Quantitative vulnerability analysis of climate change for agribusinesses and Agricultural development projects: A case of Bloemfontein, South Africa

By

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DECLARATION

I, Ntombizodwa Elizabeth Lunga, hereby declare that the work in this dissertation is the original product of my own efforts. All sources used and discussions made have been acknowledged with complete references. This work is submitted in partial fulfilment of the Master in Disaster Risk Management and I also declare that this work has never been submitted in any form or anywhere else for any degree.

Signature: ____________________________ Date: ___________________

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I would like to thank my family for their consistent support during the course of my studies, particularly, my husband Velile Lunga who did a great job of taking care of the kids when I was away for weeks. My grateful thanks to my supervisor, Dr Bernard Moeketsi Hlalele, for his advice, encouragement and the drive. To my study partner, Mr Sunnyboy Ngudi, thank you for the support and believing that we will do it. My colleagues and friends for their patience and support, you are all special in different ways in my academic life. Finally, great appreciations my supervisor at work Mr A. Mafunda for consistently asking how is my school work and how am I coping? It meant a lot thank you.

DEDICATION

This study is dedicated to both my late mother and father; I know they are proud of me because they always believed that one day I would do better life, to my children (Nompumelelo, Njabulo and Luyanda Lunga) this is a challenge, I expect you to do better than me. Not forgetting our saviour, the Lord Almighty who is always looking after me, protecting and giving me strength to do good and through Him, my study is now complete.

ABSTRACT

Climate change vulnerability is a complicated and vital occurrence, which involves both social and physical / environmental features. Climate change causes a high level of stress to the society and to the environment at large. It also increases the likelihood of drought occurrences in most parts of the country. The study aims to develop a comprehensive picture of current and future climate change vulnerabilities and to provide information on how to assess adaptive methods and the capabilities to manage the risks associated with climate change uncertainties. The method used for the study is quantitative methodology. Data was collected from NASA online database. Microsoft excel was used to sort, calculate and analyse data. Data was quality control tested and found to be homogeneous. The normalisation of data for vulnerability index computation was done using the Iyenga-Sudarshan method. Descriptive statistics for both stations is presented outlining the minimum and the maximum values of the variables which are (Temperature, Precipitation, Humidity and Wind speed) as well as the variance which measures the fluctuation of the variables. This study area showed that the main influence was from the rainfall since it has a relatively higher variance than any other variable. For inferential statistics, a Mann Kendall's test was ran on excel software to analyse the trends for both the stations. The results of the test showed no statistically significant trends, revealing a constant situation. All the stations vulnerability index was in the vulnerable range. The study area was therefore found to be vulnerable. The most probable climate change problem anticipated is drought due to decreasing precipitation level and increasing wind speed levels, and due to these observations, it can be predicted that in the next coming years the study area will experience drought. It is therefore recommended for the farmers and agribusiness are to plough drought resistant crops and the government together with the Non-Governmental Organisations to assist in the construction of dams and reservoirs for saving water and educating farmers on how to survive from drought conditions.

KEY WORDS: Vulnerability, Climate Change, Impact and Adaptation, Vulnerability Index

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LIST OF ACRONYMS AND ABBREVIATIONS

ACPC	African Climate Policy Centre
CCAM	Climate Change Adaptation and Mitigation
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DJF	December January February
DWAF	Department of Water Affairs and Forestry
DRR	Disaster Risk Reduction
FAO	Food and Agriculture Organization
HFA	Hyogo Framework for Action
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
KPA	Key Performance Area
NASA	National Aeronautics and Space Administration
NEMA	National Environment Management Act
NDMC	National Disaster Management Centre
NGO	Non-Governmental Organisation
UN	United Nations
UNFCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
UNEP	United Nation Environment Programs
UNICEF	United Nations International Children’s Emergency Fund
UNISDR	United Nations International Strategy for Disaster Reduction
WHO	World Health Organisation

CHAPTER 1: STUDY OVERVIEW

1.1 INTRODUCTION

Climate is one global variable, which has a profound impact on every aspect of human life (Van Nieker et al., 2009). The ecosystem, political power structures, cultures, social circumstances and developments are all guided by climate. Climate change as a global phenomenon is undisputed (Van Nieker et al., 2009). According to Adger (2016), years and years of scientific research on global warming and change in climate has displayed that humans have an impact on the changing of global climate, mainly, due to greenhouse gases emission (Adger, 2016). It is highly recognized that changes in weather impacts are increasing adverse conditions in developing countries. Parke et al., (2019) emphasizes the fact that Agriculture is one of the most vulnerable sector to climate change. Previous studies have revealed that projected losses in agricultural production threaten national economy as well as the regional and global supply chain of these industries (Parke et al. 2019). The projected impacts of climate change are a threat to crop production in areas currently experiencing food insecurity.

Studies have proven that developing countries rank low on economic and health indices and that climate change will increase their vulnerability due to their - conditions of living, low or no income, their extreme reliability on climate-sensitive sectors and their inability to adapt (Mc Cathy 2001). Change in climate is a possible danger to world food security due to its detrimental impacts on dryland crop cultivation and rain-fed agriculture, which is the foundation for small-hold agriculture. A projection of approximately three million food producers feed their families through farming, therefore, climate change could increase hunger in the rural-urban areas of South Africa (Statistics South Africa 2007).

Parts of Africa are currently troubled by climate induced impacts and are highly vulnerable to its impacts (Madzvamuse 2010). The negative climate change effects on development requires urgent remedial action as stipulated in the Sustainable Development Goal 13, which calls for countries to take their part in climate action. Climate weather Changes will have an effect in the entire world, yet poor people in less fortunate countryside’s and less fortunate people in rich countries are usually the most affected (Madzvamuse 2010).

Same as many other countries in the region, South Africa has a dual economy on agriculture consisting of developing small-scale farmers and commercial farming. The country consists of seven climatic zones, which run from semi desert, subtropical and on sea circumstances in the east where approximately 1000mm of rain annually and the conditions of dry desert in the west with minus 1000mm rain/year. The mean annual rainfall for South Africa is about 464mm/year and that is lower than the global mean averaged value of 860mm (South Africas weather and climate 2019). Agricultural operations include - intensive crop cultivations, crop farming in high summer rainfall areas and in winter rainfalls, mixed livestock to farming sheep, in semi-arid regions and cattle farming in the bushes.

South Africa is suffering severe impacts of changing climate due to higher temperatures and climate inconsistencies. The noted level of heating is 2°C in 100 years or greater additional to double the global rate of increasing temperatures for the western and North East parts of South Africa (Department of Environmental Affairs 2017). It is proven that these excessive weather events in South Africa are increasingly growing with heat-wave found to be possible; dry periods being prolonged lightly and magnitude of rainfall rising. Climate will impact on national and global industries, but the rural communities whom their livelihoods depends on agriculture will be highly vulnerable (Parke et al. 2019).

In accordance to the Intergovernmental Panel of Climate Change Fifth Assessment report (ARS), changes in climate has a likelihood of increasing the occurrences and the speed of various events and that will accelerate the risks of slow- onset events like rise in sea-level and droughts (IPCC 2013). Changing climate conditions is transforming the image of disaster, by not just increasing weather-related risks and being subjected to the variabilities of weather extremes. Rising of sea-level temperatures, but also in increasing communities' vulnerability through an increase in stress on water scarcity, agriculture and ecosystems (Dyssel 2018). Farming command unities are facing many common challenges related to their exposure to climate variability and change. Smallholder farmers are most vulnerable due to finance difficulties and costly inputs, such as improved seed varieties (Agricultural Model Intercomparison and Improvement Projects 2020).

This study is aimed at assessing climate change vulnerabilities in the Free State Province of South Africa. This province is located in the centre of South Africa and specialises in cultivation of seed potatoes. Increase in temperature is anticipated to have adverse effects on livestock, agriculture dominates the landscape, with arable crops which makes nearly two-thirds of the gross agricultural return of the Province (Agmip 2020). Livestock products contribute 30%, almost 40% of total white maize production and 38% of yellow maize come from the Province. In addition, soybeans, sorghum, sunflower and wheat are well bred in the Eastern Free State where the farmers also specializes in the producing seed and about 40% of potato yield (Agmip 2020)

1.2 PROBLEM STATEMENT

According to the Free State Department of Tourism (2008), changes in rainfall and temperature trends might have a negative impact on crops, whereby some crops are no longer feasible to be grown and there is a need for extra irrigation with other crops. (Free State Department of Tourism, Environmental and Economic Affairs 2008). The Envirotech Solutions (2015) states that the increase in temperature is expected to have a direct or indirect negative impact on livestock, due to extreme temperatures and less rainfall, as well as grazing space needing to be decreased. In addition, during the extreme hot environment, livestock are subjected to extreme perspiration resulting to excessive water intake, and if there is not sufficient water available, these animals can die due to thirst (Envirotech Solutions 2015). In recent years, the Free State Province has been experiencing dry conditions, which has had a negative impact on crop production and resulted in the death of livestock. This has adversely affected the farmers' finances and it has reduced the Province's gross agricultural production (Envirotech Solutions 2015).

The Province has been suffering from severe water scarcity because of drought, and in October /November 2015 the Province was declared a disaster area due to severe drought and this has an adverse effect on the availability of drinking water, as well as water available for large and small-scale agriculture (Envirotech Solutions 2015). A number of researchers have recommended adaptation measures nationally and local levels, therefore, it is crucial for researchers to assess and monitor these measures' impact and effectiveness. This study aims establish a comprehensive picture of present and future climate change vulnerabilities and to provide information on how to assess adaptive methods.

1.3 SIGNIFICANCE OF THE STUDY

The purpose of this study is to analyse the vulnerability of farmers and communities in the Free State Province, to the changing weather conditions. It is true that extreme weather is affecting the whole world, but the extent differs from region to region and from locality to locality (Belay 2016). Coping mechanisms, also will differ from community to community. This means that studies are needed to understand the extent of vulnerability at different levels as well as the coping strategies, which may be required. The study's focus is in Bloemfontein with two stations which are Bloemfontein Airport and J.B. Hertzog. The findings of the study may be used to help the communities and farmers to better understand the extreme weather conditions as well as to promote agricultural development.

This will also assist in developing awareness campaigns or the public education for the farmers, farmworkers and the communities affected; these will allow them to take part in fighting the effects of climate change. Findings will form the bases for further investigation by other researchers who are interested in the topic, and also give direction to policy makers on how to design agricultural adaptation policies and encourage effective adaptation.

1.4 AIM OF THE STUDY

The aim of this current research is to establish a comprehensive picture of present and future climate change vulnerabilities and to provide information on how to assess adaptive methods and the capabilities to manage the risks associated with climate change uncertainties.

1.5 OBJECTIVES

- To determine the status quo of the climate change in the study area.
- To assess the presence of monotonic trends, if any, in the proxy variables in the study.
- To assess the vulnerability level of the study area from four selected climate proxy variables.
- To predict vulnerability level aimed at providing an early warning system for mitigation and adaptations.

1.6 DESCRIPTION OF STUDY AREA

According to the Department of Agriculture and Rural Development (2018), Free State Province is located in the heart of South Africa, which comprises of nine provinces, namely, Gauteng, North West, Mpumalanga, Northern Cape, Eastern Cape, Western Cape, Limpopo, Free State and Kwa Zulu Natal. The detailed map below displays South Africa and the surrounding countries, which are Botswana, Mozambique, Zimbabwe, Swaziland, Namibia and the small kingdom of Lesotho. South Atlantic Ocean and the West Indian Ocean form the coastlines of South Africa.

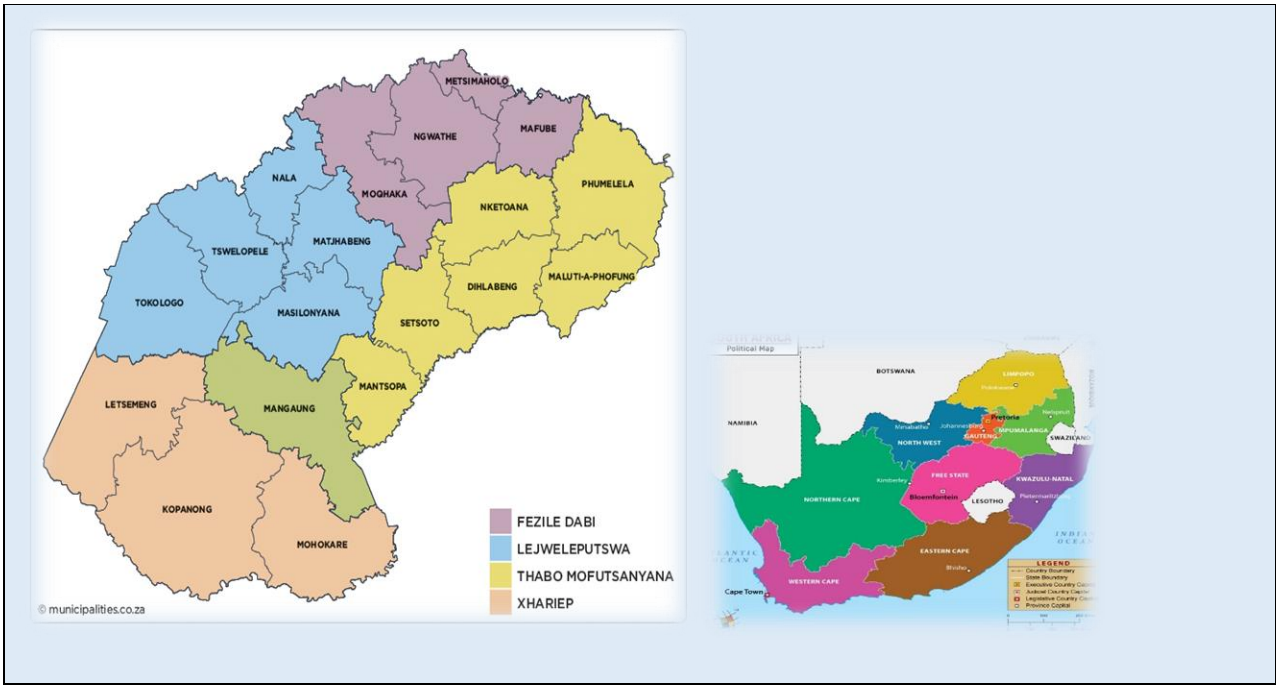


Figure: 1 Map of the Free State Province in South Africa and location of municipalities

Source: Hlalele, 2016

The Free State Province, the study area, is bordered by Northern Cape, North West, Eastern Cape, Mpumalanga, Gauteng Province and Kwa Zulu Natal, as well as the international boundary of Lesotho (N8 Corridor). (Department of Agriculture and Rural Affairs 2017/18). The Klip River formats the Orange and Vaal River from the southern, northern and western borders, as well as a section of the eastern border of the Province (Free State Provincial Growth and Development Strategy FSGDS 2007).

The Free State Province is the 3rd biggest Province in South Africa, with a land 129,480 km2 and the population of 2 834 714, which is 5.15% of the national population (Free State Municipalities, 2012). This Province comprises of a single metropolitan municipality, the Mangaung Metropolitan Municipality, consisting of the city of Bloemfontein as the main economic centre in the Province and Bloemfontein Airport and J.B. Hertzog being our study area. J. Hertzog a small cattle and sheep farming town in the Free State. Other four district municipalities - Lejweleputswa District, Thabo Mofutsanyane District, Fezile Dabi District and Xhariep District (Free State Province: Department of Economic Development, Tourism and Environmental Affairs, 2014). The Free State has few trees, as it mostly consists of grassland, and the southern region has some Karoo vegetation (FSGDS 2007). It is granary of South Africa, with agriculture in the centre of its economy, and mines being the biggest employer (South African History Online 2011). The Free State is a province of farmland and it is widely rural, full of mountains, goldfields and extensively-dispersed townships. (Free State Municipalities 2012). About 90% of the Province is being developed for crop production; it also produces around 34% of the country's maize production, 185 of red meat, 37% of wheat, 33% of potatoes, 53% of sorghum, 15% of wool and 30% of groundnuts. The Province is also heading the chemical industry as it is home for a huge synthetic fuel company, Sasol (Department of Agriculture, Forestry and Fisheries 2015). The climate is conducive and the soil is fertile; these promote a growing agricultural industry. This province is very cold during winter months and is a summer rainfall region. The temperature can drop to -9.5 degrees Celsius in the eastern mountain regions. The southern and western areas are semi-desert areas, and 532mm is the Province's mean annual rainfall (FSGDS 2007).

According to the Free State Tourism Centre (2008), Bloemfontein is the capital city of the Free State Province and is part of Mangaung Municipality located in the Transgariep Area almost in the middle of the Province and in the country as well. The Gariep dam is primarily used for irrigation, domestic and industrial use as well as for power generation. Bloemfontein is the judicial capital and the sixth biggest city in South Africa and curves on the main road, has air links and rail connecting west and east, south and north. The commercial capital of Free State and the economic hub of Mangaung is Bloemfontein. The city lies on a high land at an elevation of 1,392metres.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This section discusses the literature reviewed in relation to climate change vulnerability and the impacts, globally, concerning human health, natural disasters, urbanization trends as well as the socio-economic factors. It also summarises climate change projections and explains how these are arrived at in order to identify the uncertainties. This section consists of the definition of terms related to the topic, the vulnerability frameworks that give guidance in the adaptive process, climate change scenarios, climate change risks' impacts internationally, in Africa and in South Africa, International disaster management policies and legislation, South African disaster management policies and legislation and an account of vulnerability studies. For this study, vulnerability indicators lay the foundation for determining the level of vulnerability in the Free State Province as are illustrated in the vulnerability frameworks.

2.2 DEFINITION OF TERMS

Adaptation – The procedure for adjusting to the anticipated weather and its impacts. In human systems, adaptation seeks to prevent damages or exploitation beneficial possibilities; in regards to natural resources, is a system of managing the climate and its effects (Disaster Management Act 2002).

Climate Change – Relates to alterations in climate conditions that can be recognized (for example, by the use statistical tests) through differences in the mean and the irregularity of its properties, which can continue for a long period of time, sometimes even decades or longer. This transformation may be because of natural processes or external drive like volcanic explosions and continuous anthropogenic changes in the structure of the atmosphere or in land use (United Nations International Strategy for Disaster Reduction (UNISDR) 2009).

Capacity – The consolidation of all powers attributes as well as available resources in a society, organisation or community to manage and lower the risks of disaster and empower resilience (UNISDR 2009).

Coping Capacity – The capability of the community, organisations and systems, utilising accessible means and facilities to control unfavourable conditions, risks or disasters. The coping ability needs continuous awareness, resources and proper management both in pre and post-disasters or adverse conditions. Coping abilities assist in the reduction of disaster risk (UNSDR 2009).

Disaster – A critical disturbance of the community or the societies functioning, because of a hazardous events relating to the conditions of exposure, capacity and vulnerability resulting in one or more of the following: environmental, human, economic and material losses and impacts (UNISDR 2009).

Disaster Risk – The probable death, harm, or broken or destroyed belongings that may happen to a system, societies or a community in a certain time period, probably driven by exposure, hazard, incapacity and vulnerability (UNSDR 2009).

Disaster Risk Management – This is an organised method of utilising the administrative resolutions, organisational and operational techniques/expertise, as well as the ability to implement strategies, policies and coping abilities of the community in lessening the effects of natural disasters and other technological and environmental hazards. This consists of different kinds of incidents, including the structural and non-structural means of avoiding or reducing the negative effects of disasters (National Disaster Management Centre 2013).

Disaster impact – This is a complete negative (economic loss) and positive effects (economic benefit), of a disaster or dangerous event. This phrase refers to the economy, people and ecological effects, and might involve fatalities, harm, illnesses and other adverse effect on humans', physical, mental and social wellbeing (UNSDR 2009).

Ecosystems – Eco-system is a working unit, which consist of human being, their inorganic environment and their working together. The elements added in a certain ecosystem and spatial boundaries depends upon the reason for which the ecosystem is designed for (Government Gazette 2019).

Early warning system – This system implies to the amount of strength required to produce and distribute useful alerting notifications in time to give people, locals and organizations, in danger from hazards, to be prepared and behave appropriately and in adequate period to reduce the probability of injury or even death (NDMC 2013).

Exposure – Property, people, systems or any other elements which are vulnerable to hazards, therefore, are subjected to possible losses (Awal 2015).

Hazard – Any occurrence, material, individual action or circumstances that may result to fatality, harm or health ill-effects, damages to property, livelihood losses and service, socially and economical disruptions, as well as damage to the environment (Awal 2015).

Livelihoods – According to the Department for International Development (DIFD) 2000 'livelihoods' are the ways in which people unify their abilities, knowledge and skills with the resources at their disposal to allow them to make a living (DFID 2000).

Mitigation – This is structurally and non-structural actions taken to minimise the impacts of natural phenomenon, degradation of environmental and technological dangers on exposed areas, households and communities (NDMC 2013).

Preparedness – These are measures and activities put in place to guarantee efficient response to hazardous possibilities, such as the issuing of effective and timely pre warning and interim moving individuals and the belongings from exposed areas (NDMC 2013).

Resilience – Capability of a structure, communities or societies subjected to dangers to withstand, consume, adapt, adjust, change and be able to bounce back from the effects of disaster in good time and in an efficient manner; it includes the appearance and rebuilding of vital simple facilities and functions, using risk management (NDMC 2013).

Vulnerability – The extent to which a family, society, individual or an establishment may be severely damaged or negatively affected by the impacts of disasters. Situations of sensitivity and vulnerability to the impacts of disaster are determined by social, economic, physical and ecological factors (NDMC 2013).

2.3 COMMONLY-USED VULNERABILITY FRAMEWORKS IN DISASTER MANAGEMENT

2.3.1 BBC Framework.

The Figure below illustrates the BBC Conceptual Framework, which essentially shows that the risk reduction decreases the level of vulnerability. Vulnerability indicators, namely, environmental, social and economic, improve once the risks are reduced.

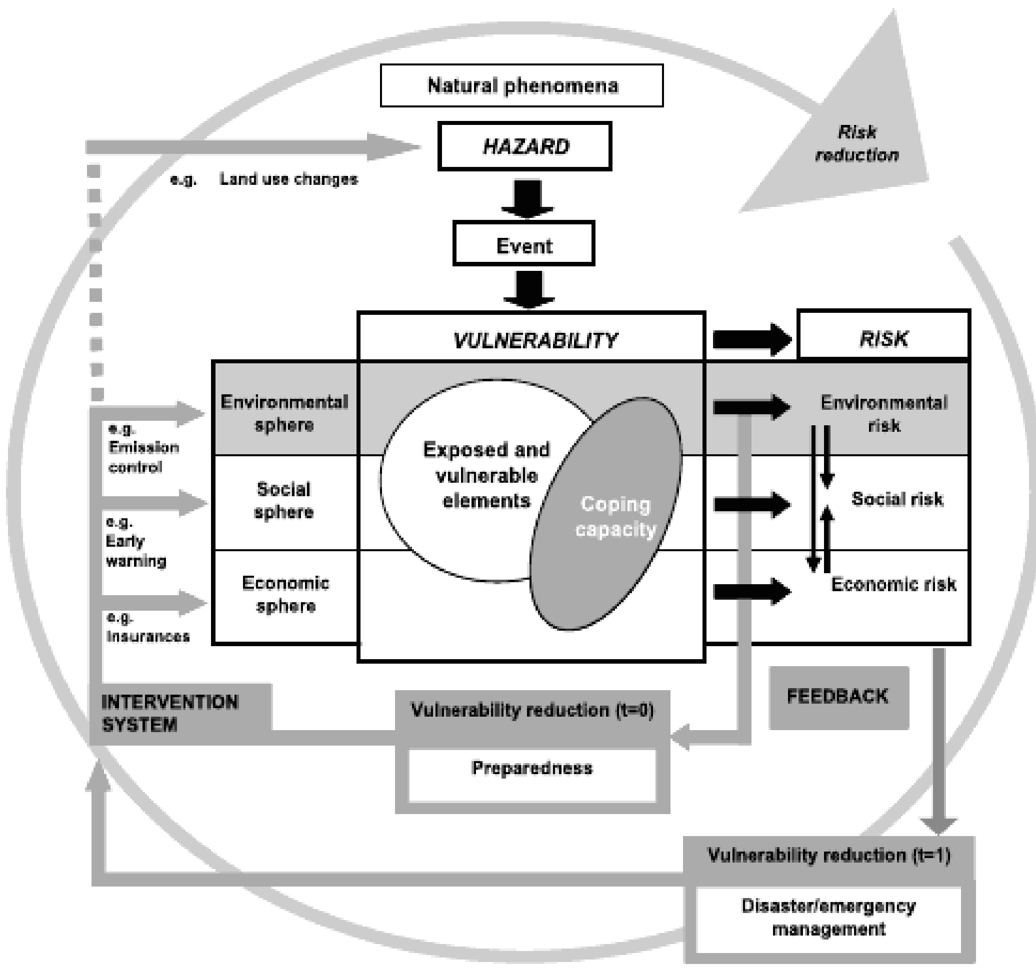


Figure 2.1: The BBC Conceptual Framework

Source: Birkmann, 2006

Figure 2.1 presents the BBC framework whose focuses is on the idea of sustainable development with exposure of components and being able to cope, where vulnerability is a procedure and must be analysed socially, economically and environmentally. This framework is easily understandable, and complex enough to depict the vulnerability facts. The BBC model indicates that phases of vulnerability are doubled. The first phase is a pre disaster (t=0) which is linked to the idea of preparation and reduction in Comprehensive Emergency Management (CEM) and the second phase is post and during disasters (t=1) which is the principal stage of the management disaster. This framework entails that the establishment of the indicators of vulnerability as well as susceptibility analysis of vulnerabilities must also discuss the sensitivity and exposing of various components in danger economically and environmentally, these should also establish coping abilities and possible intervention techniques.

This framework emphasises on the need to concentrate on socially, environmentally and economical dimensions of vulnerability, clearly connecting and merging the idea of sustainable development into the vulnerability framework. The different elements and links shown in the BBC conceptual framework with special attention to key elements of vulnerability. These also suggest a risk reduction strategy, since the intervention encompasses ways to lower vulnerability and means to lower the consistency and magnitude of occurrences, such as floods, drought or landslides linked to hazards of natural origin (Birkmann 2006). This conceptual framework deals with the risk management of severe events and disasters with the aim of advancing climate change adaptation. The primary focus of the framework is on natural hazards exposure and changing climate as well as social vulnerability. It consists of four components of indicators: 1) Susceptible to natural phenomenon of floods, drought, storm surges as well as earthquakes; 2) Exposure as a function of public infrastructure, condition of houses, food and the overall economic framework; 3) Coping capacity as a function of governance – pre warning systems and disaster preparedness, health services, social and economic security, and 4) Adaptive capacity to future natural disaster and climate change. Figure 2.2 below illustrates in detail the components of vulnerability to climate change.

2.3.2 Sustainable Livelihood framework

This is Department for International Development (DIFID) framework, which talks about the vulnerability in relation to five livelihood capital, transformation of structures and processes, livelihood strategies as well as livelihood outcomes. Figure 2.3 below demonstrates the framework.

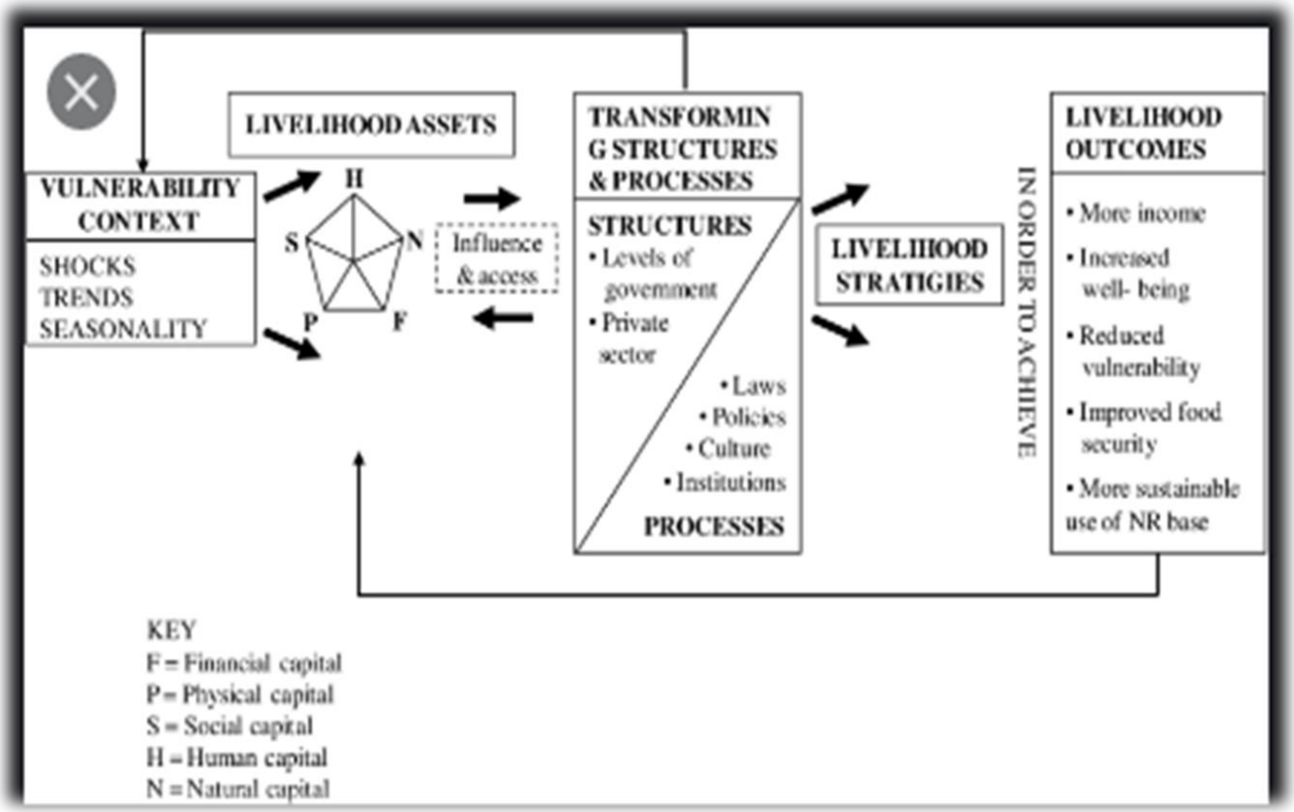


Figure: 2.2 Sustainable Livelihood framework

Source: DFID (1999)

This outline is based on DFIDs series of sustainable livelihood guidance sheet (DIFD 1999 – 2000). The sustainable livelihood introduces the important aspects that has a negative affect people's lives, and the relationship thereof. The framework is important in planning as well as creating new developmental activities and evaluating the participation of livelihoods sustainability made by current actions. This framework produces a list for critical matters and outlines how they link with each other, attracts attention to main influences and processes, prioritizes numerous interactions between different factors which have an effect on livelihoods (DFID 1999) The sustainable livelihood framework is designed to be a flexible instrument to be used in preparation and guidance and is a tool to better our understanding, especially, on the livelihoods of the poor. It was designed by the sustainable rural livelihood Advisory Committee, building on early work by the Institute of Development Studies. Vulnerability Context creates the ecosystem in which human being exist. Livelihoods and their belongings are negatively affected by phenomenon's as well as by shocks and seasonality of where there is little or no control over (DFID 1999).

Livelihoods' and assets' priority concern is people. There is a need to obtain proper understanding of people's capacities and how to better their coping abilities. This approach was established with the hope that people's needs and their series of assets will influence their livelihood outcome; Human, Natural, Financial, Social and Physical Capital are different types of livelihood assets and there is a relationship among them. These assets are expressed visually as a pentagon and they also help in identifying entry points for strengthening livelihoods. Transforming Structures and Processes, within the livelihood framework are the organisations, Structures, Policies and the Legislations that shape livelihoods. They function from the local household to the international arena, in all spheres of government and from private to public sectors. Sustainable livelihood comprises of two major terms, 'sustainability and livelihoods. Within the livelihood framework, the term, sustainability, is usually connected to coping abilities and being able to bounce back from previous shocks, as well as to maintain the natural resource base (DIFID 1999).

The sustainable livelihood approach views poverty as vulnerability to shock, and there is a need to reduce this by building on the livelihood asset of household, expanding their access to a number of assets and gently creating a household's resilience. Generally, the approach focuses on increasing households' coping abilities and adaptive strategies in the way that will suit the community's needs. This project intends to clarify the potential role of the sustainable livelihood approach as expanding people's resilience to climate change, hence, enabling them to adapt. It is known that Africa is vulnerable to climate change because its inability to cope with the impacts thereof is much less as compared to the well-developed regions like the USA and the Europe. Sustainable livelihood increases people's resilience to climate-related shocks, such as drought (DIFID 1999).

Building up an adaptation system that includes sustainable livelihood activities might strengthen and promote measures in other areas of priority, such as the alleviation of poverty, conservation of biodiversity, management of water and the mitigation of disasters. These synergies between the adaptation and the national development goals should then be recognised and build upon.

2.3.3 Progression of vulnerability – PAR Model

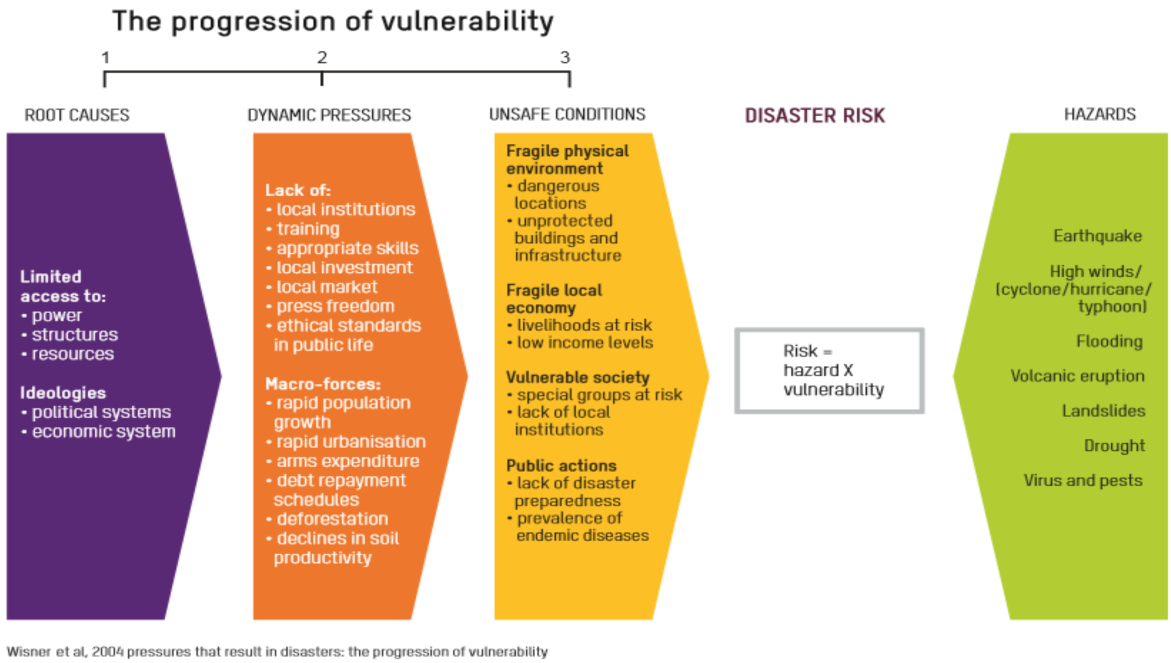


Figure: 2.3 Progression of Vulnerability Framework
Source: (Wisner et al., 2004)

Figure 2.3 above presents the Pressure and Release (PAR) model, which was developed as part of detailed study of human exposure to natural phenomenon by Blaikie, Cannon, Davis & Wisner (1994). This model consists of two vital dimensions which are hazards and vulnerability, and together they strengthen the disaster risk. The level of risk will therefore be determined by the speed of danger and the level of individual's vulnerabilities. A disaster will never occur if there is only a hazard and vice versa. In order for us to understand the intricacy of people's vulnerability, both the vulnerability and hazard should be analysed. The foundation of the pressure and release model (PAR) has identified that a disaster is the combination of two different powers and this creates vulnerability on one side and exposure to hazards on the other side. The rise in pressure can come from either sides, but to relieve the pressure, vulnerability reduction should occur. The behaviour and tendency of hazards can be better understood through analysing its force, warning signs, pre-warning, speed of onset, recurrence and the length of action. There are three layers of social processes which lead to vulnerability - these are - Root cause, Dynamic Pressure and None safe conditions (Blaikie et al., 1994).

Weather-connected hazards must also be taken into consideration and studied in the scope of changing climate, as the frequency, intensity and seasonally of climate relate to incidents (Thorpe 2012). Susceptibility to climate change is normally higher when communities rely on natural resources and the ecosystem. While vulnerability should be analysed on a different case levels basis, it can safely be said that poorer societies are more susceptible to climate extremes and severe weather occurrences; this is because of insufficient resources, properly secured houses, proper infrastructure, insurances and technology (Thorpe 2012). Almost the entire Free State Province has a high level of susceptibility to climate change, due to the fact that farming mainly depends on rain, and climate change has direct or indirect impact on precipitation and significant pressure on natural resources. This in itself illustrates the level of vulnerability in the Province; this is exacerbated by a high level of poverty, poor health and agricultural dependency of most of the communities (Maplecraft 2010).

2.4 CLIMATE CHANGE SCENARIOS

According to National Department of Agriculture NDA (2000), South Africa's increasing temperatures, lowered rainfall amount and scarcity of water have a negative impact on the agricultural system. These includes a reduced amount of appropriate land for both pastoral and arable agriculture, decreasing yields and a reduced length of growing season, specifically, in the margins of semi-arid and arid areas (NDA 2000). Different weather scenarios help in explaining the confusion existing about people's contribution to climate change, how the earth responds to human activities and the implications of different approaches to mitigation and adaptation measures. Climate change scenarios are no exception nor prediction of the future, but rather projection of what might happen by creating plausible, coherent and internally-consistent description of probable climate change features (Macmillan 2010). The IPCC (2007) has projected Africa's climate change as follows - because of climate change, about 75% people will be exposed to increasing water shortages by 2020. In a number of countries, yields from rain-fed agriculture could be decreased up to 50% by 2020. In many African countries, agricultural production, as well as, access to food is projected will be extremely vulnerable. Going further, the situation will negatively affect food supply and increase poor nutrition. Projected sea-level rise will have an effect on low-lying areas with large population towards the end of the 21st century. Five to eight percent growth of arid and semi-arid land in Africa is estimated under a range of climate scenarios by 2080 (IPCC 2007).

Changes in climate events have been noticed since 1950 and there has been increasing evidence that the severity and frequency of these climate events will change in future (Davis-Reddy &

Vincent 2017). Comprehensive assessment of climate change extremes for South Africa was provided by Field, (2012) as well as (Seneviratne et al., 2012) showing that there is extreme possibility that heat waves and warm temperature periods will rise up and that the amount of cold temperatures will reduce. There is also some strong indications that droughts will increase in certain seasons because of the reduced rainfall or a rise in evapotranspiration, and that extreme rainfall events will increase.

2.4.1 Temperature Projections

Projections in South Africa give a rise in average annual temperature of 2.5 – 3.5°C by mid-century. This would cause seasonality, lowered and altered rainfalls in the Karoo fringe and extreme temperatures and reduced rainfall will have an effect on fodder production. There will be tree encroachments, hence, rangelands will be lost resulting from the rise in temperature and the decrease in grasslands, because of carbon dioxide concentration. According to Shewmake (2008), households which possess livestock, have been found to be less vulnerable than families who rely on rain-fed agriculture only.

There is a projected increase in temperature in the central interior of South Africa by 1 -3°C with extreme hot days expected to rise to 70 days in twelve months, in the western part of the Free State. Large parts of the Province may experience an increase in heat wave by 20 – 30 days in twelve months, which may have an impact on human and animal health, on crop yield and may also be the cause of fires in grassland areas. The Western Free State will experience an increase high fires, up to 80 days per year (Envirotech Solutions, 2015). Throughout the month of October day-time temperatures will generally reach heights of around 28°C and at night a minimum temperature drops to around 9°C. In recent time the highest recorded temperature in October has been 36°C with the lowest recorded temperature of 3°C.It is almost certain that the increase in the frequency and magnitude of warm daily temperature and a decrease in cold weather will happen in the 21st century on a global scale. There is also a possibility that the length, frequency and the intensity of warm or heat waves will increase over most land areas (Envirotech Solutions 2015).

Africa is projected will be warm during the 21st century, with the heat possibility higher than global warming, all around the continent and in all seasons. The arid sub-tropical regions are projected to become warmer than the moist tropics; these results will be constant with a continuous-monitored temperature trends over subtropical South Africa (Kruger & Shongwe 2004). We already know that climate change gives effect to temperature rise and all other related variables, and as a result drought, floods and other hazards may take place. Free State Province is therefore exposed to climate change vulnerabilities by virtue of the fact that the Province mainly dependent on agriculture, among other economic activities. Floods and drought have a direct impact on agriculture because of soil erosion and reduced precipitation.

2.4.1.1 Extreme temperatures

Based on CCAM downscaling projections, it is anticipated that the frequency of annual extreme hot days will rise in the future (number of days when the temperature is over 35°C.). Even within the CRP4.5, temperatures will rise for up to 80 days per annum, by the end of the century. Extreme temperature sensitive sectors, being exposed to such events, will certainly cause an increase risk in the future (Reddy et al., 2017).

2.4.2 Rainfall Projections

Reduced rainfall will have a negative effect on large-scale agriculture, which depends on irrigation, the rural poor who rely on the rain-fed agriculture and the small-scale farmers. This will have an impact on the national economy and the national food security. Projected impacts of the scarcity of water will result in the cultivation of various crops the rangelands by 2050. South Africa consists of approximately 4.8 million small-scale farmers who are operating on an area of about 17 million hectares (Gbetibuo & Ringler 2009). These small-scale farmers are mostly dependent on rain-fed agriculture and that exposes them to the risks of climate change.

South Africa is a water-stressed country and is classified as semi-arid. The country receives less water than the world's annual rainfall which is 850mm average in a year; South Africa's average annual rainfall is 450mm per year. Rainfall in South Africa indicates seasonal variability, whereby the rain occurs mainly during summer months (November to March) while in the South West region of the country, the rain occurs during the winter months (May to August). South African rainfall patterns differ from west to east. In the North West region, the rainfall usually remains under 200mm, while most of the eastern region gets from 500mm to 900mm of rainfall per year. Per annum, the central part of the country gets up to 500mm of rain with huge variations happening nearer to the coast. Regions receiving at least 40mm of rain have a critical role to play, for example, land to the west is good for livestock grazing; crop cultivating is on the land that is irrigated and the land to the east is good for crops production. The Free State Province falls under the regions that receive less than 500mm of rain annually, even though the Province has a critical role in South African economy (IPCC, 2012).

2.4.2.1 Heavy rainfall events

CCAM's downscaling projections, suggest that a rise in the frequency of heavy rainfall events (within 24 hours, 20mm of rain falling) will take place over the eastern parts of Southern Africa - Mozambique, parts of Zambia, Tanzania, west coast of Madagascar and the north east corner of South Africa. The rise in heavy rain days in the eastern region is pushed by changes in the tropical cyclone landfall, which originate in the Indian Ocean (Malherbe et al., 2018). Thunderstorm changes (together with hail and lightning) are not easy to project since they occur at resolutions (IPCC, 2012 and Stocker et al., 2013). Some studies suggest that there is a possibility of a rise in the frequency of severe thunderstorm over tropical and subtropical Africa in warm climates (Engelbrecht, Landman & Engelbrecht 2013).

2.4.3 Wind Speed Projections

Wind speed and direction were analysed to measure the probable changes in South Africa, within the mid 21 century by 2051 – 2075 (Fant, Schlosser & Strzepek 2015). Compared to the historical period (1981- 2005) seasonal day-to-day increases hardly reach 6%, decreases occur to a maximum of 3% and these are variables between different seasons and areas, within the country. In every season, except for December, January and February (DJF) in the Highveld regions, wind speeds are projected to increase, indicating that air pollution-dispersing positions might increase. Dominant wind direction at 850hPa is projected to stay constant in these places, excluding the West and Eastern Cape Provinces in most of the seasons. The findings of this study are in line with those of Jury (2013) in his twentieth century assessment; he did not found any trends in the surface zonal winds, but the future projections found severe easterly flow along the South African south coast (Fant et al.,2015).

2.4.4 Relative humidity

According to Davis (2011) average moisture patterns of South Africa reflect an obvious east to west gradient across the subcontinent (below the equatorial region) with humidity level being the lowest over the western interior and higher in the east, due to the moisture source from the Indian ocean. Humidity again shows obvious diurnal and seasonal variations with humidity being at a maximum in summer and minimum in winter. This simply means that the east- west gradient is more evident in summer than in winter.

2.5 CLIMATE CHANGE RISK IMPACT

In recent years, changing weather patterns has created an impact on natural resources and the entire continent and oversees. Negative impacts of changing weather have been more common on crop yields; this has caused significant impact on food production globally. Heat stress, drought and flood events may result in the reduction of crop yields and livestock productivity (International Strategy for Disaster Reduction (ISDR) 2008). The drought situation in the province of Free State in 2015/2016 is a good example of this. The Table below illustrates the impacts associated with climate change

Table 2.1 Impact Associated with changes to climate

Changes to climate variables	**Impact**
Higher Temperatures	▪ Rising vaporisation and decreasing water balance ▪ Drought intensity increases ▪ Lowered alpine winter snow cover ▪ Decreased range of alpine environment and species ▪ Increase strain to coral reefs
Extreme temperatures, extreme hot days and extreme heat waves	▪ Increasing strain in livestock and wildlife ▪ Increasing veld fires ▪ Increasing damaged crops ▪ Increasing cases of death and serious illnesses, especially in older people
Higher minimum temperatures, fewer cold days and frost days	▪ Reduced heating energy intake ▪ Less damage to crops ▪ Reduced cold-related morbidity and mortality
Decrease in precipitation	▪ Decrease average runoff, stream flow ▪ Impact on rivers and wetland ▪ Decrease in hydropower potential ▪ Reduced water quality ▪ Decreasing water resources
Increased severity of drought	▪ Will decrease crop yield and rangeland productivity. ▪ Increasing veld fires
Decrease relative humidity	▪ Increasing veld fires ▪ Increasing comfort of living conditions at higher temperatures
More intense rain	▪ Increased pressure of disaster-relieve systems ▪ Increases soil erosion ▪ Increases flood risk ▪ Increases flood runoff
Increased intensity of cyclones and storms	▪ Increasing storm surge, leading to coastal flooding, coastal erosion and damage to coastal infrastructure. ▪ Increasing harm to coastal eco systems

Source: UNFCCC, 2007

2.5.1 International climate change risk impacts

According to the IPCC (2014) extreme weather events have been increasing since 1950, with climate change exacerbating the events. This weather situation is expected to continue to 2035 and even up to 2100. Due to global warming, there is an increase in heat waves, floods, storms, veld fires and drought. Increases in temperature negatively affect human populations' health and their crops and destroys the ecosystem. Global warming causes heat wave and increases droughts, especially in the dry regions; atmospheric water vapour increases while the hydrological cycle energises and leads to stronger winds, floods and heavy rain. Within these current years, climate change has created negative impacts on natural and human system, on the entire planet and throughout the globe. Rainfall changes or dissolving ice and snow has altered hydrological systems; this affects water resource in regards of quantity and quality (IPCC 2014).

Effects from similar climate-related events, such as drought, heat waves, cyclones, wild fires and floods disclose significant vulnerability and exposure of some ecosystems and a lot of human systems to current climate variabilities. Climate-related hazards increase other stressors, usually with negative outcomes for livelihood of people living in poverty (IPCC 2014). The impacts of change in climate maybe be noticeable in some communities or groups, for instance, if the community is relying on agriculture or coastal livelihoods together with the ones who are currently vulnerable, underprivileged and discriminated. People in Marshal Islands usually experience disruptive floods and storms that damages houses and endanger people's lives. The 2018 heat wave in the northern hemisphere made front page news all over Europe and America, although some negative effects felt in Pakistan where more than 60 fatalities; most of them were labourers performing duties in the intense heat as the temperatures rose up to 44°C. Areas that are already affected by drought will most likely encounter water reduction for irrigation (IPCC 2014).

Climate change may have a severe effect on food production around the world. The occurrence of drought, floods and heat waves may cause reduction in crops yield and livestock productivity. Basic human needs, such as food, water, shelter are affected by climate. Changes in climate may put these under pressure with the higher temperatures, sea level rises, changes in rainfall and more recurring extreme events (IPCC 2014). Individuals and groups will be affected by climate change in different ways. Kids and babies will suffer due to their special digestive system, physiology and their needs for growth. Decreases in water, sanitation, food, adequate housing, health, education and development are likely to be particularly harmful to children (Amnesty International). The natural resources - water and food security - may also be threatened by climate change. Even though climate change is a global matter, the impact differs across the planet, in both magnitude and the rate of change, in different continents, counties and regions (IPCC 2014). Asia's continual growth will be in question as weather conditions worsens the pressure on accelerated urbanisation, development of industries and economic growth have placed on natural resources. The principal concerns will be the accessibility of enough clean water, of which will be an issue by 2050 for probably over than one billion people. The ongoing melting of ice in the Himalaya region is expected to cause an expansion in floods and rock avalanche and to influence water resource in the upcoming twenty to thirty years. Asia's coastal zones, particularly, its overcrowded districts, will be more likely to experience increasing floods due to rising sea levels and flooding rivers (ISDR 2008).

Australia and New Zealand might experience recurring excessive events like heat waves, drought, fire, flooding, landslides and storm surges. These circumstances will proliferate the pressure on water supply and agriculture; they will also change natural ecosystem. Decreased seasonal snow cover and shrinking glaciers will cause more problems. Coastal areas are projected to be endangered by the ramifications of rising sea levels and increasingly harsh and recurring storms, and floods in the coast by 2050 (ISDR 2008). Europeans will have to manage with glaciers retreating and extension of permafrost, decreased rainfall in Southern Europe and probability of extended drought conditions in certain areas, and extended flash floods risks. Extreme temperatures and heat waves will expand medical risks and the recurrence and severity of veld fires. Minimised forestland, agricultural production and increased vulnerability of low-lying areas of the coastal to increasing sea level, are possible. Many sectors of the economy will be impacted. The South of Europe, low water levels will decrease hydropower performance, tourist industry and, overall, agricultural produce (ISDR 2008). Latin America's rainfall patterns changes and the evaporation of glaciers will largely decrease the quantity of water left for individual use, farming and power generation. Climate change is expected to lead to increasing salinization of water source and degradation of agricultural land in drier areas. The level of productivity for some crops and livestock will decrease, unfavourable effects on food safety. Increasing may lead increasing floods risks on low-lying coastal areas (ISDR 2008).

North America will encounter reduction of mountain snow because of higher temperatures which will cause an increase in winter floods, decreased summer flows, as well changing seasonal accessibility of water. A number of region are anticipated to encounter extended heat waves, with higher risks health effects. Furthermore, continued extreme temperatures will rapidly escalate the risks of veld fires where coastal communities will be in danger, when the severity of tropical storms rises (ISDR 2008). Polar Regions are expected to encounter decreases in the thickness of glaciers, increase of ice sheets, and changes in the environment. The impact on societies in the Arctic will be observed in changing in infrastructure and cultural or indigenous living conditions. Small island states, coastal systems and other low-lying areas are most susceptible to the impacts of changing climate, increasing sea levels and rising weather events. Numerous communities are more likely to be at risk of floods, storm surges, erosion and other coastal dangers yearly due predicted rising sea levels by the 2080s, particularly in the large deltas of Asia and Africa, as well as, in small island states. By mid-century, decreased water resource are anticipated in plenty small islands, for example, in the Caribbean and Pacific (ISDR 2008).

2.5.2 Climate change risk impact in Africa

There are instances of extreme temperatures throughout the African continent and in all the seasons when compared with the global average. Dryer sub-tropical regions are becoming warmer than moist tropics (Christensen et al., 2007). Africa's socio-economic and environmental systems are extremely susceptible to the weather extremes for instance floods and drought (African Ministerial Conference on the Environment AMCEN/UNEP 2020). For example, in the early 1970s, Sahel obtained international prominence in time of that tragic drought, where 300 000 humans and millions of animals died (de Vaal 1997; Mortimore 1998). These drought conditions still continue even up to now, however, with increasing signs of wetness, especially, the La Nina years during the 1990s (Ogallo 1993). The economic losses from the drought in Africa, in the mid-1980s, totalled a couple of hundred million US$ (Tarhule and Lamb 2003).

The majority of the people in Africa still do not have access to safe drinking water. In addition, a huge number of people still lack adequate sanitation. By the year 2010 it was expected that over 400 million people would be living in about 17 water-scare African countries (World Water Forum 2000). Food production, ecosystem protection and socio-economic development will be severely constrained due to the lack of adequate water. Number of illnesses in Africa for instance malaria are mostly influenced by climate induced factors. The African highlands have also observed a strong correlation of the malaria epidemic and the anomalously high rainfall (Githeko & Ndegwa 2001) as well as the s regions of Africa, which are semi-arid (Thomson et al., 2006 & the International Research Institute IRI 2005). Africa with the high economic costs of malaria, the increasing malaria occurrences could lead to rising poverty levels. For example, Sachs and Malaney (2002) has noticed fivefold differences in the GDP amongst malaria and non-malaria-prone countries.

By 2020, a number of countries in Africa, farming could be lessened by almost 50%. Areas of arid and semi-arid lands in Africa will possibly rise by 5-8% by the 2080s (ISDR, 2008). The Intergovernmental Panel on Climate Change (IPCC) describes, climate vulnerability, as the extent at which an organization is exposed to and not being able to handle the negative effects of climate change, as well as climate variability and more. Africa's extreme economic dependency on activities and products related to climate, makes the continent extremely vulnerable to climate change. Sensitivity to climate change affects the water, agriculture, health sectors and the whole ecosystem, as well as bringing changes to the degree and occurrence of these events. The rising of mean sea levels, will put African cities in danger, especially the cities closer to river deltas. Sensitivity to rising temperatures from the agricultural sectors, as well as changing rainfall amounts will disturb food security in the continent. (African Climate Policy Centre ACPC 2013).

Climate change affects different aspects of African cities, such as infrastructures, ecosystem and economic development. Multiple stresses and low-adaptive capacity cause African continents to be more vulnerable to climate variability. Currently, the stressors include - poverty, food insecurity, political conflicts and ecosystem degradation. Climate change impacts might also cause people to be displaced, therefore, increasing internal migration. There is growing evidence of impacts, such as flooding, drought, deforestation, and land degradation leading to migration in Africa (Abebe 2014). Changes in precipitation patterns and temperature will lead to the reduction of food production in some parts of Africa. Features such as increased demand and decreased ground-water recharge will have a negative effect on water resources. Climate change may disrupt ecosystems and crucial products and services they provide, like oxygen and protection from the floods; in addition, climate change will reduce biodiversity and wetland region, leading to the loss of soil and trees. The poor and vulnerable communities usually rely on ecosystem services, hence, are possibly the worst affected by the impacts of climate change (Abebe 2014).

2.5.3 Climate change risks impacts in South Africa

South Africa is famous for its tremendous beauty, rich biodiversity and ample beautiful wildlife, nonetheless, people and the natural assets in this country are at real risk of the impacts of climate change. South Africa hosted a COP17 in Durban on the 28th of November to the 9th of December 2011 and that is when South Africans received a wakeup call of this climate change issue. In the past 60 years, temperature has been changing tremendously and it is predicted will be continually rising; in the coastal regions, temperatures are expected to rise by 1 -2°C. By the year 2050 rises of 3 – 4 °C is expected in the interior regions. A rise of 3 – 4°C has been predicted in the coastal regions as well as a predicted rise of 6 – 7°C by 2100 in the interior regions. Changes in precipitation trends are also expected (Griffin 2012). Figure 2.4 below shows the number of people who were affected by extreme weather events in South Africa over the past years.

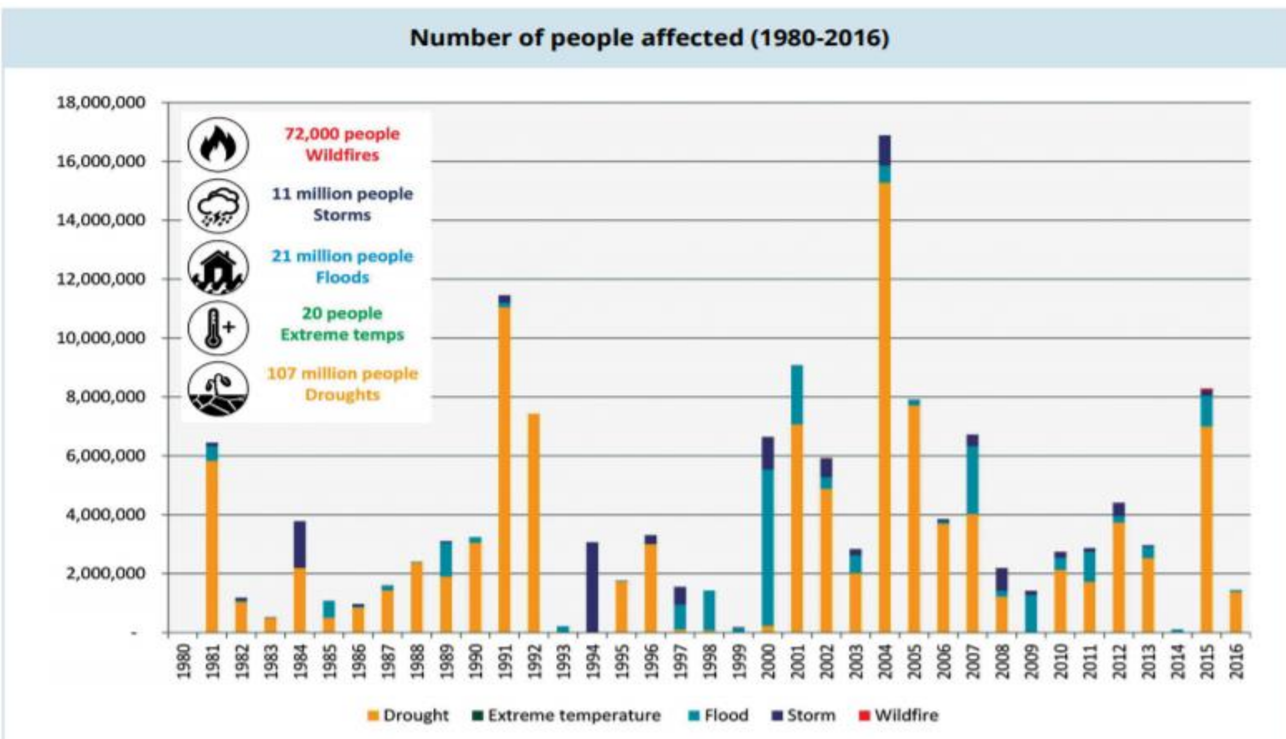


Figure: 2.4 Number of people affected by the extreme events in South Africa.

Source: EM-DAT CRED, 2016.

Figure 2.4 reveals the number of recorded climate disasters in South Africa. The occurrence of these events can force farmers out of business and not only farmers but multiple sectors. The impact range from primary or direct effects, such as infrastructure damage and death and secondary damages such as health and loss of livelihood (Easterling et al., 2000).

2.5.3.1 Socio-economic impacts of climate change in South Africa

South Africa is vulnerable to extreme weather events, especially floods, fires, drought, and heavy storms. Climate change events account for a high percentage (67%) of fatalities due to natural disasters. In the previous 40 years (1980 – 2015), there are 491 documented climate disasters documented by the South African Development Community (meteorological, hydrological and climatological); these have resulted in 110 978 fatalities, and has left 2.47 million people with no homes and affected an estimated 140 million people (Emergency Events Database EM–DAT Centre for Epidemiology of Disasters CRED 2016). During 2013/2014 financial year, the extreme weather-related events have caused South African insurance industries over R1 Billion in claims (Uys 2014). Some social impacts which occur as a result of climate change are discussed below.

Water: In South Africa, water resources are already under pressure, hence, it is known as a water-stressed country with annual rainfall of 500mm; as the climate changes this will lead to a decline in surface-water availability. This is a country with limited water, necessitating attention to water management structures and priorities. It is situated in a region with rising levels of water scarcity, water-quality problems, together with a growing population and unfavourable matters around social and economic development; the arising stress on water resources, from climate change can exacerbate these problems. In addition, supply and demand pressures of water, because of land degradation, population growth as well as supply problems, have an effect on water resources in the region (Mc Mullen & Jabbour 2009). Presently in Africa there are 14 countries which have experienced water scarcity; 11 countries are expected to be water-stressed by 2025 (Rutashobya 2008); areas affected by drought are likely to become wide-spread. Heavy rains may increase in frequency which will cause a rise in flood risk. By mid-century, there will be water scarcity, in dry tropics which receive water from the melting mountain ranges, as above one sixth of people in the world rely on the melting water from the mountain ranges (ISDR 2008).

Health Impacts: A number of rural areas in South Africa are populated by a huge number of children and the elderly as those of a working-age have migrated to urban areas in search for work. Children and the elderly are more vulnerable to climate change due, for example, to inadequate health information. Severe poor nutrition in children less than five years of age have been observed and is because of poverty and communities' incapacity to grow enough and right kinds of food (United Nations International Children Emergency Fund UNICEF 2011). Human being are exposed to several effects of climate change, for example - heat waves cause heat stress and cardiovascular diseases. Extreme events or severe weathers like floods and droughts cause injuries and fatalities, as well as indirect impacts, such as, cholera and meningitis (Patz et al., 2005).

Examples of indirect health impacts are related to mental health – anxiety, despair, depression and post-traumatic stress. Extreme weather-related effects include injuries and fatalities, as well as indirect impacts, like cholera; air pollution-related effects are cardiovascular diseases, and asthma. Some effects of lack of water and food supply are - harmful alga bloom, malnutrition, diarrhoea, water-borne diseases (cryptosporidiosis and cholera), vector-borne disease (Zika virus, malaria, dengue and encephalitis) as well as, allergies (respiratory allergies and poison ivy) (Patz et al., 2005).Health risks from climate change, therefore, involves the ones that are directly related to the increase in extreme weather conditions, such as floods, heat wave cyclone, storm surge and drought and those due to growth in moulds, pollen and spores.
Climate change-related health illnesses usually include, different patterns of infectious diseases, food insecurity increases, population displacement and scarcity of water, among other factors (Mash, 2008). Analysis of weather changes in the department of health shows that South Africans might be exposed to the rising water and vector-borne illnesses, specifically, malaria and bilharzia which results from changes in the eco system (Kiker 2000). The predicted changes of weather are likely to change the health status for millions of South Africans, as well as increase the number of fatalities, and illness due to extreme heat, drought, flooding, fire as well as the storm. Rising number of poor food supply, diarrhoeal and malaria diseases in parts of the country will expand susceptibility to public-health challenges and countries' growth and development goals will be jeopardised by long-term damages to public health systems, from these incidence (ISDR 2008).

Economic impact

Income, in the form of household income may come from formal or informal employment. Families with high incomes are less susceptible to poverty, and stressors that are caused by climate change, because they have better adaptive capacity than households with lower or no income. The status of employment for the person who is the head of the house is an important contributing factor for adaptive capacity, since being employed and unemployed means a huge difference in income availability and poverty alleviation. Societies, industries and settlements that are located closer to the coastal areas and the river flood plains are among the most vulnerable, as well as those whose economy is more connected to weather susceptible resources. This, particularly, shall applied to areas which are susceptible to extreme weather events and those places which are experiencing accelerated urbanization. When these extreme weather events become more severe or more persistent, the social and economic expenses of those events, rises up (ISDR 2008).

Agricultural conservation

Predicted water scarcity for South Africa will have a negative effect on the agricultural sector, especially, on irrigation, which is known as an adaptation strategy in the semi- dry regions. The agricultural industries use lots of water, taking up to 62% water for irrigation, domestic uses 8% while forestry uses 3% (Department of Environmental Affairs and Tourism DEAT 2004). This compromises national food safety since over 90% of agricultural activities is in the manufacturing of food; however, not only the agricultural industry will be affected, but other economic sectors will also be affected. Changing water availability because of changes in weather events, therefore, will have a huge implication on the economy (Ashton & Turton 2005; Turton 2008a; Turton & Ashton 2008).

Whilst some high and mid-latitude areas will prosper from high agricultural productions, for others in the lower latitudes, especially in seasonally dry tropical regions, the higher temperatures and persistency of droughts and flooding are more likely to have a negative impact on crop production, which can cause a rise in a number of people at risk of hunger or poverty and an increase in a number of people displacement and migration. (ISDR 2008).

Adaptation strategies could include - greater use of technology for water harvesting, conserving soil moisture; transporting water more efficiently when there is a reduction in precipitation; being able to manage water to prevent water logging; erosion and nutrients leaching where there is an increase in rainfall; changing the location or timing of crop operations; diversifying income by integration with other farming activities like raising livestock; improving effectiveness of weed, pests and disease management practices through the use of integrated pests and pathogens management; development and the use of species and varieties which are resistant to pests and diseases; the maintenance of quarantine capabilities and monitoring program; as well as the use of climate forecasting to decrease production risks (Stark, Mataya & Lubovich 2009).

2.6 POLICIES AND LEGISLATIONS

2.6.1 International Disaster Management Policies and Legislation

Policies and legislations serve as a foundation for strengthening community resilience. They are important for the reduction of risks caused by natural hazards and for preventing new risks from happening. In 2005, the Hyogo Framework for Action pointed out the usefulness of good legislation to support disaster risk reduction (DRR). The Sendai Framework for Disaster Risk Reduction for 2015 – 2030, was adopted in March 2015 and is the successor to the Hyogo Framework for Action, 2005 – 2015. The former calls for an improved analysing of data and strengthening the appropriate legal frameworks.

The Hyogo Framework for Action, 2005 – 2015

The Hyogo Framework for Action (HFA) 2005 – 2015 focused on Building the Resilience of Nations and Communities to Disasters. The role of the Hyogo Framework was to provide a foundation for the application of disaster-risk reduction. The agreement at the world conference in Japan in January 2005 was on "the substantial reduction of losses of lives and the economic, social and environmental assets of the communities and the countries". It pointed out that countries need to upgrade the integration of risk reduction related to the current climate change variability and future climate change. The Hyogo Framework had five priorities for action - ensure that disaster risk reduction is a national and local priority with a strong institutional basis for implementation; identify, assess and monitor disaster risk and enhance early warning; use knowledge, innovation and education to build a culture of safety and resilience at all levels; reduce the underlying risk factors and finally, to strengthen disaster preparedness for effective response at all levels.

SENDAI Framework for Disaster Risk Reduction 2015 – 2030

The Sendai Framework for Disaster Risk Reduction was adopted at the Third United Nations World Conference in Sendai in Japan, March 2015, to provide continuity to the Hyogo Framework for Action. The Framework states that changing weather is another underlying disaster risk drivers and that climate change can cause serious disasters (UNSDR 2015). The Sendai Framework aimed to accomplish the following outcomes within 15 years - the massive decrease of disaster risks and fatalities but rather, an improvement in livelihoods and health and in the physical, social, economic, cultural and environmental assets of people, business, societies and countries. Taking into consideration, the knowledge obtained through the implementation of Hyogo Framework for

Action, the key priorities of the Sendai Framework are to prepare for climate-related disasters and to build resilience (UNSDR 2015).

United Nation Framework Convention on Climate Change 1992 (UNFCCC, 1992).

The United Nations Framework Convention on Climate Change (UNFCCC), accepts people's and countries' vulnerability to climate change and suggests measures to reduce the outcomes through adaptation. This can only be implemented through capacity building, financial support and the transfer of technology to developing countries. The Concun adaptation framework is a recent development with regard to adaptation within the UNFCCC and it was signed at the 16th COP in Concun in 2010. The Concun adaptation framework is a technique to allow the least developed countries to implement and formulate National adaptation plans as well as to understand how to determine damages and losses (UNFCC Adaptation Committee 2014).

The Humanitarian Charter

Humanitarian bodies devoted to this charter and to the Minimum Standards plan to obtain clear standard of service for individuals affected by disasters and encourage the compliance to fundamental humanitarian principles. The Humanitarian Charter confirms the significance of the following ethics – freedom to live with respect; differentiate amongst combatants and non-combatants; the law of non- refoulement and the International laws on immigrants (The Sphere Project 2004).

2.6.2 South African disaster management policies and legislation

In accordance with the international trends and South Africa's national aim of efficient and productive management of our nation's resources, the country's disaster management policies and legislation underscore the value of protecting human, economic and property losses, and preventing environmental degradation (Government Gazette 2014).

The Constitution of the South African republic, Section 41(1) (b)

The Constitution states that all spheres of government are required to secure the wellbeing of the people of the South African republic. Part A of Schedule 4 of the Constitution classifies disaster management and matters related to it as areas of concurrent national and provincial legislative competencies. This simply means that provincial and national government have both the powers and duties in regards to disaster management. The local government also has powers to handle a number of functions related to disaster management under Part B of Schedule 4 and 5 of the Constitution (Government Gazette 2014).

Disaster Management Act, 2002 (Act no 57 of 2002)

In the Disaster Management Act, ‘disaster’ is defined as - a sudden or progressive, widespread or localised, natural or man-made occurrences which cause or threaten to cause, fatalities, injury or diseases, property, infrastructure or environment damage or destruction to the communities wellbeing and is of a magnitude that is above the ability of the affected community to cope with its effects using only their own resources (Government Gazette 2014). Section 20, 33 and 47 of the legislation force disaster management centres through ought the sectors of government (national, provincial and municipal) to give advices to the state authorities, the private enterprise, non-governmental organisations, societies and humans, on how to weigh, avert or minimise disaster risks. These include - how to assess the level of risk; analysing of the susceptibility of communities and households to any hazards that may happen; expanding the strength capacity of communities and households to minimise the dangers and impact of disasters that may arise, supervising the probability of, and early warnings to, incidents that may happen; the developing and delivering of proper prevention and mitigation methods and the amalgamation of preventing and mitigating methods with development-plan program (Government Gazette 2014).

National Disaster Management Framework, 2005

The National Disaster Management Framework is the lawful document designed by the DMA to explain the need for consistency across multiple interest groups, through the provision of an understandable, honest and inclusive framework on disaster management that is suitable for the entire Republic of South Africa. The framework indicates that the National Disaster Management Centre (NDMC) is liable for the establishment of an effective institutional arrangement for the development and approval of integrated disaster risk-management framework. The Framework consists of four Key Performance Areas (KPAs) as well as, three supporting Enablers to reach the goals set out in the KPAs. (Government Gazette 2014).

Disaster Management Amendment Bill of 2015

This Bill amends the main Act in the section, the Disaster Management Act, 2002 (Act No. 57 of 2002). The Act requires that each national, Section 25(c)(i), each provincial, Section 38(c)(i) and each municipal, Section 52(c)(i) organ of state as well as each province (Section 39) and each local sphere (Section 53) to formulate a disaster management plan, pointing out how the concept and principles of disaster management are to be practised in each functional area, along with the anticipated climate change impacts and risks for the organ of state. The Amendment Bill again requires that the respective organs of state must show how they will invest in the reduction of disaster risk and climate change adaptation, in the ecosystem; the management must include community-based approaches as well (Government Gazette 2014).

The National Water Act, 36 of 1998

Together with Water Service Act, 108 of 1997, the National Water Act, 36 of 1998**,** supplies South Africa with a complete and cohesive body of water laws. The National Water Act does not only explain the response strategy for water scarcity that might happen due to climate change, but it also creates frameworks that create flexibility for handling the anticipated results of disaster occurrences (Madzwamuse 2010).

National Veld and Forest Fire Act 101 of 1988 (NVFFA)

It is well known that one effect of climate change is the increase of veld fires. The National Veld and Forest Fire Act 101 of 1988 aims to manage any veld fires through prevention and combating the forest, veld and mountain fires when they occur. The Act consists of both the prevention and the firefighting measures (Madzwamuse 2010).

The National Environment Biodiversity Act, 2004

The Act supplies a legislative backing for – the managing and conserving of South Africa's biodiversity in the framework of the National Environmental Act of 1998; the preservation of the eco system that needs protection; the continuous usage of indigenous biological resources, as well as outlining the development and duties of the South African National Biodiversity Institute (Madzwamuse 2010).

2. 7 VULNERABILITY STUDIES

Climate change is a cause for concern in the whole world, particularly for the African continent as well as South Africa. For the purpose of this research, the Free State Province is also vulnerable to climate change. According to (Pandve et al., 2015), vulnerability is recognised as a function of two components - the impacts that an event may have on human, is referred to as 'capacity' or 'social vulnerability' and the risk that an extreme event may occur, is called an 'exposure'. Human activities and agricultural activities are treated as the highest source of sensitivity to climate conditions and climate variability (Pandve et al., 2015). Vulnerability consists of capitals - environmental, social and economic - where each capital is measured by its indicators. The indicators weighted accordingly to environmental indicators are - land degradation, deforestation, soil erosion and vegetation type; social indicators are - initial wellbeing, education, gender, household size, civil society and social networks; economic indicators are - livelihood income, alternative income, employment security, land ownership and land size (Jordan 2011). These indicators assist in determining the level of exposure of people to vulnerability because if these indicators which are due to climate change effects are not present, then people are not vulnerable. Policies and regulations that oversee the development and the administration of the required resources for the poor people, should involve accessibility to natural resources, provide education, ownership of land, financial assistance and freedom of association (Dulal et al., 2010). A better livelihood for the poor will improve their adaptive capacity (Dulal et al., 2020). For this study, climate change has a direct bearing on the direction of vulnerability in the Province of the Free State. Vulnerability index will be used in this study to determine levels of vulnerability in the Free State Province. This is justifiable by the fact that, climate change is the principal cause for natural hazards such as floods, drought, and cyclones, among others. Literature has shown that, the people who suffer the most in such situations, are vulnerable people, hence, the study about vulnerability to climate change as indicated in Chapter 1.

2.7.1 International studies of vulnerability to climate change

Whitmarsh (2005) conducted a study of public understanding of and public response to climate change in the south of England in 2005. A mixed-method approach (quantitative and qualitative) was used to assess the community's understanding of climate change in England. The findings of the study demonstrated that the financial incentives are the strongest motivation for the reduction of energy usage, which is one of the causes of climate change. The conclusion was that there is also a need for attitude and behavioural change and that climate change mitigation policies should provide enough opportunities for behavioural changes, for example, the use of public transport instead of everyone using his / her own transport.

Karl, Melillo & Peterson (2009) conducted a research about Global Climate Change Impact in the United States using both qualitative and quantitative methods. The study was outlining expected future climate variability impacts in New York. The researchers recommended that an effective climate change constitution might protect jobs and businesses and establish a safer environment for generations to come. Their findings were that - climate change in the United States is projected to grow; climate change will stress water resources, hence, livestock and crop production will be highly challenged; there will be higher risks on human health and that future climate will rely upon the choices made today.

A team of researchers from London Climate Change Partnership (LCCP) conducted a study into the impact of climate change in 2002. The aim of the study was to assist and ensure that London is ready and prepared for any changing climate and the methods used for collecting information were both qualitative and quantitative. The suggested recommendations were that - there is a need for citywide planning; adaptations to climate change must be deliberated upon and medium and long-term decisions made. From the interaction amongst these measures, the management of flood risks, through water-harvesting measures, communication and engagement with authorities, business and public sectors, should prepare a successful climate-change preparedness plan.

2.7.2 Studies of vulnerability to climate change in Africa

Africa is the second largest continent in the world and has a climate that ranges from the hyper-arid to very humid. A proportion of Africa's population (about 60%) just above the age of 15 are illiterate (UNDP 2003). Nearly all African countries are classified under 'low-human development' category. Vulnerability to climate change in Africa will be mostly dependant on its present and future adaptive capacity. This is influenced by matters, such as economic development level, levels of education, accessibility to credit and the ability to adapt to technology. These factors are not applicable to all African countries and this makes it difficult to have a uniform climate change assessment as a continent (UNDP 2003). Africa has extreme unpredictable and variable climate types that are not entirely understood by the climatologists, nevertheless, the records do show that Africa has been warming up at the rate of 05° C every 10 years with higher levels of warming in the June - November season than in December to May, in the 20th century. The long term rainfall in the semi-arid regions of West Africa was the most significant climate change that has ever occurred. For example, in Sahel there has been a 25% rainfall decrease in the past 30 years, although, this decreasing amount of rainfall has been more moderate in other regions, but not in Sahel (Nkomo, Nyong & Kulindwa 2005).

(Chaplin et al., 2017) conducted a study about the impacts of climate change on food security and livelihoods in Karamoja. Their main objective was to commit to, and promote efforts in mainstreaming the adaptation of climate change into broader resilience, programming measures and to promote proper adaptation policies and programs that gives support to the most vulnerable. The methodology used was a systematic random sampling and the quantitative approach. Data was collected using a standardised questionnaire and data was exported to the Microsoft excel and SPSS was used for the analysis. Findings showed that households with no educated member were 27% more likely than those with some education. Both chronically ill and disabled-headed household and female-headed household were 13% more likely man-headed household and not being able to be members of a group.

Recommendations were - to encourage the community on water harvesting and conservation schemes; make communities aware of the threats posed by climate change; improve access to climate information service; encourage agro-forestry schemes, and mainstream gender in climate change-related interventions.

(Awojobi & Tetteth 2017) conducted a study about the impacts of climate change in Africa. The study analysed the impacts of climate change in Africa, and acknowledged results of previous studies - that climate change mostly has an impact on infrastructure, ecosystem and human health in Africa. The literature for the study was electronically done and was basically qualitative with a blend of quantitative method of analysing the climate change impacts. Recommendations were that, there should be an incorporation of adaptation strategies into sustainable development so to reduce the stress on natural resources and improve environmental risk management, as well as, the social wellness of the vulnerable.

A study about climate and Africa was conducted by Collier, Conway and Venables (2008) on the bases that, due to the high dependency on agriculture in Africa, the impact of climate change is more likely to be severe, while the adaptation capacity is limited; the study used a qualitative method. The recommendations were that, the government should provide information on how to maintain the incentives and to enhance the economic system. Support for agricultural research is also a community responsibility, hence communities should engage in research, although, this will result in an increase in requests on public expenditure, however, it is important to draft infrastructure strategies to deal with adverse climate.

A desktop study was conducted by Taddesse (2010) about the effects of climate variability in Africa. The study's main concern was that Africans are among the lightest polluters, however, experts state that they will suffer severely from climate change in their search for water and food security, economic and political sustainability and sustainable development. The researcher recommended that by enhancing agricultural productivity, this might provide growth, income and employment in disadvantaged rural areas and that would lead to the reduction of rural to urban migration. In addition, there is an important need of addressing the issue of alternative energy, such as solar, hydro and wind power to reduce deforestation problems, drought, soil degradation and overgrazing in many parts of Africa.

Adaptation Strategies in Africa

Adaptation is an action whereby communities make themselves to better understand unfavourable situations and the ability to cope with such an uncertain future. Adaptation to climate change includes taking the right measures to lessen its negative impacts by making proper adjustments and changes. Adaptive measures to cope with extreme events have not been entirely adopted by countries. Adaptive techniques, like, early warning systems, training, knowledge and transfer through interactions, institutions and community forums to work for disaster prevention and preparedness are necessities. Adaptive measures taken by Africa is considered extremely low, nevertheless, numerous factors have been identified that can assist Africa to withstand the impacts of climate change. Following are the specific adaptation methods that are being employed to reduce the impacts of climate change (Boko et al., 2007, Christensen et al., 2007).

2.7.3 Studies on vulnerability to climate change in South Africa

In South Africa, a variety of studies related to climate change and vulnerability have been conducted. A study was done in 2009 where there was a mapping of the South African farming sectors and their vulnerability to climate change and variability by Gbetibouo and Ringler (2009); this was done using a quantitative approach to climate change vulnerability, around the nine provinces of South Africa. The methodology used had both strengths and the limitations. Current findings show that there is limited data for the district level farming which will, therefore, require a macro approach. Findings also show that, Eastern Cape farmers will be facing high exposure to extreme climate events, however, the Province has a high adaptive capacity due to its high level of wealth, high infrastructure development and easy access to resources.

A study was conducted in the Free State Province by Matela (2015) on the topic Vulnerability and adaptation to climate variability: a case of emerging farmers in the Eastern Free State, South Africa. The mixed-method approach was used for the collection and analysis of primary and secondary data. Findings were that there is still a need for the Department of Agriculture and other stakeholders to support farmers, not only financially but also with relevant skills and information since crop production is complicated by unexpected weather conditions. Government should also ensure policies are developed, to provide skills' support through training for farmers to better cope with unexpected weather variations associated with climate variability. This simply means that vulnerability is real in the Province despite interventions by the provincial government.

Chersich and Wright (2019) conducted a case study entitled Climate change adaptation in South Africa on the role of the health sector,. A systematic review method was used to assess progress in climate change adaptation from literature indexed in PubMed and Web of Science. Findings were that few studies have presented interventions from high quality research designs. Another finding was that there is limited evidence of the country's preparedness plan for extreme weather events or the capabilities of the health sector to respond to the extreme weather events.

South Africa is very vulnerable to climate change due to the high number of people living in the informal settlements; these areas are vulnerable to extreme weather conditions, and they have a shortage of proper houses to provide protection against heavy rains, strong winds and cold weather. As most areas of South Africa experience low rainfall, some rural places face more challenges in accessing safe drinking water. Shortage of water will cause problems in the future and climate change is making the situation worse (Griffin 2012); climate change is one of the main concerns in South Africa. The increase of annual mean temperature is at 1.5 times the noted global average of 0.65°C in the last 5 decades and the consistency of rainfall extremes have raised. These changes are very likely to continue. Climate change presents a serious threat to South Africa's water resources, infrastructure, health, ecosystem service, biodiversity and food security. Looking at South Africa's poverty level, these climate change impacts will create challenges for the national development. People's livelihoods in Africa, including South Africa, are attached to the climate of the area (CSIR 2010).

Adaptive measures in South Africa

Climate change predictions are still not 100% accurate to give highly specific guidance. Drought-affected areas are more likely to increase and the poor has the least or no capacity to adapt to the extreme weather that is expected (USAID 2007). Adaptation to the rising weather variabilities, diversification and buffering strategies, such as water harvesting, small scale irrigation, soil and water conservation, cropping-system changes, livelihood diversification, integrated crop management and diversification of higher value crops are some of the appropriate measures (USAID 2007).

Building resilience to climate change

Protecting livelihoods by alleviating poverty, through creativeand continuous employment creating programs by Alinovi & Romano 2009 was a study done to investigate resilience. The results suggested some strategies - providing short-term employment for the unemployed people and financial assistance to build up their ability to cope with shock and stress; food assistance for the needy; social welfare/security schemes for socially-marginal and poor people; developing or continuing of adaptive research for all enterprises, such as crops, fisheries, livestock and forestry to better the agricultural intervention to climate change (Alinovi & Romano 2009).

Coping with changing climate in South Africa

Selling of livestock is one of the most common strategies of farmers in semi-arid areas in coping with drought (Thomas et al., 2007). As far as Western Cape is concerned, livestock farmers were the worst hit by the drought and roughly 30 000 cattle's were sold in the region as farmers were not able to provide food for their herds (Thomas et al., 2007).

Supplemental feeding is another method of coping and that includes the use of ground maize stalks or cut fodder/ wild plants. People are advised to plant grass for fodder, use molasses and stock feed for the cattle and use chicken waste with grass and salt as feed during harsh dry season. Sometimes temporary relocation can be practised in such conditions (Thomas et al., 2007).

Other important components of coping and adaptive capacity are human and civic resources. Included in this category are – improvement in the level of education, access to training programs, literacy development, as well as other important factors that can enhance how quickly an individual can adapt to new employment opportunity or a change in living conditions brought by climate change.

2.8 SUMMARY

This chapter analysed literature on vulnerability to climate change. The discussions paid attention to vulnerability indicators - social capital, economic, environment and political capital. Climate change variables are used to study the presence of the monotonic trends in temperature, precipitation, humidity and wind velocity. The chapter analysed the definition of terms that are relevant to the literature. Vulnerability frameworks that support livelihoods and give guidance on sustainability and adaptation were discussed together with the relevant policies and legislations in disaster management as well as using the climate change scenarios to describe probable future climate for preparedness measures and coping mechanisms. Findings from vulnerability studies done by other researchers locally and internationally were interrogated. Observations were made of international, regional and local climate change risks impacts as well as their adaptation measures, so that South Africa can learn how other countries are coping and adapting.

Climate change risk impacts were outlined and the literature showed the high cost in numbers related to monetary, displaced people and mortality rates, internationally, regionally and in particular, the Free State Province of South Africa. Policies and legislations were examined, whereby, it was shown that there is enough legislative frame work in place, internationally, regionally and locally, and that these frameworks evolve as and when the need arises. Climate change scenarios give a clear indication of previous history and current climate trends. The literature suggests that, climate history is useful in order to enable decision-makers and scholars to make future climate predictions for informed decision-making to take place. Climate change scenarios were, therefore, discussed internationally, regionally and locally, as climate change is a worldwide challenge.

Vulnerability framework explains the relationship between vulnerability and related capitals and indicators. This was formulated to guide decision-makers in order for them to address critical aspects of service delivery at national and local levels, depending on the makeup of the government in the relevant country. South Africa also has its own legislative framework, although, it also depends on international vulnerability framework for decision-making purposes. Socioeconomic impacts of climate change were also discussed in this chapter, the literature review in this case show that communities in many nations, including the Free State Province are affected.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

This section intends to analyse and discuss the data collection and analysis, clearly showing their validity and reliability as well as ethical considerations applied in the research. To attend to the key research objectives, this research used quantitative methods. The study is based on secondary data from two stations in Bloemfontein - J.B Hertzog and Bethlehem Airport. The quantitative data was analysed statistically to support the main argument of the research, involving adaptation and planning strategies. This study evaluates the vulnerability created by climate change.

3.2 RESEARCH METHODOLOGY

Schwardt (2007) interprets research methodology as the philosophy of how a research should progress; it includes analysing the assumptions, procedures and principles of a certain research proposal. According to (Schwardt 2007, Cresswell & Tashakkori 2007, and Teddlie & Tashakkori 2007), methodologies clarify and explain a set of questions that deserves to be investigated; what generates a subject of inquiry; hypothesis that can be tested; how to shape a research question in a manner that it can be reviewed by using certain design process, as well as the selection and development of proper ways of data collection. Methodology is a guideline on how activities and approaches are undertaken. To formulate this study, a quantitative approach was employed.

3.3 RESEARCH DESIGN

Leedy (1997) interprets a research design as a study plan, which gives the general framework for compiling data. MacMillan and Schumacher (2001) interpret it as an idea for selecting a problem, information compiling processes to give answers to the study questions and the research sites. They also points out that the aim of a research method is to present outcomes that are legitimate. For Durrheim (2004), a research method is an important framework that acts as a link amongst the study question and the implementation or the execution of the research approach. This study used the quantitative method for the collection of information and analysing. This method allowed the researcher to trace the four variables of climate change: humidity, wind speed, precipitation and temperature trends and relationship. Furthermore, the quantitative approach permitted the researcher to compare using these four statistical variables, for the past 37 years, for the two stations of Bloemfontein (J.B. Hertzog and Bloemfontein Airport).

3.4 DATA COLLECTION

Data on selected indicators were taken from the website. Climate change and projection data (Temperature, Precipitation, Humidity and Wind velocity) were used to obtain indicators relating to future climate change and daily trends of climate for the two stations in Bloemfontein; these were acquired from the National Aeronautics and Space Administration (NASA) online database. This helped in giving measurements on the changing climate within the selected areas. Statistical data and standards were considered for the review.

3.4.1 secondary data

Secondary data was used for this study. This type of data involves using information, which has already been collected by other researchers for different purposes (Nichmias & Nichmias 1992). Punch (2005), explains secondary data as the re- analysation of already collected data, while Ryman (2004), refers to secondary data as the interpretation of information by other researchers who were not engaged when data was collected; the same definition is given by Reason and Bradbury (2001), who interprets it as the analysis of data by anyone excluding the ones who were in charge for its authentic commissioning. Frankfort, Nichmias & Nichmias 1992, William 2003, and Kiecolt & Nathon 1985, included another element of definition by indicating that secondary data analysis refers to the outcomes of a research based on collected data by others. While these explanations are worded differently, they all in agreement that secondary data had been collected by others for other research objectives.

3.4.2 Advantages of secondary data

There are numerous reasons why researchers may choose to do analysis of secondary data. Conceptual and substantive reasons since for some research studies, the only available data may be the secondary data; for example, social and political historians mostly depend on secondary data (Nichmias & Nichmias 1992). Secondary data analysis gives opportunities to establish similarities. This is of importance in a research as the outcomes of a research obtains credibility if they re- appear in different studies (David & Sutton 2004). Sometimes, data collection for the primary data is costly and it is not easy to get funds. Researchers will, therefore, choose secondary data because it is cheaper and less time-consuming to obtain LeCompte & Schensul (1999). Another reason is because the data collection and the design of the study are already complete, therefore, secondary data saves money and time (Dale, Arbor & Procter 1988) Gaining access to global and cross-historical information is easy online and the data can be of high quality.

In addition, it is crucial to consider that for a long time now, secondary data has been part of social science research (Punch 2005). According to Nichmias & Nichmias, (1992) secondary data has a creative tradition in the social science field.

3.5 DATA QUALITY CONTROL

Ensuring data quality is the process that enables one to recognise suspicious data after it has been gathered. Quality control involves both manual and automated methods to test whether the data meets the appropriate standards for quality outlined by the end users (Abeysirigunawardena et al., 2015). A fundamental indicator for quality is the appropriate valuation of reliability and validity of the research. If the error margins are lower and reports of the outcomes for a research are of high standard, then definitely the research has quality. Kimberlin & Winterstein (2008) report that if the measurement is very precise then the researcher will find a true score. In fact, the base of a good research is trustworthiness, whereby validity and reliability of data assist to make resolutions, therefore, the researcher to ensure the success of this research, the data adhered to the standards of quality as described in the research literature.

Reliability refers to a measurement that provides with stable results with the same values (Blumberg, Cooper & Schindler 2005). According to Chakrabartty (2013) reliability measures repeatability, consistency, precision and trustworthiness of a research. It demonstrates the point that the data is free of errors and ensures a stable measurement throughout the various items in the measurement. Reliability shows that the observed scores of a measurement are real. It is a necessity, but not the sole component of validity (Field & Bernan 1989). In quantitative research, reliability means consistency, repeatability and stability of the results. The coefficient of reliability lies between 0 and 1 with 1 equals the perfect reliability and no reliability equals to 0. The test-retest and other methods are normally calculating reliability by the use of the statistical test of correlation (Traub & Rwley 1991). For high –stake settings, reliability must be greater than 0.9 and for lower ones the acceptable values may be 0.7 or 0.8. Reliability greater than 0.8 is considered high and that is the general rule (Dawning 2004). Reliability is subdivided into two types - stability and internal consistency; there are also two ways to test reliability, which are: test-retest reliability and parallel-form reliability. In this study a test-retest reliability method was used whereby the researcher repeated the test, three times and obtained the same results.

Blumberg et al., (2005), explain validity as the level to which an instrument measures what it intends to measure. Robson (2011) explains ‘validity of a research’ as a tool that evaluates the extent to which the instrument measures what it is assigned to measure; it is the level at which results are accurate.

Hawkins (1980) defines an outlier as an observation that diverges away from other observations and creates suspicions that it was created in a different way. Outliers has also been described as numbers that are “doubtful in the researchers’ eyes” (Dixon 1950). Outliers can have a harmful impact on the analysis of statistics. Firstly, they always increase variance error and reduce the strength of a statistical test. Secondly, if not randomly distributed, they can reduce normality. Thirdly, they can control estimates that may be substantive (Rasmussen 1998, Schwager & Margolin 1982 & Zimmerman 1994).

Causes of outliers are from data errors, such as human errors, for example, they can be created during data collection, recording or entry (Huck 2000). Information from an interview may be incorrectly recorded and outliers may arise from motivated or intentional misreport as sometimes, participants will purposefully report wrong information on survey or experiments (Huck 2000). A sampling error is another cause of outlier. Outliers may also occur from faulty distributional assumptions where wrong presumptions are made about a distribution (Iglewicz & Hoaglin 1993).

To deal with outliers, they should be carefully investigated as usually outliers contain very important information about an investigation that is still in progress or is in the recording process or the gathering of information stage (Dhakal 2017). Prior to considering the probable removal of points from the data, one should seek an understanding of why they appeared in the first place and whether it is possible that the same values may re-appear; outliers are usually bad data points (National Institutes of Standard and Technology 2012).

Safekeeping of genuine outliers and still not violating your assumptions is vital. One way of accommodating outliers is by using transformations (Osborn 2002). By the use of transformations, higher scores can remain in the data, and closer rankings of scores stays, but the skew and the error variances, which are present in the variables, can be removed (Hamilton 1992). Another alternative to transformation is through truncation where extreme scores are registered to the highest / lowest acceptable scores. With truncation, data ordering is maintained, and the lowest or highest scores stay constant, but the distribution challenges are reduced. Rather than changing or truncation, researchers sometimes use different robust procedures to safeguard their data from being corrupted by the presence of outlier (Barnett & Lewis 1994).

For this study, the researcher finds no need to deal with outliers because, there was no significant change in data, according to the homogeneity test.

Homogeneity means that the instrument or tool measures one contrast. Homogeneity testing is extremely important for referencing materials, since they should prove the validity of approved values and their insecurities in the review of individual units or proportion (Pauwels, Lambetry and Schimmel 1998). The main aim of homogeneity testing is to check, on a number of units that is reasonable, that the entire units of the certified reference material (CRM) might consider them as being the “same” (between –unit homogeneity testing) when a set of approval is expected (Pauwels et al., 1998). Homogeneity tests are very important in climatological research to portray the true variations in weather and climate. Non-homogeneity appears in climate data due to numerous reasons including instrumentation faults and amendments in the adjoining areas of the instrument. The results will display incorrect trends if homogeneity is not tested before the trend analysis. Most common types of homogeneity test are (i) Petitt test, (ii) Standard Normal Homogeneity Test (iii) Bushland’s Test and (iv) Von Neumann Ratio. For this study, the Petitt test was used and the data was found to be homogeneous.

Stationarity is a shift in time created by any changes in the shape of data or distributions. This means that the absence of change in data, over a period of time, implies that the data has stationarity. According to Thomson (1994), if the basic distribution properties, like the mean, covariance and variances are stable over time, then the data has stationarity. The homogeneity test conducted showed that the data set does not have any significant change over time, and that shows that the data has stationarity.

3.6 DATA ANALYSIS

LeCompte & Schensul (1999) interpret data analysis as a procedure which a researcher employs to reduce data to a story interpretation. This definition means that data analysis is the process of minimizing huge volume of data collected to make it easily understandable. For this study, Microsoft Excel was used to sort, calculate and analyse data. The data was found to be homogeneous after using the homogeneity test to determine if there were any changes in the data, may be due to equipment failure.

To compute the vulnerability index in the study area, Temperature, Precipitation, Humidity and Wind speed were used as input variables of Vulnerability Index. Vulnerability index is computed in order to determine a single figure rating for vulnerability, in order to determine vulnerability index in the Free State Province. Data obtained was analysed and presented using Microsoft excel, tables and graphs.

Before a vulnerability index can be calculated, functional relationship of variables should be determined by normalising the data. Normalisation is defined by Codd (1965) as a process of reorganising data in a database so that it reduces data redundancy and dependency. The formulae below were used to normalise the data for vulnerability index computation, where the normalisation value is between 0 and 1 (Hlalele 2019).

Normalisation Formulae

$Xij = \frac{Xij - Min\,\{Xij\}}{Max\{Xij\} - Min\{Xij\}}$ ……..…………………………………………………………...…Eqn 3.1

For increasing functional relationship of the variables,

$Xij = \frac{Max\{Xij\} - Xij}{Max\{Xij\} - Min\{Xij\}}$ ………………………………………………………………..…Eqn 3.2

Decreasing Functional Relationships of the variables,

Where:

X_{ij} and y_{ij} represents normalised indicators scores

X_{ij} denotes the value of indicator "j"

Min{Xij} Is the minimum value of indicator "j"

Max{Xij} is the maximum value of indicator "j"

For vulnerability index, Iyengar Sudarshan formula was used and it is as follows,

$VI = \sum_{j=1}^{k} wjXij$ ……………………………………………………………Eqn 3.3

Where w's ($0 < w < 1$ and $\sum^{k}_{j=1} \; wj = 1$) are weights vary in respect of indicators on vulnerability.

After data is normalised per variable, the data was then imported into Microsoft Excel Software for analysis, using the set formulae.

Statistical Analysis

Descriptive statistics used to report the minimum and maximum of temperature, precipitation wind speed and humidity and the mean average of these variables for both the stations. Variance is also used to measure fluctuation of the weather. Mann Kendal's test was used for the trend analysis. The trend analysis is measured by p-value. Where p-value is above 0.05 that means there is no trend. If the p value is less than 0.05, then the trend is increasing and then S is the slope. For the analysis, the researcher used Microsoft Excel Software to sort and calculate data, after which the Fractal stages of vulnerability were determined to test the level of vulnerability. This software was used to sort and calculate vulnerability index, and for plotting of charts.

3.7 ETHICAL CONSIDERATION

Researchers need to have consideration for confidentiality, privacy and granting of permission when conducting aspects of research, such as data collection. The researcher in this instance did not have to ask for any permission because the data was from a freely-available online database, however, the researcher applied for ethical clearance from the University of Free State in this regard. Plagiarism was avoided by full referencing of the sources used in the research.

3.8 SUMMARY

This section illustrates the methods used, which was the quantitative method for the interpretation of results, data collection, methods used for collecting data and where the data was retrieved. Data quality control focuses on the importance of validity and the reliability of the data to ensure the success of the study. The discussions also explained the measuring instruments for homogeneity, stationarity, as well as the outliers. Climate change variables which are temperature, wind speed and humidity were used to compute the vulnerability index. The following chapter explains more on the calculations, charts, tables and the normalization of data.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 INTRODUCTION

An investigation was conducted of which the objectives as per chapter one were to identify the vulnerability status in the study area, to identify the trends for the four variables of climate change for this study which are precipitation, temperature, humidity and wind speed for the Bethlehem Airport from 1981 to 2018 and J.B. Hertzog from 1981 to 2018, for 37 years' period for both stations, to assess the vulnerability level of the study area from four selected climate proxy variables as well to predict vulnerability level aimed at providing an early warning system for mitigation and adaptations.

The aim is to present the results received from the archived data. Data was collected from NASA online database that contain historical data of the world weather forecast and climate information. The trend analysis has been done for all months of the years, season and the whole year. This study used vulnerability index approach to assist the agribusiness and the agricultural development projects to be able to develop mitigation strategies in response to vulnerability to climate change risks. Vulnerability Index interprets research findings into valuable guidelines that allow practitioners and policy makers to notice the upcoming and anticipated threats to biodiversity.

4.2 SECONDARY DATA

The purpose of data analysis is to modify data to prepare for additional analysis, also to outline the main features and sum up the findings. Topics covered in the Data Analysis include plotting of graphs and the discussing the results.

4.2.1 Vulnerability variables

Vulnerability variables are temperature, humidity, precipitation and wind speed as illustrated in the figures below for both sampled stations.

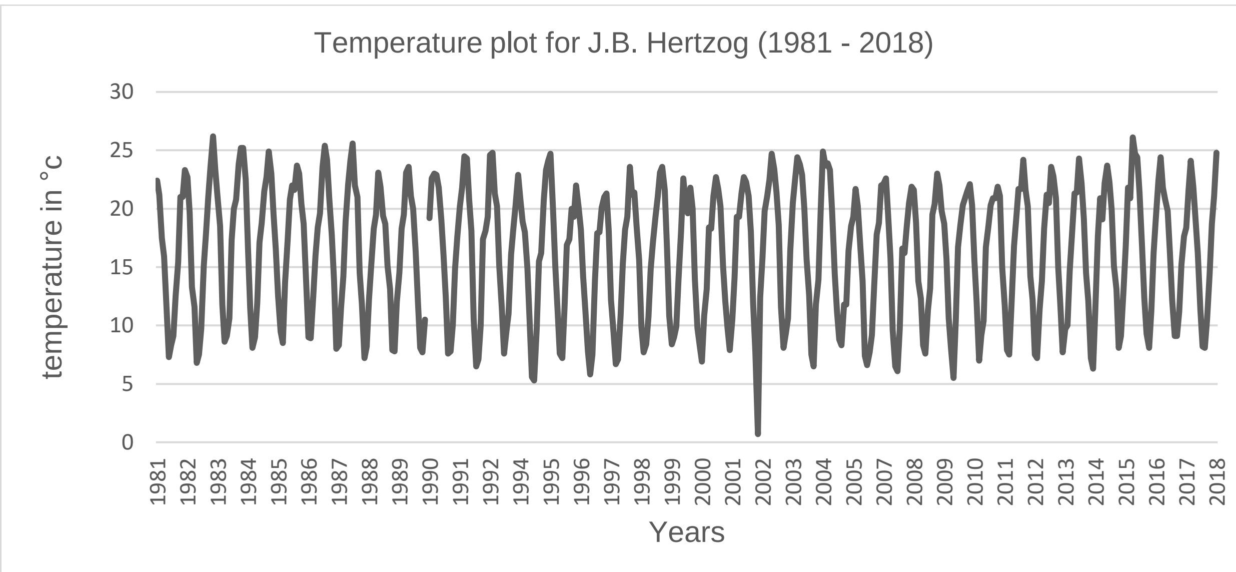


Figure 4.1 Temperature trends for J.B. Hertzog (1981 – 2018)

Figure 4.1 Shows standard temperature for J.B. Hertzog weather station presenting the trends of annual temperature. Temperature reading during the study period varies between 0.7°C and 26.2°C. Higher temperatures due to the absence of rainfall as illustrated on figure 4.1 or limited amount of rainfall that is observed in the study area. Figure 4.1 shows the rising annual temperature as well as lower temperature trends. Higher temperatures occurred in 1983 where a maximum of 26.2°C was observed. Significant decrease was observed in 2002, where the temperature dropped to a low of 0.7°C and just in the same year, a gradual increase is observed to a higher level of 22.7°C.

This station shows that temperature is rising gradually and rising temperatures will cause heatwaves which are harmful to animals and plants as well as wild fires. According to Futurelearn. Com (n.d.), heat waves can be the cause of heat stress to both animals and plants and have negative impact on the production of food. In animals, heat stress can cause lower productivity and fertility. Animals immune system can also be negatively affected making them prone to certain diseases.

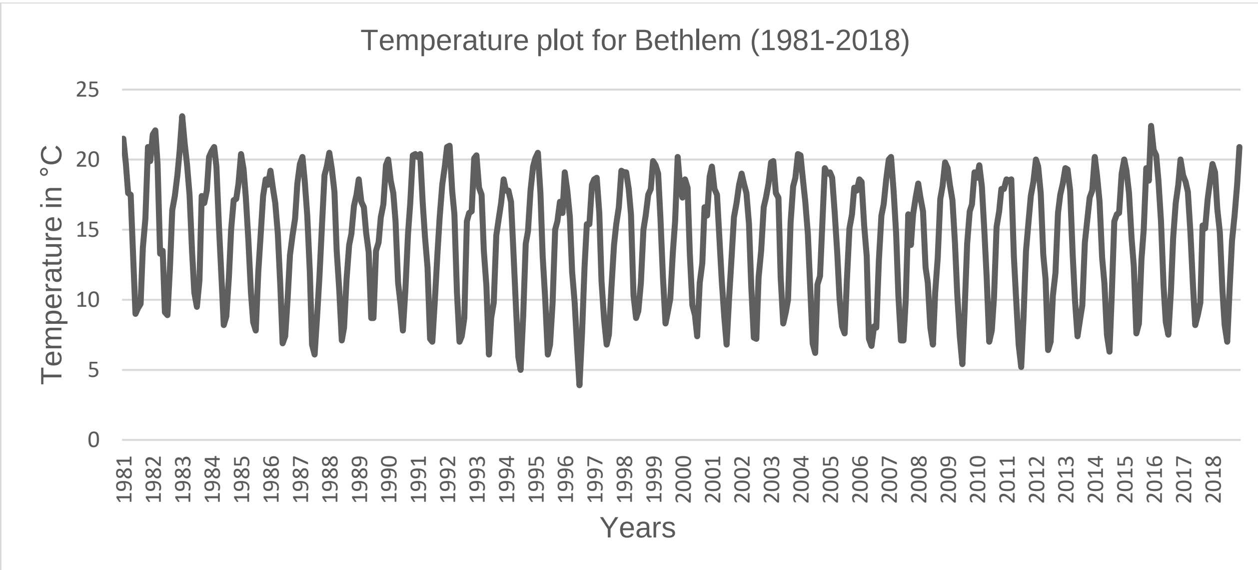


Figure 4.2: Temperature trends for Bethlehem Airport (1981 – 2018)

Figure 4.2 above presents the temperature for Bethlehem Airport weather station from 1981 to 2018 where there is a clear indication that temperature varies over the years of study period. The year 1983 experienced the highest temperature of 23.1°C compared to other years. Temperature reduction is observed in 1996 where a minimum of 9°C is noted. Again, an increase in temperature is observed years repeatedly to 2016 where an extreme rise of 22.4°C is reached as well as 2018 going forth. That supports the facts observed by other studies that temperature trends are gradually rising up.

The study area shows that temperature trends are rising gradually and the increasing temperature will cause heatwaves which are harmful on animals and plants as well as wild fires.

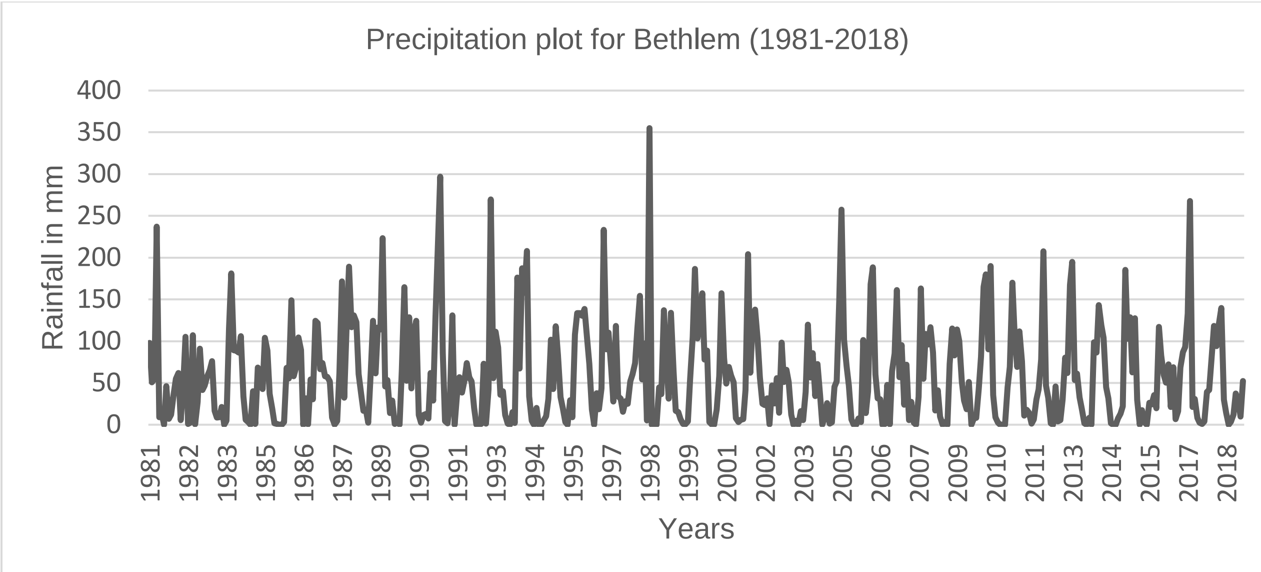


Figure 4.3 Precipitation trends for Bethlehem Airport (1981 – 2018)

Figure 4.3 illustrates the precipitation trend from 1981 to 2018 for Betlehem Aiport. The observed decreasing rainfall patterns from 1981 where the rainfall ammount dropped up to 0.0mm. The graph indicates that precipitation varies in years and the observation shows that the rainfall is verry limitted in this station. The maximum rainfall received was in 1998 where the ammount of 355mm was rechead. In most of the observed years a partial or no rain is observed. No increase in the rainfall pattern for this station for the past 4 decades. In 2015 again no rainfall was received where the area reached a minimum of 0mm was observed.

A comprehensive study conducted in 2014 indicated that rainfall trends are consistantly lowering and that might have a negative effect on food production, Joblessness and an increase in crop diseases. Lowered rainfall may also cause drastic reduction in soil fertility (Kasaigili et al., 2014).

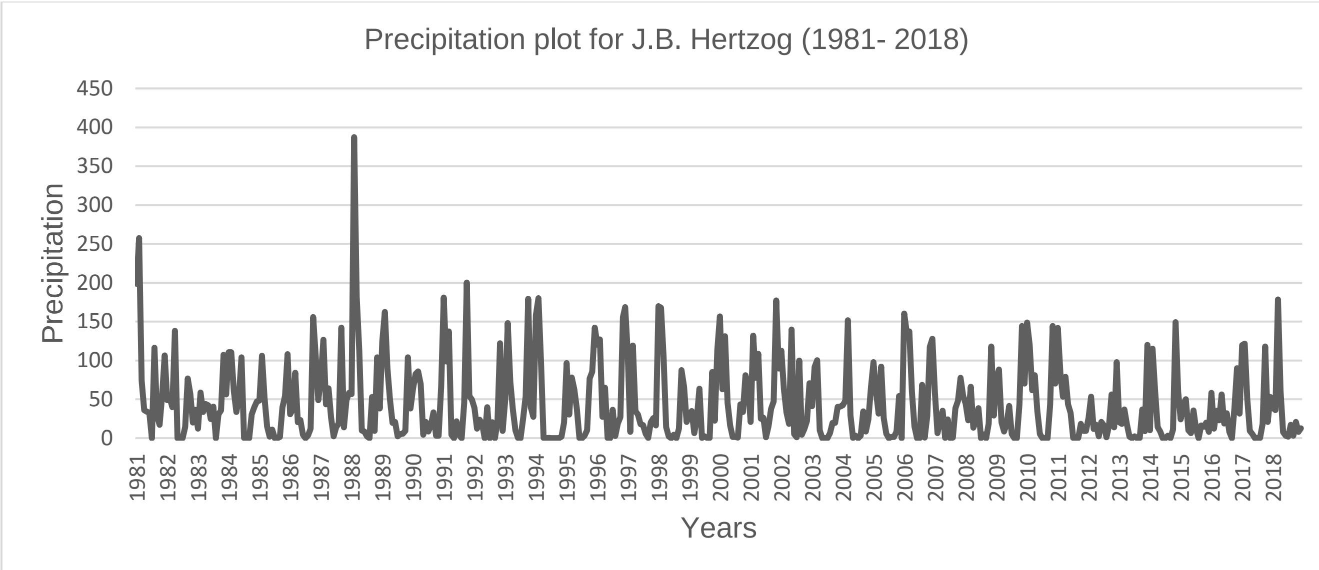


Figure 4.4: Precipitation Trends for J.B Hertzog (1981 – 2018)

Figure 4.4 shows the precipitation records for J.B. Hertzog for the past 41 years. The observation shows that the amount of rainfall is not rising above level. In 1981, the minimum rainfall recorded was at 0.mm and then it rises back to the constant of 76.96mm. The precipitation amount varies in years but never exceed the 400 mm constant and that simply explains that the rainfall amount never increased above 400mm for the past 41 years. In the year 1988, a maximum amount of rainfall received was 387.36mm which was almost good but with no consistency because in the same year later a 0mm was observed. The trend in years is negatively similar, never increases above 200mm of rainfall. Noticeably, the trend remains constant at a lower rainfall level.

The precipitation trends for the study area remains at a lower level and that can lead to the incidents of drought which may directly affect the agribusiness and people's livelihoods (Ndamani & Watanabe 2014).).

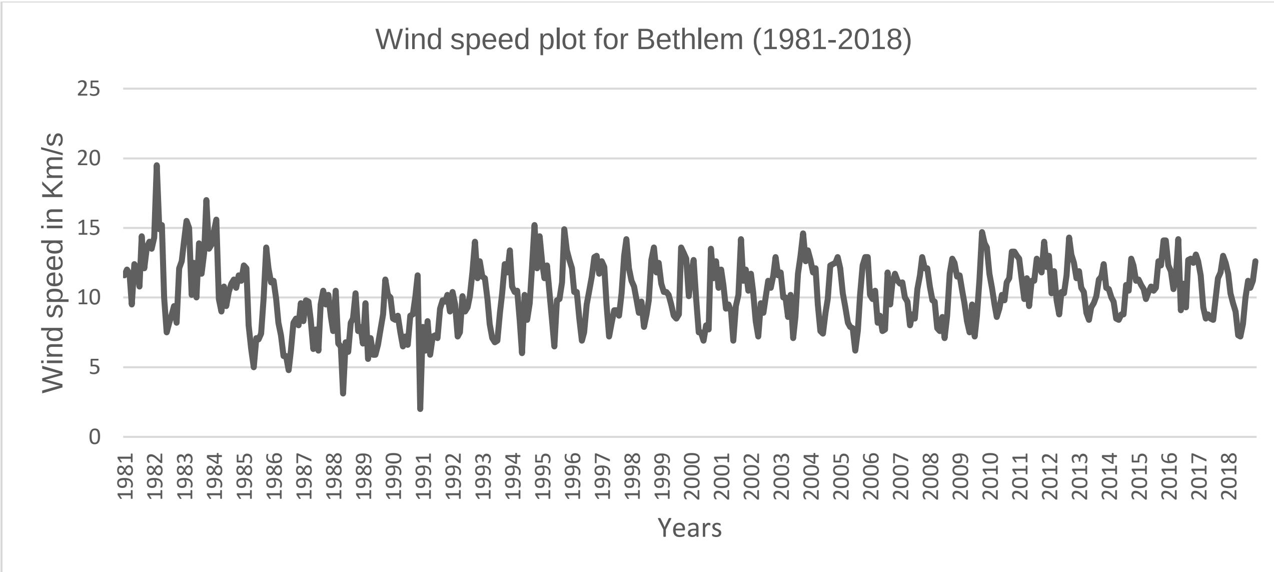


Figure 4.5: Wind Speed for Bethlehem (1981 – 2018)

Figure 4.5 presents the annual wind speed trends for Bethlehem Airport from 1981 - 2818. The results are showing an increasing trend in wind speed in most of the years selected. Not only the increasing trends are observed but the slight decreasing as well. In 1982 we see an increasing wind speed of 19.5km/h which gradually drops down with14.9km/h in the same year.In 1990 a decrease in wind speed is observed where a 2km/h is observed and that was the minimum speed received for the years observed. The graph shows that there are decreasing trends but mostly the increasing wind speed is observed in this station, wind speed is rising in the area.

Wind speed more than 50km/h leads to lodging of crops leading to extreme loss. Long exposure to winds cases morphological changes. Wind increses crop water requirements by increasing evapotranspiration due to removal of accumulated air near the leaves. Heavy wind during flowering reduces pollination and decreases fruit set in all crops (Agriculture India Farm Department n.d.,)

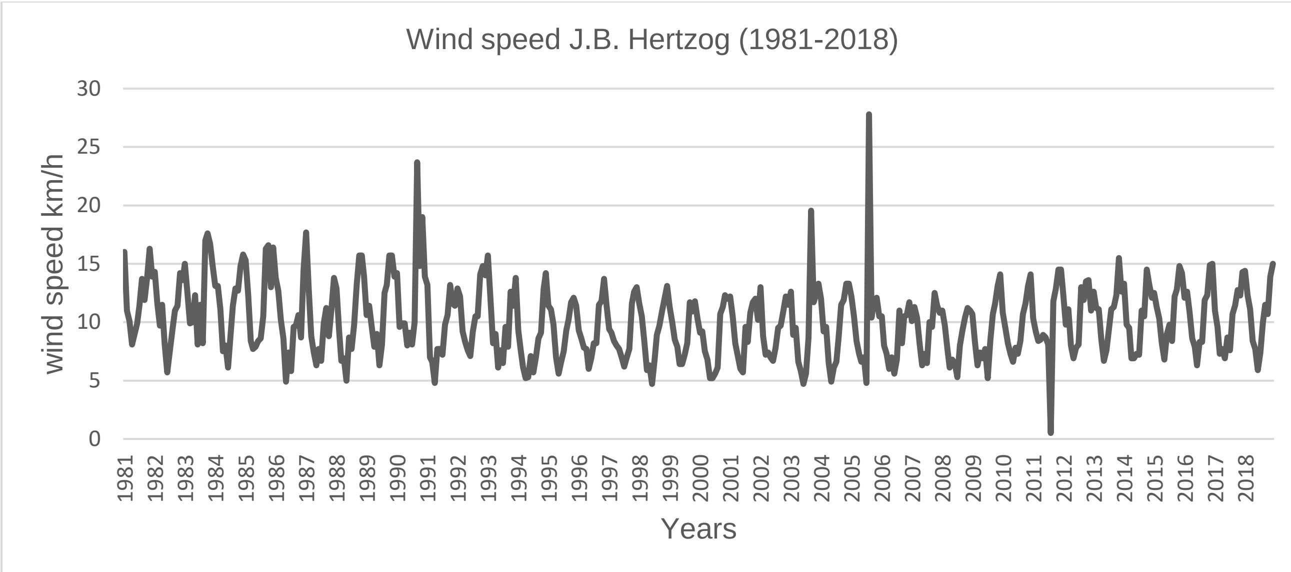


Figure 4.6: Wind Speed for J.B. Hertzog (1981 – 2018)

Figure 4.6 presents the annual wind speed trend for J.B. Hertzog. The observation shows that this station has a tremendous increase in wind speed. Fluctuating trends are observed but consistently the upward movement of wind consists, in 1990 an extreme wind speed of 23.7km/h is observed then dropping down back in 1991 with a 4.8km/h, in that way it shows that the wind speed is not at a constant level in this area but it fluctuates in years. Nevertheless, the wind speed trend indicates that there is an increase of wind speed in this area. The maximum wind speed reached was in 2005 where a 27.8km/h was reached and a minimum wind speed reached was in 2011 where a 0.51km/h was observed.

With the increase in wind speed in the study area, the effects on crops such as changes in plant motion, physical leaf damage, uprooting of plants, sandblasting and combined abrasion and tearing. Wind speed can also disrupt the irrigation systems and soil loss. Consistent wind can also cause dryness in the area.

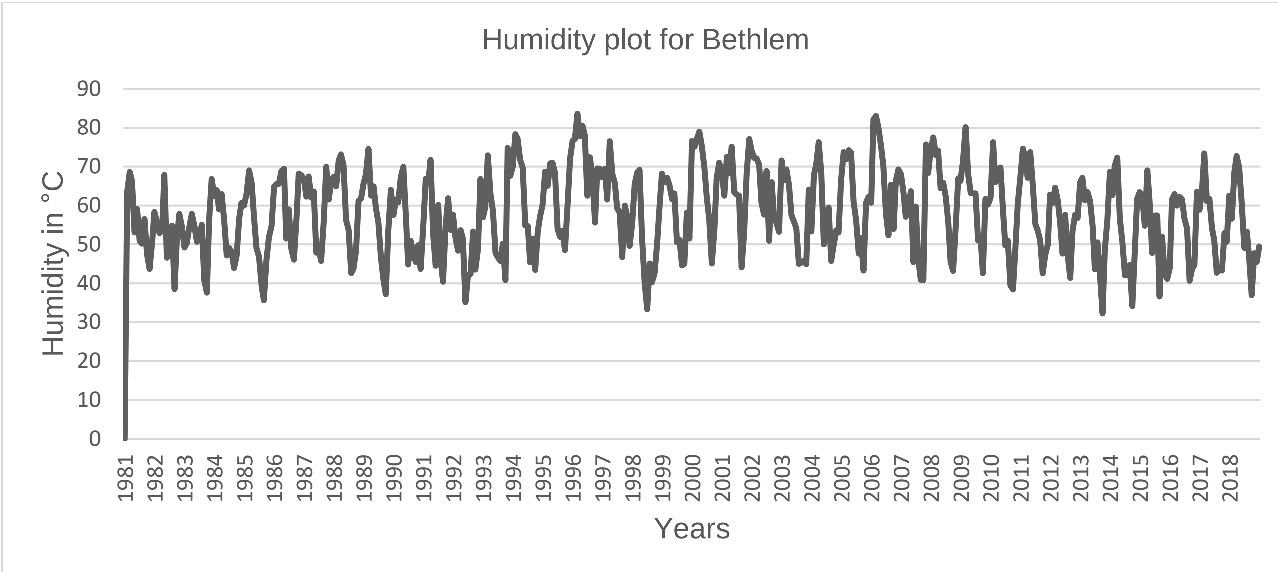


Figure 4.7: Humidity plot for Bethlehem (1981 – 2018)

Figure 4.11 shows a reduction in relative humidity for the examined period. In the beginning of 1981, a 0°C is observed going steadily up to the same year where it reached 68.6°C.The trend in this station also fluctuates going high and low. There is a significant reduction in relative humidity for this station. The maximum of 83.6°C was observed in 1996, and through the observed years it is noted that relative humidity has a significant reduction.

Farmers should take note that if humidity is low, plant growth is usually compromised as crops take time to regain sealable size (Peery 2020). Leaves often fall down, growth is difficult and the overall quality is poor. Humidity may be high or low but the loss of quality reduces the selling price of crops and increases production cost, both of which reduces profits (Peery 2020).

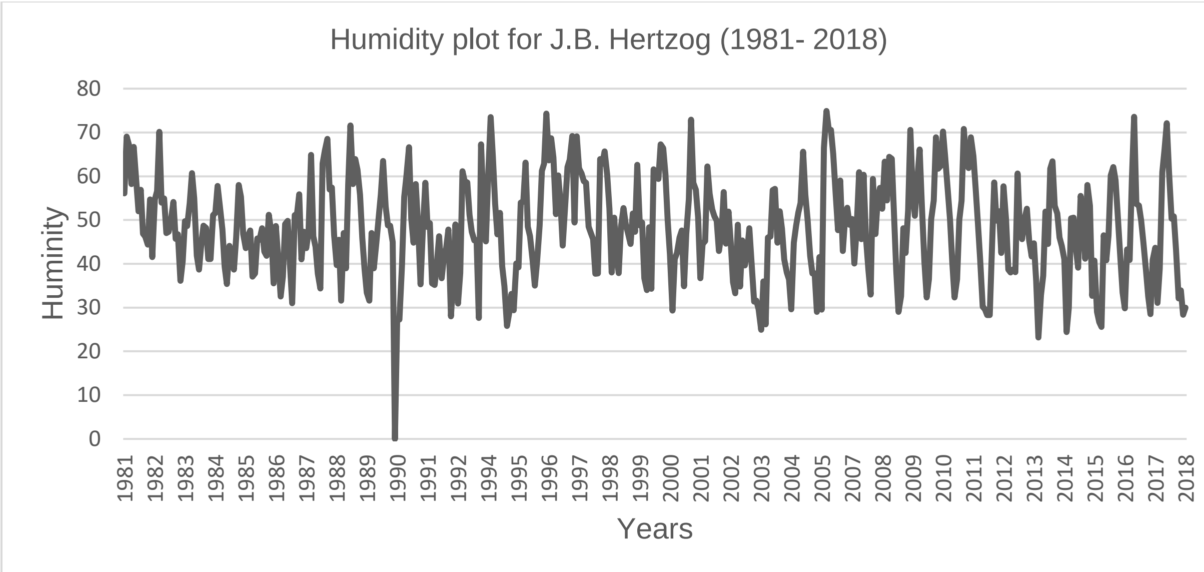


Figure 4.8: Humidity plot for J.B. Hertzog (1981 – 2018)

This station shows relative humidity trends for the period of 37 years from 1981 to 2018. The observation shows a significant reduction in relative humidity, from the beginning of 1990 where a 0°C is observed. Fluctuating trends are observed in this station but in most years, humidity is decreasing in a constant level.

Both the stations show the decreasing trends of humidity and when humidity levels are low, there will be no more transpiration which will lead to water deficits in the plant. As a result, stomata will be slightly or completely closed and carbondioxe will be blocked. Humidity can affect crop growth by indirectly influencing leaf growth, photosynthesis and likelihood of diseases (Hoffman & Jobes 1978; Sadras & Milroy 1996).

4.3 DATA ANALYSIS

Data Analysis is an approach used for reviewing, cleansing, changing and modelling data with the aim of uncovering effective information, answering the objectives of the study, informs conclusion and supports decision making.

4.3.1 Vulnerability status quo

The descriptive analysis below, show the status quo of climate change regarding vulnerability in the study area.

Table 4.1: Descriptive statistics (Quantitative data): J.B. Hertzog

Statistic	Average Temperature (0C)	Relative Humidity (%)	Precipitation (mm)	Wind Speed (km/h)
N	504	504	504	504
Min	0.7	23.2	0	0.51
Max	26.2	74.9	387.36	27.8
Sum	8200	24560.21	22190.19	5084.47
Mean	16.26984	48.73058	44.02815	10.08823
Std. error	0.2504123	0.4839334	2.182964	0.1367121
Variance	31.60398	118.0325	2401.728	9.419861
Stand. dev	5.621742	10.86428	49.00743	3.069179
Median	17.6	48.4	27.82	9.85
25 prcntil	11.325	41.1	6.6025	7.7
75 prcntil	21.1	56.675	62.74	12.1
Skewness	-0.2809735	0.05790675	1.838955	0.7399694

Table 4.1 is the descriptive statistics for the four variables of climate change, where the minimum and the maximum of variables are observed. The four mentioned variables are essential in determining the vulnerability index. The variance differs from variable to variable, and the variance in this regard measures the fluctuation of the variables. Descriptive statistics reveals that if the variance is relatively high then the station has a problem, for example if the area experiences relatively higher temperatures then the next day is extremely cold and next day is rainy then that area has a problem. It is noted that precipitation has a relatively higher variance and the wind speed has a relatively lower variance in this station. This means that, the main influence of climate change in this station is from the rainfall since the rainfall has a relatively higher variance than any other variables. It is clear that the station is vulnerable to rainfall and this is not good for farmers.

Table 4.2: Descriptive statistics (Quantitative data): Bethlehem Airport station

Statistic	Average Temperature (°C)	Relative Humidity (%)	Precipitation (mm)	Wind Speed (km/h)
N	456	456	456	456
Min	3.9	32.2	0	2
Max	23.1	83.6	355	19.5
Sum	6622.6	26567.9	26052.4	4700.02
Mean	14.52325	58.26294	57.13245	10.30706
Std. error	0.2061138	0.4972664	2.712536	0.1073025
Variance	19.37221	112.7569	3355.181	5.250307
Stand. dev	4.401387	10.6187	57.92392	2.291355
Median	15.6	58.25	42.55	10.3
25 prcntil	10.7	50.2	8.6325	8.7
75 prcntil	18.2	66.875	88.3125	11.975
Skewness	-0.3959102	-0.03679325	1.447032	0.004919325

Table 4.2 above demonstrate the descriptive statistics of Bethlehem Airport where it observed that precipitation has a relatively higher variance as compared to the wind speed with a relatively lower variance, it also shows that climate change is also influenced by the rainfall. All in all, this station has a higher rainfall variance as compared to the other station and that means amenities and agriculture in this area are more exposed to dangers than in J.B. Hertzog.

4.3.2 Trend analysis

Trend test analysis. Mann Kendal's test was used for the trend analysis. The trend analysis is measured by p-value. Where p-value is above 0.05 that means there is no trend. If the p value is less than 0.05, then the trend is increasing and then S is the slope.

4.2.3.1 Trend analysis for J. B Hertzog

Table 4.3: Trend test analysis: Mann Kendall' s test, J.B. Hertzog

Statistic	Average Temperature (°C)	Relative Humidity (%)	Precipitation (mm)	Wind Speed (km/h)
S :	-1152	-10127	-9350	-5539
Z :	0.30474	2.6809	2.4767	1.4663
p-value:	0.76056	0.0073428	0.01326	0.14256

Table 4.3 above shows the trend analysis for J.B Hertzog where the average temperature, relative humidity, precipitation as well as wind speed are measured against the p-value. The observed values of the variables are illustrated to be above or below 0.05. It is seen that, the p-value for average temperature is above 0.05, with the value of 0.76, meaning that there is no trend. On the other hand, for relative humidity and precipitation, it seen that the p-value is less than 0.05, meaning that there is a statistically increasing trend in that regard. The S-value (slope) for both Relative humidity and precipitation is negative and this means that the area has significantly decreasing trend, the area is vulnerable to decreasing rainfall and humidity. If there is little or no rainfall and the increase in dryness, the area might possibly be facing the drought conditions in the near or far future.

4.3.4 Trend analysis for Bethlehem Airport

Table 4.4: Trend test analysis: Mann Kendall' s test, Bethlehem airport

Statistic	Average Temperature (0C)	Relative Humidity (%)	Precipitation (mm)	Wind Speed (km/h)
S :	-3589	1212	-1994	10616
Z :	1.1037	0.37249	0.61315	3.2655
p-value:	0.26973	0.70953	0.53978	0.0010928

The shows the results of a trend analysis test for Bethlehem Airport where a p-value for the temperature has no trend, which is 0.27 and is above 0.05% and the relative humidity with no trend with a p-value of 0.71 as well as precipitation with no trend at a p-value of 0.54. For temperature, relative humidity and precipitation there is no statistically increasing trend, and wind speed gives a significantly decreasing trend with a p-value below 0.05% and the slope is positive which means that the wind speed is increasing and that is a statistically increasing trend which has a potential to increase climate change due to dryness increasing very fast. The study area vulnerable due to the trends observed and there are drought possibilities due to less amount of rainfall and the increasing wind speed

4.3.4 Vulnerability Index

Table 4.5: Vulnerability box measure: used to measure the level of vulnerability.

Stages of vulnerability	**Value in percentage**
Less vulnerable	0<VI<0.2
Moderate Vulnerable	0.2<VI<0.4
Vulnerable	0.4<VI<0.6
Highly Vulnerable	0.6<VI<0.8
Very highly Vulnerable	0.8<VI<10

4.3.5 Descriptive statistics for vulnerability index for Bethlehem Airport

Table 4.6: Vulnerability index series descriptive statistics: Bethlehem Airport

Statistic	Vulnerability index time series
N	492
Min	0.2700915
Max	0.9954155
Sum	251.437
Mean	0.5110508
Std. error	0.003809698
Variance	0.007140791
Stand. dev	0.0845032
Median	0.5084929
25 prcntil	0.4421175
75 prcntil	0.5712016
Skewness	0.601873
Kurtosis	1.76108
Geom. mean	0.5042434
Coeff. var	16.53519

Table 4.6 shows the vulnerability index for Bethlehem Airport. The minimum and the maximum vulnerability index are observed. A mean, which is the average vulnerability index for Bethlehem

Airport, is on 0.51. The mean average was observed at a vulnerability index box where 0.51 is sitting between 0.4 and 0.6 and that is vulnerable stage. The station is vulnerable to climate change.

4.3.6 Descriptive statistics for vulnerability index for J.B Hertzog

Table 4.7: Vulnerability index series descriptive statistics: J. B. Hertzog Airport

Statistic	Vulnerability index time series
N	456
Min	0.2041012
Max	0.6639277
Sum	199.5897
Mean	0.4376966
Std. error	0.003714181
Variance	0.006290583
Stand. Dev	0.0793132
Median	0.4405613
25 prcntil	0.3849741
75 prcntil	0.4960493
Skewness	-0.2415539
Kurtosis	-0.3409784
Geom. Mean	0.4300097
Coeff. Var	18.12059

Table 4.7 is the vulnerability index series descriptive statistics for J.B. Hertzog station where we see a minimum vulnerability index and a maximum vulnerability index. A mean average vulnerability index for the study area is 0.44. The mean found was then compared at the vulnerability index box Table 4.5 where the mean value is between 0.4 and 0.6 and that is vulnerability. The area is vulnerable.

4.3.7 Average vulnerability index

To determine the vulnerability level for the whole study area, both the mean average for Bethlehem Airport and the mean average for J.B. Hertzog station were combined and then divided by two to get the mean average for the study area. The Vulnerability Index for the study area is 0.47. Comparing the mean vulnerability index to Table 4.5 the vulnerability box measure, 0.47 measures between 0.4 and 0.6 which is a vulnerable stage. That means that the overall study area is vulnerable to climate change. According to the individual variables, Table 4.3 and Table

4.4 the trend test analysis, it is observed that there is a statistically decreasing trend on temperature and relative humidity in J.B. Hertzog due to the p-value below 0.05%, in Bethlehem Airport the wind speed is increasing with a positive slope. With rainfall and humidity decreasing and the wind speed increasing the study area is heading for a possible drought vulnerability.

4.3.8 The following graphs are the Vulnerability Index plot together with the time in years of observation. Using the Mann Kendall's test to determine the vulnerability level of both the stations and assessing whether there is a pattern for Vulnerability Index. This may assist in determining the climate change preparedness plan for the study area.

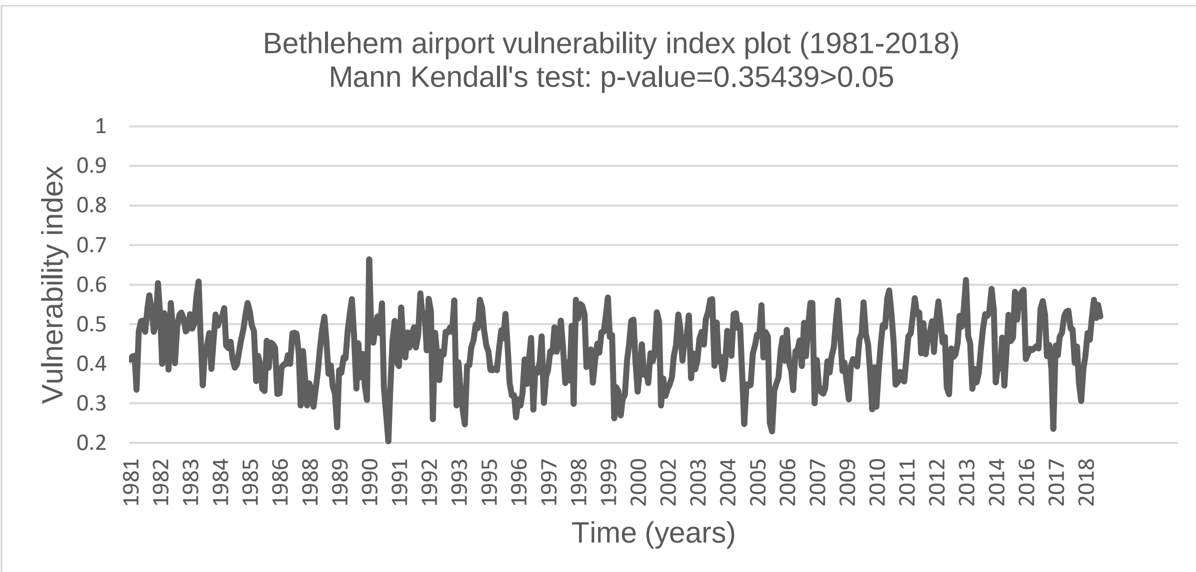


Figure 4.9: Vulnerability Index plot for Bethlehem Airport (1981 – 2018).

A Mann Kendall's test was done with a p-value of 0.35439 which is above 0.05% and that means there is no trend. The trend is stable or constant. According to the Mann Kendall's test the station has no trend and is constant but the vulnerability box measure Table 4.5 above will prove whether the constant level is a safe or dangerously constant. The p-value measures between 0.4 and 0.6 on the vulnerability box and that means that the area is vulnerable to climate change.

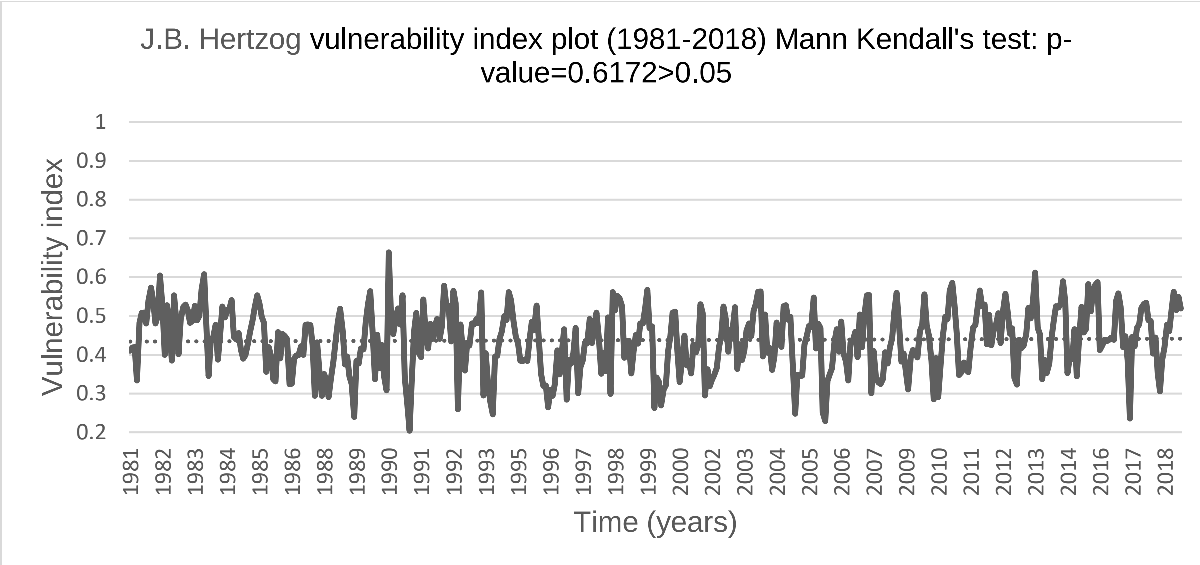


Figure 4.10: Vulnerability Index plot for J.B. Hertzog (1981 -2018).

A Mann Kendall's test was performed for this station and the p-value results are 0.6172 which is above 0.05% and that means there is no statistically significant trend as determined by the Mann Kendall's test. The situation is constant but there is a need to find out where in the vulnerability table is the p-value sitting. Table 4.5 above shows that the p-value of 0.62 measures between 0.6 and 0.8 on the vulnerability box measure table and that means that the area is vulnerable. For both stations, it is noted that there is no statistically significant trend as determined by the Mann Kendall's test, the situation remains vulnerable for the both stations.

4.3.5 Vulnerability level aimed at providing an early warning system

The vulnerability level was determined in tables 4.5, 4.6 and 4.7, implying that, the study area is vulnerable. The vulnerability level therefore means that, the mitigation strategies needs to be activated in order for the impacts to be minimised.

4.4 SUMMARY

This chapter dealt with the analysing if data, from the raw data received from NASA online database. Graphs are plotted to observe the precipitation, relative humidity, wind speed and temperature trends. Descriptive statistics for the stations were done to determine the minimum and maximum of the variables and to find the variance for the stations. A trend test analysis was done to determine the p-value and the slope of the variables as well as to determine whether the stations are vulnerable or not. The observations shows that both the stations are vulnerable and that means that the study area is vulnerable to climate change drought possibilities in the next five years.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter give the summary of the findings from the literature and the analysis of data. The conclusion summarises the findings and answers to the objective. Recommendations are based on the findings.

5.2 CONCLUSION

The Study analyses the vulnerability of farmers and agribusinesses due to climate change in Bloemfontein. The aim of the study is to develop a comprehensive picture of current and future climate change vulnerabilities and to provide information and how to assess the adaptive methods and the capabilities to manage climate change uncertainties. Climate change variables are used to study the presence of the monotonic trends in temperature, precipitation, humidity and wind speed for the data collected from 1981 to 2018. Vulnerability frameworks that support livelihoods and give guidance on sustainability and adaptation were discussed together with the relevant policies and legislations in disaster management as well as using the climate change scenarios to describe probable future climate for preparedness measures and coping mechanisms. Findings from vulnerability studies by other researchers locally and internationally were interrogated. Observations were made of international, regional and local climate change risks impacts as well as their adaptation measures, so that South Africa can learn how other countries are coping and adapting.

This study was carried out to assess the climate change vulnerability for two stations which are Bethlehem Airport and J.B. Hertzog in Bloemfontein. Data collected from Bethlehem Airport and J.B. Hertzog in Bloemfontein begins from 1981 and ends in 2018. Data used is tested to be homogeneous. The Iyenga- Sudarshan method was used for the computation of vulnerability Index. The raw data was collected from NASA online database. The results are received from the archived data. The trend analysis was undertaken for all months and years. The graphs were plotted to give the climate weather trends in relative stations.

Descriptive statistics for both stations is presented outlining the minimum and the maximum values of the variables as well as the variance, which measures the fluctuation of the variables. This study area shows that the main influence is from the rainfall since it has a relatively higher variance than any other variable.

A trend value test was made using the Mann-Kendall's test to analyse the variables for both the stations. Given the p-value amount of 0.05% to compare the variables. The individual station vulnerability index proved that the situation is vulnerable because both the stations p-values is lower than 0.05%. The situation is constant because it is not rising to a higher level or decreasing to the lower level of the vulnerability index plot from 1981 to 2018, it is stable and that means that there is no statistically significant trend as determined by the Mann Kendall's test. The study area is vulnerable due to the trends found from the individual variables, where in Bethlehem Airport it observed that the wind has a positive increasing trend and that can exacerbate drought conditions due to the increase in dryness. It is noted that J.B. Hertzog station, presents a decreasing trend in precipitation and humidity and that can also encourage the drought conditions due to lack of water. Both the stations p-values are vulnerable in the vulnerability measure box Table 4.5. The overall study areas vulnerability index shows that the whole study area is vulnerable. It is then predictable that in the next coming five to ten years the study area will be experiencing drought and the Mann-Kendall's test shows that the situation is constant and that makes the prediction to be almost sure that the drought condition are possible.

5.3 FINDINGS

Findings in this study were presented in line with the objectives as well as the literature review. Climate change causes vulnerability to agribusiness and the communities. Climate change is already affecting agriculture in a number of ways including through changes in temperature, precipitation, humidity and the wind speed. Crop production is also negatively affected.

5.3.1 Status quo of climate change

The variance was used measure fluctuation of the variable, where the trend for individual variables were observed. For this study area, precipitation has a relatively higher variance than other variables where the wind speed has a relatively lower variance. The main influence of climate change in this study area is from rainfall. Little or no rainfall may cause the agribusiness to be vulnerable to the drought possibilities.

5.2.2 Monotonic trends

Mann Kendall's test was used for the trend analysis where the p-value was used to measure the trend analysis. Where the p-value is above 0.05 then there is no trend and where the p-value is below 0.05 the there is a statistically increasing trend. The observed trends in the study area shows rainfall and humidity with a p-value less than 0.05 and that is not good because the trend is increasing. Wind speed also gave a p-value less than 0.05, which is a statistically increasing trend with a positive slope. Trends observed presents a lower rainfall and humidity, temperature has no change and the wind speed increasing. No rainfall and increased wind speed causes dryness. That simply means that the area is vulnerable and drought possibilities are expected.

5.2.3 Vulnerability level of the study area

To determine the vulnerability level for the whole study area, both the mean average for Bethlehem Airport and the mean average for J.B. Hertzog station were combined and then divided by two to get the mean average for the study area. The Vulnerability Index for the study area is 0.47. Comparing the mean vulnerability index to Table 4.5 the vulnerability box measure, 0.47 measures between 0.4 and 0.6 which is a vulnerable stage. That means that the overall study area is vulnerable to climate change.

5.2.4 Prediction of the vulnerability level

A Mann Kendall's test was performed for the study area and the p-value was above 0.05 and that means that there was no statistically significant trend as determined by the Mann Kendall's test, the situation is constant. The trend is has been constant for years, so we are almost sure that in the next coming years the study area may suffer from drought.

5.4 RECOMMENDATIONS

The findings of the study have revealed that the study area is vulnerable to climate change and that drought possibilities are imminent. This information should be made available to farmers and agribusiness for their preparedness. The distribution of this information will be the beginning of a productive farming because this will enable farmers to respond in time. Recommended means of disseminating this information will include sharing of the results at farmer's workshops, research teams to do presentations at the information day events, consolidate the information results into flyers or booklets that can be handed over to the farmers and using cell phones, posting the information on social media for easy access.

5.4.1 Education

Initiative should be undertaken to educate farmers to: i) Start ploughing drought resistant crops, ii) rain water harvesting for drought preparedness because this is another strategy for drought mitigation, iii) education regarding scarcity of water and how can water be saved and the means of saving water, iv) Agriculture department and the None Governmental Organisations to assist farmers by providing skills and train them so that they are able to manage or cope with climate variabilities.

5.4.2 Early warning systems

Farmers have the right to be provided with accurate climate and weather forecast because in most cases they have no idea of the upcoming weather to prepare themselves. Extension officers should also do the farm visits to alert the farmers and assist with further advises (South African Weather Service)

5.4.3 Drought resistant fodder plants

Creating fodder banks and pasture management for livestock is important in agriculture. Fodder banks will save animals during the drought period, although it is still not clear on the length of time can a fodder be stored.

5.4.4 Drought tolerant crops

This is another way to save water in the farms, drought tolerant plants have qualities that reduces loss of water and increases water absorption. These crops have the ability to grow even in times where there is less rain. Farmers also need to explore different ways of bringing these crops to farming (Annandale et al., 2002 and Ncube & Langerdie 2015). Farmers are recommended to plant crops during different times of the year or planting crops that survive better in hot and dry conditions (Cline 2007).

5.4.5 Irrigation and rainwater harvesting

Developing other means of increasing water supply involves rainwater harvesting and using treated wastewater for irrigation is another water supply method that has always been in use. Rainwater harvesting is capable of supplying water with the help of some infrastructures such as water tanks and dams as well as the sustainability of agriculture in times of water scarcity because of draught (Baloyi 2010). Farmers are encouraged to practice water harvesting techniques, adopt new crop varieties, changing their planting dates and cultivating methods to new crops (Ndamani & Watanabe 2014).

5.4.6 Agriculture preservation

The application of crop rotation by farmers promotes water usage and encourages production and fertility, the system diminishes pets and disease. Soil rotation assists in balancing soil nutrients productively. Therefore, agricultural conservation is another means of food production improvement in smallholder farming.

5.4.7 Government and the NGOs involvement

Government to assist on drilling more boreholes, because ground water has a huge role in agriculture. Drilling boreholes will form the basis for the improvement of ground water accessibility for farmers. (Barker, White & Houston 1992) Ensuring correct position of boreholes and groundwater review are important for obtaining required results. Construction of dams and reservoirs can manage flooding and contains water efficiently and restrict the outflow of water from the grasslands. Access to credit for farmers should be available so they can be able to manage agricultural drought in good time. Farmers should be provided with enough grazing land (Barker et al., 1992)

REFERENCES

Abebe, M. A., 2014. Climate Change, Gender Inequality and Migration in East Africa.

Abdalla, A. A., 2006. Environmental Degradation and Conflicts in Dafur: Expriences and Development options, in Environmental Degradation as cause for conflict in Dafur. - Conference Proceedings:, University for Peace, Addis Ababa, Ethopia.

Abesirigunawardena, D.S., Jeffries. M., Marley. M., Bui. A.O.V. Data Quality Control and Quality Assurance Practices for Ocean Networks Canada Observatories Challenges and Opportunities

Acosta Moreno, R., Skea. J.A., Gacuhi, D. L., Greene, W., Moomaw, T., Okita, A. Riedaker & Tran Viet Lien., 1996. Industry, Energy and Transportation: Impacts and Adaptation in Climate change. Cambridge University Press, Cambridge.

African Climate Policy Centre, 2013, Vulnerability to Climate Change in Africa.

Adger, W. N., 1999, Social Vulnerability to Climate Change and Extremes sin coastal Vietnam. World Development.

Agriculture India Farm Department, n.d., 13 Important Effects of Wind on crop production. Agriculture-aajtak.blogspot.com

Agricultural Model Intercomparism and Improvement Projects (Agmip), 2020, Assessing regional small scale and commercial farming systems. Free State. South Africa.

Alinovi, L. & Romano. D., 2008, Towards the measurement of household resilience to food insecurity: An Application to Palestinian Households.

Annandale, J. G., Jovanovic, N. Z., Mpandeli, N. S., Lobit, P. & du Sautoy, N., 2002, Two Dimensional Energy Interception and Water Balance Model for Hedgerow Tree Crops. Paper presented at Southern African Society of Horticultural Sciences congress at Cedara, Kwazulu Natal, 15-17 January 2002.

AMCEN/UNEP. 2002. Africa Environment Outlook: Past, present and future perspectives. Earthprint, Hertfordshire.

Ashton, P.J. & Turton. A.R., 2009, Water and Security in Sub Saharan Africa: Emerging concepts and their implications for effective water resources management in the southern African Region.

Ashton, P.J. & Turton, A.R., 2008 Hydropolitics and Transboundary River Basin Management Naunces in the Southern African Development Community.

Barker, R.D., White, C.C. & Houston, J.F.T., 1992, Borehole siting in an African accelerated drought relief project. In “Hydrogeology of Crystalline Basement Aquifers in Africa. Ed. Wright, E.P. and Burgess, W.G. Pp.183-201.

Awajobi, N. & Tetteh, N., 2017, The impacts of climate change in Africa.

Baloyi, J. K., 2010, An analysis of constraints facing smallholder farmers in the Agribusiness value chain: A case study of farmers in the Limpopo Province, University of Pretoria, Pretoria, South Africa.

Belay, F., 2016, Households Vulnerability to Climate Change and Adaptation Strategies: The case of Chokwe Mountain Watershed, Eastern Gojjam Zone Ethopia.

Bernett, V. and Lewis T. 1994. Outlier in Statistical Data. (3rd Edition) Wiley online Library.

Birkmann, J., 2006, Measuring Vulnerability to promote disaster resilient societies. Conceptual framework and definitions.

Birkmann, J., 2006, Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies. United Nations University Press, Tokyo JPN.

Blaikie, P., Cannon T., Davis I. & Wisner B., 1994, At Risk: Natural Hazards, Peoples Vulnerability, and Disasters. London: Routledge.

Blumberg, B., Copper. D.R.& Schlinder. P.S., 2005, Business Research Methods. London Mc Graw-Hill.

Burges, J., 2011, Climate Change: Childrens challenge. United Kingdom. UNICEF. www. unicef. Org.uk/climatechange.

Cervigni, R., Logos, A., Chinowky, P. & Neumann, J. L., 2016, Enhancing the Climate Resilience of Africa's Infrastructure: The roads and bridges sector.

Chaplin, Daniel, Byekwas, Flavia, Semanbo,m Med, Mujuni, Godfrey, Bantaze, James, Nyasimi, Mar, Wabyona, Edgar, Krishnaswamy & Sidharth., 2017, The impacts of climate change and livelihoods in Karamoja.

Chakrabartty, S.N., 2013, Best Split- half and Maximum Reliability.

Chersich, M.F. & Wright C.Y., 2019, Climate Change adaptation in South Africa: A case study on the role of health sector.

Christensen, J.H., Hewitson, A., Busuioc, A., Chen, X., Gao, I., Held, R., Jones, R.K., Kolli, W.T., Kwon, R., Laprise, V., Magaña Rueda, L., Mearns, C.G., Menéndez, J., Räisänen, A., Rinke, A., Sarr, P. & Whetton., 2007, Regional Climate Projections. Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge United Kingdom and New York, NY, USA.

CISR, 2010, A Climate Change Handbook for North Eastern South Africa. CISR, Pretoria.

CISR, 2010, ACSIR Perspective on water in South Africa in 2010, Council for Scientific and Industrial Research, Pretoria.

Clements, R., 2009., Economic Costs of Climate Change in Africa.

Cline, W., 2007, Global Warming and Agriculture: Impact Estimates by Country.

Codd, E.F., 1965. Testing Homogeneity.

Creswell, J.W., 2012a. Qualitative inquiry and research design: Choosing among five approaches Nebraska: Sage.

Creswell, J. W. & Tashakkori, A., 2007. The New Era of Mixed Methods

Dhakal, C.P., Dealing with outliers and influential points while fitting regression. Journal of Institute of Science and Technology

Dale, A., Arbor, S. & Procter, M., 1988, Doing Secondary Analysis. London, UK: Unwin Hyman.

Davis, C., 2011, Climate Risk and Vulnerability: A Handbook for South Africa.

David, J. & Sutton. A., 2004., Secondary Data Analysis.

Davis-Reddy. C.L. & Vincent. K., 2017, Climate Risk and Vulnerability. A handbook for South Africa. CSIR Pretoria South Africa.

Department of Agriculture and Rural Development, 2017/18, Free State Province.

Department of Economic Development Tourism and Environmental Affairs, 2014, Provincial Statistics Free State Province.

Department of Environmental Affairs, 2011a, Governance of Climate Change in South Africa.

Department of Environmental Affairs, 2015b, Departmental Policy Review Report as Input to Preparations for Actions Required to Develop National adaptation plan.

Department of Environmental Affairs, 2017, South Africa's Third National Communications under the United Nations Framework Convention on Climate Change. Pretoria.

Department of Tourism. Environmental and Economic Affairs, 2008, Free State Province.

Department of Environmental Affairs and Tourism, 2004, South African National Climate Change Response Strategy Report. Pretoria, RSA.

Department for International Development, 1999/2000, Sustainable Livelihood Guidance Sheets. London: DIFD.

Department for International Development, 2004, Climate Change Deepens Poverty and Challenges Poverty Reduction Strategies, Global and Local Environment Team, Policy Division, DFID, Crown Copyright

Department of Water Affairs and Forestry, 2001, Regulations relating to compulsory national standards and measures to conserve water. Department of water Affairs and Forestry. Pretoria.

Dixon, W. J., 1950, Processing Data for Outliers.

Doolan, D.M. & Freelicher, E.S., 2009, Using an existing data set to answer new researchquestions:A methodological review.

Durrheim, K., Terre Blanche, M., 2004, Research Design. University of Pretoria.

De Waal, A., 1997, Famine Crimes: Politics and the Disaster Relief Industry in Africa. Oxford.

Dyssel, J., 2018., Disaster Management Overview, Legislation and guidelines. Republic of South Africa.

Easterling, D.R., Meehl, G.A., Parmesan, C., Changnon, S.A., Karl, T.R. & Mearns, L.O., 2000, “Climate extremes: observations, modeling, and impacts”, Science New York.

Engelbrecht F.A., Mc Gregor J.L. & Engelbrecht C.J., 2009, Dynamics of the conformal- cubic atmospheric model- projected climate change signal over Southern Africa. International Journal of Climatology.

Engelbrecht C.J., Landman, W.A. & Engelbrecht F.A., 2013, The relative contribution of synoptic types to rainfall over the Cape south coast region. 29th Annual Conference of the South African society for Atmospheric Sciences, September 2013, Durban.

Emergency Events Database Centre for Research on Epidemiology of Disasters, 2016, (EM-DAT CRED)

Envirotech Solutions, 2015, Let’s respond toolkit. Free State Province.

Fant, C., Schlosser, C.A. & Strzepek, K., 2016, The impact of climate change on wind and solar resources in southern Africa.

Field, C.B., 2012, Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Field, C.B., Barros, V. R., Mach K. & Mastrandrea M., 2014, Impacts, Adaptation and Vulnerability. Working group II Contribution to the IPCC 5th Assessment Report – Technical Summary.

Frankfort-Nichmias. & Nichmias, 2002, The use of Secondary Data in Business Ethics.

Futurelearn.com. n.d., Impacts of Climate Change on Agriculture. www.futurelearn.com

Gbetibuo. G.A. & Ringler. C., 2009., Climate Change Perception and Adaptation of agro-pastoral communities in Kenya.

Government Gazette, 2019, National Climate Change Adaptation Strategy. Pretoria.

Githeko A.K. & Ndengwa W., 2001, Predicting Malaria Epidemics using climate data in Kenyan Highlands. A tool for decision makers, Global Change and Human Health.

Graffin. J., 2012, Report on the Impact of Climate Change in South Africa.

Guha-Sapir. D., Wallemaca. P.H.P. & Below. R., 2016, Annual Disaster Statistical Review. The numbers and trends. EM-DAT CRED. 2016.

Hamilton. L.C., 1992, Resistant Normality Check and Outlier Identification.

Hawkins, 1980, Identification of outliers, Chapman and Hall. London.

Hlalele, B. M., 2019, Iyenga-Sudershan method application to drought social vulnerability. Free State Province, South Africa.

Hoffman, G.J. & Jobes, J.A., 1978, Growth and water relations of cereal crops as influenced by salinity and relative humidity.

Huck. S.W., 2000, Reading Statistics and Research (3rd Edition) New York Longman.

Hyogo Framework for Action, 2005 – 2015, International Strategy for Disaster Risk Reduction. Hyogo, Japan.

Intergovernmental Panel on Climate Change, 2007 Fourth Assessment Report of the IPCC on Climate Change, Cambridge University Press, Cambridge, UK, 2007.M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Iglewicz, B. & Hooglin, D.C., 1993, How to detect and handle outliers. Milwaukee, WI... ASQC Quality Press.

Intergovernmental Panel on Climate Change, 2012, “Summary for Policymakers” in Managing the risks of extreme events and disasters to advance climate change adaptation, eds. C.B. Field, V. Barros, T. Stocker, et al., Intergovernmental Panel on Climate Change, Special report edn, Cambridge University Press, Cambridge, UK/New York.

Intergovernmental Panel on Climate Change, 2013, Climate Change: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change, 2014, Impacts, Adaptation and Vulnerability.

International Research Institute for Climate and Society, 2005, Sustainable Development in Africa: Columbia University, New York, USA.

Jordaan, A., 2011, Drought Risk Reduction in the Northern Cape. South Africa.

Jury, M.R., 2013, Climate Change Trends in South Africa.

Karl, T.R., Melillo, J.M., & Pieterson, T.C., 2009, Global Climate Change Impacts in the United States. Cambridge University Press.

Kasaigili, J.J., Levira, P., Liwenga, E. & Mdemu, M.V., 2014, Analysis of Climate Variability, Perceptions and coping strategies of Tanzanian Coastal Forest Dependent Communities.

Kiker., 2000, Building Water Security Resilience Towards Climate Variability.

Kimberlin. C.L. & Winterstein. A.G., 2009, Validity and Reliability of Measurement Instruments used in Research.

Kruger, A.C. and Shongwe, S., 2004, Temperature Trends in South Africa: 1960 – 2003. International Journal of Climatology 29, 1013 – 1033.

Kruger, A.C., 2006, Observed Trends in daily precipitation indices in South Africa: 1910 – 2004. International Journal of Climatology 26, 2275 – 2285.

Leedy, P.D., 1997, Practical Research Planning and Design (6th Ed) New Jersey. Prentice Hall.

Le Compte, M.D. & Schensul, J.J., 1999, Analysing and Interpreting Ethnographic Data. Walnut Greek, C.A: Altamira Press, a division of Sage Publication.

Lesolle, D., 2012, Southern African Development Community Policy Paper on Climate Change: Assessing the Policy Options for SADC member States. SADC Gaborone.

Malherbe, J., Iyahen, E., Engelbrecht, F. & Chamunorwa, M., 2018, The Extreme Climate Index (ECI), A tool for monitoring regional extreme events.

Mare, F., 2018, Farmers go hungry after drought. University of Free State, Department of Agriculture. Free State South Africa.

Madzvamuse, M., 2010, Climate Governance in Africa: Adaptation Strategies and Institution, Cape Town City.

Maplecroft, V., 2010, Climate Change Vulnerability Index.

Matela, F., 2017, Vulnerability and Adaptation to Climate Variability: A case of emerging farmers in the Eastern Free State, South Africa.

Mc Cathy, J.J., 2001, Climate Change 2001. Impact, Adaptation and Vulnerability contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University press, Cambridge, UK.

McMillan, J. H. & Schumacher, S., 2001, Research in Education. A Conceptual Introduction (5th ed.). New York: Longman.

Mc Mullen C., & Jabbour, J., 2009, Climate Change Science Compedium, UNEP/Eartprint.

Mendelson. R., Dinar A., & Dalfet A., 2000, Climate Change on African Agriculture. The World Bank.

Mulugeta, G., Marais S., Barnett M. & Wagsaether K., 2012, Biodiversity, Climate Change and Sustainable Development – Harnessing synergies and celebrating success.

Mimura, N., 2014, Adaptation Planning and Implementation in Climare Change. Cambridge University Press. Cambridge, United Kingdom and New York. NY. USA

National Aeronautics and Space Administration, 2015 Responding to climate change. (NASA) online database.

National Department of Agriculture, 2000, Abstract of Agricultural Statistics. Pretoria. South Africa.

Ncube, B. & Lagardien, A., 2015, Insights into Indigenous Coping Strategies to Drought for Adaptation in Agriculture: A Karoo Scenario.

Nichmias anNcube, B. & Lagardien, A., 2015, Insights into Indigenous Coping Strategies to Drought for Adaptation in Agriculture: A Karoo Scenario. d Nichmias. 1992. Impacts of Modernisation on Religious Institutions.

Nkomo, J.C., Nyong, A. & Kulindwa, K., 2005, Impacts of Climate Change in Africa.

Nobel, P.S., 1981, Wind as an ecological factor. Springer, Berlin Heidelburg.

Nyong A. O. & Fiki C., 2005, Drought Related Conflict Generation, Resolution and Management in Sahelian Northern Nigeria. Paper presented at international workshop on Climate Change and human security. Olso, Norway.

Ogallo, L. A., 1993, Dynamics of Climate Change over Eastern African Proc. Indian Academy of Sciences.

Osborne, J.W., 2004, The Power of Outliers (And Why Researchers Should Always check for them).

Oppelheimer, M., Campos M., Warren R., Birkmann J. Lubbe G., O`Neill B. & Takahashi K., 2014, “Emergency Risks and key Vulnerabilities” Climate Change.

Parke, I., Bourgoin, C., Martinez-Valle, A. & Laderach, P., 2019, Vulnerability of the Agricultural Sector to Climate Change: University of Southern Quinsland, Australia.

Patz. J., Campbell-Lendrum., Holloway T. & Foley, J.A., 2005, Impacts of Regional Climate Change on Human Health.

Pandve, T.H., Chawla. P.S., Fernandez, K. & Singru, S.A., 2011, Assessment of Awareness Regarding Climate Change in Urban Community.

Peery, J., 2020, How does Humidity Influence Crop Quality. PROMIX

Powels, J., Lamberty, A. & Schimel, H., 1998, Homogeity Testing for Reference Material.

Punch, K.F., 2005, Introduction to Social Research. Quantitative and Qualitative Approach. Sage Publications Ltd, London.

Rajagopalon, V. A., Framework for Climate Change Vulnerability Assessments: Government of India New Delhi.

Rayman, B., 2004, Analysis of the Effectiveness of Secondary of Existing Data in Quantitative Techniques.

Rajasekar, S., 2014, Resume of research. School of Physics, Barathidasan University India.

Rasmussen. J.I., 1998, Evaluating Outlier Identification test: Mahalanobis D squared and Conrey D. Multivariate outliers.

Reasons, P. & Bradbury H., 2001, A Handbook of Action Reasearch.

Robenson, 2011, Qualitative Research Methods.

Rowson, H.M., Begg, J.E. & Woodward, R.G., 1977, The effects of atmospheric humidity on photosynthesis, transpiration and water use efficiently of leaves of several plant species. Planta 134 (1). 5-10.

Rutashobya, 2008, Impact of Climate Change on Water Resources in South Africa: A Review.

Sandras, V.O. & Milroy, S.P., 1996, Soil water thresholds for the responses of leave expansion and gas exchange. A review. Field crop.

Sayer, A., 1992, Method in Social Science: A realist approach (2nd Ed), London Routledge.

Schwardt, T.A., 2007, A Students Guide to Methodology. University of Ptretoria.

Schwager, S.J. & Margolin. B.H., 1982, Detection of Multivariate Outliers. The annals of statistics.

Seneviratne, S., Easterling. D., Nicols. N. & Goodess. C.M., 2012, Changes in Climate Extremes and their Impact on Natural Physical Environment.

Shackly, S., Wilby, R., Trunpenny, J.,Wright, A., Hunt, A.,Chritchtoon, D., Clarke, S.,Kersey, J. & Trevorrow, E., 2002, London Warming: The impacts of climate change in London.

Shewmaker, S., 2008, Vulnerability and Impacts of Climate Change in South Africa’s Limpopo river basin. Western Washington University.

South Africa’s Weather and Climate, 2019, South Africa Gateway. Southafrica-info.com

Statistics South Africa. Census, 2011, Mangaung, Free State Province.

Stark, J., Mataya, C. & Lubovichk 2009, Climate Change Adaptation and Conflict: A Prelimenary review of the issues. Bangladesh.

Tarhule, A. & Lamb P.J., 2003, Climate research and seasonal forecasting for West Africans: Perceptions, Dissemination and Use.

Thomas, D.S.G., Twyman. C., Osbahr. H. & Hewitson. B., 2007, Farmers responses to intra-seasonal precipitation trends in South Africa.

Thomson M.C., Doblas-Reyes F.J., Mason S.J., Hagedorn R., Connor S.J., Phindela T., Morse A.P. & Palmer T.N., 2006, Malaria early warnings based on seasonal climate forecasts from multi-model ensembles.

Thorpe, J., 2012, Climate Change Risk and Supply Chain Responsibility. How should companies respond when extreme weather affects small-scale producers in their supply chain. OXFAM.

United Nations Framework Convention on Climate Change, 1992, New York. (UNFCCC).

United Nations International Children Emergency Fund, 2011, Climate Change: Children challenge. United Kingdom. UNICEF

United Nations International Strategy for Disaster Reduction, 2009, Terminology on Disaster Risk Reduction. Geneva, Switzerland. (UNISDR)

Uys, D., 2014, Climate Change Risks Require Combined Effort.

Wadinga, S., 2005, Vulnerability to Climate Induced Malaria in East Africa, ALACC case study, ALCC, START, Washington.

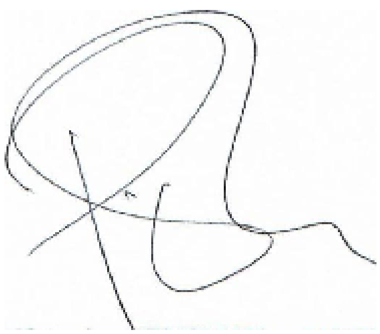
Whitmash, L.E., 2005, A Study of Public Understanding and response to climate change in the south of England. University of Bath, England.

Van Nieker, D., Templehoff. J., Falling. W., Thompson. L., Coetsee. C. & Martens. Y., 2009, The effects of climate change in two flood laden and drought stricken areas in South Africa: Response to climate change- Past, present and future.

Wisner, B., Blaike P., Cannon T. & Davis I., 2004, At Risk Natural Hazards, Peoples Vulnerability and Disasters.

16 June, 2020

This is to certify that I, **Dr P Kaburise,** of the English Department, University of Venda, have proofread the research report entitled - **QUANTITATIVE VULNERABILITY ANALYSIS OF CLIMATE CHANGE FOR AGRIBUSINESSES AND AGRICULTURAL DEVELOPMENT PROJECTS: A CASE OF BLOEMFONTEIN, SOUTH AFRICA** - by Ntombizodwa Elizabeth Lunga (student number: 2016330710). I have indicated some amendments which the student has undertaken to effect, before the final report is submitted.



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GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

01-Jul-2020

Dear Mrs Ntombizodwa Lunga

Application Approved

Research Project Title:
Quantitative vulnerability analysis to climate change for agribusinesses and Agricultural development projects: A case of Bloemfontein, South Africa.

Ethical Clearance number:
UFS-HSD2020/0949/0107

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
Chairperson: General/Human Research Ethics Committee

AdPlessis

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