absorptive capacity of the plants) (Simonsen *et al*., 2016). Another example include the managing of the potential impacts of gradually increasing temperatures such as an increased concentration and range of pests and pathogens that comprise human and livestock disease vectors, such as malaria and ticks (DRDLR, 2013).

Apgar *et al.,* (2015) reported that by employing complex adaptive systems in the rural communities will enable rural communities to accept unpredictability, uncertainty and acknowledging a large number of perspectives towards the changes in the social-ecological systems. Apgar *et al.,* (2015) further indicated the importance of actors within the social-ecological systems, their importance and their understanding on how actors within the system think and how their mental models influence the actions they take (Simonsen *et al*., 2016; Apgar *et al.,* 2015).

Tschakert and Dietrich (2010) define resilience as anticipation, dealing with change, adapting and transforming in response to change and continuously learning about the interaction, development or change between the socio-ecological system and rural communities by revising existing knowledge to enable adaptation to change and approaches to management. Existing and available knowledge from rural communities of different types and different sources on decision making opening new ideas and opportunities in the climate change resilience of the rural communities is important. Continuing with the process of building knowledge management systems, positively contribute in the improvement of the stakeholder participation through active engagement of all relevant stakeholders that are important in building socio-ecological resilience in rural communities (Krasny et.al, 2015). Active stakeholder engagement further builds trust and relationships between stakeholders such as scientists and rural communities, for example, needed to improve the legitimacy of knowledge and authority during decision making processes. The success in building partnerships or relationships between relevant stakeholders, contributes positively to the formation of polycentric governance where governing bodies are able to interact to make and enforce rules within a specific policy arena and this will further improve active collaborations or participation across different government and organisational institutions thereby promoting connectivity and improve decision making processes through acquiring knowledge, appointing the relevant people and promote learning across different levels and cultures.

The state of finance, politics, and institutions in rural communities can determine the ability for those rural communities to be resilient towards climate change by considering interactions, interconnections, and interdependence between human and biophysical components and also considering the nature of the resilient process which needs to be flexible, learned and changed. Resilience is independent nature towards exposure to shocks and stresses caused by disaster risks. Resilience is also an important tool that can be utilized to test the assumption for all rural communities and environmental systems to acquire knowledge from previous exposure. In the resilience process, dynamics in relation to social issues of power and sense of agency is important. It is important to strengthen resilience in the rural communities based in the short term aid to reduce resilience in the long term and further, highlight temporal dimension to resilience (Folke, 2006, Adger *et al.,* 2005; Twyman *et al.,* 2011, Walker *et al.,* 2006),

2.7. Relationship between Vulnerability and Resilience

There is a link between vulnerability, resilience and adaptive capacity on the biophysical environment in relation to climate sensitivity in terms of social or economic factors that can reduce the consequences of changes in the environment (NCCARF, 2016). The relationship between ecosystem and rural community's vulnerabilities, resilience and adaptive capacity need to be highly taken into consideration as understanding the root cause of vulnerabilities, the ability that rural communities and the ecosystem have towards climate change resilience and adaptive capacity is crucial on resource allocation when building on current strengths and on opening new opportunities for support (Table 2).

Table 4: **Sectors and varibles used in the vulnerability-resilience indicators (VRIM)**

Source: (*NCCARF ,2016)*

Sectoral indicators	**Proxy variables**	**Proxy for**
Food security	Cereals production/ crop land area	The degree of modernization in the agriculture sector; access of farmers to inputs to buffer against climate variability and change.
	Protein consumption/capita	Access to the population to agricultural markets and other mechanisms (e.g. consumption shift) for compensating for shortfalls in production.
Water resource sensitivity	Renewable supply and inflow of water	Supply of water from internal renewable resources and inflow from rivers divided by withdrawals to meet current or projected needs.

Settlement/ infrastructure sensitivity	Population of flood risk from sea level rise	Potential extent of disruption from sea level rise
	Population without access to clean water	Access to population to basic services to buffer against climate variability and change
	Population without access to sanitation	
Human health sensitivity	Completed fertility	Composite of conditions that affect human health including nutrition exposure to disease risk and access to health services
	Life expectancy	
Ecosystem sensitivity	% Land managed	Degree of human intrusion into the natural landscape and land fragmentation
	Fertilizer use/ cropland area	Nitrogen phosphorus loading ecosystems and stresses from pollution
Human and civic resources	Dependency ration	Social and economic resources available for adaptation after meeting other present needs
	Literacy	Human capital and adaptability of labor force
Economic capacity	GDP (market)/capita	Distribution of access to markets, technology, and other resources useful for adaptation
	An income equity measure	Realization of the potential contribution of all people
Environmental capacity	% Land unmanaged	Landscape fragmentation and ease of ecosystem migration
	SO2 per area	Air quality and other stresses and ecosystems
	Population density	Population pressure and stresses on ecosystems

It is clear from Table 2, that changes in climate will lead to the insecurity of food production and supply as a result of a reduction in the production of crops and therefore there will be more demand and low supply of food resources. Water scarcity will rise as a result of air pollution. Settlements will be affected by the rise of and shortage of acceptable quality of water. The wellbeing of the human population will be affected in a form of infertility and reduced life expectancy. Ecosystems services will be scarce due to both anthropogenic and natural changes. The impact of climate change adaptation can be easily addressed by meeting social and economic needs of rural communities while allocating the required resources for current and future needs. Economic adaptation resource that is required in the rural communities that might be affected by the changes in climate and can be useful includes GDP as per capita, access to local and global markets, the introduction of new technology amongst others. There will be economic impacts such as the challenges will arise in the sustainability of the environment; this will be perpetuated by high population density which puts pressure on the environment.

Climate impacts may vary according to different communities and may result in important distributional consequences. Different rural communities may value impacts and vulnerabilities differently in relation to both human and natural ecosystems (Adger, 2006).

In order to identify and respond to climate risks and vulnerability of a specific rural community it is best to take into account the national risks such as risks that occurs in the whole country so that it is easy to develop a guiding analytical framework for understanding generic risks and vulnerabilities in terms of typological characteristics of rural human settlements. As adopted from DRDLR Climate Change Adaptation Sector Strategy for Rural Human Settlements of 2013**,** three typologies have been identified in order to provide constructive vectors for analysing the vulnerability of any particular community or location. They are informed by the understanding that vulnerability is a product of institutional arrangements, including systems of administration and governance such as land ownership. The interactions of social, economic and demographic factors accompanied by high poverty levels, high unemployment rates, population density and access to basic services contribute to the climate change vulnerability. Table 3 below indicates community typology, drivers of vulnerability and adaptive capability.

Table 5: Community typology, drivers of vulnerability and adaptive capability

Source: DRDLR, (2013)

Community Typology	Drivers of vulnerability	Adaptive capability
Institutional: Local government arrangements, Administration of land	Insecure land tenure/lack of access to land, gender discrimination, corruption, lack of public awareness, inadequate disaster preparedness, inappropriate technologies	Integrated and participatory planning, equitable and transparent resource allocation, civic participation, timely flow of information and warnings
Socio-Demographic: Community profile and size Services and infrastructure	Poverty, inequality, lack of access to infrastructure and services, population density	Appropriate sanitation solutions Rainwater harvesting Sustainable energy solutions Sustainable agriculture Economic opportunities and growth
Bio-Spatial: Coastal/inland East Coast/West coast Summer /Winter rainfall	Breakdown of eco-systems services Dependence on climate sensitive natural systems Vulnerability to coastal erosion/flooding/droughts	Restore and conserve integrity of ecosystems Relocate buildings/communities Irrigation

In order to manage risks and increase resilience within the context of climate change, it is of the utmost importance to consider who and what is vulnerable to extreme weather, while taking into consideration how climate change will affect the existing climate risks or how it will develop new risks that will affect the future and provides a framework for action. Chapter 3 provides an overview of current insights into the plausible climate future projections of South Africa and the Limpopo province, climate change predictions for South Africa, the impact of climate change on rural communities and the disaster risk and climate change in the MDM and the Limpopo province at large.

2.8. Conclusions

Rural communities structured their everyday lives around historical and current climate conditions. Rural communities practice rain-fed agriculture of which sustainable development of production is influenced highly by the unpredictable rainfall and temperatures. The availability and quality of surface water is affected by an increase in temperatures which is accompanied by the number of warm and very hot days due to the impact it has caused on the evaporation affecting surface water while reducing the quality of soil and promoting soil degradation that has resulted from increased acidity, nutrient depletion and at the same time reducing the microbiological diversity, lowering water retention while increasing runoff. Temperature increases also play a positive or negative impact on crops and growing season length depending on local topography, precipitation, and crop types. An increased number of warm and hot days also result in the occurrence of heat waves which have an impact on human and livestock health from heat stress, particularly for the very old and young, and those already suffering from illnesses. Heat waves also result in the risks of veld fires that impacted on the crops, property, and infrastructure (Schär, 2015).

Rural communities that are dependent on the surface water resources for agricultural practices and domestic use will be faced with a shortage of water during the period when temperatures increase causing an increase in the number of consecutive dry days while decreasing runoff and stream flow. Impact on the loss of soil moisture will affect crops and increase the risk of soil erosion due to the wind and this will further increase the risk of veld-fires and resultant damage to property, grazing, and crops (Polade, 2013; Alexander, 2016).

Occurrences of floods decrease temperatures while increasing the number of wet days in an extreme rainfall event (Alexander, 2016). The impacts of floods damage properties and crops from winds associated with violent storms, loss of life (human and animals), increased risk of water borne diseases, damage to water infrastructure, irrigation systems and water reticulation. The occurrences of extreme rainfall in a form of thunderstorms are usually accompanied by lightning which is associated with death in the rural communities.

Rural community's sustainable economic development and poverty eradication are faced with an increasing big threat of climate change and disaster risks. It is therefore important for rural communities and relevant stakeholders to engage in the integration of climate change and disaster risks strategies and plans for future planning of rural development for the benefit of sustainable rural livelihoods. Disaster risks are affected by climate change as a results of potential increase in weather conditions and climate hazards, and an increase in the vulnerabilities of the rural communities to natural hazards (e.g. land degradation that negatively affect the state of the ecosystem, reduction in water and food availability and the changes in the rural communities' livelihoods). An increased impact of climate change coupled with the existing impacts of disaster risks pose more pressure on the environment that has already been affected negatively, for example, by land degradation, an increased population growth which results in rural communities to settle in unplanned settlement areas and that will result in the reduction of rural communities' abilities to cope with even the existing levels of weather hazards

Limpopo province is faced with the influx of immigrants from the neighbouring countries that contribute to population and economic growth that is considered to be drivers of climate change. The main economic sectors that are contributing to the impact of climate change in the province includes the power generation from coal and the power stations which are the main source of $CO2$, mining related activities, high flow of vehicles and heavy duty vehicle such as trucks that delivers goods in countries such as Mozambique, Zimbabwe, Botswana and other African Countries. Limpopo province is dominated by rural areas where it is dominated by poor sanitation which results in Methane emission. Agricultural practices that include deforestation and land transformation, methane emissions from cattle and game and the application of fertilizers drives the changes in climate in the rural communities and around the globe

The next chapter 3 gives a brief background of MDM and also highlighting social and economic status of rural communities with MDM.

CHAPTER 3: STUDY AREA

3.1 Geographical location

The research focused on the Mopani District Municipality (MDM) in the Limpopo Province (Figure 12). MDM geographical location is situated in the north-eastern part of the Limpopo Province, which is about 60 km East of Polokwane. MDM consists of five local municipalities which are the Greater Giyani (87.4% rural); Greater Letaba (93.3% rural); Greater Tzaneen (82% rural); Maruleng (88.7%rural) and Ba-Phalaborwa (84.9% rural) (StatsSA, 2011).

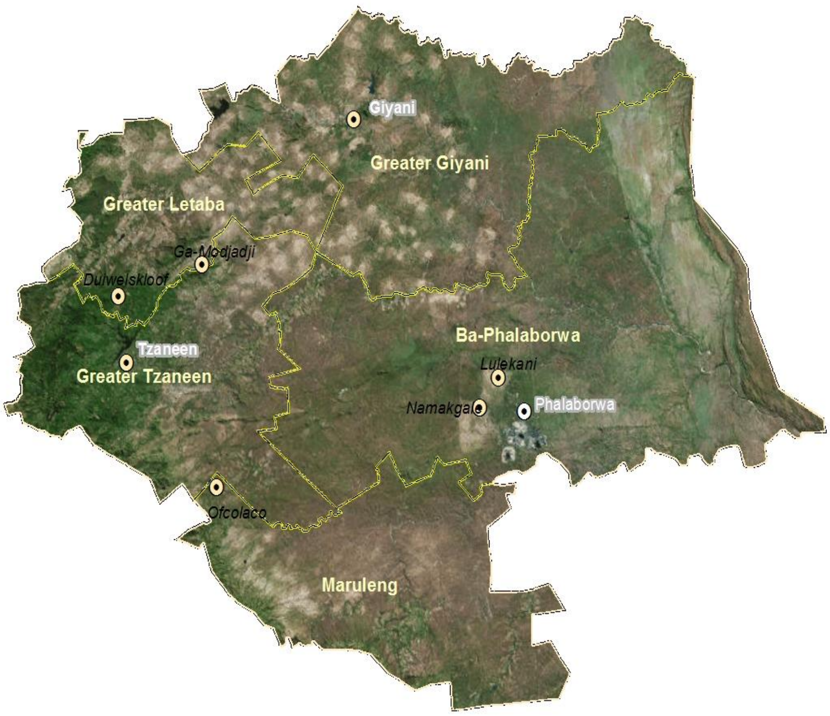


Figure 12: Geographical location (Mopani District Municipality)

Source: (Author: Khwashaba ME, 2016)

3.2. MDM living conditions, economy and agricultural statistics

Natural disasters such as drought, heat waves, floods and veld fires impacted on the environment and people from rural areas that live in it. It is therefore important for the rural communities to improve and be ready for the stresses and shocks that resulted from natural disasters in order to be able to cope and recover from the changing environment around them. For sustainable rural development after the occurrence of natural disasters, rural communities are urged to be able to maintain and improve their living standard, taking into account their living materials, social assets and economic opportunities taking the impact on their natural environment.

Socio-economic conditions in the rural communities are very important in the current lives of the rural communities and in their future lives as they play crucial roles in their everyday lives as individuals or as a family for their social and economic status (User, 2016).

Figure 13 indicate the number of Child, Female and Elderly headed household (Y-axis) per local municipality (X-axis). Child headed household is highest in Greater Giyani by 4.02% and lowest in Ba-Phalaborwa by 1.34%. Female headed households are highest in Greater Giyani by 57.3%, Greater Letaba by 56.8%, Maruleng by 53.7% Greater Tzaneen by 47.8% and lowest in Ba-Phalaborwa by 39.5%.Female and elderly headed families may have social concerns such as high level of poverty due to gender inequalities in the labour market. These social concerns may result in the spread of diseases such as malnutrition, diarrhoea and so forth.

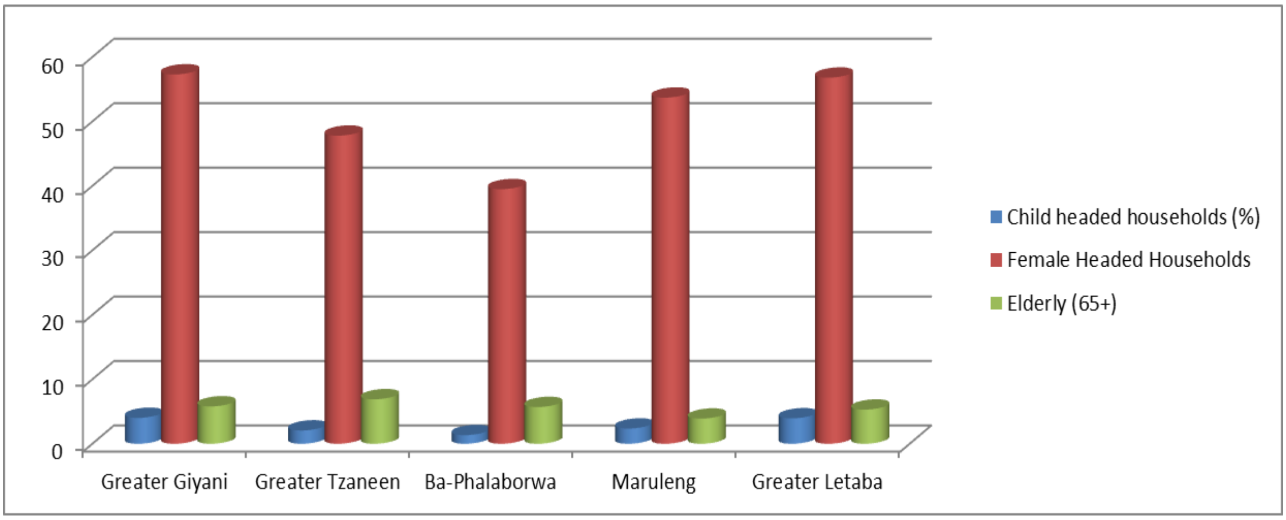


Figure 13: MDM households heads (Female, Children and Elderly)

Source: StatsSA, (2011).

MDM has estimated medical scheme coverage of 9.4% and falls into socio-economic Quantile 2. Children under five (5) years who suffer severe acute malnutrition incidence has been estimated for 4.7 per 1000> TB (pulmonary) case findings of index 2.1% and this has been reported as fluctuating over the years. Children under five (5) years who suffer from diarrhoea with dehydration incidence increased from 14.6% during the past years to 21.3 per 1000 children in 2013/14 (The District Health Barometer of the Health Systems Trust of South Africa 2013/14 report edited by Broumels M, 2014). In order for the female headed families that dominate rural communities of the MDM and other rural people to sustain their livelihood, they need employment to provide them with sources of income and to have access to credits. Educational level of people in the MDM is very low and that resulted in the high number of people to be non-competitive in the professional market and not economically active. Census 2011 indicated the high number of the unemployment rate in the MDM rural communities. Figure 14 indicate the number of employed, unemployed, not economically active people and discouraged seek workers (Y-axis) per local municipality (X-axis). Unemployment rate is highest in Greater Giyani by 47%, Greater Letaba by 40.3%, Maruleng by 39.9%, Ba-Phalaborwa by 37.4% and lowest in Greater Tzaneen by 36.7%. Figure 5 shows average household income majority earn between R9601-R19600 with Greater Litaba by 26.0%, Maruleng by 25.1%, Greater Tzaneen by 25.0%, Greater Giyani by 21.8% and Ba-Phalaborwa by 18.7%. Followed by income from R19601-R38200 with Greater Tzaneen showing 22.0%, Greater Letaba with 21.0%, Maruleng with 20.2%, Ba-Phalaborwa with 18.% and lastly Greater Giyani with 18.7%

Due to rural conditions dominating MDM, 25,9% of the people who are mostly disadvantaged and illiterate are employed in the farms and 39% are employed in the government and the percentage of people that are employed in the government is in the Greater Giyani Municipality. The other sector that employs people in the MDM includes industries (mining, trade) and private sectors such as transport, tourism, manufacturing, construction, and energy.

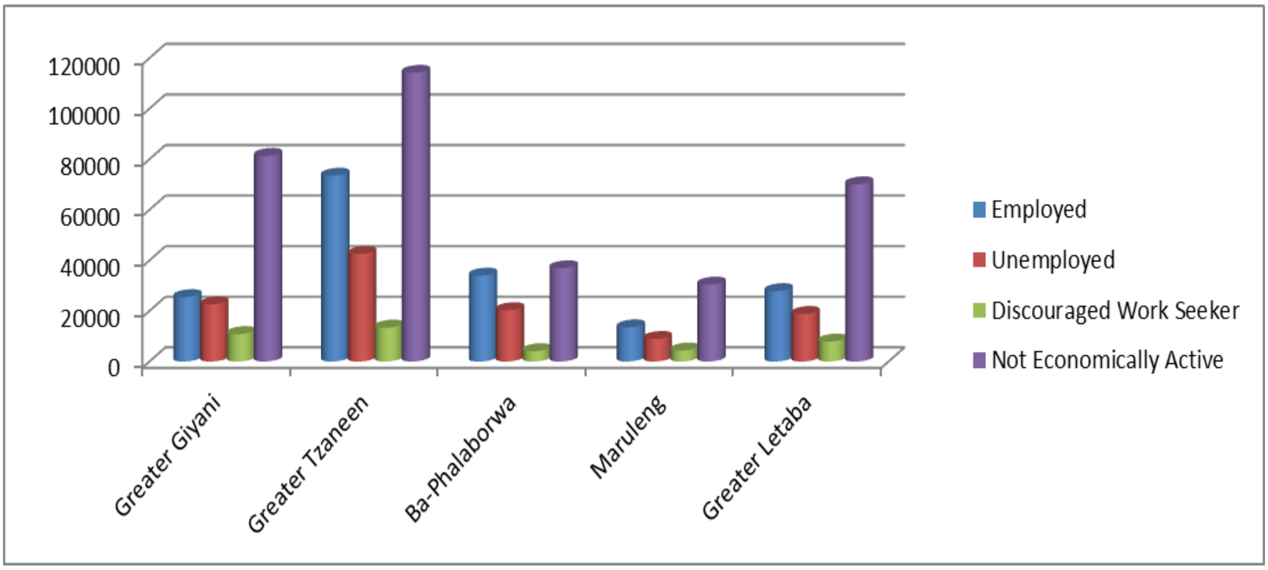


Figure 14: MDM employment status

Source: StatsSA, (2011).

Beside the employment opportunities in the rural communities that play a role in the sustainable development of rural people, access to basic services is also very crucial. For example, water is a need for drinking, eating, cooking and washing in the lives of people every day. Basic services in the rural communities also play a role in poverty eradication, for survival in their everyday lives, for the improvement of the quality of lives and for economic development (agro-industry).

MDM basic services are dependent on government services and where there is a lack of service by government; rural communities find ways to provide for their basic services like fetching water from the rivers and drilling their own boreholes. Figure 15 indicate the sources of water (X-axis) per local municipality in terms of percentage (Y-axis). The source of water for almost all the municipalities is regional/local water scheme (operated by the municipality or other water sources. All the municipalities also use boreholes as a source of water but the lowest percentage of using a borehole as a source of water is in the Ba-Phalaborwa municipality. Maruleng municipality depends on the rivers/ streams. MDM consists of two catchment areas which are the Luvuvhu or Letaba Water Management Area and the Middle Letaba Dam (Groot, Middle, and Klein Letaba Rivers). Storage volume for the Luvuvhu or Letaba WMA on average is now 497.88 million cubic meters (75.47%) and 30.68 million cubic meters as compared to the period of 2010 (70.8%). MDM consists of over 20 large dams, and with nine (9) dams being used for primary consumption (domestic, industrial and commercial) estimated at 273 million cubic meters per annum and the remaining dams are used for irrigation mainly for the agricultural sector and uses the greatest portion of the available yield in the district, which is estimated at 70%, leaving 30% for the other water users (DWA, 2013).

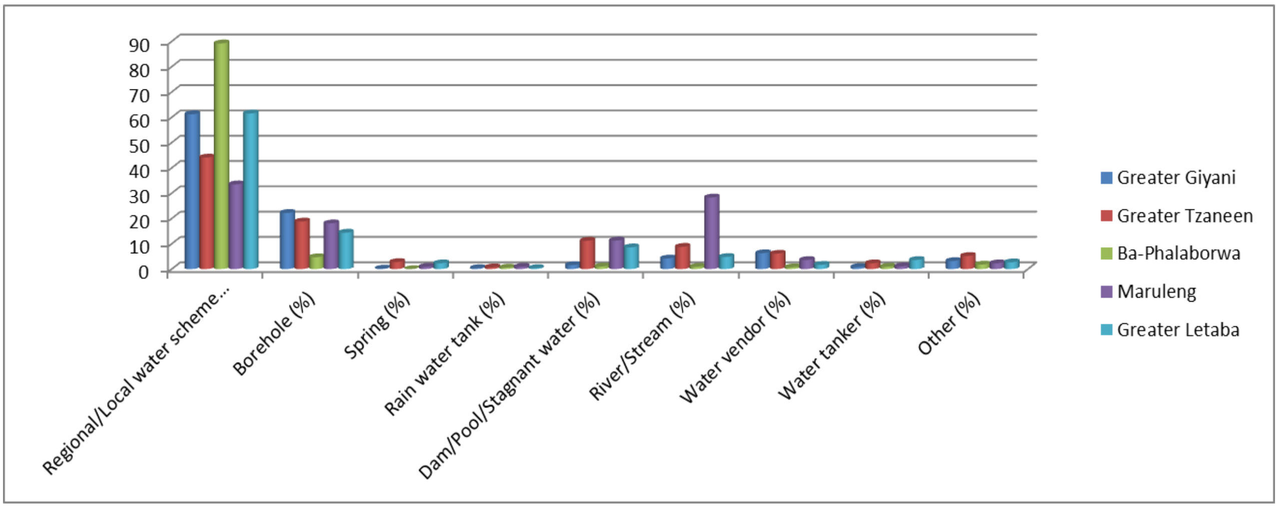


Figure 15: MDM source of water

Source: StatsSA, (2011)

Most rural communities in the MDM create their own dumping waste sites in their backyard while other urban municipal areas rendered formal sanitation services (Figure 16-17). Indicate the type of sanitation and refusal disposal (Y-axis) as per local municipality in terms of percentage. shows that the toilet facilities and sanitation is mostly pit toilet without ventilation in all the municipalities and highly used in Greater Letaba with 56.7% less used in Baphalaborwa municipality by 26,3% and only flush toilets are highly used in Baphalaborwa by 40,5%. The refuse disposal is own refuse dump in all the municipalities and highest in Maruleng by 79.3%.MDM have five waste disposal sites in the district municipality which serve the urban areas. The Tzaneen waste disposal site is the only one that has a permit to operate and is well managed. In rural areas there is no refuse removal. Residents' disposal sites are unprotected (MDM IDP, 2016/17). MDM lacks proper sanitation and this further contributes to the increase of vulnerability to heat stress or diseases and pathogens such as cholera and malaria when the extreme temperature increases.

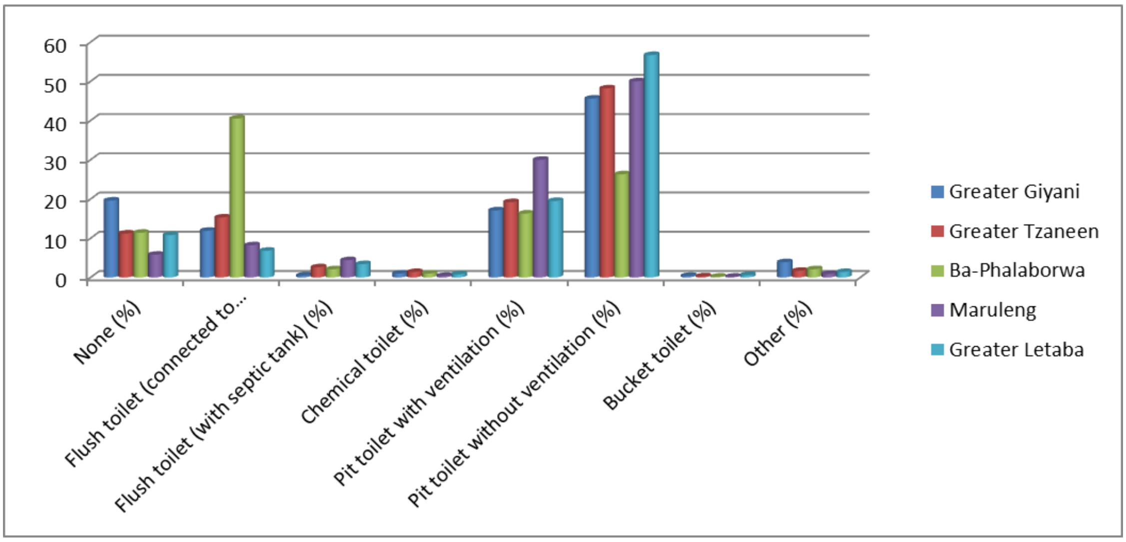


Figure 16: Sanitation

Source: StatsSA, (2011)

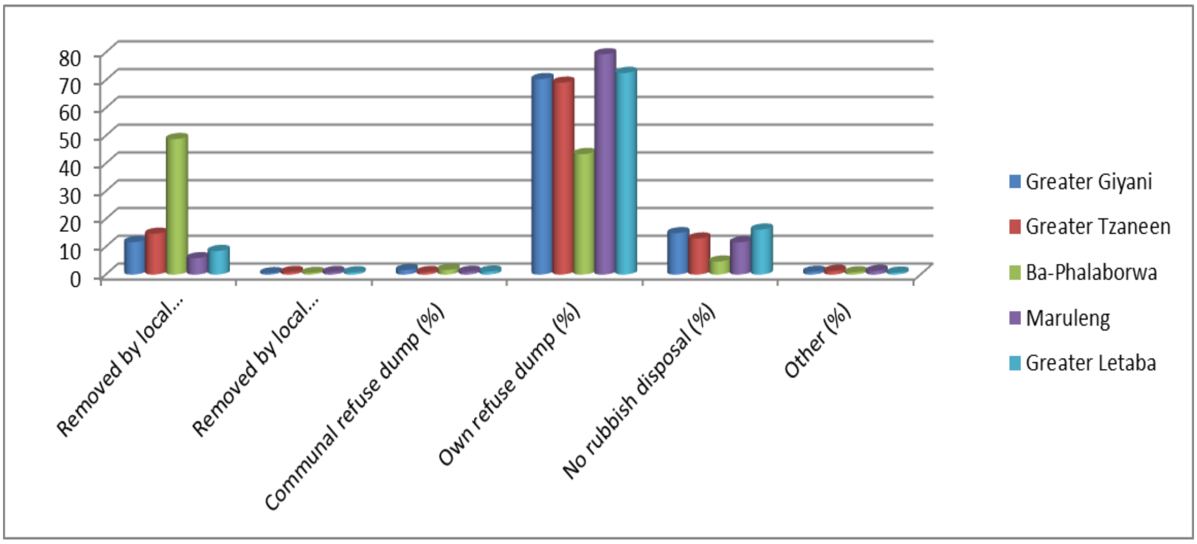


Figure 17: Refuse disposal

Source: StatsSA, (2011)

The source of energy is also the most important required basic service in the rural community's livelihood for cooking and lightning. According to Census (2011), the majority of people in the MDM utilise electricity for lightning and wood for cooking. (Figure 18) indicate source of energy (Y-axis) as per local municipality (X-axis). As the majority of people in the MDM utilises wood for cooking in their everyday lives this poses a threat to the environment and to the women as they walk long distances to collect wood and may also result in the deforestation, which may lead to the loss of species and trees that aid in the water cycle by absorbing rainfall during rainy seasons and produce water vapour released into the atmosphere that contributed positively in the lessening of water pollution. The roots of the trees also contribute positively in anchoring the soil during soil erosion. Soil erosion have a negative impact on the streams and rivers as they results in water pollution decreasing water quality and contribute to poor health in the rural communities (Live science, 2016).

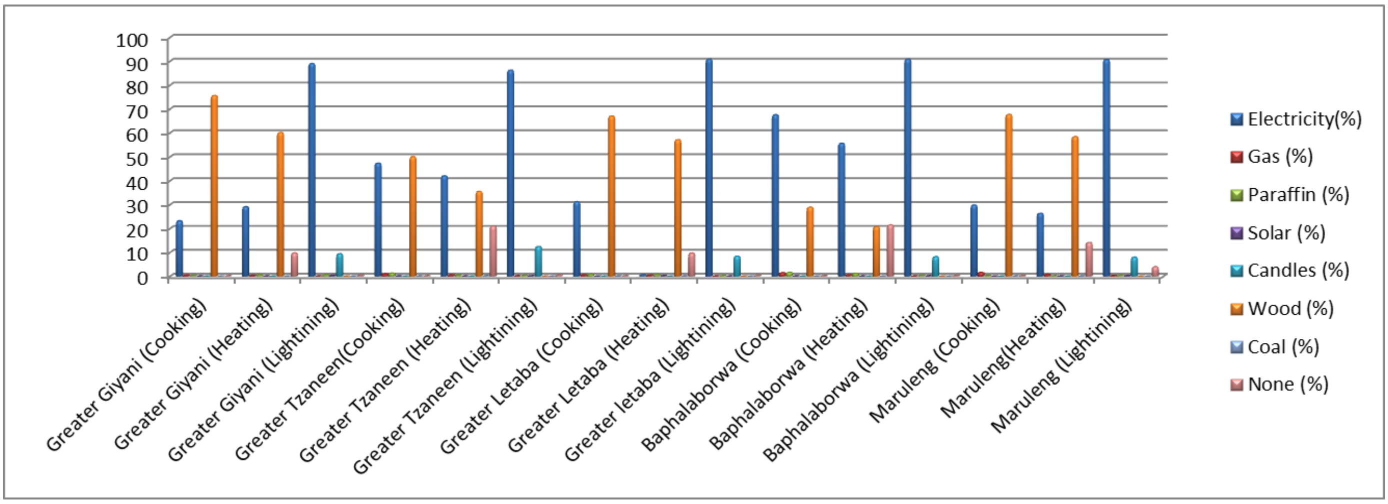


Figure 18: MDM source of energy

Source: StatsSA, (2011)

In order for rural people to feel safe and comfortable in their communities, they require infrastructures (housing, clinics, schools, roads, and telecommunications) that will also aid them in responding to the impact of extreme events. According to the MDM IDP (2016/17) the rural communities are mostly accessed by dirt roads or even footpaths. The gravel and dirt road are highly vulnerable to degradation during rains seasons and results in the difficulties in providing disaster relief services when disaster strikes in that particular rural community. MDM IDP (2016/17) also indicated the challenge of insufficient hospitals, health centres, clinics and mobile clinics in the MDM rural communities. With respect to infrastructures material that has been used for building houses Census (2011) indicated that the main construction material in the district is corrugated iron/zinc. Besides the formal housing in the district, there are other areas that are still dominated by houses that are of poor conditions due to the fact that some people live in informal housing (shacks) and others in traditional dwellings (huts). MDM rural communities are under traditional authorities where town planning is non-existent and some informal settlers just reside or settle in areas that are not suitable for residential zoning and possibly on high flood plain areas.

In order for rural communities to have a sustainable economic development based on their agricultural practises, they require access to land. Agriculture in the MDM plays a role in the employment, livelihoods, and food security. MDM rural communities rely heavily on agriculture (crops or livestock) (Figure 19) indicate the type of agricultural practice (X-axis) as per local municipality in terms of percentage (Y-axis). According to the MDM IDP (2016/17) there is a challenge on land tenure which contributes negatively in the rural communities accessing the land for utilisation for productive agricultural activities and agro-processing and these poses an economic threat for rural people as they heavily rely on agriculture (MDM IDP,2016/17)).

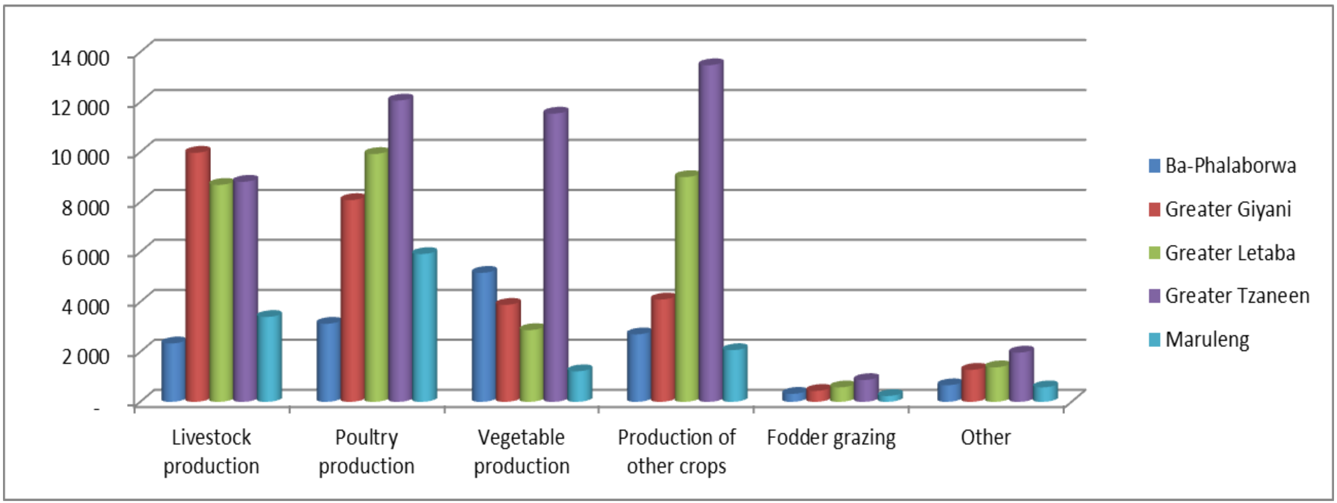


Figure 19: MDM Agricultural practices

Source: StatsSA, (2011)

3.3. Ethical Considerations

A research proposal for undertaking the study of vulnerability and resilience of local communities from the Mopani District Municipality in a changing climate has been presented to the scientific panel of the sub-program “Air Quality and Impacts” of the North-West University. The panel judged that the research study has minimal ethical risks and granted the permission to continue with the research. During focus group interviews the safety of the researcher has been considered and the time for all focus groups has been respected. The researcher travelled to the focus groups in an open and safe environment. All focus group participants were not subjected to any harm in any ways whatsoever. The researcher respected the dignity of all participants by showing respect for their views and opinions. The researcher before conducting the interviews requested the focus group to choose time and date suitable for interviews. The researcher ensured that all participants' privacy has been protected. The researcher provided an adequate level of confidentiality of all data that has been used in the study. In the formulation of questionnaires, the researcher ensured that there is no offensive, discriminatory, or any other unacceptable language. The study ensured that there is no exaggeration about the aims and objectives of the study. ACCESS bursary is the only funding which has financed the study and no any other funders. During the study period communication with all the people who contributed towards the success of the study had been done with honesty and transparency. The study acknowledges all the peer researchers or authors of the articles or references used in the dissertation.

The next chapter 4 assessed the current and predicted change of climate risks for the MDM.

CHAPTER 4: FUTURE CLIMATE CHANGE OVER THE LIMPOPO PROVINCE AND MOPANI DISTRICT MUNICIPALITY IN SOUTH AFRICA

4.1. Introduction

Global surface temperatures have been observed to be increasing by at least 1°C as a result of increasing greenhouse gases that have been influenced by industries development for the past five decades. In South, Africa temperatures have been observed as increasing significantly in the current decades. In fact, over the interior regions, the rate of temperature increase over the period of the year 1961 to 2010 has been about twice as large as the global rate of temperature increase (Engelbrecht *et al*., 2015). Generally, temperatures are increasing at a higher rate in the African subtropics than in the tropics (Engelbrecht *et al*., 2015). In South Africa, there is little evidence of pronounced changes in rainfall that can already be detected. Significant changes are confined to a small part of the southern interior (increasing trend) and the far northern parts of the Limpopo Province (decreasing trends) (Kruger, 2006).

It is likely that climate change will increasingly impact the global economy, through systematic changes in temperature and rainfall, but also through increases in the frequencies and intensities of extreme events. Urban areas and rural areas generally exhibit very different vulnerabilities to climate change. Sustainable economic development in the rural communities under climate change thus requires proper planning for the present-day climate variability and future changes that might affect the social and economic issues of rural people. Rural people are highly dependent on agricultural products that in turn are frequent rain fed and also vulnerable to the occurrence of temperature extremes.

This research focuses on climate change indicators that measure changes over time, with the indicators being temperature, precipitation, and their extremes. Natural hazards such as droughts, heat waves and high fire danger days that result from changes in precipitation and temperatures are assessed for the Limpopo Province as well as Mopani District Municipality (MDM) for present-day and future climate. The assessment is based on simulations of the regional climate model CCAM, which was applied at the CSIR to project climate over the period from the year 1961 to 2100, for both low and high mitigation scenarios. The nature and extent of natural hazards are assessed to identify specific potential hazards that could pose a potential threat or harm to people, infrastructures, livelihoods and the environment on which the rural communities in the MDM depend on.

4.1.1. Understanding climate variability and change in South Africa, Limpopo Province, and Mopani District Municipality

It is of the utmost importance to have an understanding of climate, climate variability and climate change towards planning and prioritising interventions that can prevent or at least alleviate impacts on rural communities.

Rural communities often live in close association with the variable climate system. Climate directly impacts social and economic conditions of rural communities, the type of agriculture they practice and sources of water for human consumption and farming practices (FAO, 2002). Many rural communities have experience and some resilience towards dealing with natural climate variability (as opposed to systematic change). Indeed, the climate of southern Africa exhibits a large degree of natural climate variability (Davis, 2011), where El Niño and La Niña events occur. El Niño conditions are generally associated with below average rainfall years over the summer rainfall region and result in drought conditions, while La Niña conditions are typically associated with above average rainfall conditions that sometimes result in floods conditions (Davis, 2011). This rainfall and associated temperature variations usually has a negative impact on livelihoods, food security and daily activities of rural communities and subsequently on socio-economic activities.

It should also be noted that in southern Africa many rural communities are located in semi-arid regions with high inter-annual rainfall variability. Such communities are particularly vulnerable to unreliable rainfall and temperatures anomalies in terms of agricultural yield (Davis, 2011; Stadel, 2008). These vulnerabilities are often exposed when El Niño elated droughts or La Niña related floods struck the rural areas.

An analysis of CRUTEMv4 time series data for Africa indicates that temperatures have been increasing at an alarming rate across the continent over the five decades from 1961 to 2010. Temperatures have been increasing by 3.2°C per century or even higher rates over Botswana, with temperatures increasing at a rate of about

2°C per century over much of subtropical southern Africa and North Africa (Engelbrecht, 2015). The observed rate of temperature increase is approximately twice the global rate of temperature increase in Southern Africa and Northern Africa. According to Kruger *et al*., (2011) South African annual mean temperature anomalies for 2010, based on the preliminary data from 27 climate stations, was about 0.8ºC above the reference period (1961-1990). A comparison of 27 climate stations indicated that the year 2010 has become the second warmest year since 1961. Even warmer years have since been documented in South Africa, including 2015 and 2016, although the relevant statistics still need to be published in peer-reviewed literature. Extreme temperature events have also been observed to be increasing across the southern African region. An increase in the occurrence of the number of heat-wave days contributing to an increase in the number of high fire-danger days have been observed to be increasing in future, with an associated reduction in soil-moisture availability (through enhanced evaporation), as reported in the Long Term Adaptation Scenario Flagship Research Project (LTAS) of the Department of Environmental Affairs (DEA) in South Africa In Africa (LTAS, 2013). The associated potential impacts on agriculture, water security and biodiversity are important factors indicating the need for initiating projects that focus on adaptation strategies in Africa. That is, qualitatively the message is clear that the southern Africa region is warming rapidly under enhanced anthropogenic forcing, and this should provide actionable messages for climate change adaptation.

When it comes to the detection of trends in observed rainfall patterns, patterns of statistically significant changes are less clearly discernible. Changes in rainfall distributions vary according to different places from year to year in South Africa. Statistically significant increases in rainfall can be detected over a small part of the southern interior, namely the eastern part of the Western Cape and the western part of the Eastern Cape, whilst statistically significant decreases in rainfall cab are detected over the far northern parts of the Limpopo Province (Kruger, 2006). Otherwise, trends in rainfall totals over South Africa are largely statistically insignificant. Although the study of Kruger (2006) has not considered data of the most recent period (more than a decade) this main pattern of change is still valid, as recently established by South Africa’s Third National Communication on climate change that is currently under revision (F.A. Engelbrecht, personal communication).

In South Africa, rainfall observations are indicating that the inter-annual rainfall variability has increased since the late 1960s and it has increased the occurrence of drought conditions intensively and widespread (Davis, 2011) argued. Davis (2011) was supported by LTAS (2013) report which indicated that rainfall reached its highest values of inter-annual variability in recent decades. It should also be noted that the identification of trends in rainfall totals over southern Africa is complicated by pronounced decadal and multi-decadal variability in rainfall. Rainfall has been above average in the 1970s and the late 1980s and the mid-1990s and below average in the 1960s and in early 2000 reverting to mean towards 2010 (LTAS, 2013). This variability, in combination with El Niño Southern Oscillation (ENSO) inter-annual variability is superimposed on any trends that may be occurring, and greatly complicates the robust identification of trends.

Regional climate models are indicative that the Southern African interior is likely to warm rapidly under low mitigation futures, indicating temperature increases as high as 4-6°C for the period of 2071 to 2100 relative to 1961 to 1990 (A2 emission scenario). In the interior regions of South Africa temperatures are projected to rise at twice the global rate of temperature increase (Engelbrecht *et al.,* 2015). An important mechanism contributing to this strong regional climate sensitivity is the strengthening of high-pressure systems in the mid-troposphere over South Africa (Engelbrecht *et al.,* 2009). Projected changes in the number of very hot days (annual totals) for 2071 to 2100 vs 1961 to 1990 under the A2 emission scenario indicates drastic increases in the annual number of very hot days by over the interior regions of Southern Africa. Over the Limpopo basin, the projected increases reach values of 60 to 90 per year. Drastic increases in extreme temperature events to impact on crop yield, livestock, biodiversity, and energy demand. The findings of the South African regional climate modelling experiments described above (Engelbrecht *et al.,* 2015) are largely consistent with analysis of the projections of global climate models that contributed to the Coupled Model Intercomparison Project Phase Five (CMIP5) of the World Climate Research Programme (WCRP) (James and Washington, 2015).

Projected annual rainfall for 2071 to 2100 vs 1961 to 1990, as obtained from the CCAM model running at the CSIR, indicates that Southern Africa is likely to become generally drier and East Africa generally wetter under low mitigation (Engelbrecht *et al*., 2015). This is also the conclusion reached in Assessment Report Four (AR4) and

Assessment Report Five (AR5) of the IPCC (Christensen *et al.,* 2007; Niang *et al.,* 2014). There is some evidence that extreme convective rainfall events may occur more frequently over the warmer southern African interior in the future (Engelbrecht *et al*., 2013). Only a limited number of studies have focussed on the future occurrence of extreme rainfall events over Southern Africa, but Malherbe *et al*., (2013) provides evidence of a northward shift in tropical cyclone tracks to northern Mozambique, whilst Engelbrecht *et al*., (2013) provides evidence of decreasing cut-off low occurrences over southern Africa.

The Limpopo Province contains large semi-arid areas (annual rainfall less than 500 mm per year) including the Limpopo river basin (Limpopo Department of Agriculture, 2014). Annual rainfall totals range from 400-700mm over most of the province, with parts of the eastern escarpment recording averages of above 1000mm (Limpopo State of the Environment Report (Phase 1), 2004). During the summer months, the temperature rises to 27°C (for the province on the average) and 20°C in winter (South Africa Weather Service, 2014). The winters are mostly free of frost. Limpopo is a summer rainfall region, and critical to livelihoods and agriculture in the province is the reliability of the summer rains. Few studies have to date focused on climate change in the Limpopo Province, let alone on the MDM. However, from the findings described above it is clear that key risks for the Limpopo Province are drastic increases in temperature including heat-wave events (likely under low mitigation) and the more frequent occurrence of El Niño induced droughts (plausible under low mitigation). The projected climate change futures of Limpopo and the MDM are explored in more detail in the remainder of this chapter (Section 4.3. Understanding climate change impacts in Limpopo province and Mopani District Municipality rural communities).

In South Africa 35.70% of the population resides in the rural areas (Tradingeconomics, 2016) and 20.7% of those rural communities per household are involved in agricultural activities and more than 65% of those rural communities households engage in subsistence agricultural activities for the provision of food to their families (RSA, 2014). A total number of farm employees has dropped from 1,6 million in 1971 to 628 000 in 2005 and that has resulted in agriculture's contribution to employment dropping from 8.3% to 1.3% (Goldblatt, 2014). There is also evidence that climate variability and extreme weather events impact significantly on South Africa's rural communities (Midgely, 2007).

Natural hazards affect the living conditions of humans and the state of the environment and they cause environmental, social and economic disruptions and destructions of living and environmental conditions of rural communities (UNISDR, 2009; IPCC, 2016;Us ,2016). Of particular interest in this chapter are the natural hazards of a climatological/meteorological nature that has an impact on the Limpopo Province and the MDM. These include drought, heat waves (Mandiwana, 2017), wild fires, flash-floods, large-scale floods, severe thunderstorms and tropical cyclones (Malherbe *et al*., 2012; 2014). These events have in the past resulted in the damage of bridges, roads, the death of animals and human beings, damage on crops (farms) and houses (News 24, 2013).

Drought conditions occurred in in the following years: 1982 to 1984; 1986; 1987; 1990 to 1994; 2002 to 2003; 2004; 2005; 2008 and 2009. One of the most recent and devastating droughts associated with above normal temperatures occurred during the 2009/10 summer rainfall season (Maponya, 2012; News 24, 2009;UNDP, 2008; SAWS, 2016; NDMC, 2017). In August 2009 drought impacted MDM where 3 394 livestock have died (iOL, 2013).

Floods occurred in the following years: 1966; 1977; 1988; 1989; 1993; 1999; 2000; 2002; 2003; 2011; 2012; 2013; and 2014. The 2000 floods resulted from tropical cyclone Eline, whilst the 2012 tropical storm Dando caused heavy rains in the provinces of Limpopo and Mpumalanga and resulted in the flooding including Maruleng Municipality in the Limpopo Province (NDMC, 2014; Limpopo preliminary reports on weather damage, 2013; News 24, 2013; SAWS, 2016). The January 2013 floods caused damage in the MDM including damage to cash crops. Access to a number of roads was cut off resulting in farming activities coming to a halt. Some infrastructure has also been washed away. A total of 134 households were affected in sixteen villages of Greater Giyani and Greater Tzaneen Local Municipalities. A total of eight (8) villages (Guwela, Gawula, Vuhehli, Xitlakati, Matsotsosela, Khashani, Mbawula, and Phalaubeni) were affected in the Greater Giyani Local Municipality, while eight (8) villages were also affected in the Greater Tzaneen local Municipality. The villages affected in the local municipality of Greater Tzaneen are

Mawa Block 8, Lekgwareng, Mokhwathi, Mandhlakazi, Mariveni, and Leretseng affected in Greater Tzaneen. The villages affected by Greater Tzaneen are Mawa Block 8, Lekgwareng, Mokhwathi, Mandhlakazi, Mariveni and Leretseng. (Limpopo preliminary reports on weather damage, 2013).

Climate variability affects individuals in the rural communities in their everyday activities (NCA, 2015). Eighty one percent (81%) of the population resides in the rural areas, 14% resides in urban areas and 5% on farms in the MDM.

Based on the information that the MDM already experiences extreme events that impact significantly on its rural communities, it is important to consider whether climate change poses the risk of an increasing number of natural hazards impacting on the MDM. To this end it should be noted that rural communities in general are affected by factors such as rapid growth and inadequate planning, overpopulation of certain areas, overutilization of natural resources (environmental degradation), poor building methods, concentration of resources and economic activities, dependency on infrastructure and services, lack of awareness, education and skills and poverty that contributes to the increase of vulnerabilities to climate change (Philip *et.al*., 2004). The MDM is no exception in this instance.

The unemployment rate is high in MDM and few people in the MDM attended higher education, implying low levels of skills in the district. Low educational levels result in lack of skills needed for other professional fields in the labour market. Rural communities characterised by a high unemployment rate have difficulties in sustaining their livelihood as they don't have a stable source of income and lack access to financial credit. Due to this high unemployment rate, rural communities will have difficulties in responding to extreme events such as drought. These aspects are highly relevant to the MDM rural communities due to their low level of education and resulting dependence on agriculture as a source of employment, livelihoods and food security. Generally, agriculture as a sector is vulnerable to the impacts of climate change as it depends on precipitation (Elliot *et al*., 2013). When climate change affects agricultural productions it directly and specifically impacted that particular crops and agricultural techniques. In the MDM rural communities rely heavily on agriculture (crops or livestock). An increase of drought events in the MDM will have an impact on crops, income to farmers and communities that are employed in the agricultural sector and will decrease grazing land productivity. Additionally, the high cost or unavailability of water for livestock increased feed transportation costs, reduction of economic development are all factors that may increasingly impact on the MDM under climate change.

An increase in heat waves events in the MDM will likely have a negative impact on human health and productivity, through heat exhaustion (e.g. nauseas, vomiting, muscle cramps and aches, dizziness, headache), heat stroke (e.g. difficulty in breathing, high body temperatures, rapid pulse, etc.) and heat cramps (COGTA, 2015; Schär, 2015). The most vulnerable people that will be affected include the elderly, children and women whose systems are already weakened by poor nutrition or illness such as HIV, and who often travel long distances on bad road conditions to gain access to public health.

The quality of lives for rural communities is dependent on the basic needs and service they require to sustain their lives. Rural communities with no basic services such as energy for cooking, running water from the taps inside their yards, increases the risks of extreme events such as temperatures affecting women, children and elderly who will walk a distance to collect water from the rivers. Sources of water get affected by an increase of extreme temperatures (i.e. drought and heat waves). During drought conditions, boreholes and rivers dried up and lack of adequate rainfall to sustain the water resources may cause water shortages in the rural communities and could result in the water challenges in the future, and climate change could worsen these conditions further.

Proper sanitation in the rural communities is of the utmost importance as it plays a major role in protecting the health of rural communities and safeguard communities from infectious diseases. The lack of proper sanitation will pose a threat to human health in the MDM as it will increase vulnerability to heat stress or diseases and pathogens such as cholera and malaria as a result of an increase in extreme temperatures.

It is of the utmost importance to have a reliable source of energy for lightning and cooking in the rural communities. The majority of rural communities in the MDM utilise electricity for lightning and wood for cooking. Collection of wood may result in the deforestation which may lead to the loss of species and deforestation which may lead to the loss of species and trees that aid in the water cycle by absorbing rainfall during rainy seasons and produce water vapour released into the atmosphere that contributed positively in the lessening of water pollution. The roots of the trees also contribute positively in anchoring the soil during soil erosion which might negatively affect by polluting the lakes, streams and other water sources as soil is washed away during erosion and this have in impact in the decrease local water quality and contribute to poor health in the rural communities (Live science, 2016).

Infrastructure (housing, clinics, schools, roads, and telecommunications) is also crucial in the rural communities during shocks and stresses associated with an increase of extreme events in the MDM such as droughts and possibly floods. Rural communities in the MDM are mostly accessed by dirt roads or even footpaths and these roads are vulnerable to degradation during rains and make it difficult to access affected communities during disaster relief. The MDM IDP, 2016/17) further indicated that there is insufficient hospitals, health centres, clinics and mobile clinics available to serve rural communities as the settlements are extremely scattered nature. MDM rural communities are mostly under traditional authorities town planning is non-existent in the informal settlements and has resulted in communities settling in areas that are not suitable for residential zoning and possibly on high flood plain areas (Schweikert *et al*., 2014).

4.2. Data and methodology

Plausible climate futures of the Limpopo Province and Mopani District Municipality were obtained from a set of regional climate model projections of future climate change over Southern Africa as obtained by the CSIR in South Africa and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia. The regional climate model used is the conformal-cubic atmospheric model (CCAM), a variable-resolution GCM developed by the CSIRO (McGregor 2005; McGregor and Dix 2001, 2008). A recent description of the model dynamics, numeric and physics as applied in the research presented here is provided by Engelbrecht *et al*., (2015).

Six GCM simulations of the Coupled Model Inter-comparison Project Phase Five (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 50km resolution globally. The simulations span the period of 1971 to 2100. RCP4.5 is a high mitigation scenario, whilst RCP8.5 is a low mitigation scenario. The GCMs downscaled include 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); the Model for Interdisciplinary Research on Climate (MIROC4h) and the Norwegian Earth System Model (NorESM1-M). The simulations are performed on supercomputers of the CSIRO (Nguyen, et al., 2011) and at 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 (Engelbrecht *et al.*, 2009; Engelbrecht *et al*., 2011; Engelbrecht *et al*., 2013; Malherbe *et al*., 2013; Winsemius *et al*., 2014; Engelbrecht *et al.*, 2015).

Following this qualitative identification of extreme weather events relevant to Limpopo, the next step was to quantify their present-day frequency of occurrence across the province. Given the complete lack of gridded observational data sets of daily weather over Limpopo, this step of the research was performed using high-resolution regional climate model simulations of Limpopo's climate. This analysis has been conducted on both a seasonal and annual basis. Maps displaying this information have been generated within a GIS environment. For example, model simulations of the present-day average maximum temperature in summer and the associated average number of heat-waves were considered. As far as possible, these simulations were verified against observational data sets of the Climatic Research Unit (CRU), although the monthly-averaged nature of the CRU data allows only the verification of the model simulations of monthly average of variables such as temperature, humidity and rainfall, and not the verification of how the model simulates daily circulation statistics. In addition to the spatial maps of present-day frequencies of high-impact weather events, a trend analysis was done for each type of event, to determine whether anthropogenic forcing has over the last five decades (1971-2000) caused any significant changes in extreme event occurrence over the Limpopo Province and the MDM. This was feasible for those variables for which time-series data of annual and seasonal frequencies of events that were available, and for which a linear trend analysis was subsequently performed.

The modelled variables considered in this research are precipitation (rainfall) and temperature (minimum and maximum). From the daily values of these variables, the following extreme event metrics were constructed: Heat-wave days; High fire-danger days; Drought; Rainfall days and Extreme rainfall days. Climatologically averages of all these variables were constructed for the periods from 1971 to 2000 and 2030 to 2050. The probabilistic natures of the projections are conveyed by showing the projected changes of each variable for the 10th percentile, 50th percentile, and 90th percentile.

Spatial maps showing the projected changes in the frequency and intensity of high-impact weather events was constructed in GIS. The analysis of projected changes was performed for various future time-slabs (e.g. 2030-2050). The analyses were performed for both low mitigation (high emissions) and high mitigation (low emission) futures.

4.2.1. Definitions of extreme weather events analysed

Various indices exist that aim to measure objectively the presence of agricultural, hydrological or meteorological drought (James *et al.,* 2015). The Standard Precipitation Index for example, measures the deficits or excess in rainfall at a particular location relative to the long-term average rainfall at that location (Kumar, 2009). Here we have opted to use the Keetch-Byran drought index (Dolling *et al.,* 2005) as a measure of drought. The index is effectively an indication of the amount of soil-moisture that is available as a result of the combined effects of evaporation and rainfall. A Keetch-Byran index value of 10 is indicative of soils that are completely dry, whilst a value of 0 is indicative of soils that are completely saturated.

Heat waves are defined as a period of abnormally and uncomfortably hot and unusually humid weather (Schär, 2015). Here we apply specifically the definition of the World Meteorological Organisation (WMO): A heat wave is an event when the maximum temperature exceeds the average maximum temperature of the warmest month of the year by 5 °C for a period of at least three days (Schär, 2015). Extreme rainfall days are defined as days when more than 20 mm of rain occur within a period of 24hrs, on the average over an area of 2500 km^2. (Engelbrecht *et.al*., 2015)

4.2.2. Statistical methods used

Towards constructing the GIS maps a defined interval classification method was used to determine the present day minimum and maximum temperatures, rainfall, heat wave days, high fire danger days, Keetch-Byram drought index and extreme rainfall. ArcMap determined the number of classes based on the defined interval size and the range of all field values. Different colour ramps were given according to different intervals to the variables distributions or variations from the lowest to the highest values over the Limpopo province (Table 4).

Table 6: **Counter intervals of different variables of extreme events**

Source: (Author : Khwashaba ME, 2016)

Variable	Present day defined intervals	Anomalies defined intervals
Minimum and Maximum temperatures	2°C	0.4°C
Rainfall	100mm	50mm
Heat waves	2days	2days
Extreme rainfall	2days	1day
High Fire Danger days	20days	20days

Keetch-Byram Drought Index	1 drought index value	1 drought index value

4.3. Projected future climates for Limpopo Province and the Mopani District Municipality (MDM)

The Limpopo Province forms part of the summer rainfall region of South Africa, with the bulk of rainfall occurring during the summer half-year of October to March. Rainfall varies greatly in space across the province – local maxima occur over the escarpment regions in the east where average annual rainfall totals exceed 800mm per year, and over the Waterberg in the South, where annual totals vary between 600 and 700mm per year (Figure 20 (b)). However, over in the Limpopo river basin in the North (the northern parts of the Capricorn and Vhembe districts), annual totals are less than 400mm per year, rendering this part of the province to be semi-arid. The MDM is the district in Limpopo that exhibits the largest rainfall variability in space. Over the escarpment region in the West annual totals exceed 800mm, whilst less than 400mm occur on the average over the Lowveld regions in the East (Figure 20 (b)). In the model simulations, the present-day annual average number of extreme rainfall days reach values of four (4) to six (6) in the Greater Sekhukhune District Municipality, and two to four days in the southern parts of the MDM. It is likely that the model simulations underestimate the number of extreme rainfall days occurring along the escarpment area of the MDM, due to the model underestimating the steepness of the escarpment at 50km resolution. The present-day minimum temperatures for the period of 1971 to 2000, which is not shown in the figures, range from 8-18°C from the Greater Sekhukhune District Municipality extending to the highest on the edges of Vhembe and Mopani District Municipality. The present day maximum temperatures for the period of 1971 to 2000 ranges from 22-32°C from the Greater Sekhukhune District Municipality extending to the highest in the Waterberg District Municipality (Figure 20 (a)). The present-day heat wave days from the period of 1971 to 2000 shows heat wave days ranging from two (2) to ten (10) days with the highest days in some parts of the Mopani and Vhembe District Municipality (Figure 20 (c)). The present day high fire danger days for the period of 1971 to 2000 (which is not shown on the figure), ranges from 20 to 200 days from the Greater

Sekhukhune District Municipality (lowest values) to the highest values that occur on the edges of Waterberg, Capricorn, and Vhembe District Municipalities.

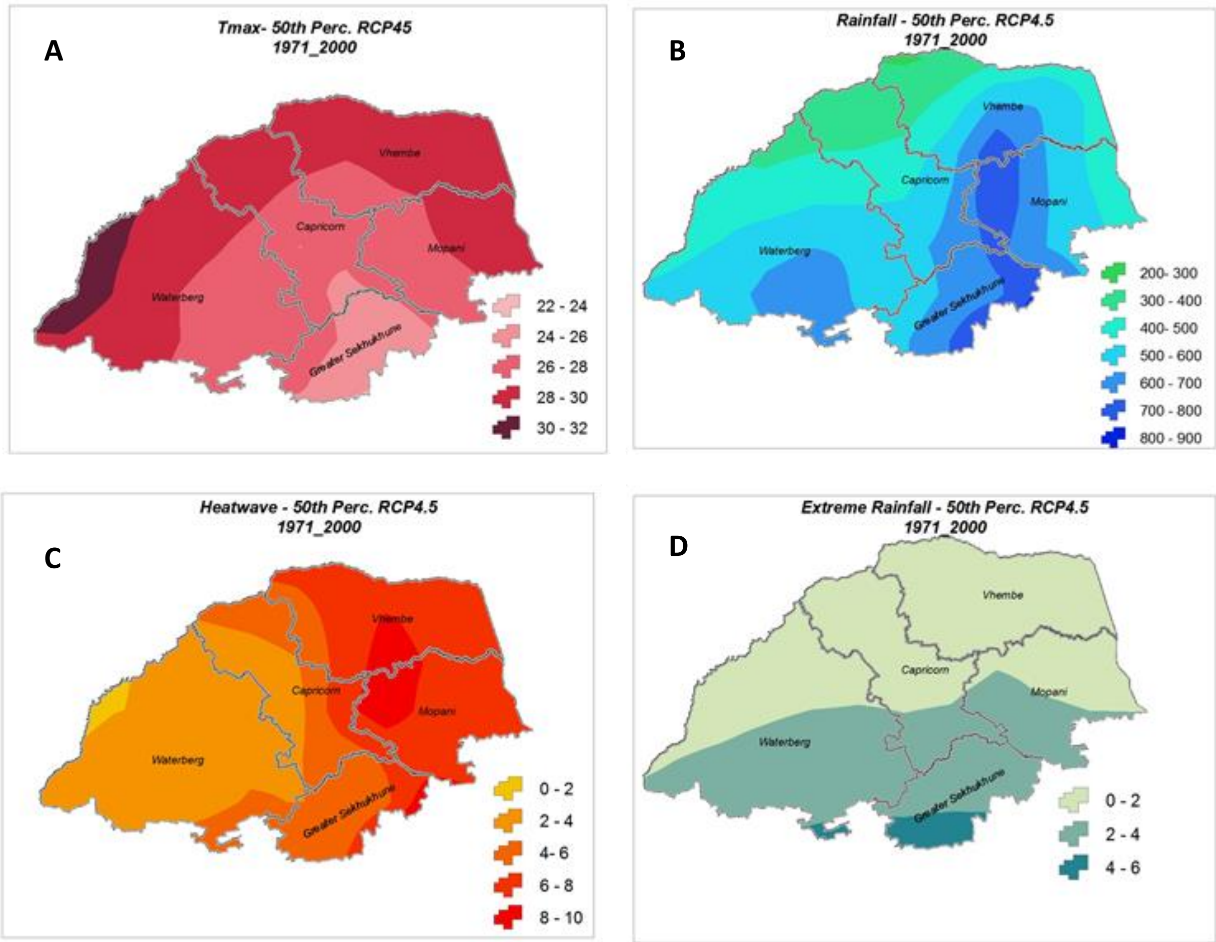


Figure 20: Limpopo province A. Maximum temperature under the RCP4.5 scenario; B. Rainfall under the RCP4.5 scenario; C. Heat wave under the RCP4.5 scenario; D. Extreme rainfall under RCP4.5 scenario

Source: (Author *: Khwashaba ME, 2016)*

The projections of future maximum temperatures as shown in Figure 21 below are based on the worst case scenario of RCP 8.5. The projections of future minimum temperatures (which are not shown in the figure) indicate an increase of 1.6 to 2.8°C with the highest increase in the Waterberg District Municipality. The projections of future maximum temperatures indicate an increase of 1.2 to 2.8°C with the highest increase in the Waterberg District Municipality and some parts of Greater Sekhukhune District Municipality.

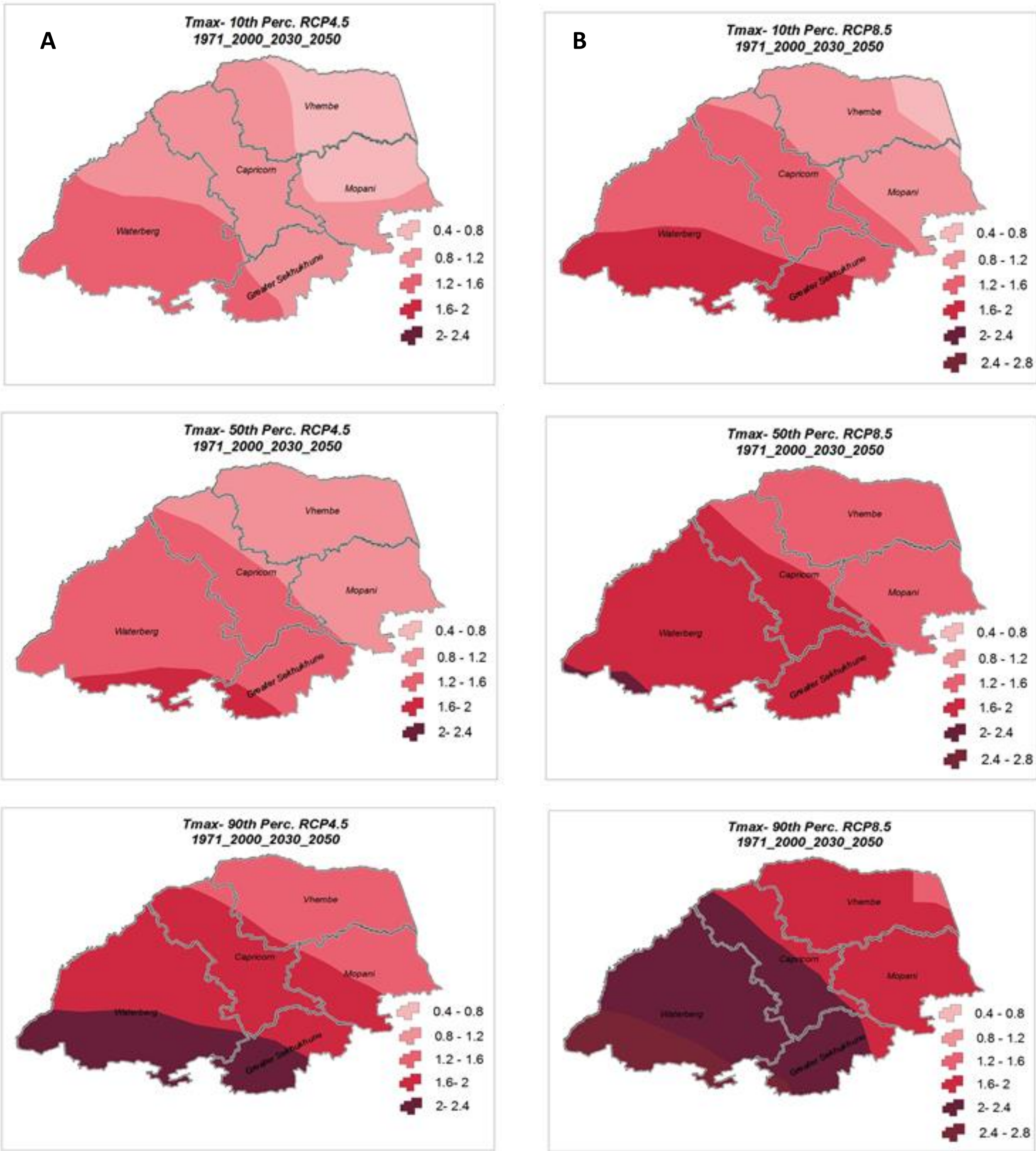


Figure 21: Limpopo Province A. Maximum temperature under the RCP4.5 scenario; B. Maximum temperature under the RCP8.5 scenario

Source: (Author *: Khwashaba ME, 2016)*

There is uncertainty in the future projections of rainfall as they show variance in different areas across the Limpopo Province. Some of the interior parts show a decrease in the rainfall by 50mm cutting across Waterberg, Capricorn, and Greater Sekhukhune District Municipalities. Most parts of the province across all the district municipalities' shows and an increase of 50 to 100mm with the highest increase in the edges of Vhembe and Mopani District Municipalities (Figure 22).

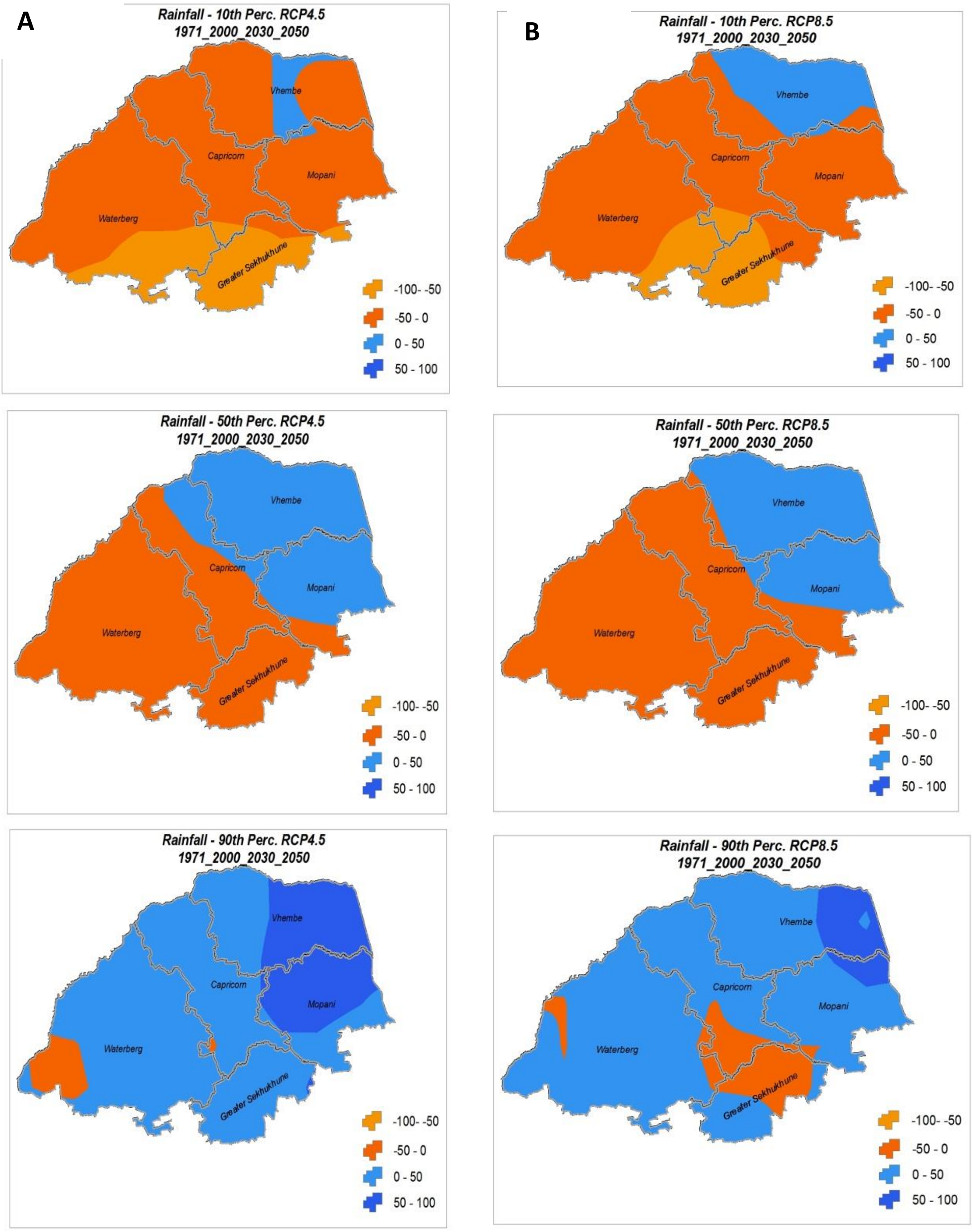


Figure 22: Limpopo province A. The rainfall under the RCP4.5 scenario; B. The rainfall under the RCP8.5 scenario

Source:(Author *: Khwashaba ME, 2016)*

The projections of future heat waves day frequencies are based on the heat wave definition as described in earlier chapters of this study. Heat waves days show an increase of 10 to 20 days from parts of Vhembe and Mopani District Municipality extending to the highest in the Waterberg District Municipality (Figure 23). Due to the increase temperatures and the number of heat wave days it has resulted in the increase in the number of projected high fire danger days which is not shown in the figure. High fire danger days show an increase of 20 to 100 days with the highest increase occurring in the Waterberg District Municipality.

There is a variation in the distribution of extreme rainfall in the Limpopo Province. There is also an uncertainty in the changes of extreme rainfall, with some small areas in the Waterberg, Greater Sekhukhune and Capricorn District Municipalities projected to experience decreases of extreme rainfall of one day per year. Most of the province is projected to experience increases in the number of extreme events, however about one event per year. Somewhat larger increases in extreme rainfall events are projected for the Vhembe District Municipality (Figure 24).

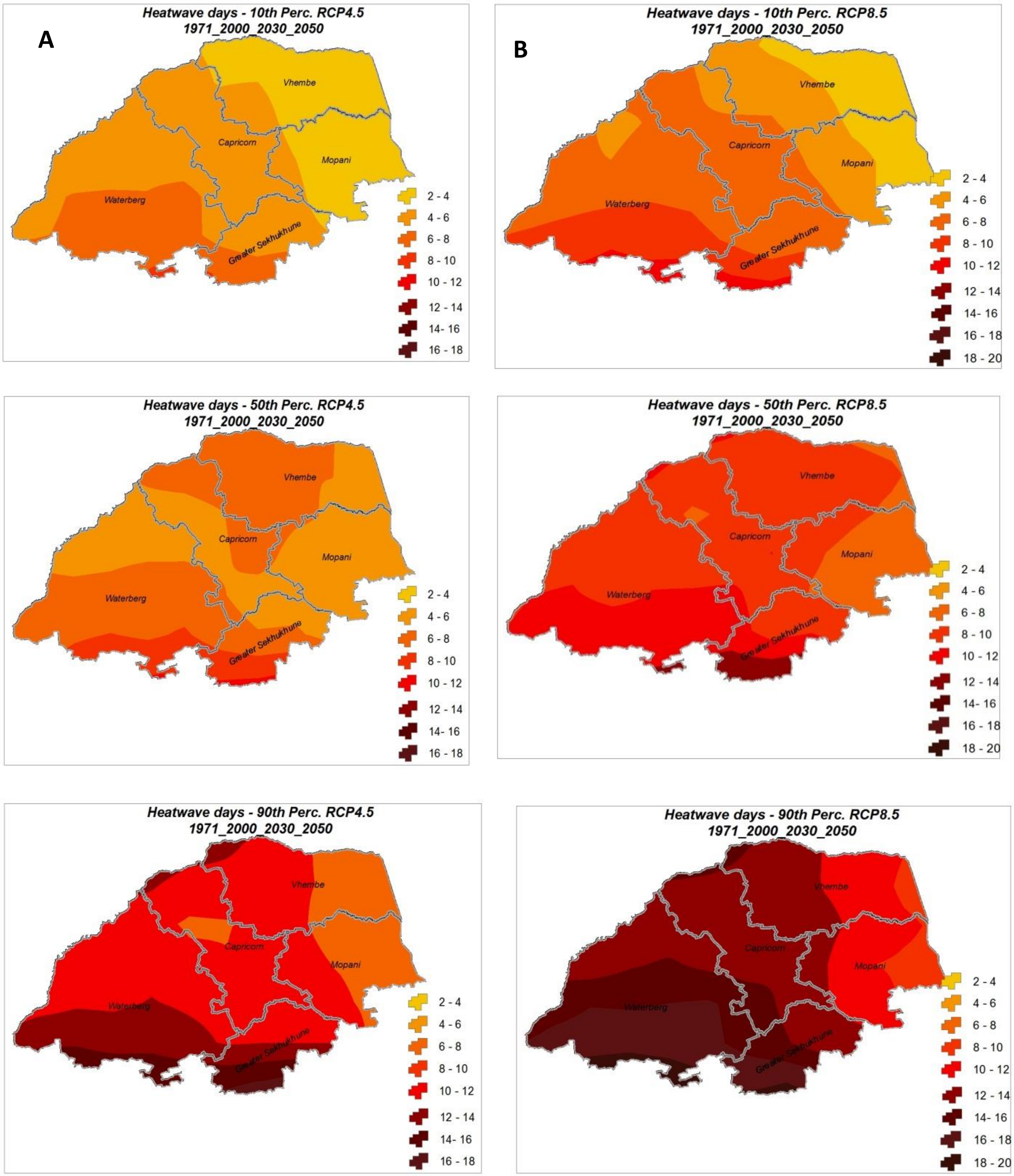


Figure 23: Limpopo province A. Heat waves under the RCP4.5 scenario; B. Heat waves under the RCP8.5 scenario

Source: (Author *: Khwashaba ME, 2016)*

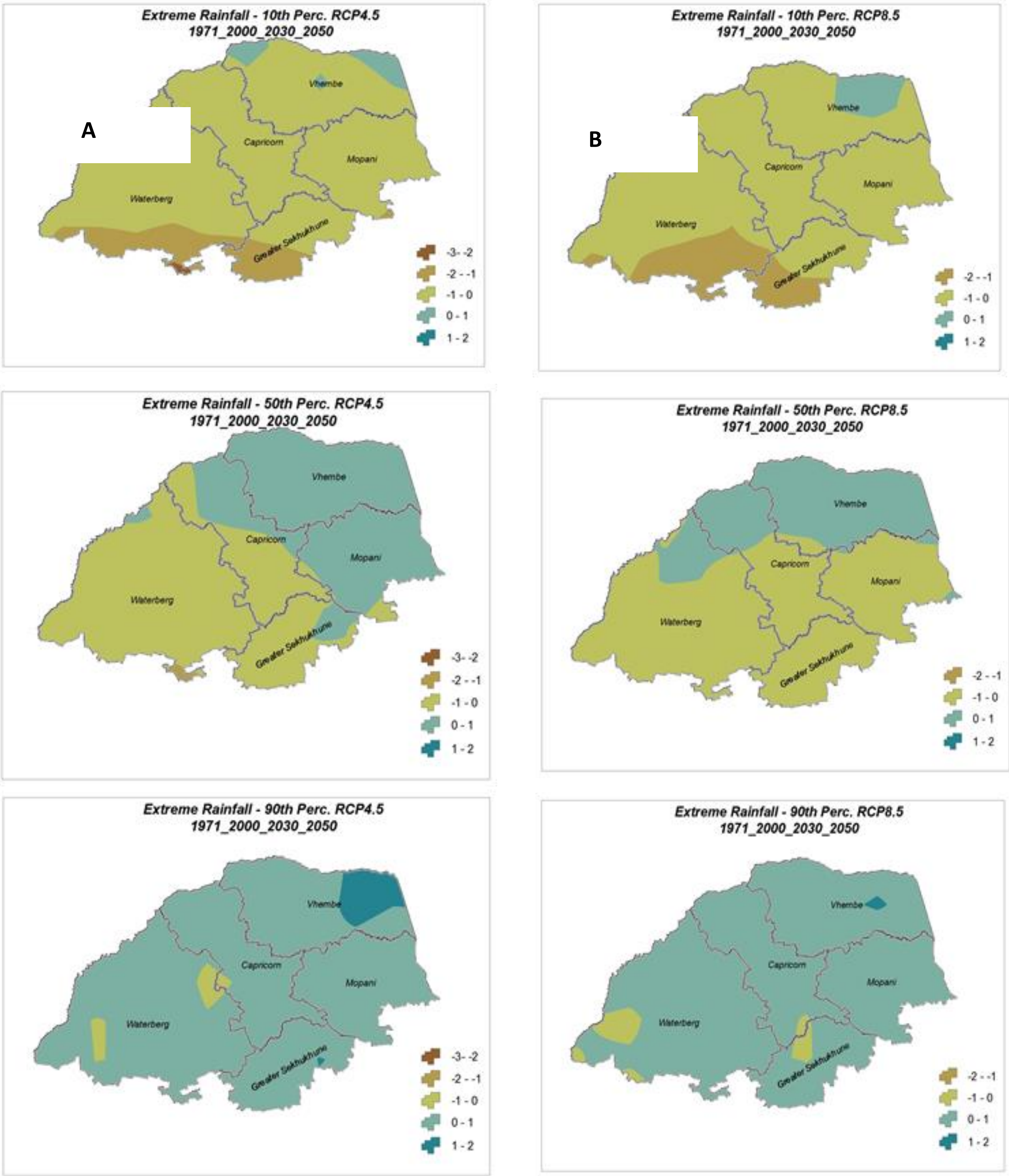


Figure 24: Limpopo province A. Extreme rainfall under the RCP4.5 scenario; B. Extreme rainfall under the RCP8.5 scenario

Source: (Author *: Khwashaba ME, 2016)*

The Keetch-Byram Drought Index (KBDI) is used to indicate the possibilities of drought in the Limpopo Province as well as in the MDM. The KBDI measures the amount of precipitation necessary to return the soil to full saturation. It ranges from the values 0 to 10; where 0 is a point of where soils are completely saturated and 10 is the maximum indicating that soils are completely dry (TWC, 2016).

For present-day climate for the period of 1971 to 2000, the KBDI reaches values of 9 to 10 index value at the edges of Vhembe, Capricorn, and Waterberg District Municipalities and that indicates the occurrence of generally dried out soils (consistent with this region being known to be semi-arid). Over the rest of the province, the KBDI typically ranges between 5 and 9 with the south-western parts of the province having the wettest soils on the average (Figure 25).

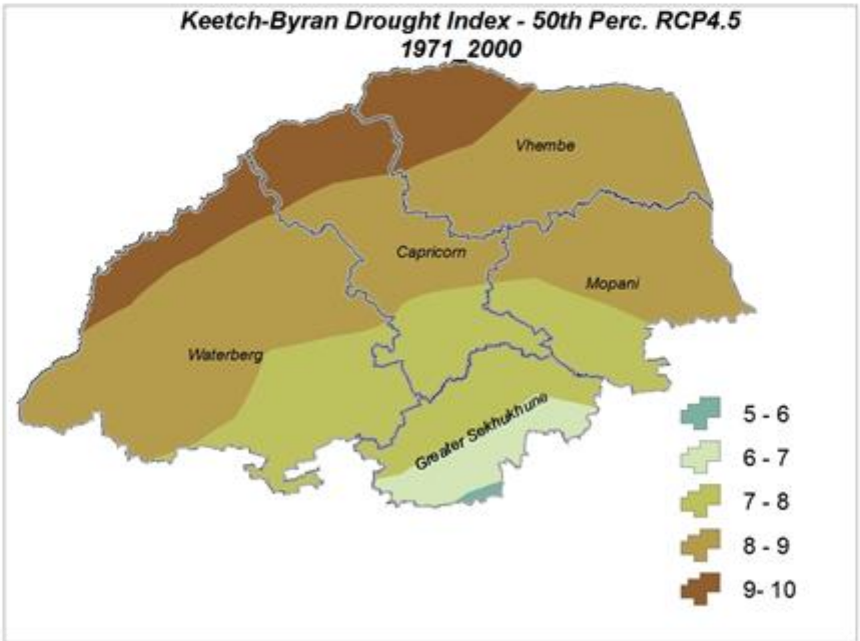


Figure 25: Keetch-Byram drought index estimates for the current climate over Limpopo province

Source: (Author *: Khwashaba ME, 2016)*

The plausible future projections shown in Figure 26 are based on the worst case scenario of RCP8.5. The future projections of KBDI indicate an increase from 0.4 to 1.6 index value with the lowest increase of 0.4 to 1.2 index value in some parts of the Mopani, Vhembe, Capricorn, and Waterberg District Municipalities. The highest increase of 1.2 to 1.6 index value is seen in the Greater Sekhukhune District

Municipality. These results imply a generally drier Limpopo and MDM under low mitigation climate change futures – a result that is partially due to reduced rainfall and partially to enhanced evaporation.

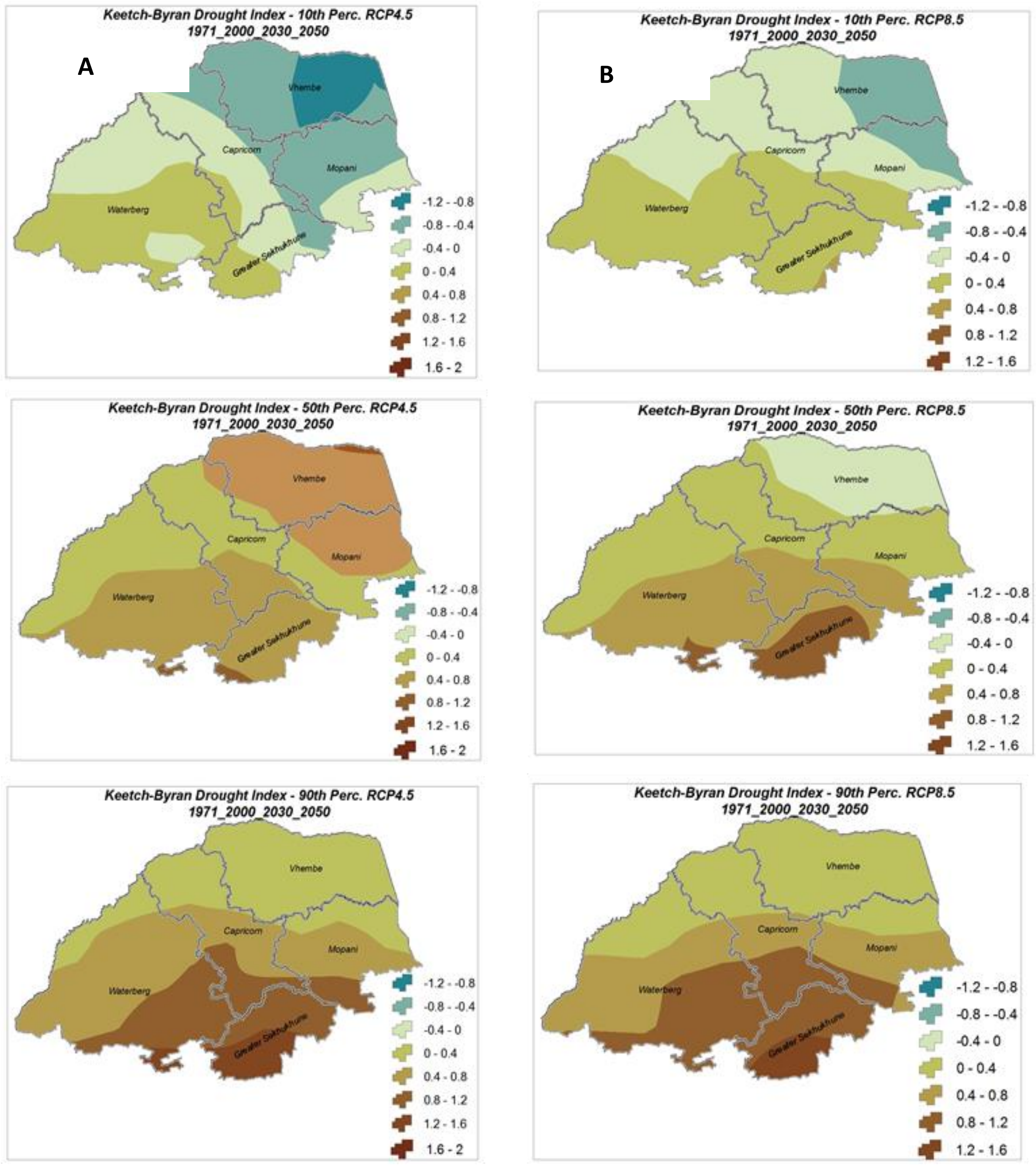


Figure 26: Limpopo province A. Keetch-Byram drought index under the RCP4.5 scenario; B. Keetch-Byram drought index under the RCP8.5 scenario

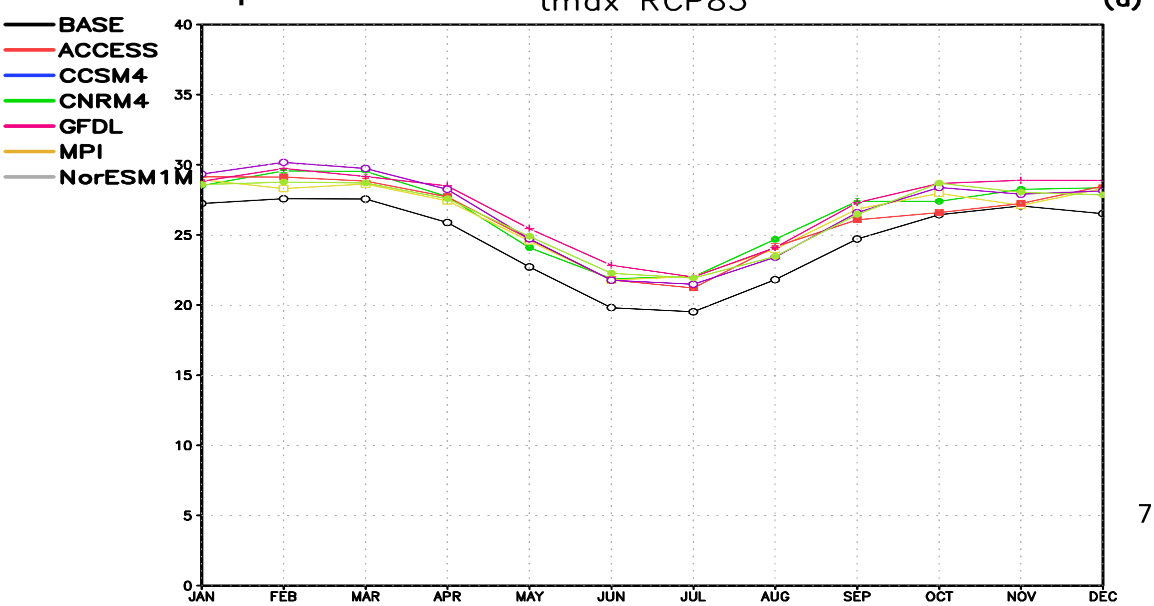
Source: (Author *: Khwashaba ME, 2016)*

4.4. Seasonal cycle in the MDM under climate change

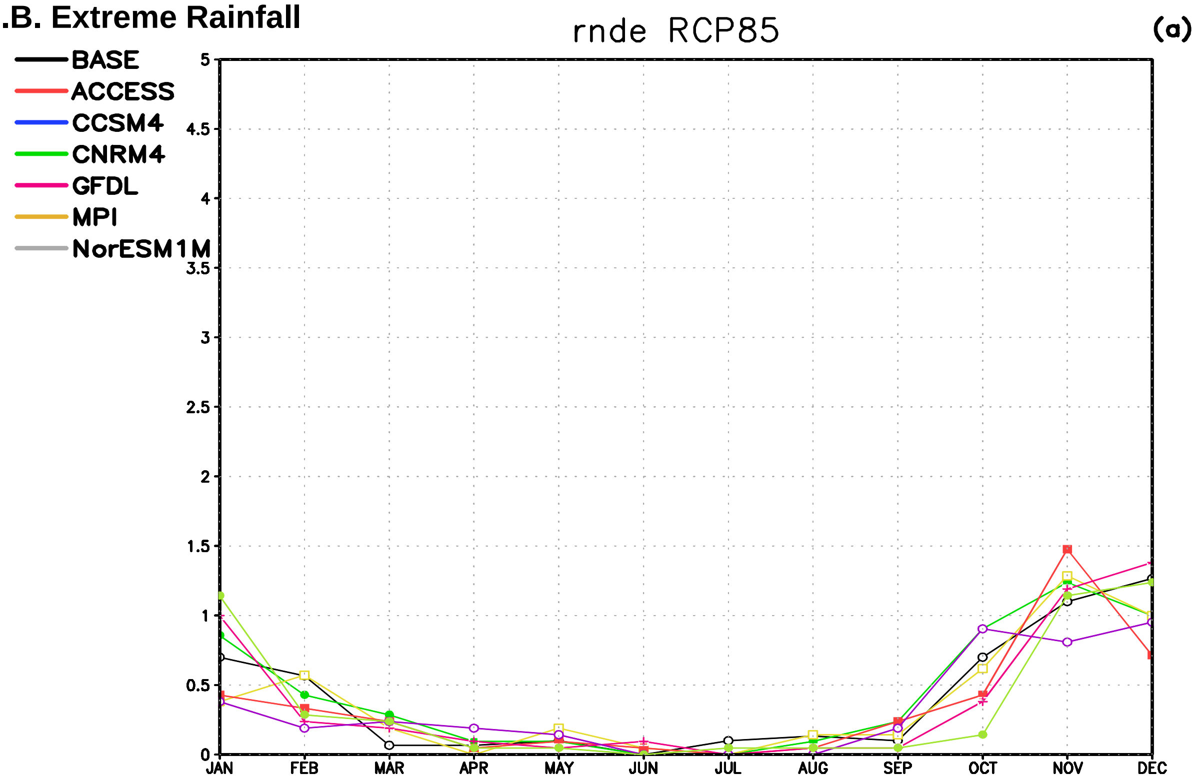
Figure 27 (A-D) shows the simulated seasonal cycle of the variables maximum temperature, heat-wave days, rainfall and days of extreme rainfall in the MDM. Maximum temperature peaks and ranges between 25 and 30°C in the summer months (December, January, February); heat wave days pick up in the month of October to November and drops in December (due to December to February typically being associated with high rainfall total sand cloud cover). Both maximum temperatures and heat-wave days attain minimum values during the winter months. High fire danger days (Figures 28 A and B) similarly peaks in the months of October to November (before the rainy season starts) and reach a minimum at the end of the rainy season in March, when soils are at their wettest; Rainfall picks up in the month of November to December reaching 80-110mm (monthly totals) and extreme rainfall pickups from November and peaks in the December with 1 to 1.5 of these days occurring on the average in this month.

Figures 27 A to D and Figures 28 A and B can also be used to discern how monthly climatologies will change in the MDM in response to enhanced anthropogenic forcing, for the period 2021 to 2050 relative to 1971 to 2000. Maximum temperatures are projected to be 2-3°C higher than the present-day across all months. An increase of heat wave days is projected to occur per month for the early summer, with an increase of one to three days projected for the early summer. Most months are projected to become drier with fewer extreme rainfall days, with the exception of the early summer, which is projected to become wetter with an increase in extreme rainfall days. Under low mitigation, soils are projected to become generally drier with an associated increase in the number of high fire danger days**.**

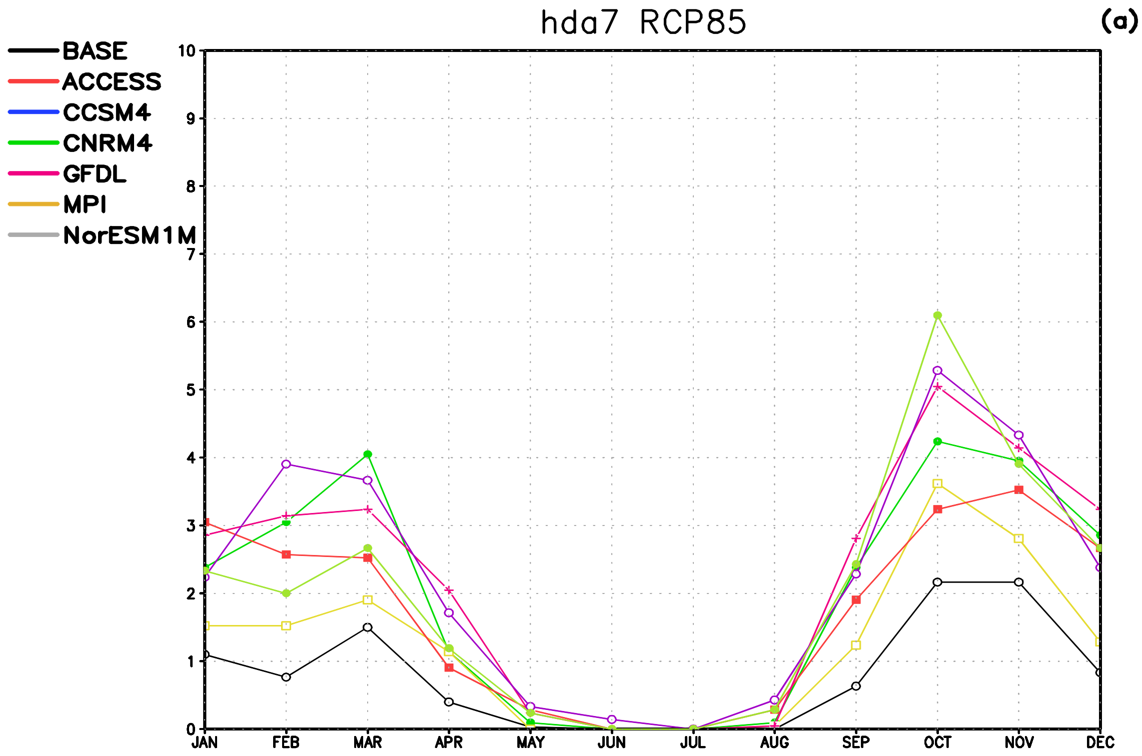
27.A. Maximum temperatures



27.B. Extreme Rainfall



27.C. Heat waves



27.D. Rainfall

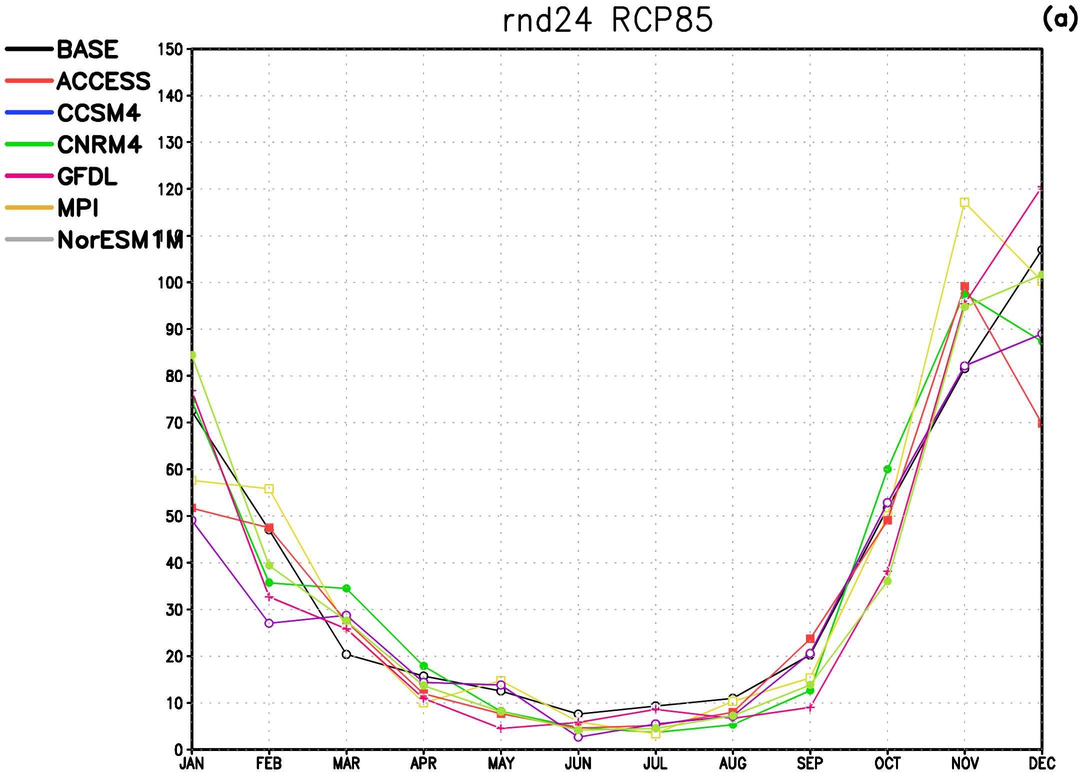
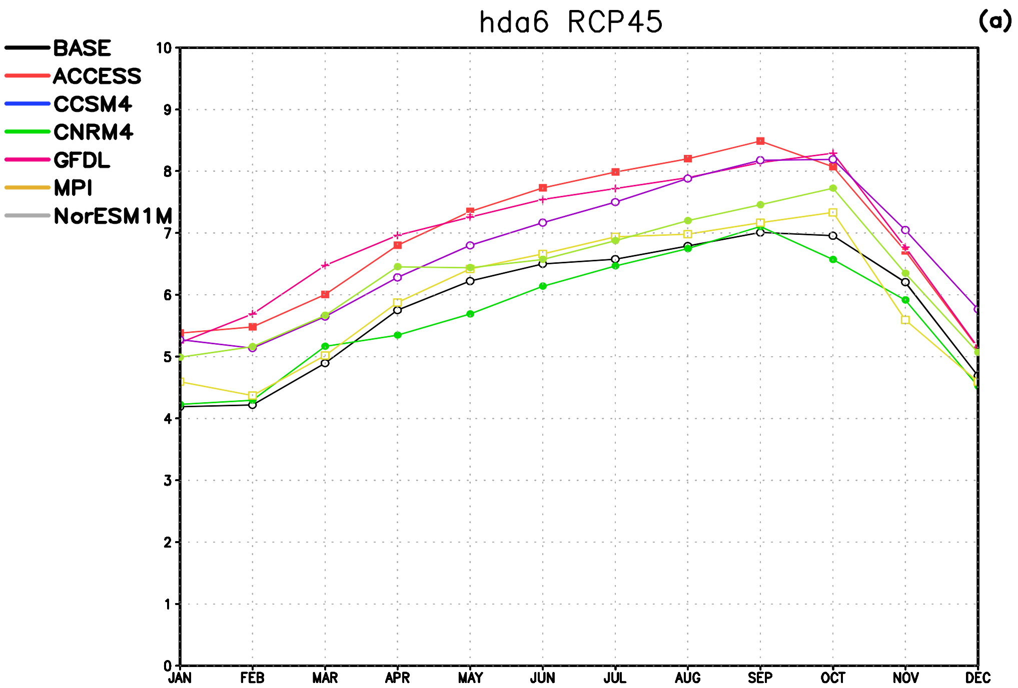


Figure 27: Limpopo province seasonal cycle and time series A. Maximum Temperatures under RCP 8.5; B. Extreme Rainfall under RCP 8.5; C. Heat waves under RCP 8.5; D. Rainfall under RCP 8.5

Source: (Author *: Khwashaba ME, 2016)*

28. A. Keecht-Byram Drought Index



28. B. Keetch- Byram Drought Index

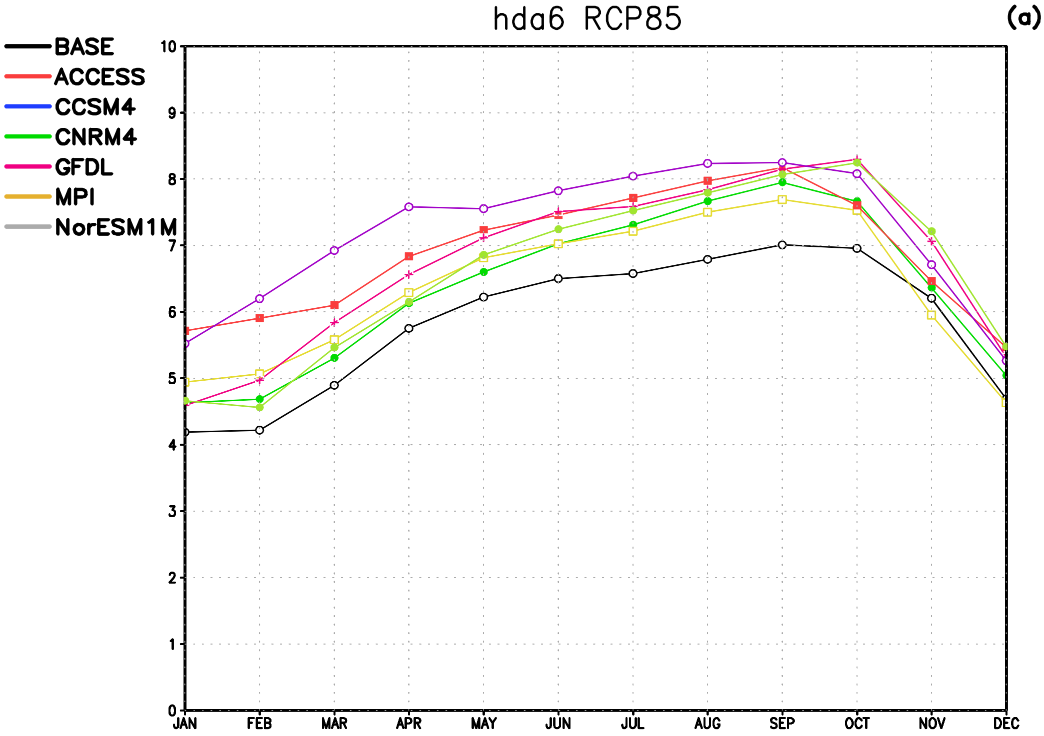


Figure 28: Limpopo province seasonal Cycle and time series A. Keetch- Byram drought index under RCP4.5; B. Keetch- Byram drought index under RCP 8.5 scenario

Source: (Author *: Khwashaba ME, 2016)*

4.5. Conclusions

Plausible projected climate changes in the Limpopo Province, as well as the MDM, are indicative of drastic increases in temperatures and general reductions in rainfall (at least over the MDM). An increase in temperature will affect the agriculture and water sectors in the Limpopo Province as well as in the MDM. The expected impacts in the agricultural sector will be felt highly through the decreased availability of livestock feed, decreased crop yield and increased livestock mortality. Consequences of such climate change impacts will plausibly be in terms of employment, food security, tourism, and shortages of water for both human and livestock consumption. Should basic services in the MDM remain at inadequate levels; the impacts will further be worsened by factors such as the poor state of water related infrastructure, water losses, lack of implementation of stringent water conservation measures in the affected areas. Water is a critical resource for growth and development in the MDM, but under climate change may become an increasingly scarce resource in the MDM

The projected increases in temperature are projected to occur in association with an increase in heat waves days and high fire danger days. These extremes will also impact negatively on the agriculture, the water sector, and human health. Overexposed to the heat will have a negative impact on the elderly, young children, sick persons and those who are overweight and unfit in the rural communities of the MDM and the Limpopo Province at large. Farmers will be required to adopt conservation agriculture methods and irrigation methods that are water efficient (i.e. irrigate in the early mornings and evenings, consider drip irrigation, etc) during drought events. Due to the streams and rivers drying in the MDM and Limpopo Province, plausible future projections of an increase in the drought events will worsen the current situation in the MDM and Limpopo Province further affecting conservation agricultural methods that might be applied by the farmers.

The identification of extreme events (drought, heat waves, high fire danger days) that will increase in future in the MDM is important in that it will assist the Comprehensive Rural Development programme (CRDP) to identify and prioritise human, natural, social and financial assets that will enable examination of current and future adaptation options for MDM rural communities and also assists in early warnings in the future climate change variability and vulnerabilities and lastly identifying areas where support is required. Chapter 5 will address vulnerabilities and resilience of the MDM rural communities in relation to the extreme events identified in this chapter.

CHAPTER 5: VULNERABILITIES AND RESILIENCE OF LOCAL COMMUNITIES IN THE MOPANI DISTRICT MUNICIPALITY (MDM)

5.1. Introduction

DRDLR provide functions on presidential outcome 7 which stipulates building vibrant, equitable and sustainable rural communities which provide security for all rural communities that reside in those areas. In order to achieve goals of outcome 7, programmes such as CRDP which provides job creation in order to eliminate poverty are implemented in the rural communities (DRDLR, 2016).

It is of the utmost importance for the rural communities to utilise the natural environment taking into consideration sustainable development and proper management of the natural resources. South Africa’s rural communities are able to achieve this through the support of government programs such as CRDP which aims in redistributing at least 30% of agricultural land to be utilised for socio-economic development that will further aid in improving the food security of the rural poor and the creation of job opportunities (DRDLR, 2013).

The success and failure in achieving the goals of CRDP depend on several issues and conditions of which amongst others includes climate change impacts. An increase of extreme temperatures events and/or an increasingly frequency and intensity of drought events may impact on rural communities in a variety of waves as indicated in the assessment of climate risks in Chapter 4. If suitable emergency response interventions and long-term adaptation interventions by different government departments and organisations are not properly planned, it can have financial implications that may affect the implementation of CRDP as in cases where government departments including DRDLR are requested to shift allocation of funds to respond to drought events or any climate change related threats (DRDLR, 2013). The shifting of allocated funds may affect the capital that is needed for economic growth.

In dealing with climate change response in the rural communities, South Africa developed The National Climate Change Response White Paper (NCCR) in 2011. NCCR ensure that rural communities that are more vulnerable to climate change are capacitated in utilising the natural environment while maintaining the status of the natural environment for sustainable future use. The NCCR promotes the increase in the resilience among the vulnerable sections of the rural population and ensures that disaster risk management structures and strategies are in place. The NCCR encourages adaptation strategies in the rural communities taking into consideration all processes that enhance the knowledge of vulnerable communities for maintaining sustainable environmental conditions while improving and managing the status of the ecosystem to continue providing required services to the rural communities (NCCR, 2011).

In support of CRDP and NCCR, it is therefore important to assess climate change vulnerability indicators in order to identify threatened regions, communities, species, and economic infrastructures. This is needed to promote awareness and to create lists of priority areas for adaptation/ resilience and to develop and implement measures to reduce climate change risks that may impact on the livelihoods of rural communities. Assessing climate change vulnerability indicators in rural communities will also assist the DRDLR in resource allocation for climate adaptation, with greater funding going to more vulnerable areas, sectors or groups. Such a process will also assist in measuring progress towards reducing vulnerability and will promote understanding factors that contribute to vulnerability by improving rural communities' ability to develop adaptation measures (Thomalla *et al*., 2006).

Three approaches can be applied in analyzing vulnerability to climate change, namely socio-economic, biophysical, and the integrated assessment approaches. Socio-economic vulnerability assessment approach takes into account social, political and economic aspects for single members of the families or group of families. The biophysical approach focused on the environmental risks that might have an impact on both social and biological systems, for example, land degradation. The integrated assessment approach focuses on both socio-economic and biophysical approaches to determine vulnerability (Tullos *et al*., 2013).

In this research, an integrated vulnerability assessment approach was considered for assessment of the vulnerability of the MDM rural communities under climate change. In order to assess vulnerability, it is important to assess the exposure of rural communities to climate risks and sensitivity of rural communities in relation to the status of natural environmental conditions and the capacity of rural communities to cope and adapt with the changes around them (Adger, 2006). Vulnerability to climate change as indicated in many types of research is determined by the relationship between exposure, sensitivity and adaptive capacity (IPCC, 2007). Exposure indicates the degree or the extent of which the ecosystems or the natural environment experience the occurrence of natural disasters (Adger, 2006) and this can be measured by their magnitude, frequency, duration and the extent of the natural disasters that has occurred (Burton *et al*., 1993). Sensitivity indicates the degree or level of the natural disasters impacts on the natural environment such as changing the status and services that the ecosystem provide and adaptive capacity indicates the ability and resources available for rural communities to respond to the impacts that have resulted from the occurrence of natural disasters or climate change (Adger, 2006). Thus vulnerability also depends on access to social aspects such as financial, political and institutional assets, instead of depending on exposure to environmental change alone (Twyman *et al*., 2011).

5.2. Data and methodology

This chapter assesses the MDM rural community's sectoral biophysical and social vulnerability impacts under climate change. Assessment of climate change sensitivity were identified through a literature review and from the analysis of spatial maps using GIS technology to display the biodiversity, ecosystem health, and land cover, distribution of invasive alien species, conservation areas, carbon sequestration, rivers and degraded areas around the district. The state of the ecological ecosystem was also observed by the researcher during field visit as another form of data collection tool with a specific focus on observing the status of grazing areas crops and water sources in the rural communities surrounding the MDM.

In order to assess adaptive capacity and resilience of rural communities under climate change and after the occurrence of natural disasters, in this research, available resources such as financial resources, government basic services, and infrastructures such as houses and roads amongst others have been considered. Census (2001 and 2011) was used to analyse the changes in basic services for the past 10 years. A constructed questionnaire was also used on focused groups' interviews. Figure 2 from Chapter 1 provides an indication of a more detailed overview of the social vulnerability indicators that were consulted during this study and the dimensions of environmental risk that were analysed. Chapter 1, section 1.4 Study design give a detailed information on the methodology used for data collection and analysis.

5.3. Climate change vulnerabilities in the MDM under climate change

Occurrence of disaster risks either naturally or man-made results in the destruction of the environment and livelihood of rural communities. Risk can be measured by the relationship between hazard, exposure, and vulnerability (UNISDR, 2007). Based on the literature review, the MDM has already experienced disaster risks that include drought, heat waves, and floods. Chapter 4 section 4.3 analysed projected future climates for Limpopo Province and the Mopani District Municipality (MDM) where it has indicated an increase in extreme temperatures, heat waves and drought conditions. The projected changes in rainfall show slight increase in some areas in the Limpopo Province and a decrease in other areas.

The negative impacts of the increase in temperatures, heat waves, high fire danger days and drought in MDM will highly impact on the agricultural sector, biodiversity, human settlement and water sector. The number of agricultural households in the MDM is 19,897 in the Greater Giyani Local Municipality out of 63,548; 36,793 in Greater Tzaneen Local Municipality out of 108,926 households; 10,628 in Ba-Phalaborwa LM out of 41,115 households; 9,427 in Maruleng Local Municipality out of 24,470 households; 22,324 in Greater Letaba Local Municipality out of 58,261. In the MDM an average of 6 640 people practice livestock production; an average of 7821 people practice poultry production and an average of 4 937 practice vegetable production, an average of 6 268 people practice production of other crops such as maize and an average of 6 268 people practice fodder production (StatsSA, 2011). MDM rural communities practice agriculture for food production. The amount of food produced in a specific year, for example, determines food security for rural communities for current and future plans. The more the rural communities harvest or produce enough productions there is surety of food security which also provides a direct link to the condition of the environment were agriculture is being practiced, for instance, the climate of an area dictates the type of crops to be cultivated in that particular area (Lizumi, 2014). Most farmers and rural communities who practice agriculture use fertilizers for crop production and if not applied properly affect the natural environment resulting in the environmental hazards that include water and soil pollution. The application of high levels of nitrates, phosphates, and potassium in water cause detrimental effects on aquatic organisms and also to human health (Puri *et al.*, 2012). It is therefore important for rural communities to be environmentally conscious and friendly for sustainable agricultural practices.

5.3.1. Assessing environment and biophysical systems in the MDM under climate change.

Rural communities depend on the ecosystems for sustainable development of their daily activities. Ecosystems include biotic communities (plants, animals, microbes) and abiotic factors (water, temperature, soil type). Climatic conditions and vegetation type define the type of an ecosystem and biodiversity of a specific geographical location. Climatic conditions and change pose a great threat to the sustainable development of the rural communities in the provision of food, water, fibres, energy, raw materials, industrial chemicals, and medicines. Biodiversity contributes to economic growth and development such as tourism and the cultivation of indigenous species (SEQ Ecosystem Services Framework, 2016).

In this research sensitivity is based on environmental risks such as degraded land, soil erodibility, irrigation demand, ecosystem protection level, invasive plant density, stream flow and availability of ground water in the rural communities of MDM. It is of the utmost importance to take into account the protection status of ecosystems in surrounding the rural communities. If the ecosystem is not protected there is a high possibility of the loss of the natural habitat and that may result in the change in the function and provision of the ecosystem services to rural communities (Vizzarri *et al.,* 2015). The MDM ecosystem is not protected mostly on the dolomite granite grassland vegetation type and well protected in the bushveld vegetation type and poorly protected mostly in the sourveld vegetation type. It is of utmost importance to protect the ecosystem as it plays a role in the biodiversity of that specific area and thus contributes economically to the communities around (DEE, 2016). Critically endangered threated ecosystem are found in the Greater Tzaneen Local Municipality extending to the Greater Letaba Local Municipality, vulnerable threatened ecosystem spread across the district and the fresh water ecosystem are also endangered (Figure 30).

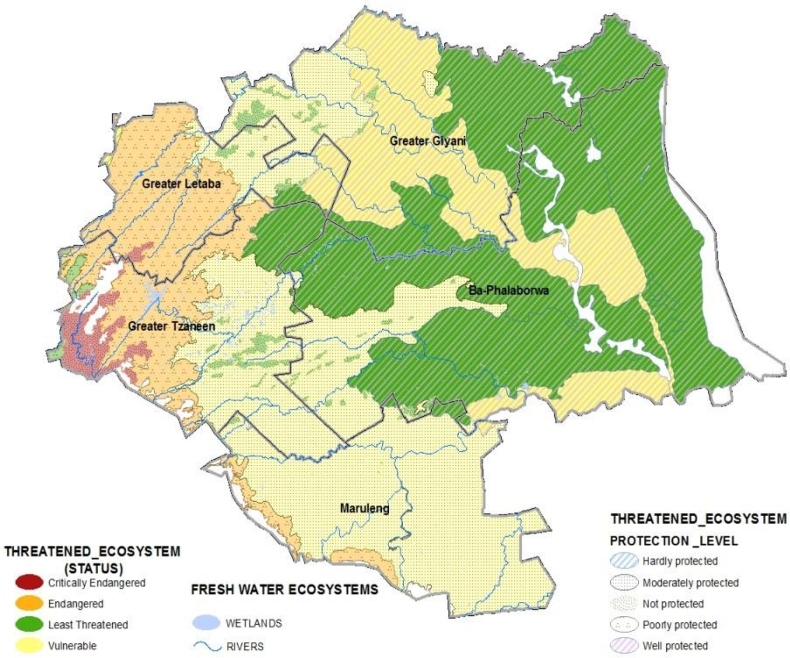


Figure 29: Biodiversity and ecosystem health in MDM

Source: Author *: Khwashaba ME, 2015)*

Sustainable land-use planning and strategic environmental assessments are important in determining the state of land cover. Degraded land affects the productivity of land, reduce biodiversity, reduce ecosystem services, and reduce vegetation cover and natural resources for the economic development of rural communities they serve (Billé, 2012). Rural communities agricultural practices that are not properly applied deforestation and overgrazing amongst others contribute further to land degradation. Natural factors that cause land degradation include droughts, floods and landslides (Baird *et al*., 2016). The distribution of invasive alien species affect biological diversity of the land, water security and the provision of ecological systems functions (Shrestha, 2013).

The land is degraded in most parts of the MDM, especially nearby settlement areas (Figure 31). Degraded land could have resulted from the interaction between the ecosystem and rural communities around the MDM though grazing, ploughing and other agricultural practices. The distribution of Invasive Alien species ranges from 0-

40% in all municipalities but shows a high density of 30-40% in the Greater Tzaneen Local Municipality. Invasive alien species have an impact on water quality as they decrease both surface water runoff and groundwater recharge (Chamier *et al*., 2012). According to the MDM IDP (2016/17) identified invasive alien species in the district includes bug weeds, pines, eucalyptus, lantana, jacaranda, paraffin boss, Mauritius thorn, Mexican poppies, potato bush, black wood, black wattle, silver wattle, castor oil and queen of the night. Alien plants that invade riparian habitats include peanut butter cassia, castor-oil, sesbania, ageratum and large cocklebur. The Invasive Alien species already affected Sekororo dam, Madeira, Hans Merensky nature reserve, Letaba river, N'wamitwa, Lekgalameetse nature reserve, Tours dam, Haernetzburg and Ebenezer dam, Modjadji nature reserve, Thabina nature reserve Letsitele River and Mamathola plantation.

A natural or undisturbed ecosystem and biodiversity play a major role in providing services to rural communities and the atmosphere while also strengthening resilience against climate change further assists rural communities in coping and reducing the impact of climate change in their everyday lives. Continuous reduction in biodiversity services and changes in the status of the ecosystem that has resulted from land degradation in the MDM rural communities weakens the ability of the ecosystem to provide required and sufficient services to cope with climate change and natural disaster risks.

Biodiversity and ecosystems services aid in regulating climatic conditions. The presence, management and maintenance of wetlands in the rural communities of the MDM will aid in the absorption and storing of carbon that will further aid rural communities to mitigate climate change impacts. Most wetlands from the MDM rural communities have dried up and it places the MDM rural communities in a vulnerable state to climate change and less resilience. The MDM is full of degraded environments, it is therefore important to restore the degraded environment and reduce pressure on nature. It is also important for the MDM rural communities to work nature in order to improve climate change adaptation and mitigation.

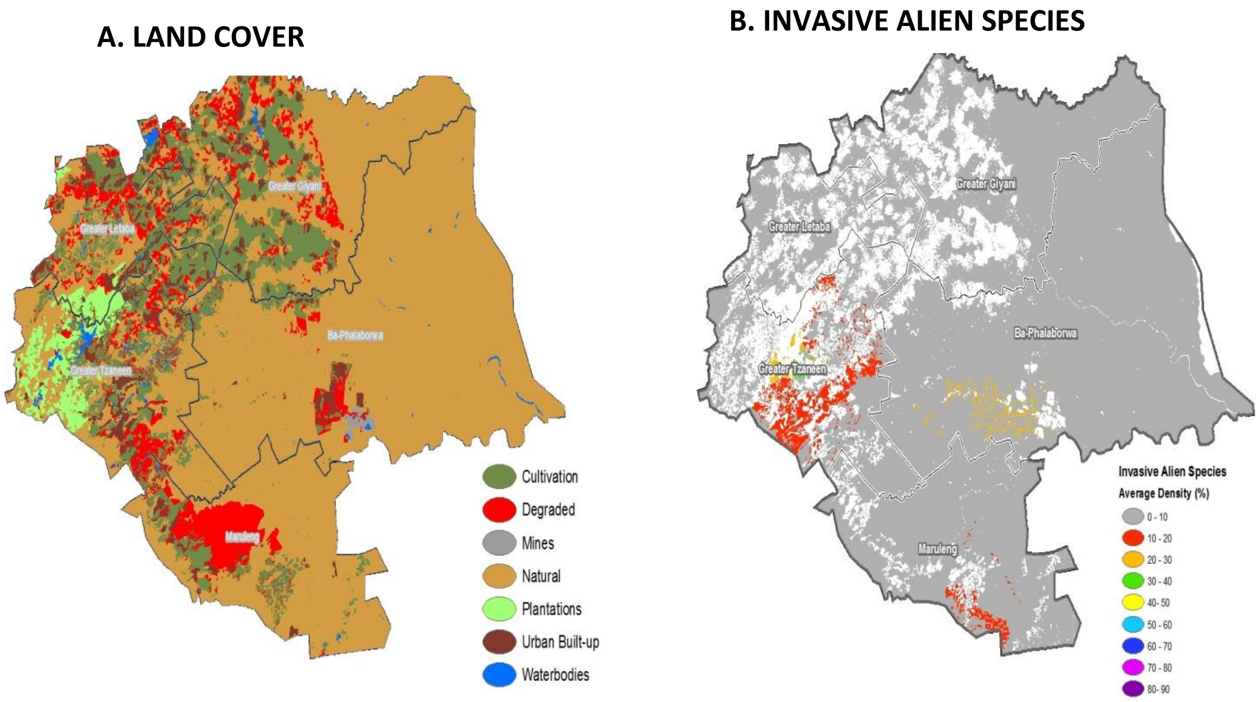


Figure 30: Land cover and the distribution on Invasive Alien Species (MDM)

*Source: (*Author *: Khwashaba ME, 2015)*

MDM rural communities are more dependent on government services which will reduce their resilience to climate change as government services also have their own challenges. Enhancement of environmental conservation in the rural communities of the MDM will aid in reducing vulnerabilities to climate change that impact on the livelihood and economic development in their everyday live. The MDM conserves only the north eastern escarpment areas focusing on the protection of endangered species only (Figure 31) and it will be beneficial to the district to conserve most parts of the natural environment for sustainable use of the natural environment.

MDM's unhealthy resilient ecosystem will act against the ability to reduce and cope with climate change impacts as the district show more degraded areas, threatened freshwater ecosystems and unprotected ecosystems. The MDM will struggle to recover or will take a very long time to bounce back from the impact and effect of occurrence of disaster risks. MDM need to effectively conserve nature through government programs and engage with rural communities in order to promote and maintain genetic and species diversity in the ecosystems. MDM need to improve in the protection of terrestrial and freshwater ecosystems through riparian buffers that will protect streams and rivers from improper agricultural practices and land use changes.

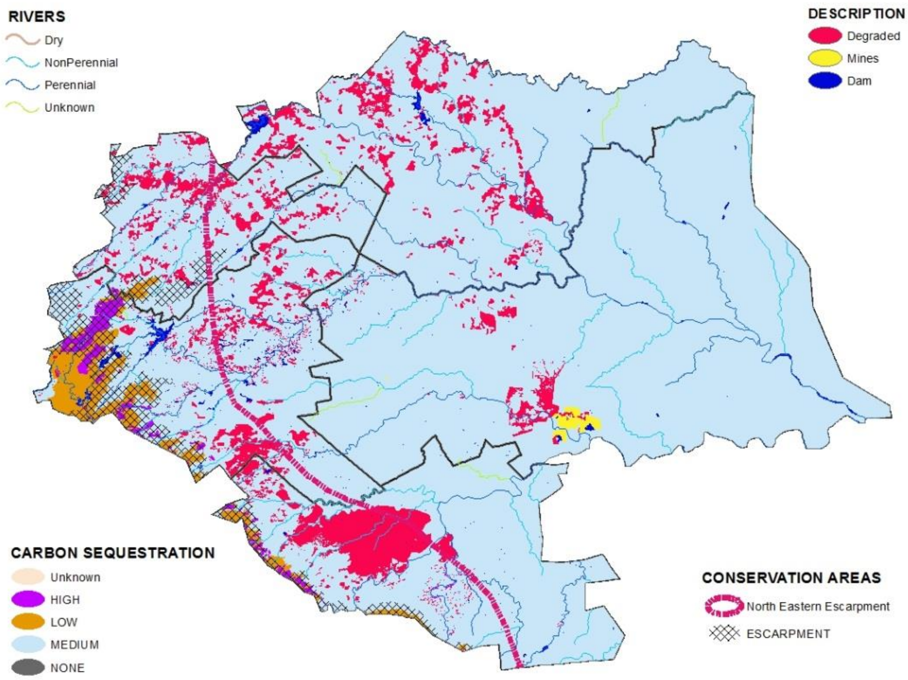


Figure 31: Conservation areas, carbon sequestration, rivers and degraded environments (MDM)

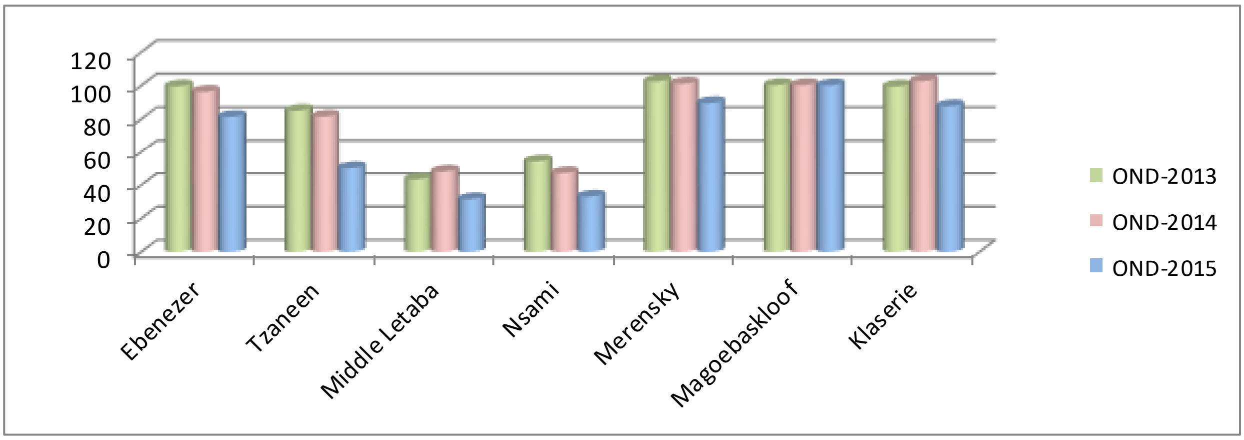
*Source: (*Author *: Khwashaba ME, 2015)*

The MDM rural communities are dependent on wood for cooking and have a negative impact in the environment (Figure 34). Rural community's dependent on social grants contributes more deforestation. Most researches indicate that deforestation activities contribute to at least 20% of global CO2 emissions (Live science, 2016). When the ecosystems are disturbed it results in the reduction of its capacity to capture and to store carbon. There are unpredictable disturbances that negatively affect the ecosystem and that causes the ecosystem to lose its resilience and the carbon sinks turn into carbon sources. Figure 31 shows that carbon sequestration is high in the escarpment and medium across the district. Carbon sequestration captures carbon and stores carbon dioxide (CO2) that promotes the reduction of climate change impact

Figure 32: Collection of wood by rural communities for cooking

*Source: (*Author *: Khwashaba ME, 2015)*

The availability of water is of the utmost importance in rural communities for their livelihood. Dam levels that serve water to rural communities in the MDM were assessed from the period of three years (2013-2016). Dam level capacity is represented in percentage and the average for three months of January, February and March (JFM) and October, November, December (OND) was used in this research to determine if the dam levels have been increasing or decreasing in the rainy months of JFM and OND) from 2013-2016. The middle Letaba dam level hardly reached 50% from 2013 to 2016 thus posing a threat to the availability of water to the rural communities it serves. From JFM in 2016 three dams (Tzaneen, Middle Letaba, Nsami) did not reach 50%, this might be due to the El Niño conditions and heat waves that have impacted the district in 2015/2016 .It is clear from Figure 34 that the Middle Letaba Dam level is of concern and the rivers that draws water from it is also drying up. Rural communities around the Greater Letaba Dam utilise the dam for fishing to support their families.



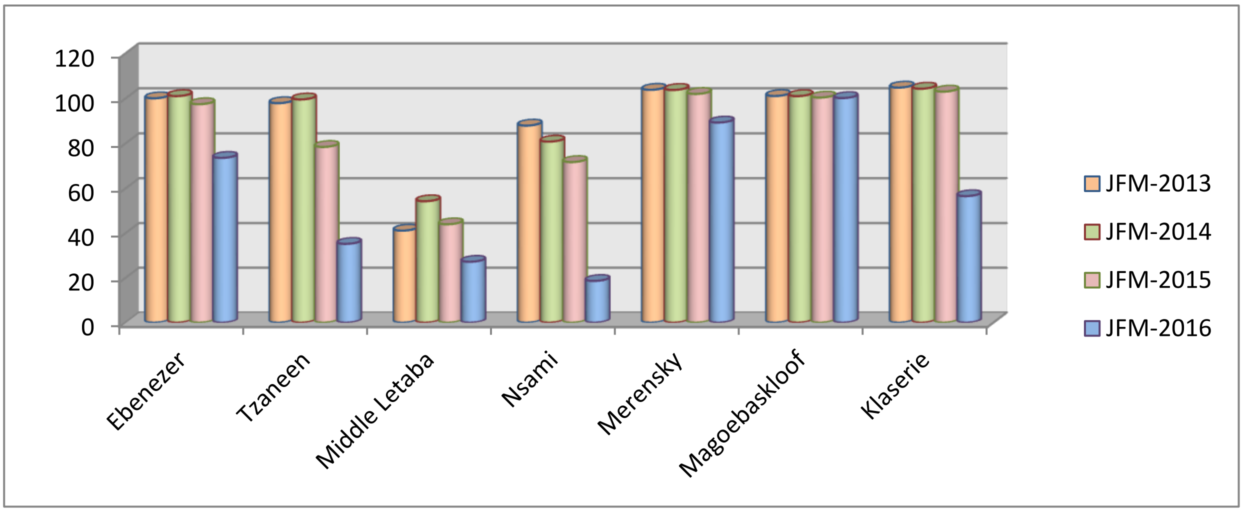


Figure 33: Dam Levels from 2013-2016 (MDM)

Source: (Author: Khwashaba M.E, 2015)

Figure 34: Middle Letaba Dam

Source: (Author : Khwashaba ME, 2015)

Community members were interviewed to find out if they are experiencing any impact on the dams that are not reaching 50% in order to supply adequate water to the communities it serves. The respondents indicated that they highly feel the impact of not having water to sustain their daily activities. The field survey was done in the times where the district was experiencing heat waves in November 2015. Findings from interviews with focus groups in relation to water scarcity were that they are experiencing temperature changes, and in that; temperatures have increased and recently it has also affected the availability of water sources. Women from the Maphela village indicated that back then the sun was too high and now the sun has gone down and that is the reason we are experiencing this heat. They also raised concerns that the amount of rainfall has decreased and most of the streams or rivers have dried out due to the scarce rainfall. Figure 35 shows a river between Hlaneki and Gonono village that has dried up. The river was used for irrigation purposes and laundry. They also indicated that these days, seasons for ploughing have also shifted and they have to wait for the rainfall to start ploughing unlike before when they were sure of the timeframe to start ploughing and the time for harvesting. They raised concerns that these changes have affected their crop productions and they are too dependent on cash crops which they have to buy, considering that the prices have gone up, it becomes unaffordable for them. They also raised concerned that they cannot depend on wild fruits anymore, due to scarce rainfall wild fruits are also scarce; the district has wild fruits such as Machidi, Marula, Tukulu, Mabilo, Tintoma, Tintsengele, Mibomu and Makwakwa. They also raised concerns that big trees are scarce that even Mopani worms are very scarce. When one needs Mopani worms, they have to buy and they are too expensive. In addition to the impact of water scarcity community focus groups also indicated that livestock's have been decreased due to theft of cattle in grazing camps which is an outcome of scarce rainfall. They indicated that there are some government programs that are assisting them with maintaining grazing camps by implementing projects such as animal and veld management

Figure 35: Dried river between Gonono and Hlaneki Village

Source: (Author : Khwashaba ME, 2015)

Groundwater is of the utmost importance as a source of water and the availability of groundwater is also dependant on the recharge from infiltration of precipitation. Extreme disaster events such as drought if it has impacted on land surface can result in a reduction of water levels below ground (Barkey et.al,. 2017). The geology of the area is important determining the availability of ground water and MDM consists of sandstones, shale, grit, conglomerate, quartzite and basalt (DWAF, 2013).

The quality of groundwater is determined by the amount of available nitrate and fluoride in the ground. Human activities such as agriculture, industry and domestic effluents contribute to the increase of nitrate and flouride levels in ground water. Natural nitrate levels in groundwater are seen as generally very low (typically less than 10 mg/l NO3). MDM's nitrate concentration level shows an ideal condition that the groundwater can be used for human consumption or agricultural activities. There is a possibility of an increase in nitrate concentration levels in areas where agriculture (both stock and crop) is practiced extensively. Concentrations of nitrate in water as measured and recommended by the department of water affairs in South Africa should be less than 5 mg/R of nitrate-nitrogen (or, alternatively, 22 mg/R nitrate (Odiyo *et al*., 2012).

The MDM shows an ideal condition that indicates that ground water can be used for human consumption and agricultural activities. In South Africa, the Department of

Water Affairs and Forestry, domestic water use guideline indicates that fluoride concentration in drinking water should not exceed 0.7 mg/R (DWAF, 2013).

Increase or decrease in temperatures and precipitation will have an effect on the *agricultural sector*.
The impacts will include:

- Damage to crop quality which will increase the costs and results in the losses to agricultural producers;
- The reduction of crop yield will contribute negatively to the income of the farmers and results in the loss of jobs;
- Increase in the cost of development of new water resources for irrigation purposes, human and livestock consumption;
- The absence of adequate rainfall, the grazing land production is reduced and unavailability of feed and water for livestock and this will make farmers to purchase fodder for example for their livestock's and this will increase costs to livestock producers and high livestock mortality rate;
- Increasing temperature will have an effect on the quality of agricultural productions that includes tomatoes, bananas, mangoes, oranges, and pineapples amongst others;
- Rural communities are highly dependent on subsistence farming and an increase in the extreme temperatures will reduce food security, and results in increase of malnutrition;
- Increasing temperatures accelerate the spread of animal diseases (e.g. foot and mouth disease, rabies, new castle disease, avian influenza); and
- The presence of Pines, Eucalyptus and Mahoganies plants in the Greater Tzaneen and Greater Letaba local municipalities increases the risk on the distribution of eucalyptus plants that has resulted from Thaumastocoris australicus infestations.

Increase or decrease in temperatures and precipitation will have an effect on *biodiversity and environmental sector*. The impacts will include:

- Increased Impact on already threatened ecosystem that is not protected;
- Land-use changes will impact the environment resulting in the loss of biodiversity and degradation of natural habitat due to significant land use change. Wolksberg Wilderness area is considered as biodiversity hotspot in the district and should be conserved together with Debengeni waterfalls, Modjadji Nature reserve where prehistoric plants Cycads are found, Manombe Nature Reserve, Provincial Merensky Reserve, Letaba Ranch, Geothermal springs in Hans merensky Nature Reserve and Soutini Baleni, Tingwadzi Heritage centre, Lekgalameetse and Muti wa Vatsonga; and
- MDM consists of priority wetlands and river ecosystems residing at Mokgolobotho, Dan, Julesburg, N'wamitwa villages (Greater Tzaneen Municipality), Majeje, Mashishimale, Makhushane villages (Ba-Phalaborwa Municipality), Makgaung (Maruleng Municipality), Ga-Kgapane & Belleview (Greater Letaba Municipality), and Siyandani, Homu, Shawela Greater Giyani Municipality and the changes in temperatures and rainfall distributions will affect the state if wetlands and river ecosystems.

An increase in extreme events resulted from an increase or decrease in temperatures and precipitation will impact on *human settlement sector* include**:**

- Extreme events will increase impact on infrastructures such as roads and bridges and houses;
- Informal dwellings such as shacks and huts will highly be affected by extreme weather events because they structures are already vulnerable. Informal dwelling in MDM that consists of shack backyard are in total of 2998 and a total of 3631 that are consists of shack, not residing in the backyard of formal structures;
- An increase in the reduction of recreational opportunities and increased impact on tourism supporting infrastructure, such as conservation area access roads will decrease income from tourism in the MDM and this will impact mostly in the Ba-Phalaborwa local municipality by the Kruger National Park; and

- Extreme heat will affect the health status of people in the rural communities and suffer from mental and physical stresses and the distribution of epidemics diseases (e.g. Diarrhoea and malaria).

Increase or decrease in temperatures and precipitation which will have an effect on the *water sector* include**:**

- An increase in the occurrence of drought conditions will decrease water quality in the ecosystem and less water will be available to dilute waste water discharges and irrigation return flows to rivers from agricultural practices. Water quality will be reduced and associated downstream health risks to aquatic ecosystems will be increased. An increased periods of drought mean less water is available for irrigation and drinking; and
- Disaster wastes, litter and washed-off debris block water and sanitation systems during heavy rains that result in flooding affecting sewer systems and other pipelines infrastructures.

5.3.2. Assessing how climate change may impact directly on rural communities and social systems (human systems, i.e. livelihoods and infrastructures) in the MDM.

Social and economic aspects in the rural communities of the MDM were used to assess climate change adaptive capacity or resilience. Crucial aspects such as access to basic services, annual household income, access to primary health care, the gender of household head, land ownership, and type of dwelling have been considered when assessing the living conditions and economic conditions in the rural communities of the MDM.

Population growth contributes significantly to the demand for natural resources in rural communities and these results in putting more pressure on the natural environment and results in environmental risks such as land degradation. From the year 2001 to 2011; population shows an increase at the Greater Giyani LM (87.4% rural); Greater Letaba LM (93.3% rural); Greater Tzaneen LM (82% rural); Maruleng LM (88.7%rural) and Ba-Phalaborwa LM (84.9% rural) (Statssa, 2011).

In the rural communities of the MDM to prevent the spread of diseases, proper sanitation is required in terms of South Africa National standard for sanitation that promote appropriate education in respect of effective sanitation, safe, clean and healthy toilet infrastructures.

In this research, a comparison was done based on the 2001 census and 2011 census access to basic services statistics and its 10 years difference. Flush toilets connected to sewage in the Greater Giyani was, 13.7% in 2001 and 11.9% in 2011 and this shows a decrease of 1.8%. Refuse removal was 10.4% in 2001 and 11.7% in 2011 which shows an increase of 1.3%. Flush toilets connected to sewerage in Greater Letaba local municipality was 7, 5% in 2001 and 6, 8% in 2011 and this shows a decrease by 0.7% and this might have been caused by the lack of water inside the dwellings then communities decided to use pit latrines instead of flush toilets. Weekly refuse removal was 7% in 2001 and 8, 5% in 2011 and this shows an increase of 1.5%. Flush toilets connected to sewerage in the Greater Tzaneen Local Municipality were 16, 1% in 2001 and 15, 3% in 2011 and this shows a decrease of 0.8%.

Weekly refuse removal was 15% in 2001 and 14, 7% in 2011 and this shows a decrease of 0.3%. Flush toilets connected to sewerage in the Maruleng Local Municipality was 11,5% in 2001 and 8,2% in 2011 and this shows a decrease by 3.3% and this might have caused by the lack of water inside the dwellings and communities decided to use pit latrines instead of flush toilets. Weekly refuse removal was 7,7% in 2001 and 5,9% in 2011 and this shows a decrease of 1.8%. Flush toilets connected to sewerage in the Ba-Phalaborwa Local Municipality was 40,2% in 2001 and 40 5% in 2011 and this shows an increase of 0.3%. Weekly refuse removal was 41,6% in 2001 and 48,8% in 2011 in the Ba-Phalaborwa Local Municipality and this shows an increase of 7.2%. A rural community with poor sanitation leads to an outbreak of diseases such as cholera and diarrhoea and is therefore crucial to take into account the percentage of the population with and without access to sanitation in rural communities. Municipalities that had a decrease in number on the usage of flush toilets might have been caused by the lack of water inside their dwellings even though there is a number of an increase in the piped water inside the dwellings.

An interview with the focus groups supported the analysis from StatsSA. They indicated that they do have toilets but mostly pit latrines and those that have RDP toilets laid complain that they are not of good material as they sometimes last for two weeks after installation and then they collapse. They also indicated that there is no refuse removal from the municipality but they just dump anywhere around there communities and inside their dwellings (Figure 36).

Figure 36 : Dumping sites around communities (MDM)

Source: (Author : Khwashaba ME, 2015)

Water is an important resource for daily activities in the rural communities including, cooking, irrigation etc. It is therefore important to monitor the quality and access to water due to the fact that rural communities with no access to basic water services rely on unsafe alternatives sources of water such as rivers, springs etc., which may be contaminated with faecal coliform, chemical pollution from heavy metals such as Zinc and Lead. Communities who rely on water from unsafe sources have a high possibility of contracting infections such as diarrhoea, bilharzia and so forth (Pickering, 2015).

In the rural communities of the MDM to prevent the spread of diseases, the quality of drinking water should be acceptable in terms of the national standard for basic water supply which promote the provision of education with respect to the use and management of water and also which encourages that no household should spend more than seven days without access to good water quality for drinking and domestic use (SERI,2011).

Piped water inside the dwelling in the Greater Giyani Local Municipality was 11,3% in 2001 and 13,4% in 2011 and this shows an increase of 2.1%. Piped water inside the dwelling in the Greater Letaba Local Municipality was 5,4% in 2001 and 10,2% in 2011 and this shows an increase of 4.8%. Piped water inside the dwelling in the

Greater Tzaneen Local Municipality was 8,1% in 2001 and 16,1% in 2011 and this shows an increase of 8%. Piped water inside the dwelling in the Maruleng Local Municipality was 5,9% in 2001 and 10,9% in 2011 and this shows an increase of 5%. Piped water inside the dwelling in the Ba-Phalaborwa Local Municipality was 29,5% in 2001 and 37,1% in 2011 and this shows an increase of 7.6%. As much as there is a slight increase from 2001 to 2011 for the installation of piped water inside the dwellings, rural communities in the MDM are still struggling to have access to water. Interviews from focus groups indicated that they depend on the water from municipality which is controlled on a weekly basis and sometimes they go up to a month without getting water due to the fact that they are being told that the dam that supplies water does not have enough water and they have to depend on other community members who have boreholes wherein they have to buy water. Others also indicated that the rivers that still have little water are residing on private farms and they are not allowed to access the water.

It is crucial for rural communities to have adequate access to basic services and without adequate access to basic services for cooking as an example will impact on the environment due to the fact that communities without electricity in their homes will depend on wood and dung for cooking. A smoke that results from burning wood or dung is harmful to human health and causes illness and death eventually; it also pollutes the air in the atmospheres (EAP, 2016). Carbon dioxide (CO_2) is one of the greenhouse gases (Carbon dioxide, Methane, and Nitrous oxide) which exist naturally in the atmosphere. Human activities in the rural communities such as deforestation and burning fossil increase the concentration of CO_2 in the atmosphere and have a negative impact on the environment such as air pollution, global warming and climate change which ultimately leads to change in rainfall patterns, species loss etc. (Casey, 2008).

Electricity for lighting in the Greater Giyani Local Municipality was 67,3% in 2001 and 89% in 2011 and this shows and increases of 21.7%. Electricity for lighting in the Greater Letaba Local Municipality was 65.7% in 2001 and 90,8% in 2011 and this shows and increases of 25.1%. Electricity for lighting in the Greater Tzaneen Local Municipality was 69.1% in 2001 and 86,2% in 2011 and this shows and increase of 17.1%. Electricity for lighting in the Maruleng Local Municipality was 58,7% in 2001 and 90,6% in 2011 and this shows and increases of 31.9%. Electricity for lighting in the Ba-Phalaborwa Local Municipality was 76,8% in 2001 and 90,8% in 2011 and this shows and increases of 14%. A comparison from 2001-2011, shows a huge increase in the provision of electricity for lighting. From interviews with the focus groups, concerns or challenges raised was that even though the municipality provided them with electricity they cannot afford to use electricity for lightning or cooking as most of the people in their communities depend on government grants and they added that they cannot afford to buy electric stoves. They also raised concerns that there are no street lights in their communities and they feel unsafe walking during the night. Other concerns raised were of insecurity when going to collect wood for cooking from the bushes as they feel unsafe from men who may attack them and the roads are very bad to move around the communities due to huge dongas, they recommend bridges for easy access from one household to another and also when they go to collect wood for cooking (Figure 37).

Figure 37: Dongas surrounding rural communities (MDM)

Source: (Author : Khwashaba ME, 2015)

Rural communities are faced with challenges of poverty and diseases such as HIV/AIDS amongst others and that constitutes a vulnerability. The loss of family members to AIDS related death; productivity losses due to illness, caring for the sick, and funerals; the direct costs of medication, as well as other burdens, have results in poor communities to be living under stressed conditions (Drimie, 2002). Female headed households in the Greater Giyani Local Municipality was 59,4% in 2001 and 57,3% in 2011 and this shows a decrease of 2.1%. Female headed households in the Greater Letaba Local Municipality was 57,1% in 2001 and 56,8% in 2011 and this shows a decrease of 0.3%. Female headed households in the Greater Tzaneen

Local Municipality were 51, 5% in 2001 and 47, 8% in 2011 and this shows a decrease of 3.7%. Female headed households in the Maruleng Local Municipality was 53, 4% in 2001 and 53,7% in 2011 and this shows a decrease of 0.3%. Female headed households in the Ba-Phalaborwa Local Municipality was 36,7% in 2001 and 39,5% in 2011 and this shows a decrease of 2.8%. The findings from focus group interviews were that most households are headed by females due the fact that most women are single mothers and few women indicated that their husbands work far from homes so they are left to look after the children. Some women indicated that they have lost their husbands due to death and they are left to head their households. Some households are headed by elderly women who are staying with their grandchildren after their mothers left to stay in the cities. Most women in the focus groups indicated the challenges they experience in their everyday lives. They indicated that they do not have a reliable source of income but depends on government social grants which are not enough to sustain on their everyday lives and to take their children to a higher level education. They indicated that after grade 12 their children stay at home not further their studies due to financial constraints. They also raised a concern about the quality of food they buy from local shops. They indicated that some of the food they buy had passed the expiry date and if they need food which is not expired, they are required to travel to major towns and are too expensive for them and in that case they are forced to depend on the local shops. Another woman from community focus group sells tomatoes and avocadoes to support their families and they buy tomatoes very expensive and sometimes they go homes without any profit. One older woman at the age of 65 indicated that she is a bread winner and stays with her unemployed children and grandchildren and she depends on grant and selling tomatoes for survival and sometimes she spends more than two days without making any profit.

The unemployment rate in the Greater Giyani Local Municipality was 60,3% in 2001 and 47% in 2011 and this shows a decrease of 13.3%. The unemployment rate in the Greater Letaba Local Municipality was 42% in 2001 and 40,3% in 2011 and this shows a decrease of 1.7%. The unemployment rate in the Greater Tzaneen Local Municipality was 42,4% in 2001 and 36,7% in 2011 and this shows a decrease of 5.7%. The unemployment rate in the Maruleng Local Municipality was 40,1% in 2001 and 39,9% in 2011 and this shows a decrease of 0.2%. The unemployment rate in the Ba-Phalaborwa Local Municipality was 40,2% in 2001 and 37,4% in 2011 and this shows a decrease of 0.2%. From the comparison of the 2001-2011 census, there is an indication that the unemployment rate has decreased in all the local municipalities of the MDM. From the interviews from focus groups they indicated that some of the women and young men are employed on the government programs such as Animal and Veld Fire Management (AVMP), Expanded Public Works Programs (EPWP) and they raised concerns that they work under contracts and the stipend they get on a monthly basis is not enough to meet their basic needs. They also raised concerns that they work under unfavourable conditions as they are exposed to heat and dangers of being bitten by snakes as they work in the bushes (e.g. eliminating invasive alien species, debushing and in the creation of gabions) and government in other cases took long to provide protective clothing. Sometimes the contracts can lapse without them having protective clothing.

The MDMs' level of education is very low as statistics indicate low levels of people who completed a higher education level. People with Higher education aged 20+ in the Greater Giyani Local Municipality was 7,4% in 2001 and 7,1% in 2011 and this shows a decrease of 0.3%. People with Higher education aged 20+ in the Greater Letaba Local Municipality was 7,4% in 2001 and 7,1% in 2011 and this shows a decrease of 0.3%. People with Higher education aged 20+ in the Greater Tzaneen Local Municipality was 6,5% in 2001 and 8,7% in 2011 and this shows a decrease of 2.2%. People with Higher education aged 20+ in the Maruleng Local Municipality was 5,2% in 2001 and 7% in 2011 and this shows a decrease of 1.8%. People with Higher education aged 20+ in Ba-Phalaborwa local municipality was 8,2% in 2001 and 12,1% in 2011 and this shows a decrease of 3.9%. Findings from the focus group were that the majority of people in their communities are unable to go to a Universities and Technikons due to financial constraints and those who can afford to go to TVET colleges do go there but after finishing their studies they are unable to get employment in government and in the private sectors. They also indicated that they are not well informed about the financial schemes like bursaries and educational loans. Due to the low levels of higher education communities feels like they are not competitive enough with the outside markets.

The MDM consists of eight health centres, 94 clinics, and hospitals (Limpopo Department of Health, 2015). The prevalent diseases in the MDM include Diarrhoea; Pneumonia; Tuberculosis; HIV and AIDS; Malaria; Sexually Transmitted Infections (STI); Non-communicable diseases, e.g. hyper-tension, sugar diabetes, etc. (MDM IDP, 2016/17). Interviews with the community focus groups raised concerns in the provision of health services around their communities. They indicated that they have a challenge with the unavailability of medicines from the clinics and they are forced to travel to the nearest hospital which is usually a distance from their communities where they are required to use public transport which in most cases they might not have fares to pay the public transport. In addition the other women from Sekgopo indicated that they experience tornado every year and there is no awareness campaign on what should they do or prepare themselves for the events of tornado, the municipality only give the food parcels after the event and this gives them challenges in cases where community members get injured as a results of extreme events where they will have to travel long distances for health services.

Access to land and land tenure in the rural communities is important as it plays a role in their agricultural economies and can impact on their everyday choices. By giving the rural communities and opportunity to have control over their land it determines the level of their wealth or poverty. The lack of access to land and insecure tenure in the rural communities often constitutes the poorest and the most vulnerable groups. If the rural communities who rely on agriculture do not have access to land they are impacted on their decision making in relation to agricultural practices, for example, they are limited in deciding the best methods to invest (both financially and in terms of labour for the purpose of improving their production, in sustainable natural resources management and in the adoption of new technologies and promising innovations (DRDLR, 2013). Inadequate access to land also leads to overcrowding in a small piece of land which ends up putting pressure on the natural resources such as soil, water, and plants. Access to land in the MDM seems to be a challenge, especially to women. Hunderd and nighty (190) land claims are currently in process, with 146 of these yet to be validated (MDM IDP, 2016/17). Delay in settling registered land claims is having a negative challenge and restrict the utilization of land for agricultural purposes and rural development. Findings interviews with the focus groups were that access to agricultural land is not easy and most community members are using their old land where their grannies used to stay. They call the land “Mashuping or Marhumbini”. They also indicated that if you are given a space in a land by other community members who own the land you are restricted to plough according to what is practiced in that land. For example, rural women plough maize in most of the fields. They also indicated that some women who are working class are able to lease land and produce cash crops and take them to the markets themselves. They raised concerns that if you are unemployed, it is difficult to sustain the production as it requires a resource that needs adequate funding. They also raised concerns that there is lack of awareness campaigns on government programs that aid rural women to create own employment and income through agriculture and if such programs are in place they benefit the few.

The MDM rural communities are mostly under traditional authorities and town planning is non-existent in the informal settlements and has resulted in communities settling in areas that are not suitable for residential zoning and possibly on high flood plain areas (Figure 38).

Figure 38: Informal settlement (MDM)

Source: (Author : Khwashaba ME, 2015)

Based on the analysis of an ecosystem and the rural communities, it is therefore also important to analyze the role of traditional leadership and the local communities in building resilience through indigenous knowledge. From the interviews with the focus group, they indicated that the way they used to do things have changed and they believe that the indigenous knowledge is being undermined by scientists as it is not recorded anywhere. They indicated that in order for them to survive after a disaster event (i.e. drought) they used to preserve some grain in a build-up structure that is specifically for preservations of grain. They also indicated that they used to also preserve dried fruits and dried meat (Mukoki). Indigenous knowledge was used as another method for predicting and forecasting of rainfall and other climate hazards. Community members were able to predict rain availability and scarcity through observing the behavior of animal and plant species (such as Mbula), too much Mbula means that there will be a lot of rain and harvesting lots of maize and when there is no Mbula it means there is a possibility of experiencing drought conditions and when the moon is surrounded by a circle of a rainbow in the evening it indicates that the rain will fall the following day. They also indicated that through their cultural believes, there was a rain calling through Queen Modjadji and rituals where always performed to appease their ancestors. They used to identify by using observations such as stars and a fruit called Mbula if there will be drought or not. By using those observations they were able to identify the right seasons to plant their crops. They used their indigenous knowledge in diverting the wind storms and preventions of lightning. The focus groups which consist of the elderly also indicated that the ancestors are now angry because communities are no longer performing ancestral rituals and they indicated that it will be best if indigenous or local knowledge is documented and an engagement with royalties together with scientists can improve the situation for the better in building resilience.

Digital access has increased the amount of information (i.e. environmental, social and economic) that can be accessed and disseminated. Access to internet and cellular phones is important for research, communication, and networking, awareness campaigns, acquiring knowledge and technological skills in order to resolve environmental, economic and social issues. It is therefore important for rural communities to have access to digital technologies for information sharing and security purposes.

5.4. Climate change adaptation options for rural communities in the MDM.

MDM rural communities are vulnerable to the impacts of climate change which affects the agricultural, water, environmental and biodiversity sectors, Infrastructures, human settlement, and health sector. Adaptation options for each sector are important in assisting rural communities to cope with the impact of climate change

5.4.1. Agricultural Sector

- Approximately 10 000 to 70 000 hectares land is not being utilised mainly in areas of Letaba/Letsitele basin area and about 1500 hectares in the Klein Letaba and has the agricultural potential for subtropical fruit, citrus fruit production, and vegetable area. The National and Provincial Department of Rural Development and Land Reform together with Department of Agriculture Forestry and Fisheries should make the land accessible to the rural communities of MDM for job creation and food security.

- The MDM should engage with the Department of Agriculture, Forestry and Fisheries to capacitate farmers and people in rural communities for agricultural management practices, such as a change in planting seasons, methods of spacing planting rows, planting density and other relevant measures that counteract the impact of limited moisture that has resulted from the impact of climate change. To implement agricultural extension programmes to promote climate-sensitive agriculture (water and soil conservation, crop selection), and also assist in research and innovation in crops and livestock farming. All relevant departments should also provide technical and financial support to small-scale and subsistence farmers, agricultural co-operatives and improved access to markets. Rural communities should also be supported by indigenous agricultural knowledge and traditional agricultural practices, to build on existing climate resilient capabilities.

- The MDM should consider phasing out of irrigation farming in areas where there is insufficient rainfall and irrigation schemes are drying out and consider relocation of the production to other areas and utilise that production area for crops are drought or heat resistance (e.g. planting of sorghum and millet) or alternatively the area can be used for grazing. And this will help in the reduction of dependence on irrigation that will further reduce water consumption without reducing crop yields, and this will promote greater resiliency in adapting to future climate changes in thus water harvesting is encouraged in the rural communities of the MDM. Introduction of more and better heat and drought resistant crops will improve current and future MDM food demand by improving production efficiencies in marginal areas, with immediate effect. The MDM rural communities should be encouraged to utilise compost of organic waste for community food gardens.

- The MDM rural communities should be capacitated in planting techniques (e.g.conservation, contouring amongst others), and planting of vegetation that will serve as windbreaks that will further help in protecting fields from water and wind erosion while retaining moisture by reducing evaporation and increasing water infiltration.

- Application of pesticides should not be encouraged to the farmers of the MDM as it will reduce greenhouse gas emissions and streams and rivers to be polluted and thus contributing to both adaptation and mitigation.
- All relevant local, national and provincial government departments such as DAFF, DRDLR, SAWS, and Disaster Management centres should provide farmers and rural communities' information on climatic conditions.
- The MDM in partnership DRDLR and DAFF should review land use planning and relevant policies in order to identify trends in land use that would be advantageous in the event of climate change.
- The MDM rural communities should reduce mono-cropping practices, for example, planting of maize year after year on the same land without rotation of other crops will impact negatively on the quality of the soil while providing opportunities for the unbuffed niche for parasites species and the rural communities will be forced to apply pesticides and artificial fertilizers. Reducing mono-cropping practices and diversify the range of different crops cultivated on the same land will reduce vulnerability as well as creating jobs and potentially reducing irrigation needs.
- The MDM farmers and rural communities should maintain different seeds stored in seed banks in order to preserve biological diversity and provide

farmers and rural communities' opportunities for making different choices and that would assist to act against the effects of climate change and maintaining food security and establishing possibilities for profitable specialisations.

- The MDM should nourish the Mopani worm and wood industries by protecting the natural environment and harvesting it in a sustainable way.
- The MDM farmers and rural communities should adopt herd mobility in the dry season because of less rangeland availability livestock grazing systems and the animal can be effective adaptation measures.
- The MDM and DAFF should support small-scale fisheries in the Middle Letaba Catchment and in other rural communities.
- The MDM should consider monitoring, reporting and impact evaluation during and after the disaster occurrences to be emphasised, this will assist in ensuring that farmer's registers are developed and updated to channel relief resources to the relevant beneficiaries (DAFF) by developing and updating of farmer registers.

5.4.2. Water sector

- The MDM should form a partnership with the Vhembe District Municipality to utilise the Nandoni Dam, in order to supply water for human consumption and engage Department of Water proper planning of water resources and infrastructures.
- The MDM and Department of Environmental Affairs to promote programmes that focus on clearing of Alien Invasive plant species.
- The Department of Water Affairs should promote and monitor sustainable use of groundwater resources.
- The MDM to promote rainwater harvesting in rural communities during rainy seasons.
- Municipal disaster centres and Water Services Authorities to be capacitated and be able to carry out their duties and develop DRR Plans (Technical

support to municipalities, Monitoring of implementation of water related projects).

5.4.3. Environment and biodiversity sector

- The MDM need to prioritise and protect ecological infrastructure and protected- by identify all the ecological infrastructure and develop a database of civil society promoting preservation and protection of ecological infrastructure and this will be achieved by engaging Department of Environmental Affairs (DEA), Provincial and Municipal Disaster Management Centres and all relevant government sectors.

- Forming collaboration between Department of Water and Sanitation and the Department of Environmental Affairs, promoting environmentally-friendly and socially acceptable sanitation solutions in the rural communities of the MDM.

- Forming collaboration between the DRDLR and the MDM to promote effective land use management plans, land reform legislative framework for communal lands informed by modelling of climate change vulnerability.

- The MDM local economic development and Department of Environment to develop “wild-life economy” through tourism, sustainable hunting, game farming, payment for eco-system services, carbon sequestration that will create jobs in the rural communities of the MDM.

- Relevant government departments (DEA, DAFF DPW, etc), NGOs to implement fire-risk management programmes, land rehabilitation programmes (Working for wetland, grassland, EPWP), extension of protected areas programmes, that will create jobs in the rural communities of MDM while maintaining good ecosystem, biodiversity and environmental health Rehabilitation of ecosystems such as wetlands that provide protection against extreme weather events will strengthen adaptation capacity of MDM rural communities.

- The relevant government department in collaboration with DEA to finance biodiversity through environmental offset requirements for development.

5.4.4. Infrastructures, human settlement, and health sector

- Engaging relevant government department to provide support the MDM to operate and maintain basic services infrastructure to avoid the impact of disasters by implementing normal programmes to be implemented as per their project plans, monitoring and reporting of those projects by relevant sectors and provision of technical capacity and support to municipalities. The MDM should engage with Department of Water and Sanitation, MISA; Municipal Infrastructure Grant, Back to Back (B2B), National, provincial and municipal Disaster Management Centre and all relevant government sectors.

- The MDM need to promote rural electrification with renewable energy solutions in partnership with the Department of Energy.

- The MDM in collaboration with Department of Human Settlements and another relevant government department need to develop and strengthen rural household infrastructure Programmes.

- The MDM in partnership with Department of Environmental Affairs need to formulate strategies for providing waste management services as part of Integrated Waste Management Planning processes to rural communities.

- The MDM in partnership with Department of Water Affairs need to promote and capacitate rural communities in rainwater harvesting systems.
- In order to maintain and upgrade rural roads, the MDM in partnership with Department of Transport and SANRAL need to develop and strengthen labour intensive programmes that will aid in job creation through upgrades and maintenance of rural roads.
- The MDM need to strengthen the relationship with Departments of Health and Basic Education to upgrade rural clinics and schools. This will improve and provide more accessible primary health care facilities and programmes such as HIV treatment and prevention will be more effective in the rural communities.

- The MDM need to collaborate with Department of Human Settlements and local municipalities around rural densification and environmentally sustainable standards to provide houses that are resilient to disaster risks and climate resilient programmes (e.g. solar water heaters and off-grid/mini grid electrification).

- The MDM together with relevant government departments should develop and implement rural waste management strategies focusing on challenges facing rural communities.

- The MDM should effectively monitor and review Rural Disaster Management Strategies for climate-related disasters and local risk and vulnerability assessments to inform disaster risk management plans and spatial development plans in terms of zoning.

- The MDM need to expand the local tourism industry through generating MDM attractions in the form of showcasing natural and cultural heritage.

- The MDM should undertake risk assessments and preparation of geographic specific risk profiles by undertaking community based risk assessments at local Level engaging all government departments.

- The MDM should establish internal DM institutional structures in collaboration with all sectors departments through an integration of disaster management in the organs of state business continuity.
- The MDM should involve State entities, Private Sector, NGOs in the initial stages of disaster management and establish partnerships with Public Sector and NGO and develop a platform for Private Sector and NGOs.
- The MDM need to build a sense of infrastructure ownership by communities to avoid vandalism and theft by implementing public advocacy and awareness programmes engaging municipal disaster management centres, councillors, political and traditional leadership.
- The MDM need to develop a database of Civil Society within district municipality and formalise relations to ensure integrated planning, collaboration, and response coordination during disasters.
- The MDM need to ensure involvement and soliciting inputs from vulnerable groups, mobilise local community groups such as civil society and develop platforms for youth Persons with a disability, Women in Disaster Management

engaging Department of Social of Development and Department of Women and Children.

- The MDM need to ensure integrated disaster response coordination, consolidate reports and disseminate/ communicate same messages by developing a Communication strategy and media plan by engaging National and provincial disaster management centre and all relevant government sectors.
- The MDM should develop a contingency plan for post disaster (i.e. drought, floods, veld fires) effects is important to avoid underlying risks.
- The MDM need to ensure that all sectors have roles and responsibilities in relation to collaboration with government sectors including the civil society's with respect to climate change adaptation options to rural communities.

5.5. Conclusions

Climate variability and change interacts with, and sometimes compounds, existing livelihood pressures in rural areas. Human settlements, biodiversity and ecosystem health, land degradation, alien Invasive species grazing capacity and availability of water can all potentially be affected by climate change (Chamier *et al*., 2012). The MDM is highly exposed to climate risks to the agricultural sector, biodiversity and environment, human settlements and the water sector. MDM's agricultural sector, biodiversity, natural environment, human settlements and water sector are of high priority with respect to exposure to risks and are highly sensitive to climate change. The MDM lacks adequate basic services and these impacts negatively on its ability to cope with the impacts of climate change. Moreover, the MDM shows a low to medium adaptive capacity as the municipality depends on rain-fed crops and government for access to basic services. The government, from the analysis done in this section, has over the past 10 years not made significant improvements in the provision of basic services. In fact, in terms of some important needs by the rural communities, there has been a decline in the required services.

CHAPTER 6: CONCLUSIONS

Based on the results from Chapter 4, future changes in climate over the MDM shows drastic increases in temperature, by 3°C for the near future period 2021-2050 relative to 1971-2000, are likely to occur under a low mitigation future. Although more uncertainty surrounds the projected rainfall futures of the MDM, a general message and plausible outcome are that the municipality will become generally drier. An exception may be the early summer period, projected to becoming wetter with an increase in the occurence of extreme precipitation.

The temperature increases that are projected for north-eastern South Africa will affect the agriculture and water sectors in Limpopo province as well as in the MDM. The expected impacts in the agricultural sector may include a decrease in the availability of livestock feed, employment, food security, tourism and water for both human and livestock consumption. Inadequate basic services impacts, if these are to persist will be worsened further by unmaintained water infrastructures such as pipelines, boreholes, pump stations aamongst others causing the uncontrolled waste of water through licking, and not having enough implementation measures of water conservation in the affected areas. Water is a critical resource for growth and development in the MDM.

The increases in the occurrence of heat waves days and high fire danger days that are to occur in association with increases in average temperatures are likely to play a key role in the decreases in crop yield and increases in livestock mortality that will plausibly occur in the MDM. However, it should also be noted that increasingly oppressive temperatures and heat wave events may also impact directly on human health in the MDM. Over exposure to heat will affect in particular the elderly, young children, sick persons and those who are overweight and unfit in the rural communities of the MDM and Limpopo province at large. The increasing risks that more frequent heat waves pose in the MDM and rural areas, in general, cannot be underestimated. The model projections are indicative that future heat waves will be unprecedented in amplitude and frequency. As a first step towards adaptation, easy access to cool water in all rural areas will be essential during heat-waves, especially for the elderly and those who are not mobile. Increased access to air conditioning, perhaps in large cooling centres that will have to be erected, may be an essential adaptation investment to make (unless economic growth is so strong that households can easily afford air conditioning).

As is clear from the likely impacts on agriculture, farmers in both the commercial and subsistence sectors are vulnerable to future climate change in the MDM. Farmers will be required to adopt conservation agriculture methods and irrigation methods that are water efficient (e.g.. irrigate in the early mornings and evenings, consider drip irrigation) during drought events. Due to the streams and rivers drying in the MDM and Limpopo province during present-day drought events, plausible future projections of an increase in the drought events will worsen the current situation in the MDM and Limpopo province further affecting conservation agricultural methods that might be applied by the farmers. The unfortunate reality is that adaptation options are limited in the MDM regions that are hot and dry under present-day climate, should these regions become even hotter and drier (as is indeed a plausible outcome projected by climate models for the municipality).

The MDM currently experiences inadequate access to basic services. A generally drier future in the MDM would result in reduced surface water availability, but due to the uncertainty of rainfall projections, the risk of an increase in extreme flooding should not be excluded. It is plausible that increased water scarcity in the district will lead to rural communities not being able to cope with climate risks such as drought conditions. A recent example that demonstrates the MDM's vulnerability to drought was the drought conditions which occurred during the 2015/2016 summer months, which affected the country and 8 provinces including the Limpopo province. Drought resulted from an El Niño event, as part of the natural climate variability of Limpopo. However, the drought impacts were worsened by the highest summer temperatures ever recorded in Limpopo. The most affected sectors were the agriculture and water sectors. The highest impacts were felt on the availability water for human consumption and livestock and feed for livestock. Unfortunately, the climate projections analyses in this research indicate (consistent with the findings of AR4 and AR5 of the IPCC) that drought events such as that of 2015/16 may plausibly occur more frequently in Limpopo under low mitigation futures.

The MDM rural communities depend highly on government interventions when it comes to adapting to extreme events and or climate change impacts. Based on the analysis of census 2001 versus 2011, there is an indication of improved basic services in the MDM. However, in reality, the field work performed as part of this research indicate that on the ground practical problems still exist. For example, there may be piped water inside a specific yard, but with no water coming out of the pipes. Most of the jobs created in the MDM are also not permanent jobs but temporary jobs with a stipend that is lower than is needed to sustain the lives of the poor. Health facilities are in place but not provide adequate services to the rural communities.

Government collaborates with non-governmental organisations to implement community based adaptation projects. In the MDM there is an organisation called Community Adaptation Small Grants Facility (SGF) which is implementing projects in five villages establishing partnership with National Department of Environmental Affairs, SANBI, South North and the local Facilitating Agency in choice Trust. The aim of the projects is to increase local resilience through the implementation of pragmatic adaptation responses. The first projects are “Enhancing Food Security through Climate-Smart Agriculture at Mamanuha village in partnership with Ramotshinyadi HIV/AIDS” by building a one hector climate-smart food garden. The second project is called the “Hariphileng” project with community members of villages in partnership with World Vision South Africa and is also focused on developing a food garden. The third project is called “Drought Resilience projects in the agricultural outskirts of the Mninginisi village” and is executed by Holani Home Based Care. In this casethe local community will benefit from the construction of a two hector vegetable garden. The fourth project is called the “Ga-Ntata Rainwater Harvesting System and Rain Gauge project”. In this case, Tsogang Water and Sanitation will work with rural community’s members of the Ga-Ntata village to address water stresses exacerbated by climate change. The fifth project is called the “Communal Small Scale vegetable garden for household’s backyards” in collaboration with Khanimamba Training and Resource Centre and will work with community members of the Homu village. As much as there projects that are being implemented in the district to deal with climate change, the district is facing water scarcity challenges and the projects that are being implemented requires water in order to be sustainable. Moreover, the district consists of many rural areas and the projects are limited to specific areas and that implies that within MDM rural communities there are people that are still struggling to adapt to climate change as they depend on government for services. In most of these projects, older women are involved in implementing the projects and there is still youth who are unemployed and sitting at home. Their adaptation capacity to changes in climate will be low as they still depend on the head of households and can't work for themselves and basic services are still inadequate to sustain their livelihoods.

Agricultural activities at MDM are facing huge risks as climate change is continuing to impact in the district. The MDM is also facing a risk of food security due to increasing temperature relate to increasing water demand, pests, and diseases, as well as crop suitability. According to the focus groups interviews, it has become clear that the communities who are dependent on agriculture are facing challenges water availability and changes in the rainfall seasons. They indicated that they depend on cash crops which currently they are not benefitting much as there is a challenge of water scarcity they end up depending on government grants for survival and those who sell cash crops buy from private farmers and they don't really make a profit.

This implies that the rural community's adaptive capacity is reduced and their continual dependence on the government will worsen the situation. Planting Maize is the most important agricultural activity in the MDM as it is a staple diet of most rural communities. With difficulties in ploughing maize, it has become difficult for rural communities to adapt to climate change as buying maize from the shops is also expensive and rural communities do not have enough to afford to buy due to their dependence on social grants. The MDM adaptation plans is recommended to take into account the allocation of water for agricultural use and properly monitor during drought conditions, the use of water by applying water restrictions across the agricultural productions while at the same time considering food security needs, and conditions relating to efficient water use.

The MDM is already facing a risk of loss of ecosystem and biodiversity and already experienced hazards such as heat waves, drought and veld fires. Due to inadequate basic services, poor rural communities are forced to travel by public transport to access basic services and they are already faced with financial constraints as they are too dependent on government grants. Due to inadequate services, MDM adaptation to climate change has been reduced and need to address existing deficits in the provision of water, sanitation, drainage, electricity, tenure, healthcare, emergency services, schools, and public transport backlogs as they are fundamental to building climate resilience in vulnerable human settlements.

MDM's reliance on government services will worsen the current vulnerabilities that are facing the district as the government is also facing its internal challenges in delivering the required services to rural communities to adapt or cope with climate change. An example can be seen from drought interventions conducted by the government from all the declared provinces in 2015/2016 year. The key challenges that were faced during interventions where that, the implementation of drought interventions where done without proper assessment of the areas that has been affected and the resources available in the loca municipalities and provinces and other existing operationa and maintanance issues in relation to infratrucures such as boreholes, pump stations, pipelines amongst others.

Improper assessment of drought interventions caused some farmers or project managers took advantage and interventions where done in the structures which were not drought related affected structures but the operation and maintenance issues, water leakages, vandalism of infrastructure and where boreholes drilled but not equipped and not functional. When responding to drought it has been found that government did not take into account risk reduction and mitigation measures. Early warnings and advisories were not taken into account to ensure proper planning and reduction of economic losses, food insecurity, and livestock mortalities. The government does have different departmental programs that can assist in the interventions of current drought but during the intervention, there was no alignment of existing programmes to disaster conditions (e.g. budget not aligned to pertinent hazards the country is exposed). The MDM falls under local government and the other key challenge for drought interventions where constraints on technical capacity within spheres of government especially the local government sphere and that implies that the local government without the necessary capacity to support rural communities who are affected by drought won't be able adapt droughts effects.

Focus groups indicated that there is a change in summer and winter temperature. They further indicated that rainfall is unpredictable and the focus group also indicated that there is a change in cultural activities and livelihood patterns which depend on climate conditions and pose a major threat to crop production which most of the communities depend on. This indicates that there is a link between socio-economic vulnerabilities, resilience and climate change. The structure of rural community's households, health status and the livelihood of rural communities, for instance; choices that they make with respect to their daily activities determine ability in maintaining and building resilience to changes in climate.

The MDM rural communities are more reliant on government services and subsistence farming. Lack of inadequate provision of basic services and reliable government programs in the rural communities will lead to putting more pressure on the natural resources and this may contribute to an increasing level of poverty on the MDM rural communities under climate change. Government's role in MDM's rural communities will increase under climate change and the interaction of government with people can have drastic impacts on their changes in climate resilience and it is therefore recommended to understand these factors. Government to deal with an increase in temperatures and extreme events such as drought and heat waves as projected for the future will be required to encourage rural communities and all relevant stakeholders to engage in active water management and other socio-economic issues thereby strengthening the leadership role of government and governance functions.

Worsened issues of climate impacts on water security and supply is the complexity of the agriculture industry, inadequate basic services that play role in the rural economics (on-going financial crisis and high dependence on government social grant), and increase in the population and demographic changes (decreasing and ageing populations), should be taken into consideration in MDM's rural communities under climate change. The government should understand those issues, as not understanding and take into account such issues would underestimate the extent of the problems and inhibit the ability to coordinate the holistic, cross-agency approach needed for successful climate change adaptation in rural communities.

The identification of extreme events (drought, heat waves, high fire danger days) that will increase in future in MDM is important in that it will assist the Comprehensive Rural Development programme (CRDP) to identify and prioritise human, natural, social and financial assets that will enable examination of current and future adaptation options for MDM rural communities and also assists in early warnings in the future climate change variability and vulnerabilities and lastly identifying areas where support is required. Government together with rural communities should also take into consideration indigenous knowledge into planning and decision making. The government should also teach rural communities to be pro-active and encourage self-employment to generate income instead of sitting waiting for government grants.

It is also recommended that researchers should not only do their research and not inform or share with government departments and policies should be integrated with research findings to influence decision making process for rural development. Rural development and planning should also consider future climate projections as they help in identifying climate stressors or risks.

All local municipalities in the MDM fall under CRDP sites and therefore it is important for all government departments together with the departments of Rural Development and Land Reform to take into accounts all the findings in MDM with regard to exposure, sensitivity, vulnerabilities and resilience related to climate change.

The MDM rural communities are vulnerable to climate change and their dependence on government is making rural communities to be less resilient towards climate change and reduce their adaptive capacity to climate change. It is therefore important to let the government know of the challenges that are being experienced in the district in relation to climate change as the government will continue managing these rural communities.

These inadequate provision of portable water and sanitation pose a threat to rural communities when it comes to poor health and diseases, food security as they are highly dependent on agriculture which affect their quality of life and their living conditions and that places rural communities on vulnerable conditions to climate change as their adaptive capacity will be lower as a results of not having required resources to cope with climate change (Poverty and Inequality in South Africa Summary Report, 1998). Dams are becoming drier in MDM and that poses a threat to water for irrigation, it is therefore recommended that MDM starts looking for other sectors such as mining and tourism for economic development in the rural communities and alternatively implements agricultural projects that are adaptable to dry conditions in the rural communities. An impact of drought and heat waves take longer to return to the normal conditions and therefore the restrictions of water due to dry conditions that South Africa engages in impacted negatively by agricultural activities. Water restrictions are used on systems facing deficits to prolong the water supply during periods of water shortage. Restrictions are applied to stop supplying less critical uses in order to avoid emptying the water resource completely.

It is therefore recommended to the government in order to enhance adaptive capacity and build better resilience towards climate change in the MDM to strengthen access to required basic services, access to information, promoting information sharing, enhance educational skills and resources (information, financial and human capacity) necessary for appropriate and timely responses to shock rural communities that are already experiencing vulnerable conditions. Government together with rural communities should also take into consideration indigenous knowledge to planning and decision making. The government should also teach rural communities to be pro-active and encourage self-employment to generate income instead of sitting waiting for government grants.

It is also recommended that researchers should not only do their research and not inform or share with government departments and policies should be integrated with research findings to influence decision making process for rural development. Rural development and planning should also consider future climate projections as they help in identifying climate stressors or risks. From this research the plausible future projections of the MDM and Limpopo province as large has been projected, vulnerabilities, resilience, and adaptive capacity has been identified and therefore it is important for all spheres of government leadership to implement projects that build resilience and promote better adaptive capacity in the MDM lessons learned from the MDM can also help in developing other municipalities in South Africa.

It is also recommended that government and traditional leaders promote and preserve customs of traditions and establish close working relationships with rural communities. It is also recommended that indigenous knowledge is documented to supplement scientific knowledge to help strengthen the relationship between rural communities and government and build long-term capacity in the system. In particular, actionable messages for adaptation in the MDM, such as those identified through this research, need to become part of the actual adaptation strategies and investments of Limpopo and the MDM and needs to influence a new range of extended services to be provided to rural communities in the MDM.

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