Impact of climate change on fresh water resources of Elliot town in the Eastern Cape

by

BEKITHEMBA NDLELA

Submitted in accordance with the requirements
for the degree of

MASTER OF SCIENCE

in the subject

ENVIRONMENTAL MANAGEMENT

at the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: Dr. L T NHAMO
CO-SUPERVISOR: Ms. M D MATLALA

NOVEMBER 2015

DECLARATION

I, **Bekithemba Ndlela**, hereby declare that this dissertation entitled: "**Impact of Climate Change on Fresh Water Resources of Elliot Town in the Eastern Cape,**" is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

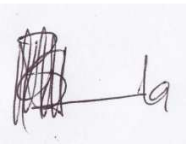
I declare that where words from a written source have been used the words have been paraphrased and referenced and where exact words from a source have been used the words have been placed inside quotation marks and referenced.

I declare that I have not copied and pasted any information from the Internet, without specifically acknowledging the source and have inserted appropriate references to these sources in the reference section of the dissertation or thesis.

I declare that during my study I adhered to the Research Ethics Policy of the University of South Africa, received ethics approval for the duration of my study prior to the commencement of data gathering, and have not acted outside the approval conditions.

I declare that the content of my dissertation/thesis has been submitted through an electronic plagiarism detection program before the final submission for examination.

I further declare that I have not previously submitted this work, or part of it, for examination at UNISA for another qualification or at any other higher education institution. Although this thesis or part of it has not yet been published in any form I consent that it should be made available as reference for future studies and parts of it can also be used for new or further research to promote the cascading of knowledge and information to difficult people in different areas.

Signed:  Date: **20 August 2015**

ACKNOWLEDGEMENTS

I would like to give a special thanks to my Supervisor Dr. L. Nhamo for all his help, understanding and guidance without whom, this research project would not have been possible. I would like to thank my Co-Supervisors, Ms. Malebo Matlala for her valuable input, guidance, understanding and patience. You helped make this research project possible and I appreciate all the hard work and effort you have put into it. I am honoured to have had such a great and supportive team working with me in this research study.

I would like to thank the following individuals and institutions for the support and guidance rendered throughout my research:
The Sakhisizwe Municipal Manager, Mr. T. Samuel and the Corporate Services Manger Ms. N. Mazwayi for the permission to conduct this research in Sakhisizwe Municipality. Also to Garth Sampson and Colleen of Weather SA for the temperature and rainfall data they provided, Mr. Vorster for facilitating data on animal and crop production in the East Cape, and Mr. Mdunyelwa for his patience, assistance and sharing of his knowledge, without whom, this study would not have been possible.

I would also like to thank my dear friend Mr. Mtowodzwa for his help with some additional computer skills. Lastly but definitely not the least, I would like to thank my family for their support and especially my wife Euphrasia for her patience, time and understanding as she would at sometimes be left alone with the children while I deal with my studies. Thank you my children Anotidashe and Hannah for constantly reminding me of the cumbersome work I had to finish before I go to bed.

To God be all the Glory!

TABLE OF CONTENTS

List of Tables

List of Figures

Acronyms

ACRU	Agricultural Catchments Research Unit
AGRA	Alliance for a Green Revolution in Africa
AgriSA	Agriculture South Africa
ARC	Agriculture Research Council
CMI	Climate moisture index
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Fisheries and Forestry
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
EC	Eastern Cape Province
FAO	Food and Agriculture Organisation of the United Nations
GCCC	Government Climate Change Committee
GCMs	Global Climate Models
GHGs	Green House Gases
GIS	Geographic Information Systems
IDW	Inverse distance weighting
IPCC	Intergovernmental Panel on Climate Change
NDA	National Department of Agriculture
PET	Potential evapotranspiration
Stats SA	Statistics South Africa
UNFCCC	United Nations Framework Convention on Climate Change
Weather SA	Weather South Africa
WRC	Water Research Commission

Definition of terms

The terms used in this study are defined below according to how they are used in this study as adopted from either the United Nations Framework Convention on Climate Change (UNFCCC) or Intergovernmental Panel on Climate Change (IPCC).

- **Adverse effects of climate change**: means changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.
- **Climate change**: means a change of climate, attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time intervals. According to IPCC (2001) it refers to the statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer) which may be due to natural internal processes or external forces or to persisting anthropogenic changes in the composition of the atmosphere or in the land use.
- **Climate variability**: variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes etc.) of climate on all temporal and spatial scales beyond that of individual weather events due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcing (external variability). (IPCC, 2001)
- **Climate system**: means the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions.
- **Climate**: average weather conditions of an area or region calculated over a long period covering a large area.
- **Emissions**: means the release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period.
- **Greenhouse gases**: means those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation.
- **Source**: means any process or activity, which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere.

Abstract

Climate change and variability have great impact on the hydrological cycle and consequently on the availability of water resources. Variations in temperature and precipitation trends that are occurring are a consequent of the increase in the concentrations of greenhouse gases, which are subsequently affecting the hydrological cycle. This in turn affects water quantity and quality, which is essential for agriculture, domestic and industrial uses. This study, done in Elliot Town and the surrounding areas of Sakhisizwe Municipality in the Eastern Cape Province of South Africa, evaluates how climate change and variability is affecting water availability and its quality in the town. The impact climate change and variability on agricultural production is also assessed. Remote Sensing, Geographic Information Systems (GIS), databases and some statistical packages have been used to collect, analyse and create spatial maps used to derive concrete conclusions. The methods used aided in spatially analysing the changes in temperature and rainfall along the years and make a comparative analysis. The study has shown that the spatial changes in the amount, intensity and frequency of rainfall affects the magnitude and frequency of stream flows; consequently, increasing the intensity of floods and droughts that have been recurring in the last few decades. The municipality is more affected by climate variability than change, and the resultant extreme climate events are affecting the water resources resulting in domestic water cuts, poor water quality and low agriculture productivity. This study recommends the importance of an awareness campaigns on climate change and variability and their effect directed towards the community, especially on novel water harvesting technologies. The study also highlights the importance of a robust early warning system to prepare the community in case of a climate shock, which is an area that needs further research.

Keywords: Climate change, climate variability, rainfall, temperature, water quality, flooding, drought, GIS, Remote Sensing, Sakhisizwe Municipality

CHAPTER 1

INTRODUCTION

1.1. Background

Climate change and variability have been studied and described extensively as is found in the volumes of literature on the subject. For example, Cruz *et al*., (2007) described climate change as the rise in rainfall, flooding and drought and other weather events affecting an area for a certain period and this change brings about completely new weather and climate trends from the norm. Climate change and variability are global problems affecting communities in their diverse complexities and compositions. Nowadays extreme weather events are frequently being experienced worldwide and there is an increase of these conditions (Easterling *et al*., 2000). Climate change and its impact on the environment are inevitable and significant impacts will be felt through the demand for water in the communities (Bates *et al*., 2008). Industrialised countries are the major contributors of greenhouse gases emissions and as long as these emissions continue unabated, climate change and variability will continue worsening (Levin *et al*., 2010). Over the years, it has been very difficult for countries to reach an agreement on the reduction of these emissions because some of them did not want to experience some loses by scaling down production or introduce costly measures in dealing with the greenhouse gases. Moreover, the worst impacts of climate change are more severe in developing countries other than the culprit-industrialised countries themselves, hence lack of urgent action (Scholtz *et al*., 2013).

Climate change has, is and will always (unless if some measures are put in place now to control and avert adverse consequences) impact on the various resources and communities in different ways and it is already affecting negatively on the water resources of South Africa. According to Davis *et al*., (2010) and Blignaut *et al*., (2009), a comparison of South Africa's temperature of the period between 1997 and 2006 has revealed that there has been an increase of around 2%. During the same period, water scarcity has increased by 6%. Schulze, (2005) attests to this by stating that South Africa's mean annual rainfall is almost half of that of the world at 490 mm making it a dry and water scarce country. It is very difficult to determine the impact of climate change and variability as it will always vary over the years and in different places (CSIR, 2001). Rainfall at

regional level, in Southern Africa, has shown variable trends showing marked inter-decadal variability (Schulze, 2005).

According to Kruger (2006), long-term variations in rainfall and temperature trends are already affecting South Africa causing high climate variability. The increase in temperatures beyond expected levels and the changing rainfall patterns (both in quantity and seasonally) have negatively affected the water sources of many areas of the Eastern Cape of South Africa. Above and below normal rainfall received during some seasons has resulted in unpredictable water supplies to Elliot Town in particular and the surroundings communities of Sakhisizwe Municipality in general. During the past seven years this researcher has been living in the Eastern Cape, has witnessed the impact of climate change in Elliot Town, having seen some plants and animals adapting to new environments but there are other species that have also migrated due to changing climatic conditions.

Because of water levels in reservoirs running low due to decreasing rainfall and high evaporation from high temperatures, the available water is usually of poor quality. Consequently, residents of Elliot Town are now resorting to boiling water they get from the taps as it is often dirty and has the risk of causing diseases if consumed directly (Karodia and Weston, 2001; Mirumachi and Van Wyk, 2010). This is a big challenge to most of the poor households as they resort to using the scarce and difficult to find firewood in the vegetation scarce Elliot environment. A minority of the residents can afford to buy purified (mineral) water as an alternative. Nevertheless, considering the high level of poverty in this community, not many can afford bottled water, and besides it is considered a luxury. It is thus imperative for the authorities concerned to find alternative ways to supply residents with clean water. With service delivery protests commonly experienced throughout the country, it becomes easy for people to blame everything on the municipality and the relevant authorities responsible for the supply of water to the public.

It therefore becomes very imperative for policymakers and other stakeholders to have a thorough knowledge of climate change and its variability and how it can affect them in the near future. Communities must also understand how they are contributing to climate changes, and know how their daily activities are affecting the quantity and quality of water resources. On the other hand, it equips policymakers with the relevant and appropriate knowledge and information on how to

handle the impact of climate change on the provision of the basic services to the community including the supply of clean water. This study focused on the impact of climate change and variability on water availability and agriculture production. According to Kang *et al.*, (2009) crop production will respond to climate change differently as in some areas it will increase and in others, it will decrease. The study also focused on adaptation strategies that should be considered to mitigate climate change impacts, and by empowering residents and farmers with knowledge on climate change and variability. The results of the study and especially the profiling of the impacts and adaptive strategies act as an early warning, which can be used in disaster preparedness.

Climate change and variability is real and is with us and its impact is already being felt globally. Nevertheless, in low-income countries the impacts are expected to be severe because of low adaptation capabilities, (FAO, 2008). Recent research has shown that South Africa will experience water shortages in the coming few years as it is already a water scarce country (Hedden and Cilliers, 2014; Archer *et a*l., 2010). Therefore, this study aims to recommend and suggest measures that would help the community in Sakhisizwe Municipality and particularly the residents of Elliot Town, to be more resilient and less vulnerable to the impacts of climate change and variability.

1.2. Research Problem

Like any other region in South Africa, climatic conditions in Elliot Town have been changing, particularly rainfall pattern and amount (Davis *et al*., 2010). Where people used to have consistent average rainfall they now experience incessant heavy downpours and sometimes this happens in winter when people would be expecting only snow. Runoff water received in the area is drained into the Thompson Dam, which lies about 4 km northeast of Elliot Town. Runoff water in the area is usually muddy and heavily polluted by the time it gets into the dam. The water is so polluted to the extent that it cannot be consumed directly from the dam, as it would need time to settle and clear up all the runoff load. However, at the same time the settled load increases siltation and therefore affects the dam's water level.

It has been also observed that during spring seasons it becomes very windy so much that water stored in open-top the reservoirs for treatment is covered with dust to such an extent that it becomes

as dirty as the water in the dam itself. Generally, there is no time of the year when there is a guarantee of clean water for the residents of Elliot. As the water remains stagnant for long, it becomes stinky causing bacteria to collect. These conditions risk the health of the people and in most cases end up using some traditional water purification method. This has affected safe water supplies making the once clean and safe water to be no longer suitable for consumption without first being boiled. In most cases, the water quality is so poor to the extent of causing waterborne diseases (Momba *et al*., 2006).

Besides, water supplies have been interrupted lately as it becomes scarcer in recent years. Water scarcity is mainly attributed to increased evapotranspiration due to rising temperatures and reduced rainfall amount, and also due to aging equipment, which constantly breaks down (McMichael, 2003). In South Africa, there have been service delivery protests as a result of the interruption of water supplies. The Sakhisizwe Municipality is no exception because its residents are also the recipients of the impact of climate change and variability on the already scarce water resources. There is, therefore, need for further research on new technologies and models that can be adopted to ensure uninterrupted clean water supplies. There is also a challenge of awareness campaigns in the municipality to conscientise policymakers and residents on climate change and variability. This study envisages equipping stakeholders in Sakhisizwe Municipality with valuable knowledge and an invaluable tool for disaster preparedness and climate change adaptation strategies.

1.3. Rationale of the Study

The study seeks to explore the impact of climate change and variability on the water resources of Elliot Town in particular and the Sakhisizwe Municipality in general. The study works towards obtaining possible solutions to climate related challenges faced in the town and the municipality. Residents of the town have been experiencing incessant water cuts prompted by the climate variability, and when the water is available, it will not be suitable for consumption, thus exposing them to health risks. Extreme climate events such as flooding and drought have been a common occurrence and at times extreme cold spells have been compounding the situation. Seasons have been very unpredictable of late and especially the rain season has become shorter (Archer *et a*l., 2010). These challenges have also been affecting agriculture production of the surrounding farms.

This study will benefit both residents and policymakers in the Sakhisizwe Municipality in their quest to provide better services to the residents. Stakeholders will be equipped with the knowledge of the various activities practiced in their locale, which are fuelling global warming, causing climate change, and thereby affecting water quality and agriculture production. The impacts of climate change and variability are profiled, suggesting possible solutions. The study will act as an early warning tool empowering stakeholders on adaptation strategies. Policymakers will be equipped with a tool to enlighten them to invest more resources in new technologies to harvest water to maintain constant quality water supplies.

The results of the study will probably help avert numerous service delivery protests by angry residents as they get an in-depth understanding of the real causes of the problems they are facing as well as being prepared for change from the daily norm. The study will assist policymakers to take some holistic approaches when dealing with challenges caused by climate change. The residents will be equipped with resources to respond positively to climate change impacts, improving efficient water usage, recycling and build additional water storage facilities.

1.4. Aims and Objectives

1.4.1. Aims of the study

The study aims to:

(a) assess the vulnerability of Elliot Town and the whole of Sakhisizwe Municipality in the Eastern Cape Province of South Africa to the impact of climate change and variability, paying particular attention on water resources and agriculture production, and

(b) profile climate change/variability impacts and develop adaptive measures as an early warning tool to alleviate those impacts.

The study focuses on the impact of climate change/variability on water resources and agriculture production in Elliot Town in particular and Sakhisizwe Municipality in general.

1.4.2. Research Questions

The following questions gave guidelines towards the execution of the research:

(a) To what extent has climate around Elliot changed over the years, and how has been the impact on water availability and agriculture production in Sakhisizwe Municipality.
(b) What measures can the municipality put in place to continue supplying constant and clean water in the advent of climate change and variability?
(c) Which adaptation strategies should the municipality adopt to avert the envisaged water shortages resulting from climate change and variability?

1.4.3. Objectives

The specific objectives of the study are:

(a) To assess the impact of climate change/variability on water resources of Sakhisizwe Municipality where Elliot Town is located.
(b) To develop adaptation strategies to alleviate the impacts of climate change/variability.
(c) To facilitate the implementation of long-term adaptation strategies to increase the resilience of households and the community to the adverse impacts of climate change and variability.

1.5. Description of the Study Area

1.5.1. Location, Area and Population

Elliot (also known as Ecowa in the local Xhosa language) is a small town in Sakhisizwe Municipality, Chris Hani District Municipality in the Eastern Cape Province of South Africa. The town is situated near the Slang River whose sources is from the nearby Lower Drakensburg Mountains, about 70 km west of Maclear Town and 65 km south-east of Barkly East. Elliot Town, which was founded in 1885, became a municipality in 1911, and was named after Sir Henry George Elliot (1826-1912), Chief Magistrate of the Transkeian territories from 1891 to 1902 (IDP, 2009). The town is located between the coordinates: 31°20’S, 27°51’E.

The town has a population of 14 376 residents (Stats SA, 2012), over an area of 28.85 km^2, giving a population density of 500/km^2. According to Stats SA, (2012), the racial composition of the town includes; Black African 93.9%, Coloured 2.6%, Indian/Asian 0.4%, White 2.7% and other 0.3%. The languages spoken in the Town are; Xhosa 87.1%, Afrikaans 4.5%, English 4.5%, sign language 1.7% and other 2.3%. These figures could have changed due to the influx of people from African other countries.

There are about 27 weather stations with complete rainfall and temperature data in Sakhisizwe Municipality, and close to Elliot Town. The records from these stations are used in this study to assess climate change/variability in the municipality. Elliot Town is situated in the centre of Sakhisizwe Municipality, and is surrounded by many rivers, which drain their waters into the Nicora Dam, as shown in Figure 1.1. Figure 1.1 shows the location of Elliot Town in Sakhisizwe Municipality and also the location of the municipality in South Africa. Figure 1.1 also shows the location and number of weather stations whose data was used in this study.

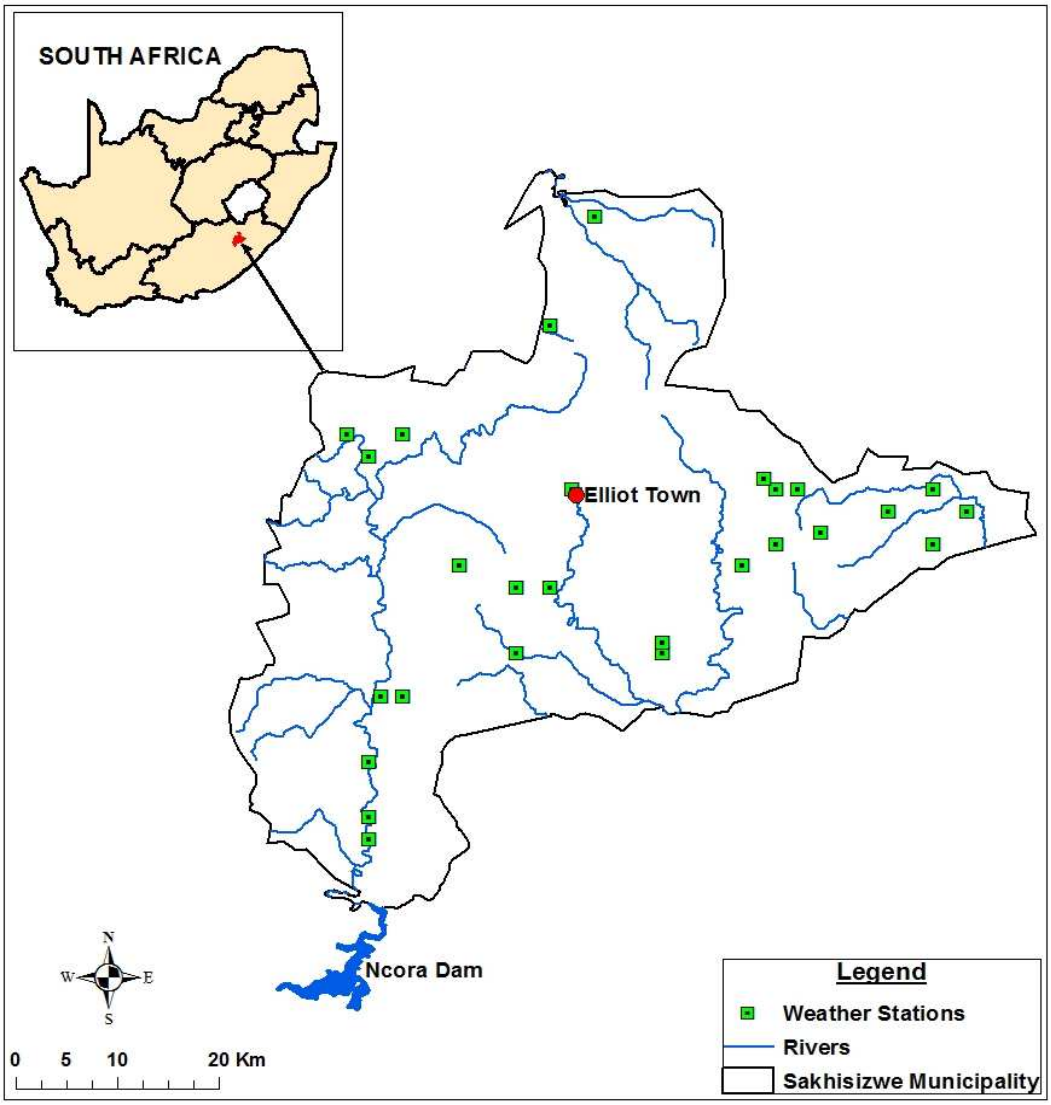


Figure 0.1: Location of Sakhisizwe Municipality in South Africa and the weather stations and water bodies found in the municipality

1.5.2. Landuse/Landcover and Topography of Sakhisizwe Municipality

The municipality has warm moist summers, cold dry winters and snow during the winter months. Its land area is dominated by grasslands with isolated agriculture land as shown in the map on Figure 1.2.

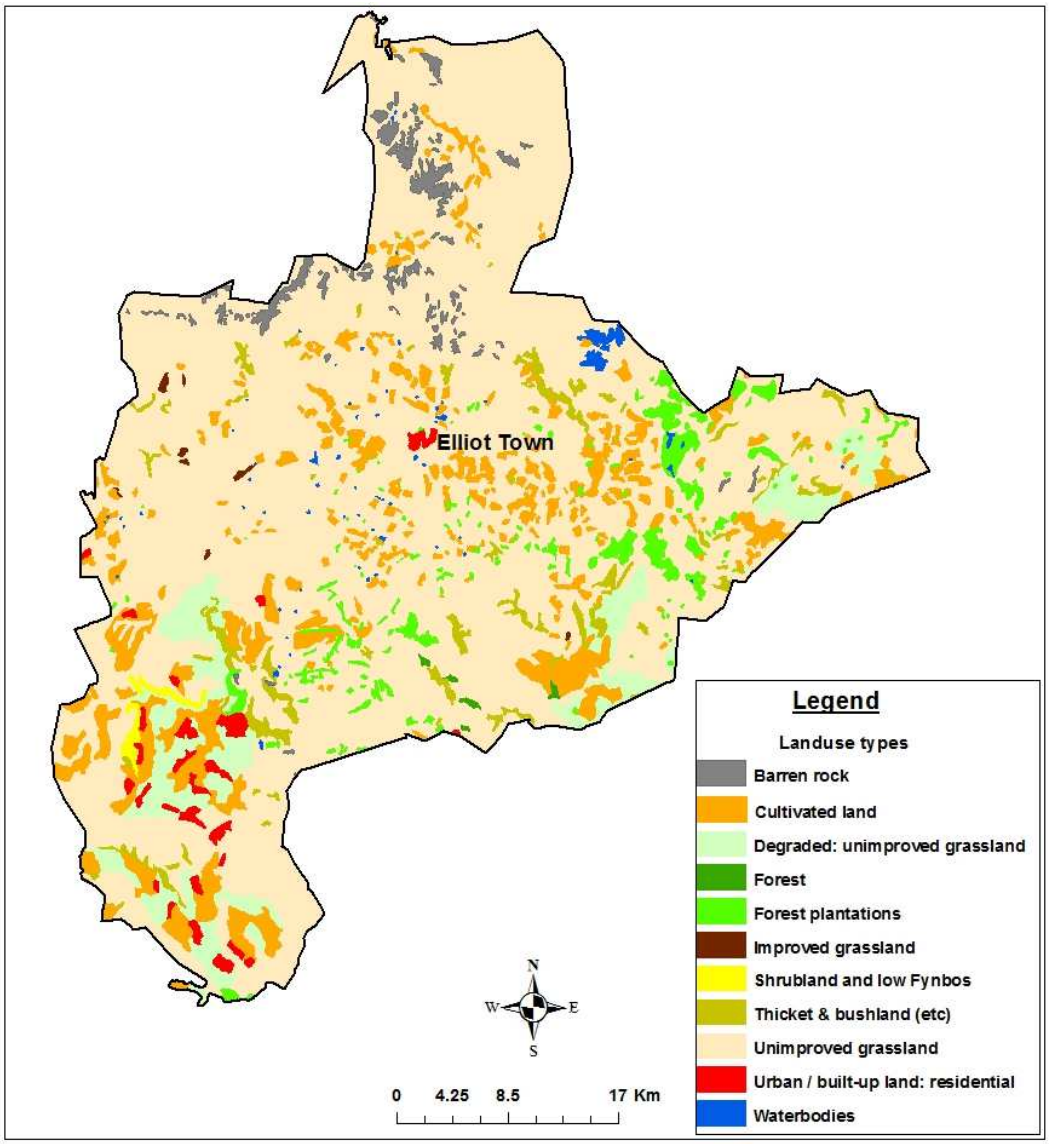


Figure 0.2: Land use/cover of Sakhisizwe Municipality as in 2003
Source: CSIR, 2003)

The vegetation is mainly Grassveld. Trees and shrubs are found on rocky hills and ridges. Dohne Sourveld is the most common transitional forest and shrub type and the sweet grass is dominated by Redgrass Themeda triandra. Unimproved Grassland make up (76%), with Cultivated Dryland (9%), Degraded Unimproved Grassland (6%), Forests Plantations (2.5%), Thicket Bushland (2.2%) and Built Up Areas (1 %) making up the balance.

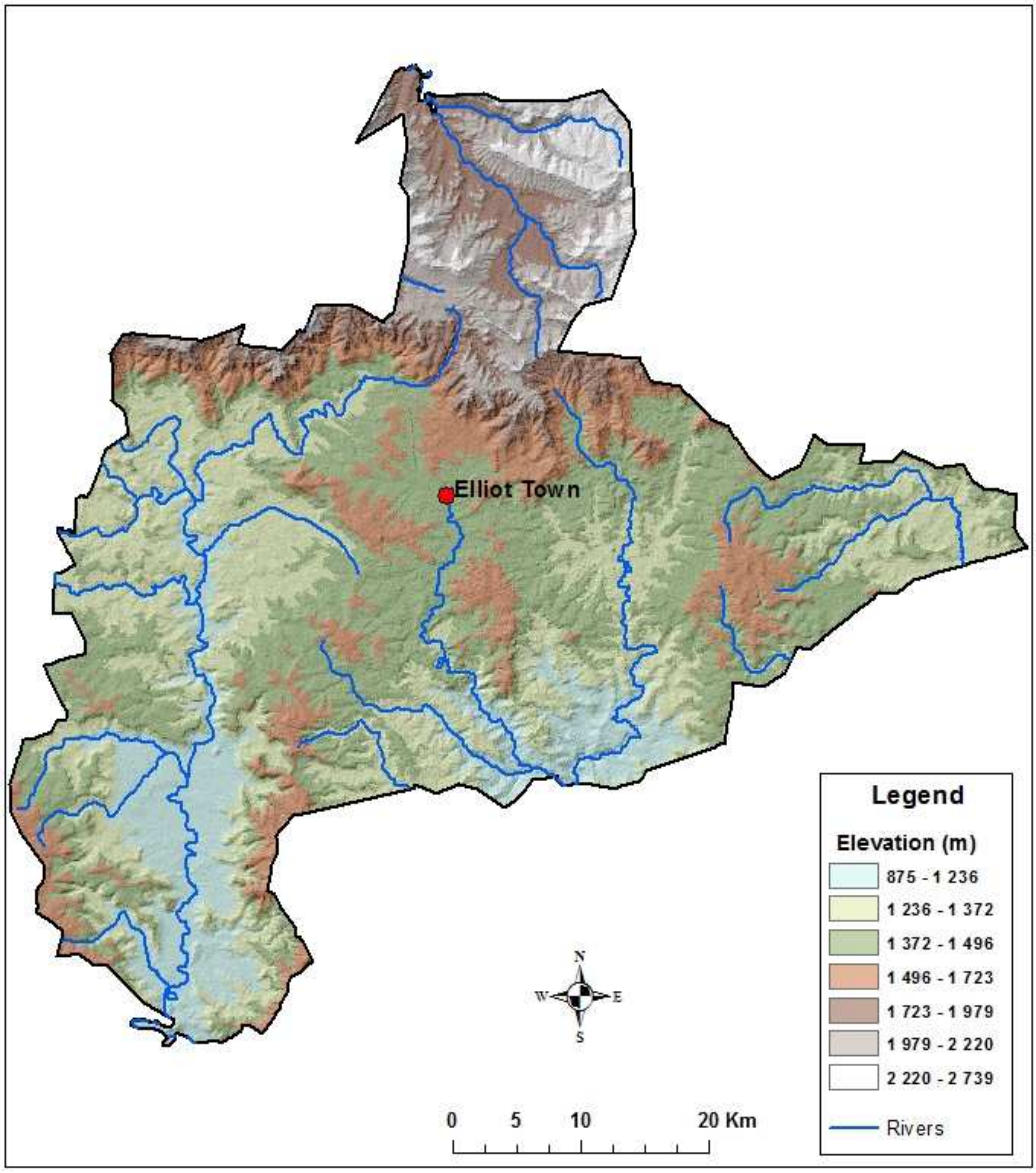


Figure 0.3: Elevation of Sakhisizwe Municipality

The land area of the municipal is gently undulating forming the Drakensberg foothills. The elevation in the area ranges from 800 m to 2 700 m above sea level as shown in Figure 1.3. The soil types vary according to topography. The low-lying area is characterised by soils with high clay content (highly erodible) and the surrounding hills consist of strong litho-soils. The area of the municipality is 2 556 km².

The Slang River, one of the major rivers in the municipality feeding the Thompson Dam, has its source from the Lower Drakensburg Mountains. After about 3 km from the foot of the Drakensberg Mountains, the Thompson Dam was built. During summer the river gets its water from runoff coming mainly from the mountains and the surrounding areas, and during the winter season it feeds from the melting snow in the mountains. This is the main reason why the Slang River is perennial (IDP, 2009). Figure 1.4 shows part of the Slang River as it descends from the Drakensberg Mountains.

Figure 0.4: The Slang River descending from the Drakensberg Mountains
Picture taken in May 2015

1.5.3. Settlement Patterns and Land Tenure

The Sakhisizwe Municipality, where Elliot Town is situated, is located within the North Eastern extent of the Chris Hani District Municipality. The municipality borders the Elundini Local Municipality (Ukhahlamba District) to the north and Engcobo Municipality to the east. To the south and west there are Intsika Yethu, and Emalahleni Municipalities respectively. The Sakhisizwe Municipal is composed of seven wards.

Most of the land in Sakhisizwe Municipality is owned by the State, especially the land that used to be the Transkei homeland during the apartheid era. This includes the land area around Cala Town, which is known for its low agriculture yields due to its terrain, which is not suitable for any agricultural activity. However, around Elliot Town there are many privately owned commercial farms.

There are different settlement categories in the Sakhisizwe Municipality namely:

(a) Scattered low-density rural residential settlements. These are found mainly in the former Transkei area, which lies to the south of the municipal area where service delivery is generally poor and land ownership is communal. There is little economic activity in these settlements except for some few shops with limited goods in stock.

(b) Communal agricultural land. These areas are found along the peripheries of the area bordering Cala Town.

(c) Commercial farms. These are found mainly outside Elliot on the periphery of the municipality.

(d) Urban settlements. These are the towns within the municipality of the municipality which include Cala and Elliot towns. The social and infrastructure services are typical of urban nature and the services are more advanced as compared to the other settlements in the municipality.

1.5.4. Agricultural Activities

The agricultural activities that practised in the Sakhisizwe Municipality include maize production and animal husbandry. Cattle and sheep rearing are practised mainly at commercial level around Elliot Town. In Cala (former Transkei) area, there are many small-scale commercial and

subsistence farmers. Most of the smallholder farmers in the area focus on cattle, sheep and goat farming although goats are kept mainly for cultural practices.

CHAPTER 2

THEORETICAL FOUNDATION

2.1. Introduction

Understanding trends in rainfall and temperature are critical in projecting future crop production and water availability in an environment of climate change and variability. Previous studies have shown that climate change and variability will impact future farming and food systems as environments are substantially modified due to shifts in seasons (FAO, 2003; Clements *et al*., 2011; Godfray *et al*., 2010; Hanjra and Qureshi 2010; Brown and Funk, 2008). Climate change will result in agriculture struggling to meet the demands of a changing global population, as the globe will experience water deficits and consequently low crop production (Barnett *et al*., 2005; UNECA, 2002). There is evident growth in demand for food and water in many areas, Elliot included, and this together with sea levels rising due to temperature increases and rainfall patterns have made the efforts to address the challenges of climate change impacts difficult to accomplish. (Camill, 2010). Faced with such situations it is therefore imperative to have some adaptive measures in place such as new technologies and applicable and very relevant policies that would be helpful in solving the problem than compounding it (Clements *et al*., 2011; Camill, 2010). The knowledge of the available adaptation options and their likely benefits or costs is highly linked to the knowledge of how temperatures and rainfall are going to rise and to decline respectively.

Agriculture is the most important activity that provides for the livelihoods of the communities and smallholder farmers in the Eastern Cape (EC). However, crop productivity is very low. For example, maize has an average yield of less than one t/ha (Archer *et al*., 2010). Low and variable rainfall, together with the increasing temperatures are the major limiting factors to crop production in the Eastern Cape (Mason *et al*., 1999). Southern Africa is the region that is expected to be affected mostly by the declining rainfall and increasing temperatures because the communities lack resources to adapt. Climate change and variability are causing shifts in areas suitable for cultivation of a wide range of crops (Mason, 1996, IPCC, 2001; Davis *et al*., 2010; Turral, 2011). Developed countries are actually expected to have an increase in cultivated area (Nhamo and Chilonda, 2012). The demand for water has tripled since the 1950s worldwide, but the supply of

fresh water has been declining (Gleick, 2003). Temperature in Southern Africa is already said to have risen by a range of between 10ºC and 30ºC (Midgley *et al*., 2011; Davis *et al*., 2010; DEAT, 2004). These changes have brought variation in the cropping season and affecting livestock types that adapt to the former temperatures. The International Panel on Climate Change (IPCC) recognises that developing countries are particularly vulnerable to climate change, especially due to lack of resources (IPCC, 2007).

This chapter explores some climate change and variability impacts already evident in Sakhisizwe Municipality where Elliot Town is located. These impacts are explained through the evidence of extreme weather events, such as flooding and droughts as well as projections of the effects on agriculture and on economic activities. This chapter also focuses on other studies that have been done in relation to climate change impacts on water availability and agriculture production. It further explores how people perceive climate change and variability and how they are presently adapting to climate induced change.

2.2. Defining Climate Change and climate variability

It is generally acknowledged that change and variability in the Earth's climate are being experienced throughout, and that their adverse effects are a common concern to humankind as shown by previous research (Nhamo and Chilonda, 2012; Archer et al., 2010; IPCC, 2007). Human beings all over the world have found it imperative to meet their daily needs by various industrial operations. Consequently, these operations have directly or indirectly contributed immensely to the greenhouse gases in the atmosphere which play a major role in the rise in global warming which in turn turns back to affect the natural ecosystems and the same human beings apparently (UNFCCC, 1992).

Therefore, climate change and variability have been taking place and it has become imperative for measures to be taken to alleviate the impacts. South Africa has also been experiencing climate change and variability as evidenced by the high frequency of dry spells and flooding in some regions of the country. It should be noted that climate change and climate variability are two different terms.

2.2.1. Climate change

Climate change is defined as change of climate, which is associated to anthropogenic activities that modify the composition of the atmosphere. These changes are observed over a comparable period of time (IPCC, 2001; UNFCCC, 1992). These changes are normally due to natural internal processes or external forces occurring in the composition of the atmosphere caused by anthropogenic activities (IPCC, 2001).

The United Nations Framework Convention on Climate Change (UNFCCC) thus makes a distinction between "climate change" attributable to human activities altering the atmospheric composition, and "climate variability" attributable to natural causes (UNFCCC, 1992). While UNFCCC attributes climate change to affect directly or indirectly to human activities, the IPCC (2014) states that, it is change in the mean and/or the variability of its properties for up to a decade or longer. This state of the climate can be proven through some statistical tests that can be conducted.

2.2.2. Climate variability

The IPCC (2012) acknowledges that there is a direct link between climate change and climate variability in that human activities, which lead to climate change, have resulted in climate variability as they produce the greenhouse gases that effect the atmosphere. According to IPCC (2001), the change on the average state of the climate on all temporal and spatial levels to extents that are above actual weather events which are as a result of processes that take place inside a climate system or anthropogenic forces. Seasonal climatic conditions become unpredictable resembling extreme weather events that in most cases cause climate shocks like drought and floods. Rains, for example, may fall intensely for very short periods causing floods, but disappear for long periods making the rain season shorter. In most cases, rain is either above or below normal, making the agriculture seasons unpredictable. In as much as climate change leads to climate variability there is also evidence that climate variability does have an effect on the various communities that depend on the climate.

2.3. Vulnerability Level of South Africa to Climate Change

Sixty five percent (65%) of South Africa is semi-arid, with an average rainfall of 450 mm/year, which is well below the world average of about 860 mm/year (Otieno and Ochieng, 2004). Only 28% of the country receives more than 600 mm of rainfall (Dyson, 2009), and this is mainly in the coastal areas of which the Eastern Cape Province is part of. South Africa is thus, described as a water scarce country with an uneven distribution of water resources in space and seasons (Davis *et al*., 2010). The annual fresh water availability of South Africa is less than 1 700 m^3 per capita (the index for water stress). The current estimate is 1 154 m^3 per capita/year (FAO, 2005). Seckler *et al*., (1998) estimate that by 2025 South Africa will be one of the countries in the world that will experience physical water scarcity with an annual freshwater availability of less than 1 000 m^3 per capita (the index for water scarcity). Although the Eastern Cape receives more than 600 mm of rain annually, it has also been affected by droughts over the years, for example, the drought that occurred in 2009 was described as the worst drought in more than 50 years (Mandleni, 2011).

Annual rainfall distribution has experienced some changes in that average rainfall has decreased to below the normal levels, which is perceived to be a direct result of an increase in annual evapotranspiration, which could exceed annual precipitation, by a ratio of up to 20:1.This explains the reason why droughts tend to be on the rise (Schulze, 1997). Previous studies have shown that average annual rainfall has been declining over the years, whilst average temperatures have been increasing in the Eastern Cape, (Mandleni, 2011; Davis, 2010).

The increases in water demand is mainly due to agricultural, industrial and domestic uses, but agriculture far surpasses the other two. What exerts more pressure on South African water resources is that only 9% of its rainfall reaches the river streams, which is lower than the average of 31% from the recorded rainfall data around the rest of the world (DWAF, 2002). A number of man-made modifications have been done on rivers worldwide (Postel, 2000), with South Africa being no exception. Based on the nature of water resource availability in South Africa, the government and the private sector have constructed a number of water reservoirs/dams to ensure sufficient water supplies for anthropogenic use (Palmer and O'Keeffe, 1990; Davies and Day, 1998; King *et al*., 1999; Ashton, 2007). According to the Water Research Commission (WRC) the

South African government has constructed more than 500 dams with a total of 37 000 million cubic meters storage capacity (WRC, 2007). These dams have resulted in natural river flow obstruction (Palmer and O'Keeffe, 1990; Postel, 2000; Revenga *et al*., 2000), water physical-chemistry and ecosystem alterations (Palmer and O 'Keeffe, 1990; Davies and Day, 1998).

Recurring extreme weather events are on the rise throughout the world and are expected to continue increasing in the future if no measures are taken to reduce the greenhouse gasses (Easterling *et al*., 2000). Prolonged droughts and periods of heavy downpours that cause flash floods are expected to be frequently experienced in the near future. For example, extreme rainfall events in Elliot Town were experienced in the months of February and March of 2014. According to AgriSA (2006) the number of areas in South Africa that are affected by extreme drought and excessive rains are increasing. The most affected areas are those with poor infrastructure, especially in marginal areas that are more fragile and subjected to natural disasters, where most people live. These extreme climate related events have caused high economic costs to the South African government. Climate related disasters do not only affect water availability, but also result in food insecurity as agriculture production is negatively affected. The most vulnerable are always the poor as they do not have the means to deal with the negative effects of drought and flooding.

2.4. Current Impacts of Climate Change

The expected impact of climate change and variability on agriculture will mainly be due to trends such as the ever-increasing population, which in turn depends on agriculture (Thomas and Twyman, 2005). Desertification and the reduction of agricultural land have led to the reduction of agricultural production, which in turn has adversely affected the livelihoods of households as people go with less food than they require.

The relationship between climate and farming activities should be well understood in order to achieve significant sustainable economic growth especially in developing countries where resources are insufficient for people to adapt. Poor countries do not also have enough technologies to develop tools like early warning systems (IPCC, 2007). In most cases, smallholder farmers and are the most affected due to constrained adaptive capacity. As extreme weather events are expected

to increase in future and yet the current levels of understanding of smallholder farmers on climate systems is still low, the impacts of climate change and variability could be dare. This will negatively affect the farmers' level of production leading to increased food insecurity at both household and national levels. Elliot Town and its surrounding areas, being a farming community, are found to be very vulnerable to the impacts of climate change.

Climate change and variability are having major impacts on smallholder farmers by adversely affecting ecosystem services which smallholder farmers depend on. According to Nhamo and Chilonda (2012) there are going to be many changes that will affect the whole agricultural production system. This in turn will have an effect on developmental programmes, which depend agriculture as the economies of most developing countries depend on agriculture.

As identified by Bockel and Smit (2009), climate change leads to a rise in temperature and a decrease in precipitation. The rise in temperature results in increased evapotranspiration, thereby affecting water supplies and crop yields. Crop production levels will greatly be affected and water quality will be reduced which will affect revenue to a great extent. Crop farmers suffer the consequences of climate change because of drought and flooding. This in turn leads to low income generation, job losses and food insecurity as farming is the main source of income and food for smallholder farmers. They will find it very difficult to maintain their infrastructure and some farmers will end up moving to other areas opening up new farms leading to more and more vegetation being destroyed. (Nhamo and Chilonda, 2012).

Ecological niches will also be affected by climate change due to the unpredictability of amount and time when the rainfall will come. Living organisms will therefore have to change their dwelling places in search better environments (Davis *et al*., 2010). Farmers are thus faced with a very difficult situation in such circumstances as they are forced to move their livestock around so often. Adapting to new environments is always a challenge.

Some of the effects of changes in rainfall and temperatures already evident in South Africa include: (a) a reduction in the amount of crops produced because of very little rainfall which leads to

changing agricultural practices thus affecting the economy of the farmers (Midgley *et al*, 2011), (b) increasing temperatures lead to the high rate of evaporation causing water scarcity (UNECA, 2006), (c) higher temperatures are causing the spread of pests and diseases, for example, the high frequency of armyworm and locusts invasion (IPCC, 2007; Patz *et al*., 2003), (d) water availability in rivers, dams and lakes is increasingly diminishing due to the net effect of increased temperatures and evaporation (Davis, 2010), (e) there are increased occurrences of floods as the incidence of sudden heavy rainfall events is increasing (Midgley *et al*, 2011; Hunter, 2003), and (f) there is an increase of water pollution and a decrease in water quality linked to erosion and high rainfall events, which increase the presence of sediment and nutrients in water bodies (Davis, 2010).

Figure 0.1: Part of Slang River as it approaches Thompson Dam
Picture taken in May 2015

Figure 2.1 shows part of the Slang River as it is about to enter Thompson Dam which supplies Elliot Town with water. The Slang River has its source on the Lower Drakensburg Mountains and after about 3 km from the foot of the mountains the Thompson Dam was built.

2.5. Summary

Previous studies have shown that climate change is perceived in terms of extreme heat, droughts and flooding which come at unexpected periods of the year, and resulting in disasters. In addition, it has been perceived in the form of declining rainfall patterns and reduced rainfall season. Water sources have been seen drying up to the detriment of the population and the farming community in its entirety. Perceptions have also been in the form of a rise in sea-level, incidences of cyclones and increased pollution. All these observations show that climate change/variability has been happening and has been acknowledged and endorsed by many countries of the world.

Climate change and variability impacts have been felt strongly in developing countries, bringing social and economic instabilities. It has negatively impacted consumer welfare and household economies. The extreme heat and excessive rains have impaired economic activity such as farming and domestic activities mainly because the economies of developing countries are agro-based. The most undesirable aspect about climate change and variability is that it has been noticed to affect the poor because they lack the resources to quickly adapt to change. The negative impacts of climate change and variability are already being felt in and around Sakhisizwe Municipality.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapters covers the Research Methodology and Design which encompass the methods and techniques by which data were collected, analysed and evaluated. It includes the sources of data used as well as the sample size used. Included in this chapter are the research design, data analysis techniques and also issues related to ethics in research. The triangulation research methodology was used to collect data in this study. The triangulation research method is a plan of action that combines methods from different paradigms and methodologies (Olsen, 2004). According to Babbie and Mouton (2001) it is one of the best ways of enhancing validity and reliability in qualitative research. In this study phenomenology as a meta-theory was applied to explain and understand the dynamics and complexities of human nature as they build their livelihood portfolios in relation to climate change. Structured interviews, observation, images, ethnography, random and stratified sampling techniques were used to effectively conduct the research. Multivariate data analysis techniques, ethnography and use of tables were other techniques used in collecting, coding, analysing and interpreting data.

3.2 Research Design

Kumar (2005) defines research as a plan, structure and strategy of investigation that is so conceived to obtain answers to research questions or problems. On the other hand, Shafeek (2009) describes research as a design viewed as a set of fundamental beliefs in a worldview, which delineates the nature of the world, and the individual's place in it. It also takes note of the variety of probable relationships to that world for an individual. Hofstee (2006) contends that in the research design section the researcher should name and discuss the overall approach to be used to test the research statement.

This study used a combination of research methods which include both quantitative and qualitative. A mixed research method according to Johnson *et al*. (2007) is the type of research that combines aspects of qualitative and quantitative methods for the broad purpose of

comprehension and validation. This research design included a field or natural experimental study. Experimental research is concerned with cause and effect relationships that are expressed in different variables (Sheehan, 1986).

The data for the study were collected during a field study from May to October 2013. Analysis of rainfall and temperature data was carried out to assess climate change and variability over time and measure the physical and socio-economic impacts with reference to the water resources in Sakhisizwe Municipality population and agriculture production were analysed in order to identify the impacts of climate change and variability on the lives of people in the municipality.

The climatic data from meteorological stations covering different areas of the Sakhisizwe Municipality were collected from the South African Weather Services. The selection of the sample area for the study was based on the data availability and the study requirements. The Slang River and the Thompson Dam were the main focus of the study as they influence the Sakhisizwe Municipality and Elliot Town in particular. This research included a field or natural experimental study (Mouton, 2001). Experimental research is concerned with cause and effect relationships that are expressed in different variables (Sheehan, 1986).

3.3 Data collection and sampling

3.3.1. Collection Techniques

Of the many methods of data collecting suggested in literature a questionnaire with interviews schedule is one of the most effective as it allows information gathering from the ground. The questionnaire has to be designed prior to the interview itself. De Vos (2005) defines a questionnaire as a set of questions on a form or template which is completed by the respondent in respect of a research project. In this study, the researcher made use of both questionnaires and personal interviews, which allowed face-to-face interactions, lasting only a few minutes. The face-to-face interviews were done for saving time, as some farmers were unwilling to respond to the questionnaires.

De Vos (2005) states that the questions should be well formulated, revised and be deemed to be clear and easy to be understood by the respondent. This is because the respondent will have to work independently and should spend a lot of time on the questionnaire as it might make him/her lose interest in taking part in the research. This ensures that errors are rectified at little costs. No matter how effective the sampling or analysis of the results, ambiguous questions lead to non-comparable responses, leading to biased responses and vague questions lead to vague answers. According to Babbie and Mouton (2001), the interviewees should only complete the questionnaire rather than to read through long and erroneous statements that are difficult to understand. Clear and precise questions are therefore important to avoid vague responses. Mbonyane (2006) stresses the importance of pre-testing the questionnaire to identify areas of the research tool that need changes.

The principal instruments used to collect data were interviews (both one-on-one and questionnaires), and also collection and downloading from the internet. People of different races, nationalities, economic backgrounds, religious beliefs and varied political persuasions inhabit Elliot. The multi-racial/cultural/economic nature of the town makes it such a complex community, which needs some exclusive techniques when collecting data depending on the group of individuals being approached. Permission was sought from the municipality to interview the residents. The permission was in written form that was shown to residents before the interview.

Semi-structured questionnaires were designed and distributed to people in the public and private organizations, employees, employers and residents from both high and low density areas. The researcher distributed the questionnaires himself. Questions for the interviews were set in such a way that they take into cognisance the different scholarly levels of the intended interviewees. These questions were therefore prepared in simple language and explicit enough to give very brief and concise answers to avoid occupying people for too long. These questionnaires helped establish the residents' assessment of the fresh water availability over the past 20 to 30 years or as long as they have leaved in Elliot. This helped the researcher understand the impact of climate change on domestic water supplies. Shot direct interviews were held with large commercial and small scale

farmer representatives to find out their perceptions about the impact climate change has had on the water resources for livestock and crops.

The researcher also liaised with Weather SA and accessed historical records of both temperature and rainfall in time series. Historical water quality data was obtained from the Department of Water and Sanitation (DWS) and from the municipality records. Farmers and farmer organisations also provided data on agriculture production. Some of the data was also downloaded from reliable data sites such as FAO and World Bank database.

3.3.2. Sampling Techniques

Sampling is the technique used to identify a subset of the population which is representative of the entire population in the process of data collection. Strydom (2005) defines a sample as some elements of the certain population, which are selected for performing a desired study. It can also be described as a subset of measurement drawn from the population in which the study is interested.

There are two main methods for sampling which are known as probability and non-probability. This study used probability sampling. Tustin *et al.,* (2005) define probability sampling as a plan in which every member of the population is accorded a chance of being included in the sample. They further define non-probability sampling as those instances in which the chances of selecting members from the population in the sample are unknown. It is a subset of measurements drawn from a population that is being focused and targeted by the study in question Strydom (2005). In this study, weather stations in Sakhisizwe Municipality were selected, bearing in mind the availability of the required historical data for a period of 30 years. This sample was done to cover a broad spectrum of the entire Sakhisizwe Municipality in order to assess and appreciate how temperature and rainfall have been changing over the years. This analysis made it possible for the evaluation of the impact of climate change on water resources and agricultural production in the Sakhisizwe Municipality. An analysis of past trends in rainfall and temperature allowed to project into the future of how these climatic factors will be like. This trend analysis was done using statistical packages and spreadsheets.

3.3.3. Sampling error

According to Gray, (2006) a common cause of error in sampling depends with the sampling frame. It is important to ascertain that all the relevant data is collected and to remove all irrelevant information, which does not answer the objectives of the study. This process is called under-coverage if some important data is left out and over-coverage is when unnecessary data is included. The members in the sampling frame have to be easily identifiable to avoid under-coverage or over-coverage.

3.4 Data sources

In this study data was collected through interviews with the residents of Elliot Town and the farmers around Sakhisizwe Municipality. Municipal employees were also interviewed to give their views and perceptive on the impact of climate change on the Sakhisizwe Municipality. Water quality data was collected from the municipality records and the Department of Water and Sanitation (DWS). Temperature and rainfall data was obtained from Weather SA and also from the Food and Agriculture Organisation of the United Nations (FAO) website. Data on agriculture production was obtained from the local Department of Agriculture, Forestry and Fisheries (DAFF) and Stats SA. Geographic Information Systems (GIS) and remote sensing techniques were used as sources of data in land use change detection. Some important information like runoff, erosion and historical data was obtained from literature.

3.4.1. Fieldwork

According to Sumbulu, (2010) fieldwork is part of research where a researcher leaves deskwork to enter the real world to collect data and for ground truthing. Interviews were conducted as part of fieldwork and ground truthing was done to verify what was obtained from remote sensing. Frequent visits to the Thompson Dam and the Slang River gave the researcher an insight of the quality of water in the river and the dam.

3.4.2. Data Coding

According to Gibbs and Taylor (2010), the process of data, coding is one, which involves combing the data for certain themes, ideas and categories and then marking similar passages of text with a code label so that they can easily be retrieved at a later stage for further comparison and analysis.

In this study, data was coded using themes that emerged from the findings and stored in spreadsheets and GIS packages.

3.5 Study Methodology

Past and current rainfall and temperature patterns and trends in Sakhisizwe Municipality of the Eastern Cape, South Africa, were analysed and the impacts of those changes on crop production in the context of climate change and variability were evaluated. An analysis of the trends of climatic factors is made in order to make a projection on future crop production in the municipality. An analysis of current vulnerability of the communities in the municipality to climate variability and a discussion of the projected impact of climate change and variability on crop production and water availability are made. Trend analysis is used to analyse temperature and rainfall data patterns, as well as the trends in crop production recorded for the past 30 years. A projection on levels of crop production in the next 20 years is made. Correlations are used to confirm the relation between climatic factors, renewable water resources availability and crop production. Geographic Information Systems (GIS) is used for spatial analysis to explain these trends. The study provides a comprehensive assessment of the municipality's water and food security challenges as they are related to climate change.

Both *in-situ* and remote sensing measurements of precipitation and evapotranspiration have limitations and are often combined to give a better estimate. Because of these issues with measurement, and the spatial limitations of historical data sets, a number of variables were used to examine the consistency of changes in precipitation. Local farmers and the residents in general confirmed have observed changes in the amount, intensity, frequency and type of precipitation in Elliot and surrounding areas. From interviews and observations by the researcher there have been increases in flash floods, even occurring where total amount of rainfall has been low. These are some of the changes caused by climate change. As temperature increases, the moisture-holding capacity of the atmosphere increases at a rate of about 7% per 1°C (Kundzewicz *et al*., 2007). It is estimated that atmospheric water vapour increased by about 5% over the oceans in the 20th century (Trenberth, 2011).

According to Turpie *et al*., (2002), water resources that are modelled using the ACRU hydrological modelling system in South Africa show considerable shift in hydrological functioning due to changes in rainfall and temperature patterns. Changes in rainfall patterns have an effect on the hydrological cycle and the precipitation changes have a direct impact on the runoff. (Kiker, 2000). However, particularly where total precipitation is decreasing, increases in the intensity of precipitation will correspond with longer dry periods between rainfall events. In addition, as temperature rises, precipitation is more likely to fall as rain rather than snow. This is especially true at the beginning and end of the snow season. The impact of rising temperatures on snowfall will affect the seasonality of river flows, particularly where snowfall is already more marginal. In many cases, peak flow would occur at least a month earlier (Bates *et a*l., 2008). In the near future, there will be an increased demand for groundwater, as people would need water for irrigation. This is also likely to be a result of reduction of surface water availability because precipitation has been highly variable, making it very difficult to predict the seasons. Groundwater levels are bound to be affected the same way as the rate of groundwater recharge is affected and this all is because climate change. A warmer climate, with its increased climate variability, will increase the risk of both floods and droughts (Wetherald and Manabe, 2002). This is the most likely scenario in the Sakhisizwe Municipality.

3.5.1. Analysis of Rainfall Trend

A study of past rainfall trends helps better understand how present rainfall patterns and totals differ from those historical patterns and assist in perceiving the changes that have been taking place along the years. An analysis of trends and fluctuations in past observed rainfall data gives indications of the direction and magnitude of possible future changes. In this study an analysis of rainfall records observed over the past 30 years from 1980 to 2010, was carried out to understand its pattern and trend in Sakhisizwe Municipality. The past rainfall trend provides the basis for projection of future rainfall changes and patterns.

Recorded rainfall and temperature data from stations in the municipality (shown in Figure 1.1) were used to calculate average annual rainfall and mean monthly temperature of the municipality. The average annual rainfall and monthly temperature of the stations was calculated for the years 1980 to 2010 and the results used to plot graphs showing rainfall and temperature trends and

patterns in the past. The calculated averages were also used to create continuous rainfall and temperature surface maps for the years 1980, 1990, 2000 and 2010 through interpolation in GIS. The interpolation of annual rainfall temperature totals for different years was done to understand spatio-temporal changes in rainfall patterns in the municipality during the past 30 years, with an aim of developing adaptive measures to alleviate the impact of climate change. The inverse distance weighting (IDW) interpolation method was used to create the continuous surface rainfall and temperature maps. The IDW interpolation method has been widely and successfully used in spatial rainfall and temperature distribution studies in many parts of the world (Watts and Calver, 1991; Childs, 2004; Lu and Wong, 2008; Chen and Liu, 2012).

3.5.2. Calculation of the Area Weighted Average Rainfall

The area weighted average annual rainfall was calculated using the Thiessen's Polygon method. Thiessen's polygon relates each point in the municipality with the nearest weather station. The process tessellates the municipal area into regions that are closer to a particular. To average rainfall values in the created Thiessen polygons, the polygons are intersected with the municipal map in GIS to calculate the area weighted average. The weighted average rainfall is calculated using Equation 3.1 as follows (Perry and Hollis, 2005; Garcia *et al*., 2008):

$$P_i = \frac{\sum_k A_{ik} P_k}{\sum_k A_{ik}} \qquad [3.1]$$

where, P_i is the municipal weighted average rainfall in *mm*; P_k is the rainfall associated with each weather station in *mm*; and A_{ik} is the area of intersected polygon associated with weather station k and municipality i in m^2.

3.5.3. Evaluation of the Climatic Moisture Index

The degree of aridity of Sakhisizwe Municipality was estimated using the Climatic Moisture Index (CMI). The CMI is an index of the relative dryness or wetness of an area, and it defines the water stress or scarcity (aridity) of a place. It is based on the combined effect of temperature and precipitation as it is linked to soil moisture, and therefore it is correlated with potential evapotranspiration. The CMI is calculated based on the methodology developed by Willmott and

Feddema (1992), using the ratio of annual precipitation (P) to annual potential evapotranspiration (PET), as indicated by Equations 3.2 and 3.3:

$$\mathrm{CMI} = \frac{\mathrm{P}}{\mathrm{PET}} - 1, \text{ when } \mathrm{P} < \mathrm{PET}, \text{ and} \qquad [3.2]$$

$$\mathrm{CMI} = 1 - \frac{\mathrm{PET}}{\mathrm{P}}, \text{ when } \mathrm{P} \geq \mathrm{PET} \qquad [3.3]$$

The index ranges from –1 to +1, with wet climate showing positive CMI and dry climate negative CMI. The CMI is an aggregate measure of potential water availability imposed solely by climate. Just like average rainfall for each country, the potential evapotranspiration (PET) of each country was calculated from data recorded from weather stations within the municipality and the results interpolated to create a continuous PET surface. The Thiessen's Polygon method was then used to calculate the area weighted average PET for the municipality. The PET and eventually the CMI was calculated for 1980, 1990, 2000 and 2010. The results were then used to assess the aridity of the municipality.

3.5.4. Runoff Estimation

Average runoff (in mm) for the municipality was estimated using annual average rainfall data and the relationship between rainfall and runoff obtained from FAO (2000) and Ashton (2002) as shown in Figure 3.1. Average annual runoff is important in water balance studies, water resource assessments and the planning and allocation of the available water resources. Expressed in depth unit, average annual runoff indexes the volume of flow in rivers per unit area of contributing basin. Runoff is, therefore, the major source of water for reservoirs. Runoff is estimated to give indications on the potential of rainfall to recharge reservoirs and to understand its trends over the years.

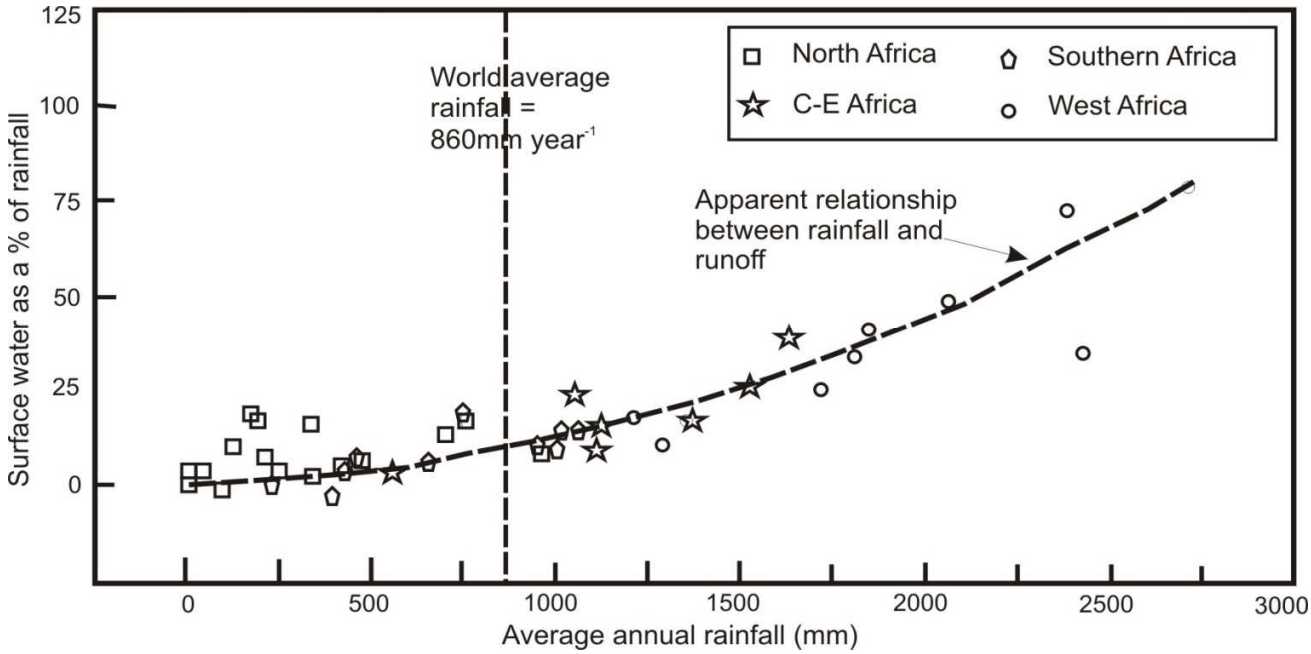


Figure 0.1: Comparison of surface runoff (expressed as a percentage of annual rainfall) versus average annual rainfall for mainland African countries. Data taken from FAO (2000)
Adopted from Ashton (2002)

3.5.5. Qualitative Research

Qualitative research is defined by Mboyane (2006) as the research that focuses on people's lives, their experiences, behaviours, emotions and feelings as well as organisational functioning, social movements, cultural phenomenon and interactions between nations. It also seeks a better understanding of complex situations, and it is often explanatory in nature and the observations are used to build theory from the ground up. It attempts to accurately describe, decode, and interpret the meanings of phenomenon occurring in their normal context. In this study sample, data was collected using direct observations and interviews. Then it was analysed using graphs, as it is deduced from narratives and individual quotes of the interviewed and observed subjects.

3.5.6. Quantitative Research

Quantitative research is an investigation of a phenomenon by testing a theory that can be measured numerically and analysed statistically Shafeek (2009). The explanations and predictions that are used to establish, confirm, and validate relationships and develop generalisations that contribute

to theory and thus sought and given. Neil (2007) states that the major strength of quantitative research is that measurement is reliable, valid and can be generalised.

This study was both qualitative and quantitative in nature as semi-structured questionnaires and semi-structured in-depth interview schedules were used in the collection of data. Questionnaires were self-administered with closed and open-ended questions covering the following areas; knowledge about climate change, understanding of the consequences of climate change, recommendations and opinions on how to overcome the impact of climate change. Quantitative data was analysed using Hydrostat method. Age, gender and economic activity status were analysed quantitatively. Descriptive data has been presented using graphs.

3.5.7. Use of Geographic Information Systems and Remote Sensing

Remote Sensing and Geographic Information Systems (GIS) provide a mechanism to locate, view and analyse a physical process on earth for spatial analyses without being in contact with the object of interest (Holcombe *et al*., 2007). These novel tools have revolutionised spatially based analysis as processes can be studied in real time, especially when combined with Global Navigation Satellite Systems (GNSS) such as Global Positioning Systems (GPS) (Vairavamoorthy *et al.*, 2006). GIS was use for data inventory and query, spatial analysis and decision-making. The capability of GIS to integrate various forms of data and store relationships between features and their locations and attributes facilitated the trend analysis and change detection in this study. Combining these functions with modelling tools enabled the conversion and analysis of large amounts of information and then into knowledge that is useful in mapping. GIS and remote sensing were used to store and analysis, create maps and compare trends over time. They were also used in landuse change detection.

3.6 Ethical considerations

Ethics guarantee some respect for people, their rights, privacy, integrity etc. (Sheehan, 1986). To ensure ethically acceptable research and to adhere to UNISA's policy on Ethics, the research proposal was approved by the Ethics Committee. The study was dependent on the use of human subjects for completion. An ethical treatment of research participants is not only essential for the welfare of the individuals themselves but also for a continued effectiveness of scientific discipline

(Stangor, 2007). The ethical aspects need to be considered at all times in order to ensure a successful research (De Vos, 2005).

3.6.1. Confidentiality

A high degree of confidentiality was exercised so as to keep any information supplied that is not for public consumption confidential. No data collected from a particular source was and will have to be shared with any third part without prior arrangements and agreement with the particular source.

3.6.2. Informed consent

All the respondents to the interviews willingly participated and freely answered all the questions they were asked without any cohesion or being compelled. They were made aware about what they were doing and why they were doing it and also that the information they were supplying was solely to be used for scholarly purposes and in the end of the research, it may be used for the benefit of their service providers for the improvement of their livelihoods.

De Vos (2005) states that obtaining informed consent is that the information gathered on the goal of the investigation, the procedures which will be followed during the investigation, the possible advantages, disadvantages and dangers to which respondents may be exposed, as well as the credibility of the researcher, be rendered or availed to potential subjects or their legal representatives.

3.6.3. Limitations

Due to the size of the area under studied and the scarcity of data, there were some limitations in the full implementation of the desired methodology. In some cases, the researcher had to rely on data downloaded from the internet and from a few interviewed people. Rainfall and temperature data obtained from Weather SA had gaps and had to be supplemented with records from Food and Agricultural Organisation of the United Nations (FAO). Some of the targeted respondents found it a challenge to understand the concept of climate change and variability and as such would need more time with the researcher who would try to explain to them until they understood. This was indeed a great challenge as the researcher would also be fully committed at work to get a slight chance to focus on the demands of the study.

3.7 Summary

The methods and techniques of data collection, analysis and evaluation were direct interviews through the administration of questionnaires and from relevant organisations like Weather SA, Municipality offices and National Aeronautics Space Agency (NASA). The sources of data used ranged from direct observation to analysis of data provided by the Weather SA, Sakhisizwe Municipality and data gathered from the internet. The triangulation research methodology was also used to collect data in this study. In this study phenomenology as a meta-theory was applied to explain and understand the dynamics and complexities of human nature as they build their livelihood portfolios in relation to climate change. Structured interviews, observation, images, ethnography, random and stratified sampling techniques were used to effectively conduct the research. Multivariate data analysis techniques, ethnography and use of tables were the other techniques used in collecting, coding, analysing and interpreting data.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Introduction

This chapter presents results of how climate change and variability are affecting the water resources of Elliot Town in the Eastern Cape and the rest of Sakhisizwe Municipality. The whole of Sakhisizwe Municipality is the town's catchment area. The results of the data analysis as well as the effects on agriculture production are presented. The results are then used to profile climate change impacts and the adaptive strategies that can be taken to alleviate those impacts. Such profile can be used as an early warning system by policymakers and other stakeholder in case of an occurrence of a climate change and variability induced shock. The developed early warning system can be exported to other areas in the country to alleviate climate change impacts.

4.2. Rainfall Pattern and Trend in Sakhisizwe Municipality

A study of how rainfall has been changing in the past helps better understand how it may change in the future. An analysis of trends and fluctuations in past observed rainfall data gives indications of the direction and magnitude of possible future changes. In this study an analysis of rainfall records observed over the past 30 years, i.e., from 1980 to 2010 (for spatial distribution maps) and from 1983 to 2012 (for graphs), was carried out to understand its pattern and trend in Sakhisizwe Municipality. The past rainfall trend provides the basis for projection of future rainfall changes and patterns. Recorded rainfall data from rainfall stations in the municipality was obtained from South Africa's Weather Bureau (Weather SA) were used to calculate average annual rainfall of the municipality. The average annual rainfall of the stations was calculated for the years starting from 1980 to 2010. The results of the rainfall data analysis were used to plot graphs showing rainfall trends and patterns in the past, a projection of possible trends, as well as to create spatial distribution of rainfall maps.

The calculated annual rainfall totals were used to create continuous rainfall surface maps for the years 1980, 1990, 2000 and 2010 through interpolation. The interpolation of annual rainfall totals for these 10-year periods was done to understand spatio-temporal changes in rainfall patterns in

the municipality during the past 30 years, with an aim of developing adaptive measures to alleviate the impact of climate change and variability. The inverse distance weighting (IDW) interpolation method was used to create the continuous surface rainfall map using GIS.

4.2.1. Rainfall Pattern and Trends

Figure 4.1 presents the rainfall pattern of Sakhisizwe Municipality from 1983 to 2012. The average monthly rainfall was calculated from data recorded at weather stations in the municipality. The graph was derived from rainfall data calculated through the area-weighted average from weather stations in the municipality using the Thiessen's Polygon method. The rainfall pattern indicates that rainfall is highly variable in the municipality and the variability has been intensifying in the last three decades.

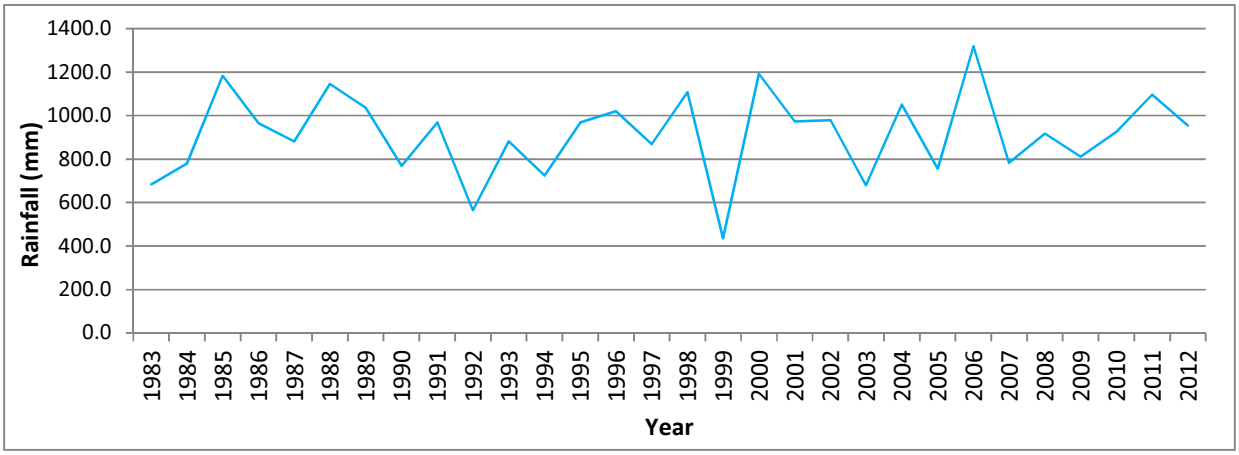


Figure 0.1: Change and variability of rainfall in the Sakhisizwe Municipality

The graph presented in Figure 4.1 indicates that rainfall variability in the municipality has been intensifying in the last few years with some years showing some very high peaks and lows, resembling the extreme climatic events such as floods and droughts respectively. The frequency of droughts and floods is also very high. The annual rainfall pattern shown in the graph shows that total annual rainfall in the municipality has been slightly decreasing as there is a slight descent in the shape of the graph from 2001 to 2012, but the decrease is almost insignificant showing that the municipality is more affected by climate variability other than climate change. The high incidence of drought and flooding is causing water scarcity and poor water quality in the municipality. At times heavy downpours occur within a short period causing floods. Rainfall variability is causing

the rain season to become unpredictable affecting agriculture. It is therefore necessary to harvest runoff to use during the dry spells and during the dry season through for irrigation.

Using the rainfall trend line shown on Figure 4.2, it is envisaged that in the next 20 years (by 2032) rainfall averages in the municipality will remain almost the same, between 900 and 1 300 mm per annum, but with high incidences of floods and droughts. The R-squared value is 0.0079, which is a good fit of the line to the data.

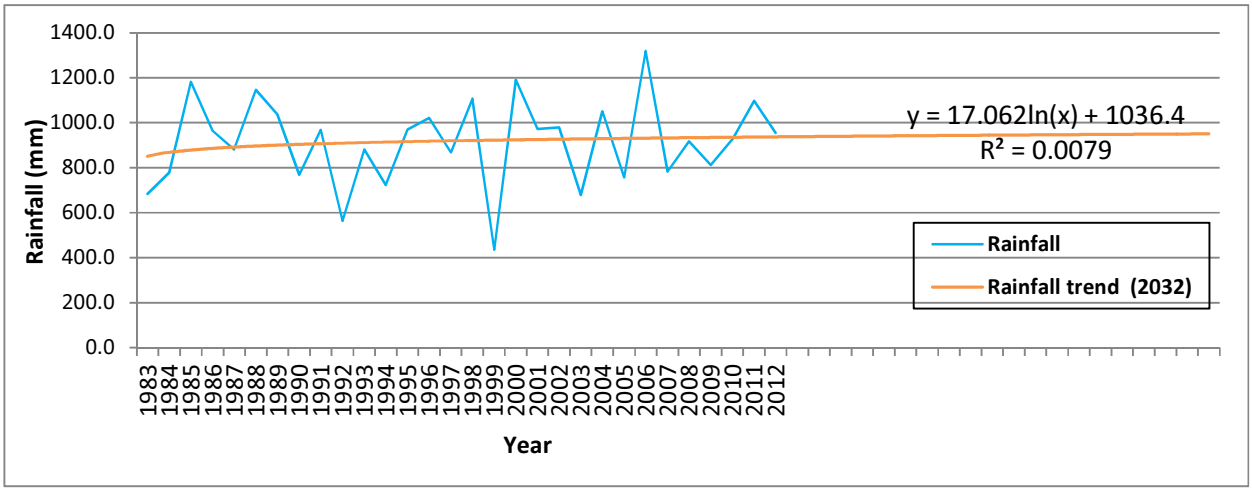


Figure 0.2: Rainfall trends in Sakhisizwe Municipality until 2032

Therefore, in terms of rainfall patterns and trends, climate change has no much effect in Sakhisizwe Municipality. Nevertheless, the intensity of rainfall variability is expected to increase causing high incidences of flooding and drought. From the results of interviews done with the local community, it is noted that at times there are heavy downpours within a short period that cause floods. Moreover, in most cases when such heavy downpours take place and there are floods, the rain season is shortened. Also there are incidences of droughts like the one that was experienced in 2010 and described as the worst drought in more than 50 years (Mandleni, 2011).

4.2.2. Spatial-temporal Changes in Rainfall Distribution over Time

The spatial distribution of annual rainfall in 1980, 1990, 2000 and 2010 in the municipality is shown in Figure 4.3 as a, b, c & d respectively. The maps were created using Thiessen's Polygon method. The IDW interpolation method was used to produce the maps shown in Figure 4.3 where changes in rainfall patterns and variability between 1980 and 2010 are observed

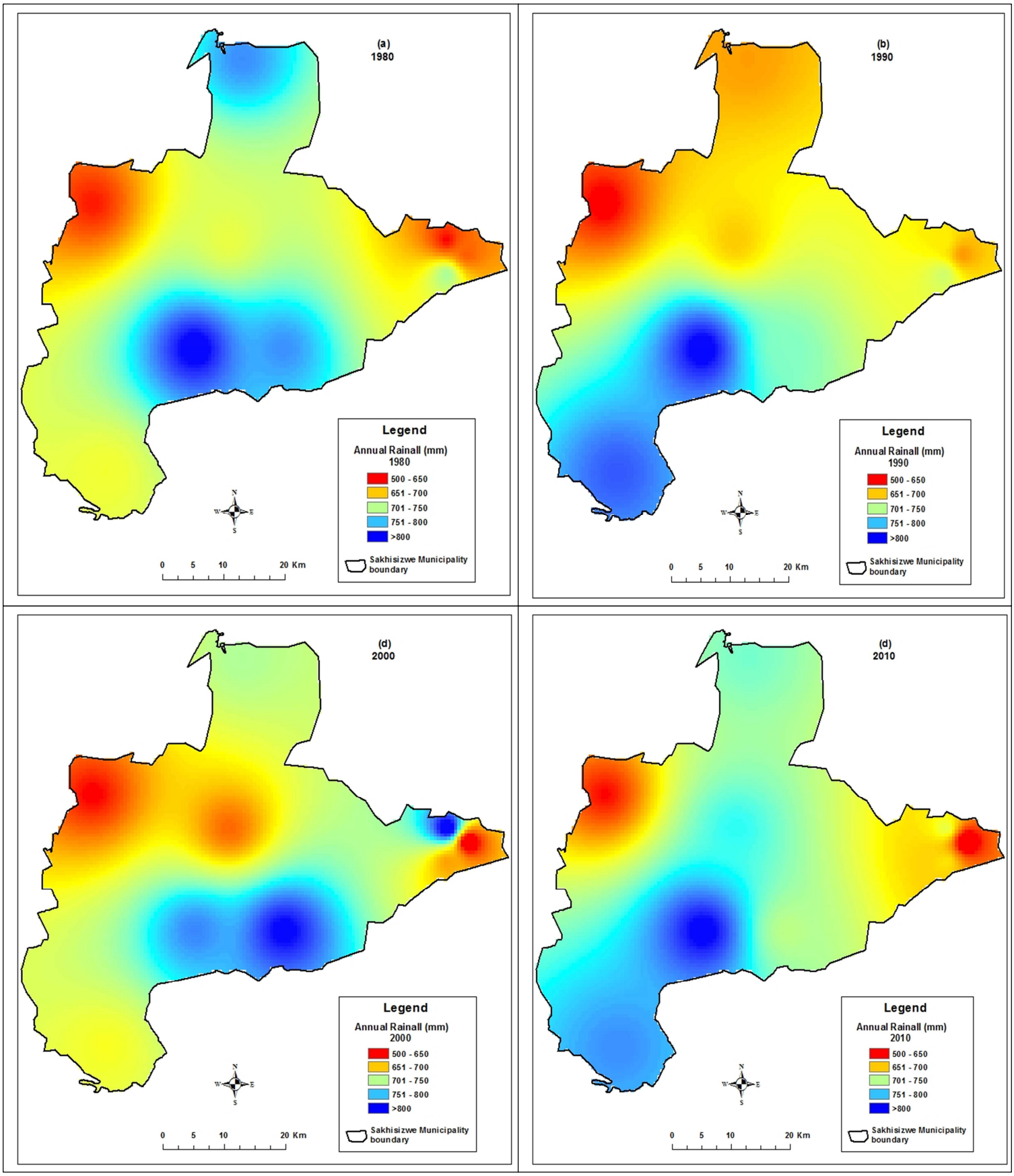


Figure 0.3: Spatio-temporal rainfall distribution in the Sakhisizwe Municipality between 1960 and 2007

The maps shown on Figure 4.3 show insignificant changes in rainfall patterns in the municipality during the 4 decades presented. The spatial distribution of rainfall for the past 30 years has been variable showing minor shifts in areas receiving high and low rainfall, but generally, the rainfall amount shows little changes. Perusal of Figure 4.3 (d) which represents the rainfall pattern of 2010 indicates high rainfall amounts have shifted to the south, a similar trend with the one presented by map (b). Maps (a) and (b) are also showing similar characteristics in rainfall distribution indicating that the spatial distribution of rainfall may be variable but the trend repeats itself.

Therefore, an analysis of Figures 4.1 and 4.3 indicates that rainfall amount in Sakhisizwe Municipality has not been declining over the years but it has been highly variable. However, combined with evidence from interviews and rainfall data analysis and as shown in Figure 4.1 the incidence of flooding and drought has been occurring with high frequency in recent years. These impacts of climate variability have therefore, been affecting the water quality and its availability in the municipality. Flooding affects water quality and drought affects water availability.

4.2.3. Water Quality in Sakhisizwe Municipality

Figure 4.4 shows some filters that were taken from a water purification shop of a local business man who after realising that the water consumed by Elliot residents is of poor quality decided to start up a water purification project. Water from the municipality reservoirs destined for human consumption is collected from household taps and then filtered through Filters 1, 2 & 3.

Figure 0.4: Domestic water quality as it passes through different stages of the purification process

At stage 3, the water is clean enough for human consumption. Filters 1 & 2 indicate the poor water quality drawn from the taps as is shown by the colour of the water. However, after being purified

through the three filters the quality improves and it is ready for human consumption. Many residents consume the water directly from the taps without removing all the mud evident on filters 1 & 2 shown in Figure 4.4, as they cannot afford to buy the purified mineral water.

4.3. Temperature Pattern and Trends in Sakhisizwe Municipality

Just like rainfall, a study of how maximum and minimum temperature have been changing in the past helps better understand how it may change in the future. An analysis of trends and fluctuations in past observed temperature data gives some indications of the direction and magnitude of possible future changes. An analysis of maximum and minimum temperature records observed over the past 28 years, i.e., from 1985 to 2013 was done to understand their patterns in the municipality to understand how they are affecting water resources. The past temperature trends provide the basis for projection of future changes and patterns. The recorded temperature data is used to plot graphs showing how temperature has been changing in the past

4.3.1. Maximum Temperature Pattern and Trends

The graph on Figure 4.5 shows the pattern and trend of maximum temperature in Sakhisizwe Municipality from 1985 to 2013. Just like rainfall, maximum temperature has been highly variable along the years, however showing an increasing trend in recent years. The projection line shown in Figure 4.5 indicates that maximum temperature has been increasing along the years and by the year 2032 it is projected to increase to an average of 23.8ºC, yet the average in 1985 was 22ºC. The projected warmer temperatures will favour the opening of more land for cultivation as the land that is normally covered by snow will become suitable for agriculture. The increase in temperatures will also trigger more high intensity rainfall that causes floods. However, the floods will continue affecting the quality of water affecting its consumption by residents and for other uses. The increasing maximum temperatures will also result in increasing evapotranspiration. The demand for water is bound to increase with increasing urban population and cultivated land. The increase in the demand for water by humans and for agriculture, coupled with rainfall variability and increased evapotranspiration, will worsen the problem of water scarcity in the municipality.

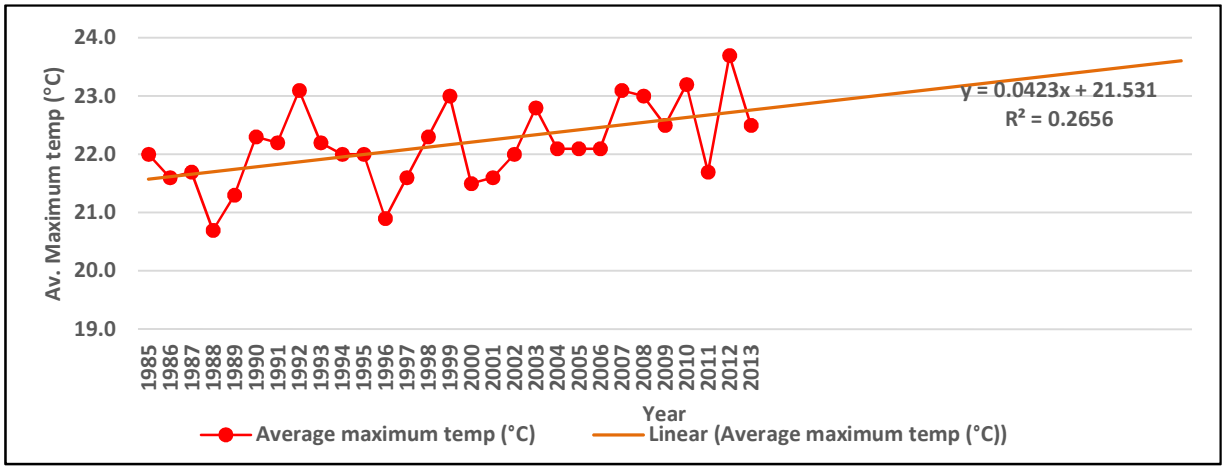


Figure 0.5: Average annual maximum temperature pattern and trend in Sakhisizwe along the years

4.3.2. Minimum Temperature Pattern and Trends

Figure 4.6 shows the pattern and trend of minimum temperature in Sakhisizwe Municipality from 1985 to 2013. Unlike maximum temperature and rainfall, which are highly variable, the average minimum temperatures in the municipality have maintained constant minimal variations along the years. The minimum temperature trend and projection has been following the same pattern since 1985 to present averaging around 6.9°C. However, there were 2 exceptional years, 2006 and 2012, that showed averages of 8°C. The variations, however, do not cause any significant impact on the availability or variability of rainfall. The projection trend-line of Figure 4.6 indicates that by 2032 the average minimum temperature in the municipality will remain the same, 6.9°C. Minimum temperature will therefore, have an insignificant impact on water availability in the Sakhisizwe Municipality in the near future.

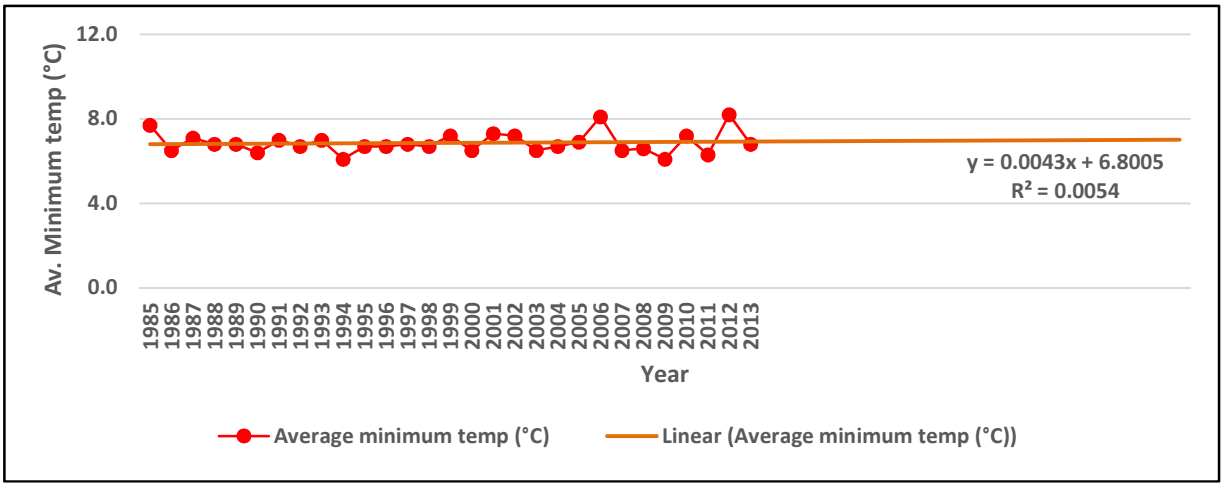


Figure 0.6: Average annual minimum temperature pattern and trend in Sakhisizwe along the years

4.4. Impact of Climate Change and Variability on Agriculture

4.4.1. Correlation between Rainfall and Cereal Production

Figure 4.7 is a graph showing the correlation between rainfall and cereal production in Sakhisizwe Municipality from 1986 to 2011. Cereal production has been highly dependent on rainfall in the municipality showing variations along the years depending on the variability of rainfall. Cereal production has been showing an upward trend because of the opening of more land for agriculture and the use of irrigation to produce crops throughout the year. According to the results of interviews done with some farmers the increase in production is not necessarily climate related but is because of technological advancement and new knowledge of farming techniques acquired from other regions.

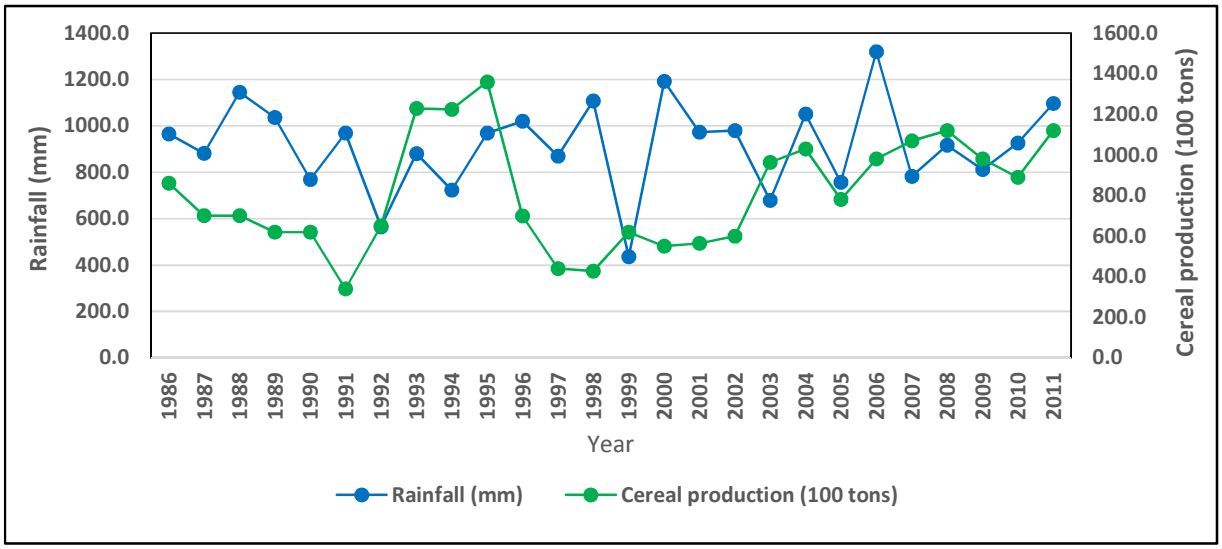


Figure 0.7: Correlation between rainfall and cereal production in Sakhisizwe Municipality along the years
Note: Cereals include maize, wheat and sorghum

4.4.2. Changes in Agricultural Area

A comparison in landuse change between maps created in 2003 and 2014 respectively, as shown in Figure 4.8, indicates some significant changes in land under cultivation. The cultivated land on map (a) which was created in 2003 by the Council for Industrial and Scientific Research (CSIR, 2003), shows small and scattered patches of land. However, map (b) developed in 2014 by the researcher, shows vast land under cultivation. The 2014 landuse map was developed from the image classification techniques in remote sensing using ERDAS Imagine. Landsat 8 satellite images of August 2014 were used to create the landuse map of the municipality. Fieldwork was

done in the municipality to verify the mapped landuse features and collect sample points. The collected points were added to some points derived from Google Earth. These ground truth points were used in a confusion matrix and Kappa analysis to verify the mapped features.

The maps show that there is an increase in area of land under cultivation as shown on the map on Figure 4.8. The increase in the area of land under cultivation could be because of more land becoming suitable for agriculture due to increase in temperature, as the Eastern Cape is a generally cold and snowy province. It is already documented that more land in colder areas will become suitable for agriculture due to climate change (Nhamo and Chilonda, 2012; Turral *et al*., 2011; IPCC, 2001).

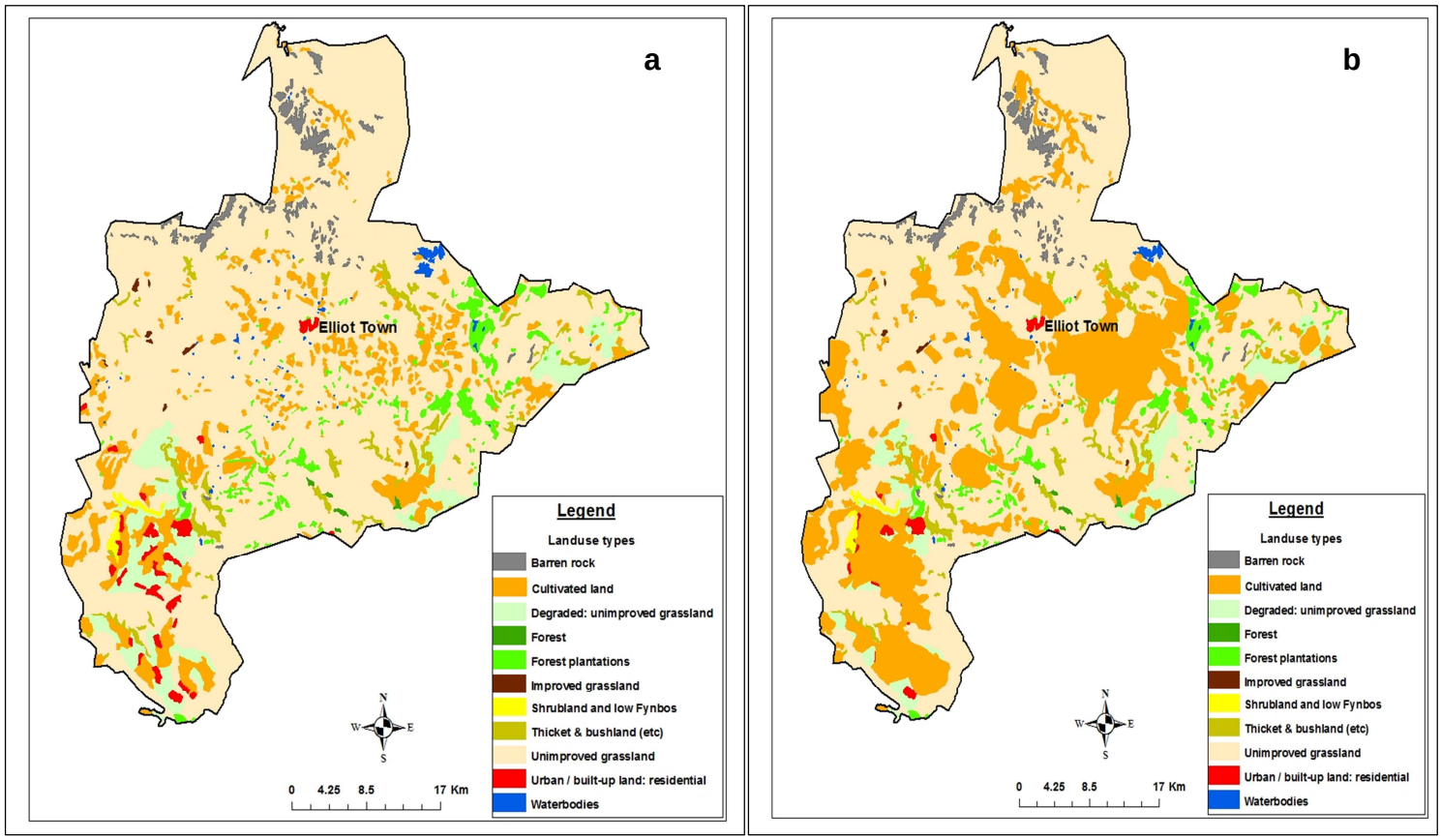


Figure 0.8: Landuse change in cultivated land in Sakhisizwe Municipality

4.5. Climatic Moisture Index (CMI) of Sakhisizwe Municipality

Table 4.1 presents the CMI of Sakhisizwe Municipality for the decades 1980, 1990, 2000 and 2010, which are all negative. The CMIs were calculated using annual rainfall (P) and annual potential evapotranspiration (PET) applying Equations 3.2 and 3.3. The negative CMI values indicate that the PET in the municipality exceeds precipitation representing a negative water balance. According to Vörösmarty *et al*., (2005), there is a classification link between CMI values and climatic conditions (CMI < -0.6 = Arid; -0.6 < CMI <0 = Semi-arid; and CMI > 0 = Humid). The average CMI for the municipality for the 4 decades is -0.72, qualifying the municipality to be a semi-arid and water-scarce according to the Vörösmarty classification (Vörösmarty et. al, 2005).

Table 0.1: Climate Moisture Index (CMI) for Sakhisizwe Municipality

Year	1980	1990	2000	2010
Rainfall (mm)	683.34	769.20	1191.99	925.96
PET (mm)	2478.00	3297.60	3422.40	3457.20
CMI	**-0.72**	**-0.77**	**-0.65**	**-0.73**

The semi-aridness of the municipality has been almost constant over the years. This is an encouraging sign for agriculture as water plays a crucial role as input to the production system. This will encourage the opening of more land for agriculture in the municipality during this era of losing agriculture land due to shifts in agriculture seasons due to climate change.

4.5.1. Runoff trend in Sakhisizwe Municipality

Table 4.2 presents the runoff in the municipality over the years, calculated using annual rainfall values and Figure 3.1. As runoff is a function of rainfall, it was also observed to be highly variable over the years just like rainfall. Perusal of Table 4.2 reveals that in 2010 runoff dropped drastically and this could be due the drought experienced in the 2009/10 season. However, in 1987 it was exceedingly high because of flooding in that season.

Table 0.2: Runoff trends in Sakhisizwe Municipality

	1980	1987	1990	1997	2000	2002	2010
Runoff (mm)	23.4	43.3	22.5	20.3	21.8	22.6	6.5

4.5.2. Water storage

Many farmers in the Elliot community have some form of water storage facilities either in the form of a small dam or storage containers. The dams, for example the one shown on Figure 4.9, collect water from streams during the rainy season and store it for use during the winter season which is normally dry or when there is little rainfall. In normal circumstances, the private dams store enough water for the individual farmer's needs during the dry season.

Figure 0.9: Small dam built in a commercial farm
Photo taken June 2015

The overhead containers are normally filled with water drawn from underground sources and mainly used in households. However, in some cases farmers draw water from rivers into some tanks erected in their farmsteads. Water is drawn from the rivers by the use of some water pumps as indicated on Figures 4.10.

Figure 0.10: Water being drawn from Slang River for storage in a reservoir
Photo taken in June 2015

4.6. Adaptation Strategies

It is projected that the municipality will mainly be affected by climate variability rather than climate change. Therefore, some climate shocks related to climate variability are expected to continue affecting the municipality. Table 4.3 shows some of the envisioned climate related impacts expected to affect the municipality. Table 4.3 highlights such impacts and provides the strategies that can be adopted to mitigate those impacts. The purpose of the profile in Table 4.3 acts as an early warning system that stakeholders can use to prepare for future climate shocks. The profiles are organised primarily to aid early warning activities as they outline possible impacts and adaptive strategies that can be taken to aid communities to withstand climate related shocks.

Table 0.3: Expected climate variability shocks and adaptation strategies in Sakhisizwe Municipality

Expected Climate Shock	Adaptation Strategies
Decreased water availability in rivers due to high temperatures and increased evapotranspiration affecting the fishing industry	Switch to more resilient livestock production systems and crops
Increased risk of water pollution and decreased water quality linked to erosion resulting to water borne diseases.	Improve and expand water harvesting and storage techniques.
Decrease in crop productivity due to the shifts of agricultural seasons and reduced rainfall amounts.	Increase land under irrigation. Soil, water and nutrient conservation practices.
Higher temperatures help the spread of pests and pathogens that affect agricultural production.	Switch to more resilient livestock production systems and crops
Decrease in the availability of clean water for domestic and agriculture uses	Expanded rainwater harvesting, water storage and conservation techniques, water reuse and irrigation efficiency
Increased incidence of floods as the incidence of heavy rainfall events increases	Improved land management, such as erosion control
Increased incidences of drought	Switch to more resilient livestock and crop varieties
Loss of wages due to little or no activity in the commercial farms and reduced income	Increase land under irrigation as an alternative to drought and flooding and improve crop and water productivity

The profiles shown in Table 4.3 give an analysis of the impact of climate shocks and offer adaptation strategies in Sakhisizwe Municipality. The importance of the profiles is to help make targeted interventions in case of a shock and to mitigate the impacts. The profiles are useful in that they are:

1. **A guide to the impacts of climate shocks.** The results unpack the impacts of climate shocks of expected to affect the municipality. They are strategic in that they assist development planners as they can identify the degree of vulnerability of the community to

a climate shock, and find ways to reduce their vulnerability and increase their adaptive capacity.

2. **An early warning system**. The profiles play an important in that they forewarn policymakers and arms them with a tool to make targeted interventions where necessary.
3. **Policy development.** Disaster management has been the main motivation behind the spread of early warning systems (Lema and Majule, 2009; Seaman *et al*., 2010). The importance of early warning systems is to improve the efficiency in the scale and timing of intervention in an emergency. Early intervention is the core of early warning systems. Such interventions often require changes in policy and practice and the profiles are a useful tool to this effect.

4.7. Summary

Elliot Town is surrounded by a farming area, which dominates the whole of Sakhisizwe Municipality. The farmers concentrate mainly in crops and livestock production. The main crops grown are maize and other small grains and, and on livestock they mainly rear cattle and sheep. An analysis of temperature and rainfall trends for the past 30 years has shown no major impact of climate change but climate variability as rainfall and temperature are highly variable in the municipality. Although insignificant, there has been an increase in maximum temperatures, causing high intensity rainfall and floods. These climate shocks have been recurring in the municipality in recent years. However, the warmer temperatures are favouring the opening of more land for agriculture. The municipality is classified as semi-arid and water scarce region, a situation that should justify the mobilisation of more resources towards water harvesting. The 20 years projection trend indicate that the intensity of climate variability will increase causing annual seasons to become unpredictable. This will call for an intensification of the use of early warning systems to prepare farmers, residents, policy-makers and other stakeholders on the possibility of an occurrence of a climate shock. According to the survey undertaken the majority of the residents in the town and the farmers in the surrounding areas are less equipped and prepared in the event of a climate shock occurring in the system. Large scale commercial farmers are more equipped and prepared as they have water storage facilities such as dams and water tanks and other resources

to sustain climate shocks, but smallholder farmers are more vulnerable as they depend entirely on rainfall for agriculture.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The study will contribute to knowledge on climate change and variability, not only to the Sakhisizwe Municipality but also to the entire country, South Africa, as well as other parts of sub-Saharan Africa. The objectives were to assess the vulnerability of Elliot Town in the Eastern Cape Province of South Africa to the impact of climate change, paying particular attention on water resources and agriculture production from the surrounding farms in the Sakhisizwe Municipality. The goal is to develop a tool that would act as an early warning system to assist policymakers and other stakeholders on measures that can be taken in case of a climate shock occurring in the system. This was achieved through developing adaptive measures to be used in case of such a shock in order to mitigate the impacts of climate change and variability in the whole municipality.

The data analysis and literature review on climate and agriculture done in this study identified and defined the impacts of climate change and variability on water resources, agricultural and households in the municipality. The results give a wealth of data and information that helps policymakers, and other stakeholders on the impacts of climate change and variability in Sakhisizwe Municipality. The results have shown that climate change is not affecting much in the municipality, but there is more of increased climate variability, which is causing the increase of floods and drought. Climate variability impacts are affecting water quality and food security especially to smallholder farmers in the municipality. Smallholder farmers do not have the necessary resources to mitigate climate related impacts like their commercial counterparts.

The extent of awareness of climate change and variability by residents and farmers was also analysed through a questionnaire. The responses given showed that the residents of Elliot Town have little knowledge on climate change and its impact. Although commercial farmers were aware of climate change, the majority lacked detailed information. Smallholder farmers had little knowledge as compared to commercial farmers. In general, the results of the study indicate that

residents and farmers are not fully informed about the concept of climate change although they have observed a slight decline in agriculture output over the years.

The study has also shown that the community's level of education was significant to understand climate change and variability. However, the level of education of some smallholder farmers was not good enough to influence awareness. The study found out that the lower the level of education the higher the chances of not being aware of climate change and variability. Formal extension services increased awareness of livestock farmers. However, among the farmers that were aware, not many received formal extension services, which seemed to increase the awareness to climate change and variability.

The study has also shown that extension service does not necessarily increase decisions to adapt to climate change and variability, but support access to information about climate change that helps to make decisions to adapt. Some residents and local farmers associate the increase in temperature with a declining in rainfall. This notion supports the view that climate change and variability are taking place and have been perceived by the whole community of Sakhisizwe Municipality.

The outcomes of this study indicate that climate change and variability are somehow positively influencing agricultural as more land is being opened for cultivation and the slight increase in maximum temperature is favouring livestock breeding. The projections made also indicate that if there were any changes in climate they would actually favour increased crop production if the challenges associated with climate change were contained.

Rainfall data analysis has shown that rainfall patterns and trends in Sakhisizwe Municipality are not changing but have become highly variable in recent years. The frequency of floods and drought has increased in recent years affecting water quality and food security. There is therefore need to adopt water harvesting technologies to mitigate the impacts of drought. There is also need to intensify irrigation in the municipality to increase water and crop productivity to mitigate the problem of water scarcity and food insecurity. Water quality will continue to be affected by flooding and this calls for the construction of enclosed water purification tanks and adopt new water purification technologies.

The greatest challenge in the municipality and South Africa at large, is lack of monitoring data (climate, soil, and hydrology) which would be needed to develop site-specific management strategies and for adapting them according to trends in climate as well as in quantity and quality of soil and water resources. There is therefore need for a concerted effort by policymakers and researchers to make use of and develop proxies from remote sensing to monitor and ultimately predict climate shocks.

5.2. Recommendations

- There is a great need to further awareness campaigns on climate change and variability and their impacts in the Sakhisizwe Municipality. This will assist in getting cooperation from residents when taking measures to alleviate climate change impacts.

- Climate change and variability management strategies must be promoted strongly in the Sakhisizwe Municipality and these must include adaptation measures to minimise the impact of climate change on livestock production, crop cultivation and water availability.

- As temperature and rainfall variations affect water availability and food security, as well as livelihoods, the community needs training on adopting and utilising water harvesting technologies and use irrigation to mitigate climate change and variability impacts.

- The government, through the relevant departments and institutions, should come up with national policies that promote research and development programmes that support the use of new technologies and practises that can be used to alleviate water scarcity and food insecurity. These policies must aim to promote irrigation and increase crop and water productivity, key elements to alleviate water scarcity and food insecurity.

- The government should also consider the adaptation programmes that reduce the impacts of climate change and variability, and these programmes could include access of livestock to supplementary feed and appropriate crop production methods in response to the prevailing climatic conditions to ensure high yields.

- The use of new research technologies such as Remote Sensing and Geographic Information Systems (GIS) need to be promoted in schools, colleges and universities, as they are important tools that are used in disaster risk reduction and early warning.

- Decision support systems and other technologies like mobile phones can be adopted as mediums to transmit information related to climate risk to residents and local farmers. These technologies transmit information in real time and are capable of mitigating risk.

- Public consultation is of paramount importance as the community is involved in decision-making and testing of opinions through research. The community will have a sense of ownership of natural resources, which will bring about their responsible use. It will also create a sense of belonging as residents of the municipality.

- The municipality should apply strict but affordable measures to households that water may be used sparingly and ensure that fresh water resources are also available for other uses downstream.

- This study should be made available as reference for future studies and parts of it can be used for new or further research to promote the cascading of knowledge and information to difficult people.

REFERENCES

AgriSA (Agriculture South Africa), 2006. A study on a Disaster Risk Management Plan for the South African Agricultural Sector. AgriSA, Pretoria, South Africa. Available at http://www.agrisa.co.za/Dokumente/Risk%20Management%20Plan.pdf

Archer E, Engelbrecht F and Landman W 2010. South African risk and vulnerability atlas, CSIR and DST, Pretoria.

Ashton PJ, 2002. Avoiding Conflicts over Africa's water resources. *Ambio*, 31(3): 236-242.

Ashton PJ, 2007. Riverine biodiversity conservation in South Africa: current situation and future prospects. Aquatic Conservation: Marine Freshwater Ecosystems 17: 44-445.

Babbie E and Mouton J, 2001. The practice of social research. Oxford University press Southern Africa. Cape Town.

Barnett TP, Adam JC and Lettenmaier DP, 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature 438 (7066), 303–309.

Bates BC, Kundzewicz ZW, Wu S and Palutikof JP, (Eds), 2008. Climate change and water: technical paper of the Intergovernmental Panel on Climate Change. Geneva, IPCC Secretariat.

Bockel L and Smith B, 2009. Climate change and agriculture policies. How to mainstream climate change adaptation and mitigation into agriculture policies? FAO, draft report version of 4 July 2009, Rome.

Brown ME and Funk CC, 2008. Food security under climate change. Science 319 (5863), 580–581.

Camill P, 2010. Global Change. Nature Education Knowledge 2(1):49

Campbell-Lendrum D and Corvalan C, 2007. Climate change and developing-country cities: chemistry of the Buffalo River (Eastern Cape), South Africa. Achives of Hydrobiologia 202: 71-83.

Clements RJ, Haggar A, Quezada J and Torres, 2011. Technologies for Climate Change Adaptation – Agriculture Sector. X. Zhu (Ed.). UNEP Risø Centre, Roskilde, 2011

Cruz RV, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, Honda Y, Jafari M, Li C and Huu NN, 2007. Climate Change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Asia.

CSIR 2003. National Landcover dataset attributes. Satellite Applications Centre, ICOMTEX. Council for Scientific and Industrial Research, Pretoria, South Africa.

Davies B and Day J, 1998. Vanishing Waters. UCT Press (First Edition). Chapter 4, pp 79-84 and Chapter 9, pp 281.

Davis C, Archer E, Engelbreht F, Landman W, Stevens N, *et al.*, 2010. A Climate Change Handbook for North-Eastern South Africa. Council for Scientific and Industrial Research (CSIR), Pretoria.

De Vos A, Strydom H and Deport CSL, 2005. Research at grassroots for the Social Sciences and Human service professions. (3rd Edition). Pretoria: Van Schaik Publishers.

DWAF (Department of Water Affairs and Forestry), 2002. National water resource quality status report: inorganic chemical water quality of surface water resources in SA – the big picture. Department of Water Affairs and Forestry. Pretoria, South Africa.

DWAF (Department of Water Affairs and Forestry), 2005. Groundwater Resource Assessment (GRA) phase 2. Available at: http://www.dwaf.gov.za/groundwater/GRAII.aspx

Dyson LL, 2009. Heavy daily-rainfall characteristics over the Gauteng Province. *Water SA* 35 (5) 627-638.

Easterling DR, Meehl GA, Parmesan C, Changnon SA, Karl TR and Mearns LO 2000. Climate extremes: observations, modelling, and impacts. Science, 289: 2068 - 2074.

FAO (Food and Agriculture Organization of the United Nations), 2008. Climate Change and Food Security: A Framework Document. Food and Agricultural Organisation of the United Nations (FAO), Italy, Rome.

FAO (Food and Agriculture Organization), 2003. World Agriculture: Towards 2015/2030. An FAO Perspective. Food and Agriculture Organization of the United Nations/Earthscan, Rome, Italy/USA.

FAO (Food and Agriculture Organization), 2005. Irrigation in Africa in figures: AQUASTAT Survey. FAO Water Reports 29, Food and Agriculture Organization of the United Nations (FAO), Rome.

Garcia M, Peters-Lidard CD and Goodrich DC, 2008. Spatial interpolation of precipitation in a dense gauge network for monsoon storm events in the South Western United States. Water Resources Research, 44: 14 pp.

Gibbs GR and Taylor C, 2010. How and what to code. University of Huddersfield.

Gleick PH, 2003. Global freshwater resources: soft-path solutions for the 21st century. Science 302 (28), 1524–1528.

Godfray HCJ, Crute IR, Haddad L, Lawrence D, Muir JF, Nisbett N, Pretty J, Robinson S, Toulmin C, and Whiteley R, 2010. The future of the global food system. Phil. Trans. R. Soc. B, 365, 2769–2777, doi:10.1098/rstb.2010.0180

Gray D, 2006. Doing Research in the real world. Sage Publications. New Delhi. London.

Hanjra MA and Qureshi ME, 2010. Global water crisis and future food security in an era of climate change. Food Policy 35 365–377

Hedden S and Cilliers J, 2014. Parched prospects: The emerging water crisis in South Africa. African Futures paper11, Institute for Security Studies (ISS), Pretoria, South Africa.

Hofstee E, 2006. Constructing a Good dissertation. South Africa. A Practical Guide to Finishing a Master's, MBA or PhD on Schedule. Johannesburg: Exactica. ISBN: 0-9585007-1-1.

Holcombe TT, Stohlgren J and Catherine I, 2007. Invasive *species management and research using GIS.* Fort Collins science centre, us. Geological survey. Fort Collins, Colorado, USA, 108–113.

Hunter PR, 2003. Climate change and waterborne and vector-borne disease. J. Appl. Microb., 94, 37S–46S

IDP (Integrated Development Plan), 2009. Sakhisizwe Municipality Integrated Development Plan 2009-2010. Elliot Town, South Africa. Available at http://www.sakhisizwe.gov.za/uploads/documents/Sakhisizwe%20IDP%202009-10%20Final.pdf

IPCC (Intergovernmental Panel on Climate Change), 2001. Climate Change: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Houghton JT, Ding Y, Griggs DJ, Noguer M, Van der Linden PJ, Dai X, Maskell K, Johnson CA (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (Intergovernmental Panel on Climate Change), 2007. Climate Change. Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Pachauri RK and Reisinger A (eds.), IPCC, Geneva, Switzerland.

IPCC (Intergovernmental Panel on Climate Change), 2007. Impacts, adaptations and vulnerability. Fourth Assessment Report. Cambridge University Press, Cambridge, UK.

IPCC (Intergovernmental Panel on Climate Change), 2012. Managing the risks of extreme events and disasters to advance climate change adaptation. In: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (Eds CB Field, V Barros, TF Stocker et al.), Cambridge University Press, Cambridge, NY, USA.

Johnson RB, Onwuegbuzie AJ and Turner LA, 2007. Towards a Definition of Mixed Methods Research. Journal of Mixed Methods Research. 1(2). Sage Publications.

Kang Y, Khan S and Ma X, 2009. Climate change impacts on crop yield, ceop water productivity and food security-A review. Progress in Natural Science, 19 (12): 1665-1674.

Karodia H and Weston D, 2001. South Africa's new water policy and law. In Abernethy CL (Ed.) Inter-sectoral Management of River Basins. International Water Management Institute, Colombo, Sri Lanka.

King JM, Tharme RE and Brown CA, 1999. Definition and implementation of instream flows. Thematic Report for the World Commission on Dams. Southern Waters Ecological Research and Consulting. Cape Town, South Africa, 63 pp.

Kruger AC, 2006. Observed Trends In Daily Precipitation Indices In South Africa:

Kumar R, 2005. Research Methodology, A Step by Step Guide for Beginners. Pearson Education, Australia.

Kundzewicz, ZW, Mata LJ, Arnell NW, Döll P, Kabat P, Jiménez B, Miller KA, Oki T, Sen Z and. Shiklomanov IA, 2007: Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210. Lars H, Marc JM and Rik L, 2009. The local impacts of climate change in the Ferlo, Western Sahel. Climatic Change, 93:465-483.

Lema MA and Majule A, 2009. Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. African Journal of Environmental Science and Technology, 3 (8), 206-218.

Levin I, Naegler T, Heinz R, Osusko D, Cuevas E, Engel A, Ilmberger J, Langenfelds RL, Neininger B, Rohden CV, Steele LP, Weller R, Worthy DE and Zimov SA, 2010. The global SF_6 source inferred from long-term high precision atmospheric measurements and its comparison with emission inventories. Atmospheric Chemistry and. Physics, 10, 2655–2662,

Mandleni B, 2011. Impact of climate change and adaptation on cattle and sheep farming in the Eastern Cape province of South Africa. Ph.D Thesis. University of South Africa, Pretoria, South Africa.

Mason SJ, 1996. Climatic Change over the Lowveld of South Africa. Climate Change 32, 35–54.

Mason SJ, Waylen PR, Mimmack GM, Rajaratnam B and Harrison JM, 1999. Changes in extreme rainfall events in South Africa. Climatic Change 41: 249–257.

Mboyane BL, 2006. An exploration of factors that lead to failure of small businesses in the Kagiso Township. College of Economics and Management. UNISA. South Africa.

McMichael AJ, Campbell-Lendrum DH, Corvalán CF, Ebi KL, Githeko AK, Scheraga JD and Woodward A, 2003. Climate change and human health. Risks and responses. WHO. Geneva, Switzerland.

Midgley SJE, Davies RAG and Chesterman S, 2011. Climate risk and vulnerability mapping in Southern Africa: Status quo (2008) and future (2050). For the Regional Climate Change Programme for Southern Africa (RCCP), UK Department for International Development (DFID), OneWorld Sustainable Investments, Cape Town.

Mirumachi N and Van Wyk E, 2010. Cooperation at different scales: challenges for local and international water resource governance in South African Geographical Journal, 176 (1) 25-38

Momba MNB, Osode AN and Sibewu M, 2006. The impact of inadequate wastewater treatment on the receiving waterbodies case study: Buffalo City and Nkonkonbe Municipalities of the Eastern Cape Province. Water SA, 32: 687-692.

Mouton J, 2001. How to succeed in your Master's &Doctoral Studies. A South African guide and resource book.

Mukheibir P, 2005. Local water resource management strategies for adaptation to climate induced impacts in South Africa, Prepared for the workshop: Rural Development and the Role of Food,

Water & Biomass: Opportunities for Development and Climate Novotel, Dakar 14-16 November 2005.

Neill J, 2007. Qualitative versus Quantitative Research: Key Points in a Classic Debate. Available at: http://wilderdom.com/research/QualitativeVersusQuantitativeResearch.html [Accessed: 29 June 2014].

Nhamo L, Chilonda P, 2012, Climate Change Risk and Vulnerability Mapping and Profiling at Local Level Using the Household Economy Approach (HEA). Journal of Earth Science and Climate Change 3:123. doi:10.4172/2157-7617.1000123

Olsen W, 2004. Triangulation in social research: qualitative and quantitative methods can really be mixed. In M. Holborn, editor. Developments in sociology. Causeway Press, Ormskirk, UK.

Otieno FAO and Ochieng GMM, 2004. Water management tools as a means of averting a possible water scarcity in South Africa by the year 2025. Water SA 30:120–124.

Palmer RW and O'keeffe JH, 1990. Downstream effects of impoundments on the water chemistry of the Buffalo River (Eastern Cape), South Africa. Hydrobiologia, 202 71-84

Patz JA, Githeko AK, McArty JP, Hussain S, Confalonieri U *et al*., 2003. Climate change and infectious diseases. In: McMichael AJ, Campbell-Lendrum DH, Corvalan CF, Ebi KL, Githeko AK, Scheraga JD and Woodward A (Eds), Climate change and human health–risks and responses. WHO, Geneva.

Perry M. and Hollis D, 2005. The development of a new set of long-term climate averages for the UK. International Journal of Climate, 25, 1023–1039.

Postel SL, 2000. Entering an era of water scarcity: the challenges ahead. Ecological Applications 10: 941-948.

Revenga C, Brunner J, Henninger N, Payne R and Kassem K, 2000. Pilot Analysis of Global Ecosystems: Freshwater Systems. World Resources Institute. Washington DC, USA.

Rischkowsky B, Thomson EF, Shnayien R and King JM. 2004. Mixed Farming Systems in transition: The case of five villages along a rainfall gradient in North-West Syria. Experimental Agriculture, 40:109-126.

Ruane J, Sonnino A, Steduto P and Deane C, 2008. Coping with water scarcity: what role for biotechnologies? Land and Water Discussion Paper No. 7. FAO, Rome.

Rust JM and Rust T, 2013. Climate change and livestock production: A review with emphasis on Africa.

Scholtz MM, Van Ryssen JBJ, Meissner HH and Laker MC, 2013. South African perspective on livestock production in relation to greenhouse gasses and water usage. South African Journal of Animal Science, 43, 247-254

Schulze RE 1997. South African Atlas of Agrohydrology and climatology, Report T82/96, Water Research Commission, Pretoria.

Schulze RE, 2005. Adapting to Climate Change in the Water Resources Sector in South Africa. In: Schulze RE (Ed.) Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. WRC Report No. 1430/1/05, pp 423-449. Water Research Commission, Pretoria, RSA.

Seaman J, Clarke P, Boudreau T and Holt J, 2010. The Household Economy Approach: A resource manual for practitioners. Save the Children Development Manual No. 6, Save the Children, London. Available at www.savethechildren.org.uk/en/54_2331.htm

Seckler D, Amarasinghe U, Molden D, de Silva R and Barker R, 1998. World water demand and supply, 1990 to 2025: Scenarios and issues. Colombo, Sri Lanka: International Water Management Institute (IWMI). IWMI Research Report 19) [DOI: 10.3910/2009.019]

Shafeek Sha, 2009. Enhancing the strategy for developing small “growth potential” firms in the Eastern Cape.

Sheehan J, 1986. Aspects of research methodology. Nurse Education Today. 6. Longman Group UK Ltd.

Smith B, McNabb D and Smithers J, 1996. Agricultural adaptation to climatic variation. Climate change 43, 7-29.

Stangor C, 2007. Research methods for Behavioural Sciences. 3rd Edition. Houghton Mifflin Company. New York.

Stats SA (Statistics South Africa), 2012. Census 2011, Statistical release P0301.4 / Statistics South Africa. Statistics South Africa, Pretoria, South Africa.

Strydom H, 2005. Ethical Aspects of Research in the Social Sciences and Human Services Profession. Van Schaik Publishers.

Sumbulu A, 2010. Writing your Research Project: Notes for SWK 323/425/512. Unpublished. University of Fort Hare.

Thomas DSG and Twyman C, 2005. Equity and justice in climate change adaptation amongst natural-resource-dependent societies. Global Environmental Change, 15: 115-124.

Trenberth K, 2011. Changes in precipitation with climate change. Climate Research. 47(1): 123-138.

Turpie J, Wrinkler H, Spalding-Fecher R and Midgley G, 2002. Economic impacts of climate change in South Africa: A preliminary analysis of unmitigated damage costs. Research Paper. Southern Waters Ecological Research and Consulting and Energy and Development Research Centre, University of Cape Town, Cape Town, South Africa, February 2002.

Turral H, Burke J and Faurés J, 2011. Climate change, water and food security. FAO Water Report 36, Food and Agriculture Organization of the United Nations (FAO), VialedelleTerme di Caracalla, Rome, Italy.

Tustin DH, Ligthelm AA, Martins JH and Van Wyk H and De J, 2005. Marketing research in practice. Pretoria: UNISA Press.

UNECA (United Nations Economic Commission for Africa), 2006, Southern African Development Report. Economic Commission for Africa (ECA), Addis Ababa, Report No: ECA/SA/TPUB/2005/4.

UNFCCC (Nations Framework Convention on Climate Change), 1992. United Nations Framework Convention on Climate Change. United Nations., New York, USA. Available at https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.

Vairavamoorthy K, Yan I, Galgale H and Govantiwar E, 2006. IRA – WDS: A GIS based risk analysis tool for water distribution systems. *Environmental modelling and software,* DOI: 10. 1016/J.envsoft. 2006. 05. 027.

Vörösmarty CJ, Douglas EM, Green PA and Revenga C, 2005. Geospatial indicators of emerging water stress: An application to Africa. Ambio, 34(3): 230-237.

Wetherald RT and Manabe S, 2002. Simulation of hydrologic changes associated with global warming. Journal of Geophysics Research, 107(D19), 4379.

WHO (World Health Organisation), 2004. Guidelines for Drinking Water Quality: Volume 1, 3rd edition. World Health Organization, Geneva, 540 pp.

Willmott CJ and Feddema JJ, 1992. A more rational climatic moisture index. Professional Geographer, 44: 84-87.

WRC (Water Research Commission), 2007. Dams in South Africa. Department of Water of Affairs and Forestry.

ANNEXES

1. Questionnaire

A.1 COMPOSITION AND CHARACTERISTICS OF FARM/HOUSEHOLD
Answer the following questions by placing a tick (√) in the appropriate box.

1.1 How long have you been in Elliot?

A. > 10 years ☐ B. 10-20 years ☐ C. 30-40 years ☐ D. 40-50 years ☐ E. <50 years ☐

1.2 In which location do you stay?

A. Masibambane ☐ B. Hillview ☐ C. Takalan ☐ D. Polar Park ☐ E. Verris ☐ F. Town ☐

G. Farm

A.2 FARM/HOUSEHOLD CHARACTERISTICS

1	2	3	4	5	6	7
Size of household >3 …….1 4-6 ……2 < 6 ……3	Gender of head of household Male…....1 Female….2	Age of head of household (years) 16-25……..1 26-35……..2 36-45……..3 46-55……..4 >56.....5	What is marital status of the household head? Single……..1 Married…...2 Divorced…..3 Widowed….4 Separated...5	Education level Pre-school…….1 Std1 ……..2 Std6.....3 Std10……..…4 Higher…....5 None...……6	Occupation Farming…….1 Employed…..2 Housewife..3 Pensioner….4 Business……5 No Job ……..6	Is farming your major source of income? Yes…..1 No……2

A.3 IF YOU ARE A FARMER, WHICH TYPE OF FARMING, ARE YOU SPECIALISING IN?

A. Crop farming ☐ B. Animal rearing ☐ C. Horticulture ☐

D. Market Gardening ☐

A.4 ACCESS TO INFORMATION ON CLIMATE CHANGE

4.1 Do you have access to information on climate change?

A. Yes ☐ B. No ☐

4.2. What is your source of information on climate change?

A. Flyers ☐ B. Magazines ☐ C. Radio ☐ D. Local newspapers ☐

E. Other (specify) _____ ☐ F. None ☐

4.3 Do you receive information on climate change through extension services?

A. Yes ☐ B. No ☐

4.4 Through what channel did you receive information on climate change?

A. Formal extension ☐ B. Farmer to farmer ☐ C. Family support ☐ D. Neighbors ☐

4.5 What kind of support do you receive for climate change effects?

A. Formal extension ☐ B. Farmer to farmer extension ☐ C. Formal credit ☐

D. Relatives in the village ☐ E. Other (specify)..... ☐ F. None ☐

4.6 Does the information you get make any difference stock population/crop production/domestic water usage?

A. Yes ☐ B. No ☐

B. LAND CHARACTERISTICS

B.1 Land tenure system

A. Private (own) ☐ B. Communal ☐ C. Permission to occupy (P.T.O) ☐

D. Renting ☐ E. Other (specify) ☐ .....

B.2 Who manages the farm?

A. Individual ☐ B. Family members ☐ C. Farmers' group ☐ D. Co-operative ☐

E. Private company ☐ F. Trust ☐ G. Other (specify) ☐……

B.3 Who owns the farm?

A. Individual ☐ B. Family members ☐ C. Farmers' group ☐ D. Co-operative ☐

E. Private company ☐ F. Trust ☐ G. Other (specify)……. ☐

C. FARMER'S/RESIDENT'S OBSERVATIONS ON CLIMATE CHANGE

C.1 How has the weather been in the past 5 years since 2008? Tick in the relevant box.

1. TEMPERATURES: A. Temperatures increased ☐ B. Temperatures decreased ☐

C. Temperatures stayed the same ☐ D. Have not observed any changes in temperatures ☐

2. RAIN: A. Rains increased ☐ B. Rains decreased ☐ C. Rains stayed the same ☐

D. Floods ☐ E. Not observed any changes in rainfall ☐

3. Are you aware of the 2003/2004 or 2004/2005 drought?

A. Yes ☐ B. No ☐

C.2 How has the weather been since 2008 to date? None….1 Average...2 Bad …3 Severe ….4

	1. Drought	2. Winds	3. Floods	4. Other (specify)
2013				
2012				
2011				
2010				
2009				
2008				

D. ADAPTATION MEASURES

D.1 Have you adapted to climate change?

A. Yes ☐ B. No ☐

D.2 What adaptation measures have you adopted to deal with the changes in temperatures and rainfall?

A. Provide portable water ☐ B. Built water storage facilities ☐ C. Hire water tanks ☐

D. Drilled boreholes ☐ E. Did not adapt ☐

D.2 If you did not adapt what made you not to adopt adaptation measures?

☐ ☐ ☐

A. Lack of information B. Lack of money C. Not aware of climate change

D. Do not know what to do ☐ E. Distance to weather stations ☐

E. HEALTH PROBLEMS EXPERIENCED AS A RESULT OF CLIMATE CHANGE

E.1 Are there any health problems you might have identified that were caused by climate change?

A. Yes ☐ B. No ☐

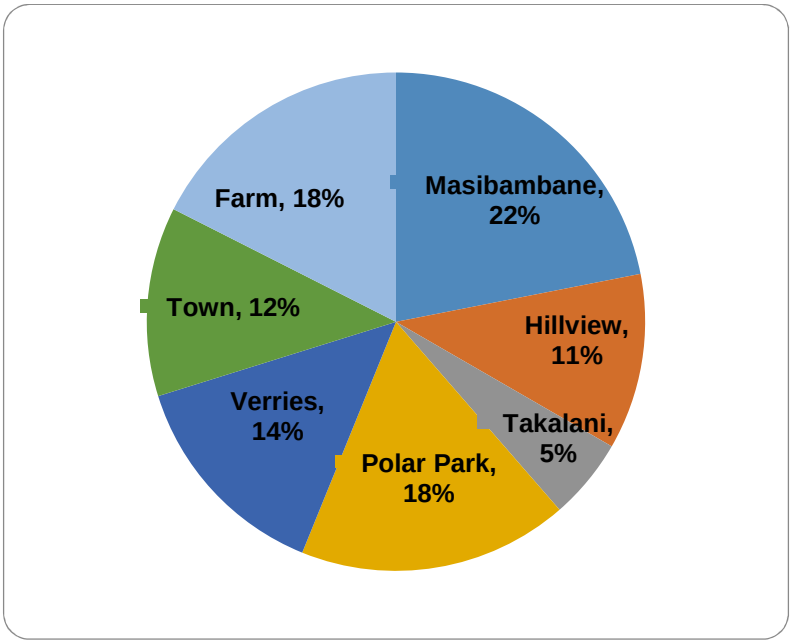
E.2 If yes what do you think needs to be done help solve the problem?

A. Educate the public about causes of climate change ☐ B. Make those contributing to climate change pay

C. I don't know. ☐

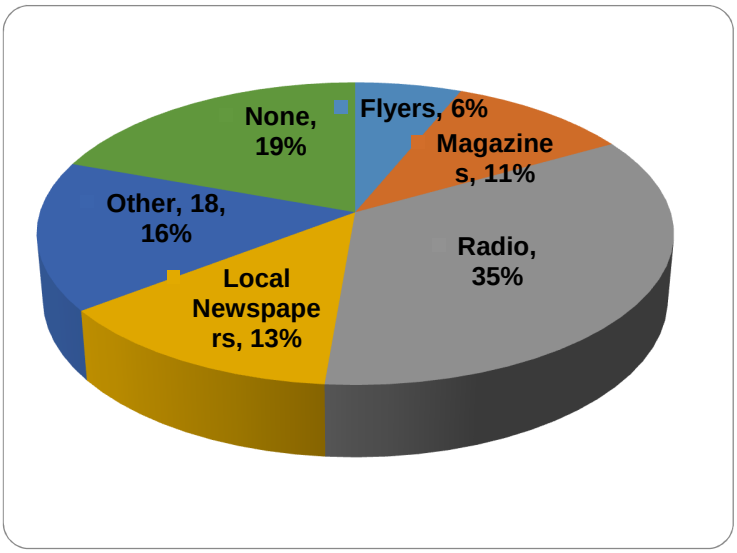
Thank you for answering this questionnaire.

2. Distribution of the population according to

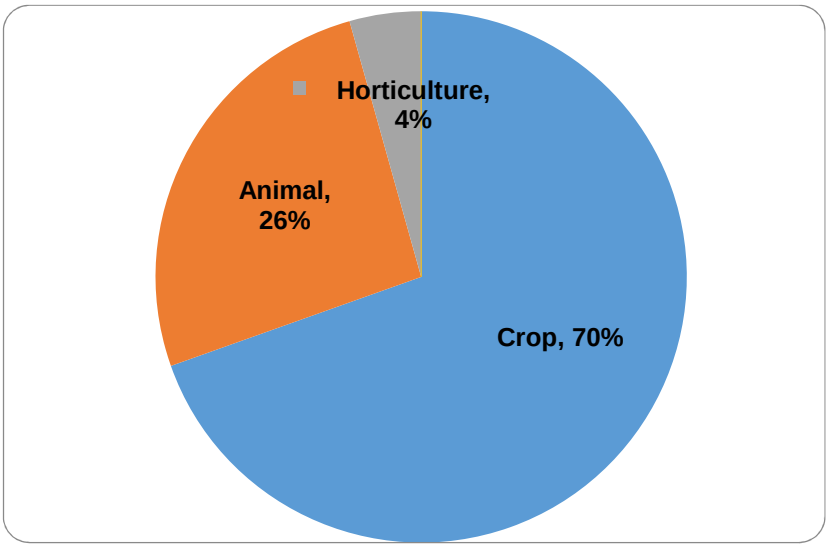


suburb/place lived

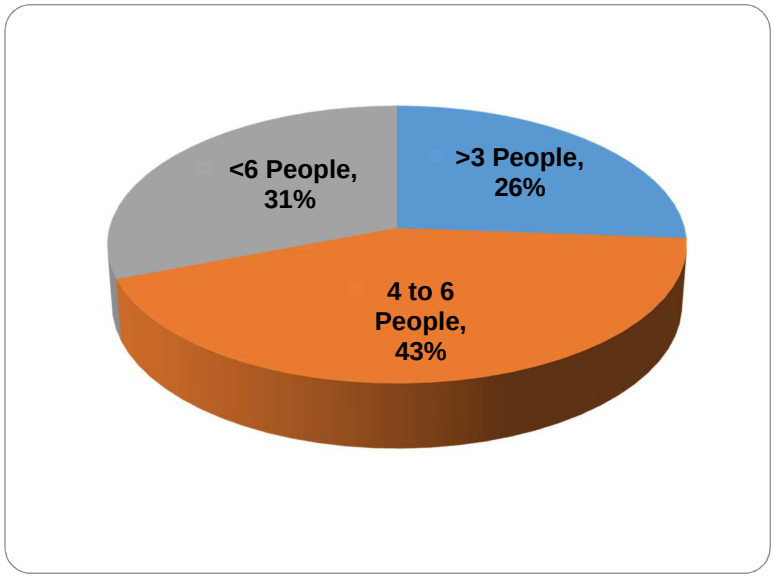
3. Source of information on climate change



4. Type of farming



5. Household size



6. Annual average minimum and maximum temperatures and rainfall

Year	Average minimum temp (℃)	Average maximum temp (℃)	Rainfall (mm)
1985	7.7	22.0	1182.0
1986	6.5	21.6	964.7
1987	7.1	21.7	881.8
1988	6.8	20.7	1145.4
1989	6.8	21.3	1037.1
1990	6.4	22.3	769.2
1991	7.0	22.2	969.0
1992	6.7	23.1	564.2
1993	7.0	22.2	881.1
1994	6.1	22.0	723.4
1995	6.7	22.0	969.7
1996	6.7	20.9	1020.8
1997	6.8	21.6	869.4
1998	6.7	22.3	1107.8
1999	7.2	23.0	435.2
2000	6.5	21.5	1192.0
2001	7.3	21.6	973.1
2002	7.2	22.0	979.4
2003	6.5	22.8	679.3
2004	6.7	22.1	1051.0
2005	6.9	22.1	756.4
2006	8.1	22.1	1319.3
2007	6.5	23.1	782.6
2008	6.6	23.0	917.5
2009	6.1	22.5	811.4
2010	7.2	23.2	926.0
2011	6.3	21.7	1097.2
2012	8.2	23.7	954.8
2013	6.8	22.5	

7. Cereal production

Year	Cereal production (100 tons)
1986	860.0
1987	700.0
1988	700.0
1989	620.0
1990	620.0
1991	340.0
1992	650.0
1993	1229.0
1994	1225.0
1995	1360.0
1996	699.0
1997	440.0
1998	428.0
1999	620.0
2000	550.0
2001	564.0
2002	600.0
2003	963.0
2004	1030.0
2005	781.0
2006	980.0
2007	1070.0
2008	1120.0
2009	980.0
2010	890.0
2011	1120.0

Note: Cereals include maize, wheat and sorghum

8. UNISA Research Ethical approval letter

UNISA University of South Africa

2013-03-01

Ref. Nr.: 2013/CAES/049

To:
Student: B Ndlela **Student nr: 45775265**
Supervisor: Dr L Nhamo
Department of Environmental Science
College of Agriculture and Environmental Sciences

Dear Dr Nhamo and Mr Ndlela

Request for Ethical approval for the following research project:

Impact of climate change on water resources in Elliott town in the Eastern Cape province

The application for ethical clearance in respect of the above mentioned research has been reviewed by the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, Unisa. Ethics clearance for the above mentioned project (Ref. Nr.: 2013/CAES/049) **is approved** after careful consideration of all documentation submitted to the CAES Ethics committee.

Please be advised that the committee needs to be informed should any part of the research methodology as outlined in the Ethics application (Ref. Nr.: 2013/CAES/049), change in any way. In this instance a memo should be submitted to the Ethics Committee in which the changes are identified and fully explained.

The Ethics Committee wishes you all the best with this research undertaking.

Kind regards,

Prof E Kempen,
CAES Ethics Review Committee Chair

PRETORIA

9. Municipal approval letter

SAKHISIZWE
MUNISIPALITEIT • UMASIPALA • MUNICIPALITY

P.O. BOX 26, CALA, 5455
ERF 458, UMTHATHA ROAD: TEL – 047-877 0167, FAX – 047 – 877 0000
P.O.BOX 21, ELLIOT, 5460
15 MACLEAR ROAD, ELLIOT: TEL – 045 – 9311011 / TEL – 045 – 9311 361
WWW.SAKHISIZWE.GOV.ZA

REF : 10/2
YOUR REF :
ENQUIRIES : N Mazwayi
DATE : 17th February 2013

ATT: Mr B. Ndlela
Elliot High School
P. O Box 93
ELLIOT

Dear Sir

PERMISSION TO CONDUCT A RESEARCH ON IMPACT OF CLIMATE CHANGE ON WATER RESOURCES

The above- mentioned matter refers.

This serves to confirm receipt and acceptance of your letter of request for permission to conduct a research on impact of climate change on water resources in Sakhisizwe Municipal area, received on the 14th January 2013, in the office of the Municipal Manager. The above mentioned office grants you a permission to conduct your research.

We therefore, request you to furnish us the outcome of your research immediately you conclude with your study.

If you have any queries concerning this letter, please contact Mrs. Mazwayi, Corporate Services Manager at this number 047 877 0167.

Yours Sincerely

11 ----------
T SAMUEL
MUNICIPAL MANAGER