

**The Analysis of the Economic Impact of Climate Change on Maize Production under different farming systems: The Case of Smallholder Farmers in Jozini Municipality, KwaZulu Natal Province, South Africa**



**Submitted**

**in fulfilment of the requirements for the degree of Master's Degree in Agricultural Economics**

**Bongiwe G. Nxumalo**

**200909204**

**Department of Agricultural Economics and Extension**

**Faculty of Science and Agriculture**

**University of Fort Hare**

**Private Bag X1314**

**Alice, 5700**

**South Africa**

**Supervisor: Prof A Mushunje**

**2014**

## **DECLARATION**

I, Bongiwe G. Nxumalo hereby declare that this thesis is my original work, and has not been submitted partially or entirely for degree purposes to any university. All the works written by other authors and used in the thesis were fully acknowledged.

.

.....

.....

Bongiwe G. Nxumalo

Date

## **DEDICATION**

I dedicate this work to my late father, my mother, my three sisters (Gugulethu, Sebeh and Londiwe), three brothers (Thabani, Skhumbuzo and Talent) and to all my friends

## **ACKNOWLEDGEMENTS**

I would like to first thank God almighty who made this research possible and granted me the patience to work throughout this research. Further I am greatly indebted and truly grateful to my supervisor, Prof A. Mushunje whose door was always opened to me for guidance, constructive criticism, persistent encouragement, enthusiasm and friendship.

Furthermore I would also like to thank KZN Department of Agriculture and Environmental Affairs for granting me the opportunity to study up to this level. Sincere gratitude also extends to the manager from the Department of Agriculture (Jozini) Mr P.K. Zungu for organizing with his staff members (extension officers) to help with data collection on the wards that they are working in. Special mention also goes to the farmers who participated in the study for their valuable time which they gave me so that I interview them.

Sincere gratitude and thanks also goes to my mother, family members especially my sister Gugulethu Khumalo who always gave me hope when I was about to give up, she constantly encouraged me. Thank you very much for your love and support. Throughout every milestone along the road, your encouragement kept me going until the end. To all my colleagues and friends, I thank you for the moral support that you provided throughout the study period. I would like to thank Dr Hosu and Dr Melusi Sibanda for their assistance with data analysis.

## ABSTRACT

Maize is the most grown crop by the farmers in Jozini. Therefore, the main objective of the study was to assess the economic impact of climate change on maize production under different farming systems in Jozini Municipality in KwaZulu Natal (KZN). The study was looking at the smallholder farmers producing maize under dryland and irrigation system. A total of 100 farmers were selected for the study (40 from dry-land and 60 from irrigating farmers). Cluster and random sampling procedures were used to select the sample. Questionnaires were used for the collection of primary data, from the respondents (maize farmers). Data was analysed using descriptive statistics (frequency, percentages), gross margin, regression analysis and the Ricardian model. Data for computing gross margins and net revenue was taken from the on-farm trials. Gross margin was used on regression analysis and the net revenue was used on the Ricardian model.

The results of the regression analysis indicated that land size, farmer's experience to farming, level of education, use of fertiliser, use of irrigation and the yield obtained were significant and have a positive relationship with farmers gross margin. The results of the Ricardian model indicated that climate change affects both farming systems, but farmers that are producing under dryland are the most affected farmers because they rely more on climate variables especially rainfall for their production. So a change in climate variables affects maize farmers' productivity and thus affecting farmers' gross margin and net revenue. The study recommends that the farmers must use irrigation in order to support maize production even in the absence of rainfall. Farmers must also adapt to the short growing season so that they will be able to produce even in the presence of climate change.

**Key words: Climate change, Net revenue and Ricardian model**

## TABLE OF CONTENTS

|  |             |
|--|-------------|
| <b>DECLARATION</b> .....                                       | <b>i</b>    |
| <b>DEDICATION</b> .....  | <b>ii</b>   |
| <b>ACKNOWLEDGEMENTS</b> .....                                  | <b>iii</b>  |
| <b>ABSTRACT</b> .....  | <b>iv</b>   |
| <b>TABLE OF CONTENTS</b> .....                                 | <b>v</b>    |
| <b>LIST OF TABLES</b> .....                                    | <b>viii</b> |
| <b>LIST OF FIGURES</b> .....                                   | <b>ix</b>   |
| <b>LIST OF ACRONYMS</b> .....                                  | <b>x</b>    |
| <b>CHAPTER ONE</b> .....                                       | <b>1</b>    |
| <b>INTRODUCTION</b> .....                                      | <b>1</b>    |
| 1.0 Introduction .....   | 1           |
| 1.1 Background to the Study .....                              | 1           |
| 1.2 Problem Statement .....                                    | 5           |
| 1.3 Objectives Of The Research.....                            | 6           |
| 1.3.1 The specific objectives: .....                           | 6           |
| 1.4 Research questions .....                                   | 6           |
| 1.5 Hypothesis .....   | 6           |
| 1.6 Justification of the study.....                            | 7           |
| 1.7 Delimitation of the research .....                         | 8           |
| 1.8 Definition of terms .....                                  | 8           |
| 1.9 Outline of the study .....                                 | 9           |
| <b>CHAPTER TWO</b> .....                                       | <b>10</b>   |
| <b>LITERATURE REVIEW</b> .....                                 | <b>10</b>   |
| 2.0 Introduction .....   | 10          |
| 2.1 Overview of climate change and its causes.....             | 10          |
| 2.2 Climate change in South Africa .....                       | 11          |
| 2.2.1 Changes in precipitation and temperature .....           | 12          |
| 2.2.2 Atmospheric carbon dioxide (CO <sub>2</sub> ) .....      | 12          |
| 2.2.3 Incidence of extreme events in south africa .....        | 13          |
| 2.3 The impact of climate change on agriculture .....          | 14          |
| 2.4 The impact of climate change on crop production .....      | 21          |
| 2.5 The impact of climate change on livestock .....            | 25          |
| 2.6 The impact of climate change on water resources .....      | 28          |
| 2.7 Maize production in south africa.....                      | 31          |
| 2.8 Factors influencing maize production in south africa ..... | 32          |
| 2.8.1 Climate.....   | 32          |
| 2.8.2 Soil.....  | 34          |
| 2.8.3 Planting date .....                                      | 35          |
| 2.8.4 Plant population density .....                           | 36          |
| 2.8.5 Fertiliser application rate .....                        | 37          |
| 2.9 Impact of climate change on maize production.....          | 38          |
| 2.10 Conclusion.....   | 42          |

|   |    |
|---|----|
| <b>CHAPTER THREE</b> .....                                    | 43 |
| <b>DESCRIPTION OF THE STUDY AREA AND METHODOLOGY</b> .....    | 43 |
| 3.0 Introduction .....  | 43 |
| 3.1 Selection and description of the study area .....         | 43 |
| 3.2.1 Population .....  | 44 |
| 3.2.2 Climate .....   | 45 |
| 3.3 Infrastructure .....                                      | 48 |
| 3.3.1 Markets and storage facilities .....                    | 48 |
| 3.4 Agricultural potential .....                              | 49 |
| 3.5 Other economic activities .....                           | 49 |
| 3.6 Conclusion .....  | 49 |
| <b>CHAPTER FOUR</b> .....                                     | 50 |
| <b>RESEARCH METHODOLOGY</b> .....                             | 50 |
| 4.0 Introduction .....  | 50 |
| 4.1 Research design .....                                     | 50 |
| 4.2 Unit of analysis .....                                    | 50 |
| 4.3 Sampling procedure .....                                  | 51 |
| 4.4 Sample frame .....  | 51 |
| 4.5 Sample size .....   | 52 |
| 4.6 Data collection .....                                     | 53 |
| 4.6.1 Orientation stage .....                                 | 53 |
| 4.6.2 The survey .....  | 53 |
| 4.6.3 Primary data .....                                      | 54 |
| 4.6.4 Secondary data .....                                    | 54 |
| 4.7 Variables for data collection .....                       | 54 |
| 4.8 Previous related studies .....                            | 55 |
| 4.9 Data analysis .....                                       | 57 |
| 4.9.1 Gross margin analysis .....                             | 57 |
| 4.9.2 Multiple regression model .....                         | 58 |
| 4.9.3 Ricardian model .....                                   | 59 |
| 4.10 Conclusion .....   | 62 |
| <b>CHAPTER FIVE</b> .....                                     | 63 |
| <b>RESULTS AND DISCUSSION OF DESCRIPTIVE STATISTICS</b> ..... | 63 |
| 5.0 Introduction .....  | 63 |
| 5.1 Demographic characteristics of sampled farmers .....      | 63 |
| 5.1.1 Gender of the farmer .....                              | 63 |
| 5.1.2 Age of the farmer .....                                 | 64 |
| 5.1.3 Level of education .....                                | 65 |
| 5.1.3 Occupation of the farmer .....                          | 67 |
| 5.1.4 Farmers income per month .....                          | 68 |
| 5.1.5 Source of income .....                                  | 69 |
| 5.1.6 Land utilization for maize production .....             | 71 |
| 5.1.7 Individuals farmers' experience .....                   | 72 |
| 5.1.8 Use of hybrid seeds .....                               | 73 |
| 5.1.9 Farmers use of fertiliser .....                         | 74 |
| 5.1.10 Farmers access to extension services .....             | 75 |

|   |     |
|---|-----|
| 5.1.11 Frequency of extension officers visit.....   | 76  |
| 5.1.12 Membership to farmers' organisation.....   | 77  |
| 5.1.13 Access to credit.....  | 78  |
| 5.2.14 Farmers' access to market .....  | 79  |
| 5.2.15 Type of soil.....  | 79  |
| 5.1.16 Farmers' awareness of climate change.....  | 80  |
| 5.2.17 Marketing channels pursued by farmers.....   | 81  |
| 5.2.18 Adaptation strategies pursued by farmers .....   | 83  |
| 5.3 Conclusion.....   | 84  |
| CHAPTER SIX.....  | 85  |
| RESULTS AND DISCUSSION OF THE EMPIRICAL ANALYSIS.....   | 85  |
| 6.0 Introduction .....  | 85  |
| 6.1 Results of gross margin analysis .....  | 85  |
| 6.2 Factors affecting profitability of maize production in jozini municipality .....          | 86  |
| 6.3 The empirical results of the economic impact of climate change on farmer's net revenue .. | 90  |
| 6.4 Conclusion.....   | 95  |
| <b>CHAPTER SEVEN.....</b>   | 97  |
| <b>SUMMARY, CONCLUSION AND RECOMMENDATIONS .....</b>  | 97  |
| 7.0 Introduction .....  | 97  |
| 7.1 Summary of the study.....   | 97  |
| 7.2 Conclusion.....   | 100 |
| 7.3 Recommendations and policy implementations.....   | 101 |
| LIST OF REFERENCES .....  | 105 |
| <b>APPENDIX 1 :QUESTIONNARE .....</b>   | 118 |
| <b>APPENDIX 2: RAINFALL IN JOZINI FOR THE PREVIOUS 20 YEARS .....</b>                         | 126 |
| <b>APPENDIX 3: TEMPERATURE FOR THE PREVIOUS 20 YEARS IN JOZINI .....</b>                      | 127 |
| <b>APPENDIX FOUR: LIST OF PRICES USED IN COMPUTATION OF GROSS MARGIN</b>                      |     |
| 128   |     |
| <b>APPENDIX FIVE: GROSS MARGIN BUDGET TEMPLATE FOR COMPUTATION OF</b>                         |     |
| <b>GROSS MARGIN.....</b>  | 129 |
| <b>ANNUAL CASH CROP INCOME AND COSTS BUDGET .....</b>   | 130 |

## LIST OF TABLES

|  |    |
|--|----|
| Table 4.1: Sample frame .....  | 52 |
| Table 4.2: Variables used for multiple regression analysis.....  | 59 |
| Table 4.3: Variables to be used in the Ricardian model .....   | 61 |
| Table 5. 1: Farmers land size .....  | 70 |
| Table 5.2: Land size under maize production .....  | 72 |
| Table 6.1: Gross Margin for maize (R).....   | 86 |
| Table 6.2: Empirical results of the factors that are affecting profitability of maize production in Jozini Municipality..... | 86 |
| Table 6-3: Empirical results of the economic impact of climate change on farmers' net revenue. ....                          | 91 |

## LIST OF FIGURES

|   |    |
|---|----|
| Figure 3.1: Map indicating the villages for research in Jozini Municipality ..... | 44 |
| Figure 3.2: Annualrainfall in Jozini.....   | 46 |
| Figure 3.3: Annual Temperature in Jozini .....                                    | 47 |
| Figure 4.1: Gross Margin components .....   | 57 |
| Figure 5.1: Gender of the respondents.....  | 64 |
| Figure 5.2: Age of the farmer .....   | 65 |
| Figure 5.3: Level of education.....   | 67 |
| Figure 5.4: Occupation of the farmer.....   | 68 |
| Figure 5.5: Farmers income per month.....   | 69 |
| Figure 5.6: Source of income.....   | 70 |
| Figure 5.7: Use of hybrid seeds .....   | 73 |
| Figure 5.8: Farmers use of fertiliser. ....                                       | 74 |
| Figure 5.9: Access to extension .....   | 75 |
| Figure 5.10: Frequency of extension visits.....                                   | 76 |
| Figure 5.11: Membership to farmer’s organization .....                            | 77 |
| Figure 5.12: Farmers access to credit .....                                       | 78 |
| Figure 5.13: Farmers access to market .....                                       | 79 |
| Figure 5.14: Type of soil.....  | 80 |
| Figure 5.15: Farmers awareness of climate change.....                             | 81 |
| Figure 5.16: Marketing channels pursued by farmers .....                          | 82 |
| Figure 5.17: Adaptation strategy pursued by farmers.....                          | 84 |

## **LIST OF ACRONYMS**

|                |   |
|----------------|---|
| <b>ARC</b>     | Agricultural Research Council                                     |
| <b>BPFAP</b>   | Bureau for Food and Agricultural Policy                           |
| <b>CEEPA</b>   | Centre for Environmental Economics and Policy in Africa           |
| <b>DAFF</b>    | Department of Forestry and Fisheries                              |
| <b>DWAF</b>    | Department of Water Affairs and Forestry                          |
| <b>EC</b>      | Eastern Cape  |
| <b>FAO</b>     | Food and Agricultural Organisation of the United Nations          |
| <b>GDP</b>     | Gross Domestic Product  |
| <b>IPCC</b>    | Intergovernmental Panel on Climate Change                         |
| <b>KZNDAEA</b> | KwaZulu Natal Department of Agriculture and Environmental Affairs |
| <b>KZN</b>     | KwaZulu Natal   |
| <b>MAFISA</b>  | Micro Agricultural Financial Institutions of South Africa         |
| <b>SA</b>      | South Africa  |
| <b>SADC</b>    | South African Development Community                               |
| <b>SAWS</b>    | South African Weather Service                                     |

# CHAPTER ONE

## INTRODUCTION

### 1.0 Introduction

This research assesses the economic impact of climate change on maize production under irrigation and under dryland in Jozini Municipality. The chapter outlines the background to the study, problem statement and the specific objectives of the study.

### 1.1 Background to the study

Climate change is defined as the adverse diversion from the normal long term weather conditions in a particular area, it includes changes in precipitation, temperature, humidity and wind velocity (Kurukulasuriya and Rosenhall, 2003). According to the Department of Agriculture Forestry and Fisheries (DAFF) (2012) climate change refers to a change in the long term patterns of temperature, precipitation, humidity and wind. The Intergovernmental Panel on Climate Change (IPCC) (2006) further explained climate change as 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).

Climate change may be due to natural internal processes or external forcings or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Changes in climate, especially changes in precipitation (both its quantity and distribution) and the higher evapo-transpiration rates predicted by climate models, will have impact on agriculture worldwide (Adams, 2006). Smallholder farmers are not the largest contributors to climate change, but they are likely to be amongst those who bear the brunt of climate change impacts. Compared to their commercial counterparts, smallholder farmers “are more directly dependent on ecosystem services and have less capacity to adapt to changing climate (IPCC, 2006).

A study conducted by Barnard (2007) in South Africa indicated that due to climate change there will be changes in rainfall pattern and temperature. Coastal regions will warm by around 3-4<sup>0</sup> C by about 2050 because of climate change. There will be significant changes in rainfall pattern and this is coupled with the increased level of evaporation, which will affect the availability of water to be used for agricultural purposes. Small-scale and homestead farmers in dry lands are

most vulnerable to climate change. Although farmers producing under irrigation are better off but it is worth nothing that climate change also decrease the availability of irrigation water.

These changes are likely to have significant effects on various sectors of South Africa's economy. These sectors include the following 1) health sector, 2) agriculture, 3) plant and animal biodiversity, 4) water resources and 5) rangelands. Mekonnen (2012) indicated that the on-going changes in climatic conditions have an adverse effect on agricultural production in South Africa through a number of limitations. Du Toit (2003) also indicated that the impact of climate change is felt by the farmers predominantly through changes in timing, frequency and intensity of rainfall events and ultimately productivity. A climatic change affects production of maize in different ways. This is most prevalent in the smallholder farming sector because they sometimes do not have means to adapt to the climatic changes.

Africa is said to be the continent that is the most vulnerable to the effects of climate change in the world as a result of national economies that are largely dependent on natural resources. Most of the developing countries are heavily dependent on agriculture. The effect of climate change on their productive croplands is likely to threaten economic development and the welfare of the population (Madzwamuse, 2010). Rising temperatures, reduced rainfall and water scarcity will collectively impact on the agricultural systems in South Africa. Significant impacts a include reduction in the amount of land suitable for both arable and pastoral agriculture, the reduction in the length of the growing season and a decrease in yields, particularly along the margins of semi-arid and arid areas. Climate change is likely to further reduce the contribution of agriculture to the Gross Domestic Product (GDP) (Morton, 2007).

The agricultural sector in South Africa contributes about 1.9% to the GDP and employs 30 percent of the labour force (Chamuka, 2011). It is also the earner of foreign exchange through exports of raw materials and agricultural products. Despite its contribution to the economy, this sector is affected by climate related disasters such as floods and extended dry spells (Mandleni, 2011).

The study by Rosenzweig *et al.*, (2007) indicated that climate change, which may make temperatures to climb and reduce the rains and also change their timing, may therefore put more pressure on the country's scarce water resources, with implications for agriculture, employment

and food security. According to Madzwamuse (2010) climate change is an impending threat facing the world in the 21st century and beyond. The results of increased temperatures, changes in rainfall patterns, extreme weather events, and sea level rise and changes in biodiversity will have significant impacts on national economies, rural livelihoods and development in general, but agriculture is expected to be most affected by these changes because it is highly dependent on climate.

According to (Madzwamuse, 2010) the growing literature on climate change and agriculture highlighted some general findings. Firstly, an agricultural sector is vulnerable to climate change physically and economically. According to Benhin, (2006) South African agriculture, have diverse types of crops, cropping calendars and production levels, as a result of the influence of the different agro-climatic zones, which varies from the dry north-western region to the wet eastern region. The major crops are maize, wheat, sugar cane, sorghum and the minor ones are groundnuts, sunflowers, dry beans, tobacco and potatoes. Climate change will affect production of these crops and thus leads to the decrease in the farmers' productivity and lowers the net revenue (Bryan *et al.*, 2009)

Maize is the most important grain crop in South Africa, being the second large crop produced in South Africa after sugar cane. It is produced throughout the country under a diverse environment. It constitutes about 70% of grain production and covers about 60 % of the cropping area in South Africa. It is a summer crop, mostly grown in semi-arid regions of the country, and is highly susceptible to changes in precipitation and temperature (Durand 2002, Benhin 2006). Although maize plant is quite hardy and adaptable to harsh conditions, a drier or warmer climate and lower precipitation could have detrimental effects on its yield (Bureau for Food and Agricultural Policy (BFAP) (2007). In addition, maize is the main staple food in Southern Africa, and its production in South Africa constitutes about 50% of the output within the Southern African Development Community (SADC) region (Durand, 2006).

Maize production accounts for about 40% of the entire area cultivated in South Africa and it is highly sensitive to climate variability and climate change (Randela, 2005). More than 70% of the South African population uses maize as the staple food. Further the maize also provides secondary industries with over a billion worth of business each year. Maize is used as both the

major feed grain and the staple food for the majority of the South African population (Le Roux, 2009). Both white and yellow maize are produced in South Africa, white maize is produced for the human consumption and yellow maize is produced for livestock feeding. About 60% of maize produced in South Africa is white and the other 40% is yellow maize (Tingem, 2009). According to Le Roux (2009) maize industry is important to the economy both as an employer and earner of foreign currency because of its multiplier effects. Maize in South Africa also serves as a raw material for manufactured products such as paper, paint, textiles, medicine and food (De La Roque, 2008).

According to Walker and Schulze (2006) maize is undoubtedly South Africa's most important field crop. It is the basis for many different food types, including corn on the cob, soft porridge, fermented porridges, dry porridges, non-alcoholic fermented gruel and even low alcohol beer (Du Toit, 2003). Maize production in South Africa is carried out using a wide range of farming systems, dominated mostly by subsistence oriented small-scale farmers and emerging medium\large-scale commercial farmers (DAFF, 2004).

BFAP (2007) indicated that in South Africa maize is primarily sold in the form of processed products such as maize meal, maize rice and samp produced by dry milling for human consumption. The by-product of milling known as maize bran (or hominy chop) is an important feedstuff used in feedlots as animal feed (Meza *et al.*, 2008).

Smallholder maize farmers in South Africa can be categorized into commercial emerging farmers who market most of their produce throughout the country, and the second group is the emerging farmers whose produce is consumed locally. The last category are the resource-poor farmers who produce less for the market as they use the traditional methods of farming and hence, they have been identified as the most vulnerable to climate changes (Dogan *et al.*, 2004). Farmers in all three categories are growing maize under the dry land conditions meaning that they rely on climate for the production of maize, hence any fluctuation in temperature and precipitation that will affect maize production by the smallholder farmers (Barnard, 2007). In general, climate change is expected to be harmful to crop farming in South Africa. However, there are expected gains and losses specific to each farming system and each province.

## 1.2 Problem Statement

Maize is the most important grain crop in South Africa, and it is produced throughout the country under diverse environments. It constitutes about 70% of grain production and covers about 60 % of the cropping area in South Africa (Dogan *et al.*, 2004). According to Agricultural Statistics (2007) the majority of maize producers are small-scale farmers, farming on less than 10 hectares and they rely on rainfall for the production of maize. Climate change may have an adverse impact on their maize production, as most of them follow low input cultivation practices using landraces and seed from previous harvest.

According to Benhin (2006) one of the most significant impacts of climate change is likely to be on the hydrological system, and hence on river flows and water resources in the country. This is especially important given the semi-arid nature of the country, where water resources are very sensitive to climate variability and change.

Walker and Schulze (2006) carried out a study in Bergville (KZN) which indicated that maize production is highly sensitive to climate change, as maize is characterized by variations in yield due to fluctuations in seasonal precipitation. The study by Walker and Schulze (2006) further indicated that maize requires different temperatures and the amount of rainfall at the different stages of growth so climatic changes at the different stages of growth will decrease yield and thus affects the farmers' net revenue. The problem underpinning the study is to investigate if there is an economic impact of climate change on maize production under irrigation and dryland farmers system amongst the smallholder farmers in Jozini (KZN).

The study will use the Ricardian model which specifically looks at the economic impact of climate change looking at how climate change will affect the farmer's revenue. Extensive research has been carried out on the impact of climate change, but little has been done on the economic impact of climate changes in maize production especially with the smallholder farmers (Benhin, 2006). As a result, the main objective of this study is therefore is to assess if there is an economic impact of climate change on maize production by the smallholder farmers in different farming system in Jozini municipality.

### **1.3 Objectives of the research**

The main objective of this study is to assess the economic impact of climate change on maize production by the smallholder farmers under different farming systems.

#### **1.3.1 The specific objectives are to:**

- Determine the level of maize production (per hectare) by the smallholder farmers under irrigation and dry land in Jozini (KZN).
- Assess the profitability of maize production by smallholder farmers under irrigation and dry land in Jozini (KZN), and
- Determine the economic impact of climate changes on maize production under irrigation and under dry land in Jozini (KZN).

### **1.4 Research Questions**

- What is the level of maize productivity under irrigation and under dry-land?
- Is maize production more profitable under irrigation than under dry land farming system in Jozini (KZN)?
- What is the economic impact of climate changes on maize production under irrigation and dry land by the small- holder farmers?

### **1.5 Hypothesis**

The hypotheses are:

- Maize productivity per hectare by smallholder farmers is not the same under irrigation and under dry land in Jozini.
- Irrigating maize farmers obtain a higher gross margin as compared to dry land maize farmers.
- Climate change has an economic impact on maize production under irrigation and under dry land conditions.

## 1.6 Justification of the study

In South Africa, about 40% of the cultivated area accounts for maize production (Winkler *et al.*, 2010). DAFF (2010) indicated that maize is the most important grain in South Africa, being the major feed grain and the staple food for the majority of the South African population. White and yellow maize are produced in South Africa.

Agriculture is the major economic and the social force in KZN province (Dawood, 2012). Sugarcane, livestock (especially cattle), forestry and the staple grains are the main agricultural activities that are dominant in KwaZulu Natal (KZN). Maize is one of the major crops grown in the province. The major growing areas are Utrecht, Newcastle, Danhouser, Glencoe, Vryheid, Bergville, Escourt, Dundee and Jozini. There are two types of maize produced in the province which is white and yellow maize.

Maize in KZN is produced by both the commercial and the smallholder farmers, because of the different climatic conditions within the province. As such in some areas within the province maize is produced under dry land and under irrigation in some areas (Zungu, 2013). In Jozini which is an area with low rainfall farmers are supplementing water requirements with irrigation (KZNDEA, 2010). Jozini farmers that are producing maize under irrigation produce throughout the year, while farmers that are producing under dry land only produce maize during the spring and summer months because they rely on rainfall.

Farmers that are producing maize in Jozini sell it at the point of production and they make a living out of selling it. Therefore based on this background study of Jozini it is important to carry out this study, since maize is one of the major crops in KZN and which is also affected by climate change. It is important to assess the economic impact of climate change on maize production both under irrigation and under dry land in Jozini. Similar study was carried out in South America which evaluated the economic impact of climate change on crop, with particular emphasis being placed on different crops, not on one crop. In that regard, this study replicates South American study but it is limited to KZN and looking at only one crop which is the staple crop in KZN. It is hoped that this study will help in policy formulations that will try and assists

farmers in Jozini to adapt to climate change and continue to produce maize because they cannot stop climate change.

### **1.7 Delimitation of the research**

The budget limited the study. This study focused on looking at the analysis of the economic impact of climate change on maize production with particular emphasis being placed on the smallholder farmers in KwaZulu Natal province only (Jozini Municipality). The study did not cover other provinces in South Africa. The study also focused on the smallholder farmers who specifically produce maize on the selected areas of study and not the commercial farmers.

### **1.8 Definition of terms**

**Climate change** – it is defines as the adverse diversion from the normal long term weather conditions in particular area, and it include changes in precipitation, temperature, humidity and wind velocity (Kurukulasuriya and Rosenhall, 2003).

**Net revenue** – It is defined as the gross revenue minus the costs of transport, packaging, posts harvest losses, hired labour, heavy machinery (ploughs, tractors) fertiliser and pesticides costs (Ngaira, 2008).

**Economic impact** – it indicates the factors that are affecting the farmer's net revenue either positively or negatively (Ngaira, 2008).

## **1.9 Outline of the study**

The study consists of seven chapters. The first chapter outlines the background information on the study. Chapter 2 discusses literature review on maize production in South Africa, with special reference to smallholder farmers and also the effect of climate change agriculture (crops and animals). Chapter 3 presents the description of the study area. Research methodology is presented by chapter 4. Descriptive results and discussion are presented in chapter 5. Chapter 6 discusses the empirical results of Gross margin and the Ricardian model. Finally chapter 7 presents the summary, conclusion and recommendations of the study.

## **CHAPTER TWO LITERATURE REVIEW**

### **2.0 Introduction**

This chapter focuses on discussing the impact of climate change on agriculture in South Africa, looking at the effect on both animals and crop production. The chapter also looks at the production of maize in South Africa in general and also the production of maize in KwaZulu Natal in particular, and the factors that are affecting maize production. Lastly the chapter also looks at the effect of climate change on maize production in Jozini Municipality.

### **2.1 Overview of climate change and its causes**

Climate change is a long-term shift in the climate of a specific location, region or planet. The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation. Further these changes occur when the climate of a specific area or planet is altered between two different periods of time, also these changes can be caused by natural processes like volcanic eruptions, variations in the sun's intensity, or very slow changes in ocean circulation or land surfaces which occur on time scales of decades, centuries or longer (IPCC,2014).

According to DAFF (2012) climate change is caused by the emission of carbon dioxide and other greenhouse gases which are changing the earth's climate, raising temperature and leading to more erratic rainfall and extreme weather events. Both natural and human factors that can cause climate change are called 'climate forcings', since they push, or 'force. Burning fossil fuels to heat our homes, run our cars, produce electricity, and manufacture all sorts of products that are adding more greenhouse gases to the atmosphere. Climate change can have adverse effects on the agricultural sector (both livestock and crop production) because agriculture depends on a specific pattern of climate in order for it to be productive.

Mendelssohn and Dinar (2009) further explained that causation for climate change is ascribed largely to the increased levels of atmospheric carbon dioxide produced by the human activity of burning fossil fuels which releases gases known as greenhouse gases into the atmosphere. These gases in the Earth's atmosphere absorb heat energy radiated by the earth and return most of this

energy back towards the surface. This process is known as the greenhouse effect. Greenhouse gases stay in the atmosphere for long periods of time. With fossil fuels constantly being burned, the concentration of the greenhouse gases continue to rise, trapping increasing amounts of heat in the earth's atmosphere and resulting in an increase of the earth's temperature over time (KabuboMariara, 2008).

According to IPCC (2007) climate change is likely to have a negative impact on agriculture because it intensifies seasonal and inter-annual rainfall variation (for example, drought in one year and floods the next), as long -term changes and trends take place (for example, rising annual mean temperatures. It may also create water and heat stress, the outbreak of pests and diseases, the loss of productive lands through the deterioration of ecosystems. Climate change also leads to additional burdens to supply chains such as increased post-harvest losses during storage and distribution. The likely consequences of such stresses include yield reductions, decreased live-stock values, post-harvest losses, and reduced food accessibility and consumption (Rosenzweig *et al.*, 2007).

## **2.2 Climate change in South Africa**

Mandleni (2011) indicated that South Africa is expected to become hotter and drier, leading to changes in agricultural production and biodiversity distribution. Weather patterns that people were used to for hundreds and thousands of years are changing and they will not return to normal. In the eastern part of the country where rainfall is expected to increase, the impact will not necessarily be positive. This is because increased rainfall at inappropriate times could cause exceptionally destructive floods and impacts to natural river courses and human infrastructure (Maddison, 2007). Changes in rainfall will affect food production and may cause increases in diseases. Low precipitation levels and relatively poor soils place heavy challenges on South Africa's ability to produce agricultural goods and services. According to the Centre for Environmental Economics and Policy in Africa (CEEPA) (2006) there are five key drivers of climate change that may affect the agricultural sector, namely: temperature, precipitation, sea level rise, atmospheric CO<sub>2</sub> content and the incidence of extreme events. The five drivers are discussed below.

### **2.2.1 Changes in precipitation and temperature**

South Africa has experienced its share of rainfall shortages, the worst being a set of serious droughts in the early '80s. The country is semi-arid by nature, having erratic and variable rainfall. It lies within a drought belt and receives, on average, only 464 mm of rain annually, which is far below the world average annual rainfall of 857 mm (Morton, 2007). It is estimated that even without climate change, South Africa will have fully utilised its total available surface water by the year 2030 (DEAT, 2004). In South Africa future annual temperatures are projected to increase by 1.5-2.5°C along the coast (illustrating the moderating influence of the oceans) to 3.0-3.5°C in the far interior. However, by the end of the century an accelerating increase in temperatures becomes evident with projected increases between 3.0-5.0°C along the coast and up to 6.0°C and more in the interior (Hoffman and Vogel, 2008) . Year-to-year variability of annual temperatures tends to increase in the northern half of the country and decrease in the south. This affects agriculture and leads to low productivity in both animal and crop production.

### **2.2.2 Atmospheric carbon dioxide (CO<sub>2</sub>)**

Carbon dioxide is the primary greenhouse gas that is contributing to recent climate change. CO<sub>2</sub> is absorbed and emitted naturally as part of the carbon cycle, through animal and plant respiration, volcanic eruptions, and ocean-atmosphere exchange. Human activities, such as the burning of fossil fuels and changes in land use, release large amounts of carbon to the atmosphere, causing CO<sub>2</sub> concentrations in the atmosphere to rise. Atmospheric CO<sub>2</sub> concentrations have increased by almost 40% since pre-industrial times, from approximately 280 parts per million by volume in the 18th century to 390 in 2010 (Maddison, 2007). Bryan *et al.*, (2009) further stipulated that carbon dioxide is naturally present in the atmosphere as part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). Human activities are altering the carbon cycle both by adding more CO<sub>2</sub> to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO<sub>2</sub> from the atmosphere. As atmospheric CO<sub>2</sub> increases, plant growth rates increase. Leaves transpire less and lose less water as CO<sub>2</sub> increases, so that plants are able to grow under drier conditions. Animal life, which depends upon plant life for food, increases proportionally. The increase of CO<sub>2</sub> affects crop production thus reducing the yield. Therefore the study will assess the

economic impact of climate change on maize production as the increase in atmospheric CO<sub>2</sub> is caused by climate change.

### **2.2.3 Incidence of extreme events in South Africa**

Drought is one of the extreme events occurring in South Africa as a result of climate change and often has a devastating impact (Brian *et al.*, 2009). Drought is a condition of climatic dryness that is severe enough to reduce soil moisture and water levels below the minimum necessary for sustaining plant, animal, and economic systems. It is called a 'creeping' hazard because droughts develop slowly and have a prolonged existence, sometimes over several years. Droughts are the common feature in South Africa. Throughout the twentieth century droughts have occurred over South Africa with great regularity (Valtora, 2009). According to the South African Weather Service any amount of rain less than seventy-five percent of normal annual rainfall constitutes a meteorological drought. In South Africa, there are three important drought periods, in which the major part of the country has experienced below-normal rainfall. Drought periods have been observed over the last fifteen years. The major drought years have been 1991/92, 1997/98 and 2001/02. The drought of the early 1990s was by far one of the most severe droughts on recorded in South Africa due to its effects on food production and vulnerable communities.

The severe impacts of drought can seriously affect the vulnerability of a people. Impacts such as the availability and price of food are regular vulnerability concerns during drought (Roberts, 2008). South also experiences floods which also affect agriculture. South Africa faces increasing occurrence of floods, tornadoes and hailstorms, heavy rains and wind, veld fire, snow and floods as a result of climate change. It also leads to the increase in the intensity of rainfall and the occurrence of floods. In South Africa the province that usually experience flooding is Western Cape. There are three types of floods has occurred in South Africa as a result of climate change (Rosenzweig *et al.*, 2007). These kinds of floods are explained below.

Flash floods which is flooding in small river basins. Flash floods are short-term events, occurring within 6 hours of the causative event (heavy rain, dam break, levee failure, rapid, snowmelt and ice jams) and often within 2 hours of the start of high intensity rainfall. Rising floods or pooling this is the accumulation of water in an area that leads to general

flooding, this mainly occurs in wetlands and areas with a high water table. This type of flooding occurs most of the time in the Western Cape badly affecting informal settlements built on wetland. The last flood type is storm surges and Coastal floods. This type of flooding happens when water is pushed to abnormally high levels against the coastline. It is caused by a combination of extreme low pressure and strong winds pushing water into a narrowing feature (Schulze *et al.*, (2012). Floods and drought which occur as a result of climate affect agriculture both animal and crop production and also affect water resources which provide water for irrigation.

### **2.3 The impact of climate change on agriculture**

Climate is the average weather in a place over many years, so any change in climate will have implications for climate-sensitive systems such as agriculture, forestry, and some other natural resources (Inter-governmental Panel on Climate Change (IPCC) (2007). With respect to agriculture, changes in solar radiation, temperature, and precipitation will produce changes in crop yields, crop mix, cropping systems, scheduling of field operations, grain moisture content at harvest, and hence, on the economics of agriculture including changes in farm profitability (Adlakha, 2011). According to Durand (2009) climate change is predicted to affect economic activity through its effects in agriculture, because temperature and precipitation are direct inputs to agricultural production. In dry areas for which rain is predicted to increase with climate change, agriculture may well get boosts from longer growing seasons and greater water supply. On the other hand, in areas where the temperatures are already near the upper bound of most plants tolerance, warming may make farming unprofitable.

Climate change will significantly impact agriculture by increasing water demand, limiting crop productivity and reducing water availability in areas where irrigation is most needed or has comparative advantage. Global atmospheric temperature is predicted to rise by approximately 4°C by 2080, consistent with a doubling of atmospheric CO<sub>2</sub> concentration. Mean temperatures are expected to rise at a faster rate in the upper latitudes, with slower rates in equatorial regions. Mean temperature rise at altitude is expected to be higher than at sea level, resulting in intensification of convective precipitation and acceleration of snowmelt and glacier retreat. In response to global warming, the hydrological cycle is expected to accelerate as rising

temperatures increase the rate of evaporation from land and sea (Kurukulasuriya and Mendelsohn, 2006).

The study by Durand (2009) indicated that rainfall is predicted to rise in the tropics and in higher latitudes, but decrease in the already dry semi-arid to arid mid-latitudes and in the interior of large continents. Water scarce areas of the world will generally become drier and hotter. Both rainfall and temperatures are predicted to become more variable, with a consequent higher incidence of droughts and floods, sometimes in the same place. The future availability of water to match crop water requirements is compounded in areas with lower rainfall

Climate change also leads to the changes in temperature in different regions in South Africa. Coastal regions will warm by around 3-4<sup>0</sup> C by about 2050 because of climate change (IPCC, 2007). There will be significant changes in rainfall pattern and this is coupled with the increased level of evaporation, which will affect the availability of water to be used for agricultural purposes. Small-scale and homestead farmers in dry land are most vulnerable to climate change, although farmers producing under irrigation are better off but climate change also decreases the availability of irrigation water. Alien invasive plant species are likely to spread more and have an ever-increasing negative impact on water resources. South Africa is vulnerable to the changes caused by climate change with large parts of South Africa already having low and variable rainfall (CEEPA, 2006).

According to Mandleni (2011), climate change is global because it affects all countries in the world. It is one of the biggest environmental challenges, and it has become a major concern to society because of its potentially adverse impacts worldwide. According to Scholes and Biggs (2004), climate change leads to extreme events such as floods, lightning, hailstorms and drought of which such events are not good for the country because they are associated with high costs. They also affect agricultural production which in turn affects the world's food security. Various studies (Inter-governmental Panel for Climate Change) (IPCC), (2007) have pin-pointed Africa as the one of the most exposed continents to suffer the devastating effects of climate change and climate variability, with huge economic impacts because of the lack of adaptive capacity. Rain-fed agriculture in Africa is viewed by many observers to be the most vulnerable sector to climate variability and the climate change.

In Africa, agriculture is negatively affected by climate change (Deressa *et al.*, 2009). Unpredictable and unreliable weather in South Africa calls for farmers to be aware of the effects that this weather pattern might have on farming in the immediate term and long term production periods. It also calls for adaptation measures that should be adopted to reduce the negative effects of climate change especially on livestock production. Thorn *et al.*, (2002) forecasted that climate change would bring about water shortages which in turn could reduce livestock and plant production. The study by Thorn *et al.*, (2002) also forecasted that changes in rainfall patterns were likely to lead to outbreaks of livestock and plant diseases. These diseases were estimated to bring about 20-30% losses of all plants and animal species. Furthermore the quality of plant material was expected to be reduced due to increases in temperature. This was likely to result in the reduction of agricultural production impacting negatively on food security and the income of households.

The Food and Agricultural Organisation (FAO) (2010) indicated that climate change will have a range of positive and negative impacts on agriculture. Climate variability is currently the dominant cause of short-term fluctuation in the rain fed agricultural production of sub-Saharan Africa and substantial areas of other developing regions. The study indicated that the most serious form is drought, when rainfall drops substantially below the long-term mean or fails at critical points in crop development. In semi-arid and sub humid areas, these rainfall deficits can dramatically reduce crop yields and livestock numbers and productivity. Such fluctuations can be countered by investment in irrigation or by food imports, but these options are not always open to low-income countries or remote regions. Indeed, the availability of water for irrigation may be reduced by the increased frequency and intensity of droughts together with long-term changes in surface water runoff or evapo-transpiration, and this may reduce irrigated food production.

According to Mendelsohn and Dinar (2009), there is sufficient evidence to suggest that climate change will affect agriculture. They suggest that there is an optimal climate range of temperature and precipitation which exists for crop and livestock production, so changes in the range of those climate variables will affect agriculture. Mendelsohn and Dinar (2009) also indicated that there are factors that change the optimal range of growth and production as a result of climate change, such factors are soil and water. For example, poor soil and not enough water will not allow crops to grow and produce at the level they could with better quality soil and more water. Madzamuse

(2010) further emphasized that the net effect of climate change on world agriculture is likely to be negative. Although some regions and crops will benefit, most will not. While in other regions the increase in atmospheric CO<sub>2</sub> are projected to stimulate growth and improve water use efficiency in some crop species, climate impacts, particularly heat waves, droughts and flooding, will likely dampen yield potential. The study also further indicated that climate change has an impact on agriculture which includes increased competition from weeds, expansion of pathogens and insect pest ranges and seasons, and other alterations in crop agro-ecosystems.

According to Durand (2009) South Africa is a dry country with less than 500mm rain on average recorded annually over about two-thirds of its area. Agriculture and other economic activities are to a large extent adapted to these semi-arid conditions. Furthermore, more than a million people are directly dependent on agriculture for their livelihood in South Africa. Climate change in this country is expected to have a severe impact on agriculture as it is accepted that the frequency of droughts will increase and there will be a higher spatial variability in rainfall and this will have a negative effect on farming on already marginal lands (Le Roux, 2009).

IPCC (2007) indicated that the statistical evidence suggests that South Africa has been getting hotter over the past four decades, with average annual temperatures increasing by 0.13°C per decade between 1960 and 2003. In addition, surface and underground water resources are limited. This indicates that the agricultural sector will be affected because agriculture depends on the climate variables which keep on changing. Carrying more research on climate change will help the farmers because they cannot stop climate change but they need to adapt to the changing climatic conditions.

According to Mekonen (2012), agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pests proliferation. Changes in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines. Although there will be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative, threatening global food security. Climate change involves the changes in precipitation and temperature. Reduction of yield as a result of the changes in the climate variables affects

farmers' revenue and they end up incurring costs of production that are much higher than the net revenue.

Ngaira (2008) carried out a study in Ghana looking at the impact of climate change and variability in crop production and food systems. The study indicated that precipitation has a direct influence on agriculture and is projected to increase for some areas and decrease for others. Changes of the timing, intensity, and amount of rain/snow mix for a location are expected to increase the management challenge of delivering water to crops at the right time through irrigation systems and practices. Excess precipitation can be as damaging as the receipt of too little precipitation due to the increase in flooding events, greater erosion, and decreased soil quality. Increases in evapo-transpiration can result in less available water even in cases when precipitation amounts increase, particularly in soils with limited soil water holding capacity. For example, excess water during corn's early growth stages may cause a reduction in growth or even death, while soil water deficit may lead to less growth and lower yields if the stress occurs during the grain filling period of growth (Gbetibouo and Hassan, 2005). This study will assess the economic impact of changes in precipitation and temperature changes on maize production in Jozini.

According to Kurukulasuriya (2003), effects of climate change on agriculture also include the effects of changing climate conditions on resources of key importance to agricultural production, such as soil and water. Seasonal precipitation affects the potential amount of water available for crop production, but the actual amount of water available to plants also depends upon soil type, soil water-holding capacity, and infiltration rate. According to a study conducted in Chile by Meza *et al.*, (2008) increases of atmospheric (CO<sub>2</sub>), rising temperatures, and altered precipitation patterns will affect agricultural productivity. Increases in temperature coupled with more variable precipitation will reduce productivity of crops, and these effects will outweigh the benefits of increasing CO<sub>2</sub>.

The study also indicated that the effects will vary among annual and perennial crops, and different agro-ecological zones. However, all production systems will be affected to some degree by climate change. The Centre for Environmental Economics and Policy in Africa (CEEPA) (2006) did a research in African countries which indicated that climate is one of the

key factors of production, that is providing the essential inputs like water, solar radiation, and temperature needed for plant and animal growth. The study also indicated that climate change has both the negative and positive impact on agriculture. Rising temperatures, reduced rainfall and water scarcity will collectively impact on the agricultural systems in South Africa.

The study done by Kurukulasuriya and Rosenthal (2003) indicated that agricultural production and productivity depends also on genetic characteristics of crops and livestock, soils, climate, and the availability of needed nutrients and energy, but changes in climate variables affects all the other factors which determines agricultural productivity. According to (IPCC (2007) climate change will mean higher average temperatures, changing rainfall patterns and rising sea levels. This will pose a major threat to agricultural systems particularly in developing countries because their economies are closely linked to agriculture, and a large proportion of their populations depend directly on agriculture and natural ecosystems for their livelihoods.

According to Akpalu *et al.*, (2008), climate is the primary determinant of agricultural productivity. Climate change affects agriculture in the sense that it influences crop and livestock production, hydrologic balances, input supplies and other components of agricultural systems. Agriculture is extremely vulnerable to climate change. Higher temperatures ultimately reduce yields of desirable crops while encouraging weed and pest proliferation. Changes in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines. Although there will be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative.

A study done by Akpalu *et al.*, (2008) in South Africa indicated that climate change scenarios include the changes in temperature and rainfall. Changes in these variables have both positive and negative effects on crop yields, negative effects reduces yields and quality of many crops, most importantly cereal and feed grains. The increase in precipitation has different effects and it differs according to the agro-ecological conditions like in the semi-arid areas an increase in rainfall benefits agriculture by increasing soil moisture, but could aggravate problems in regions with excess water, while a reduction in rainfall could have the opposite effect. An atmosphere with higher CO<sub>2</sub> concentration would result in higher net photosynthetic rates. Higher

concentrations may also reduce transpiration (i.e. water loss) as plants reduce their stomata opening,

Chamuka (2011) did a study in Swaziland, which indicated that climate change will have an impact on soils. In most of the times climate change predicted a small variation of average rainfall but large variation of extreme meteorological events and such trend will increase the risk of floods as well as the frequency and the succession of dry years. According to Knox *et al.*, (2011) droughts and floods will cause a more important degradation of the soils and therefore a loss of the production potential for grazing and cropping. In many parts of the world, the impact of climate change will be an additional pressure on soils already undergoing advanced degradation processes. Erratic and reduced rainfall resulting from climate change will bring out salinization of soil and water.

Climate change impacts will have substantial effects on global water availability in the future. Changes in rainfall patterns and other water balance components like potential evapotranspiration resulting from the increase of temperature will contribute substantially to water scarcity. The drier conditions expected in some areas like the Mediterranean basin or South Africa will cancel the positive potential impact of higher CO<sub>2</sub>. Water competition between different strands of human activity will be one of the defining issues. The global demand for non-irrigation water will increase by two-thirds by 2025 (Rosegrant *et al.*, 2005).

Climatic changes induced by global warming exert a selection pressure that will modify the biodiversity of pathogens (Lovejoy, 2008), their biomass and the epidemiology of the infections they cause. Pathogens that are able to maintain and disseminate better in drought conditions would be expected to become dominant in areas where aridity would be increased under the influence of global warming. This study focuses on the economic impact of climate change on maize production looking at the farmers that are producing under irrigation and also the farmers that are producing under dry-land. According to the literature both of this group of farmersthey are affected by climate change but farmers that are producing under irrigation are better off because irrigation sometimes is used as the adaptation strategy to the changing climate. Farmers are also affected by climate change because if rainfall is more than the amount required by the

crops for growth and development again that can lead to crop failure and negatively affect farmers revenue.

#### **2.4 The impact of climate change on crop production**

According to Akpalu *et al.*, (2008) climate plays an important role in crop production since plants require suitable temperature, rainfall and other environmental conditions for growth and development. Changes in temperature and rainfall would affect crop production, the degree of which varies with latitude, topography, and other geographic features of the location. Akpalu *et al.*, (2008) indicated that recent research has suggested that some impacts of climate change on crop production are occurring more rapidly than anticipated. Crop production is directly affected by many aspects of climatic change stemming primarily from average temperature increase, change in rainfall amount and pattern, rising atmospheric concentration of CO<sub>2</sub>, change in climatic variability and extreme events and lastly the rise in sea level.

Knox *et al.*, (2011) did a study in Sub-Saharan Africa which looked at the implications of climate change on crop yield and food accessibility in Sub-Sahara Africa. The results indicated that crop production is affected by many aspects of climate change stemming primarily from average temperature increase, change in rainfall patterns. The study also indicated that increases in mean maximum and minimum temperature are forecasted for most regions of the world as a result of climate change. It is expected that countries with low latitude (tropical and sub-tropical regions) where water availability is low would be at risk of decreased crop yield at even 1 to 2<sup>0</sup>C of warming as a result of increased evapo-transpiration and lower soil moisture levels thus resulting in the agricultural land located in tropics becoming unsuitable for cropping and some grasslands becoming unsuitable for pasture and that result in yield reduction. The results also indicated that as a result of changes in rainfall amount and pattern the temperate region (wet areas) could become wetter and drier areas could become drier. The change in rainfall can affect soil erosion rates and soil moisture both of which are important for crop yield.

Another study done by Kurukulasuriya and Rosenthal (2003) in America indicated that there are number of factors that determine crop yields but primarily temperature and precipitation are the most factors which determine the yield. The study also indicated that although in some regions

temperature and precipitation changes will have limited production benefits, agricultural experts agree that in general a changing climate will result in overall lower agriculture yields. Crop exposure to higher temperature leads to slow crop development. Ngoma (2008), carried out a study in Zambia, looking at the effect of climate change on crop production, the study indicated that rising concentration of CO<sub>2</sub> affects crop production both positively and negatively because the increase in atmospheric CO<sub>2</sub> is beneficial to plants and it acts as a fertilizer by enhancing growth and development of crops. Also the increase in atmospheric CO<sub>2</sub> will stimulates photosynthesis and improves water use efficiency thus results in yield increase. However the increasing CO<sub>2</sub> level does not only contribute to increase yield but it also the major cause of greenhouse effect.

According to Walker and Schulze (2006) stages in the development, or duration, of entire life cycles of agricultural pests and diseases are closely related to temperature thresholds, and are thus affected by global warming. Climate change acts to accelerate critical life stages of these pests, thus potentially increasing the potential for crop damage and increasing the costs of various forms of control. Changes in temperature, amount of carbon dioxide (CO<sub>2</sub>), and the frequency and intensity of extreme weather could have significant impacts on crop yields.

Oseni and Mararimbi (2011) did a study in Swaziland which was looking at the impact of climate change on crop production, and the study indicated that warmer temperatures may make many crops grow more quickly, but warmer temperatures could also reduce yields. Crops tend to grow faster in warmer conditions. However, for some crops (such as grains), faster growth reduces the amount of time that seeds have to grow and mature. This can reduce yields (i.e., the amount of crop produced from a given amount of land). For any particular crop, the effect of increased temperature will depend on the crop's optimal temperature for growth and reproduction. In some areas, warming may benefit the types of crops that are typically planted there. However, if warming exceeds a crop's optimum temperature, yields can decline.

Higher CO<sub>2</sub> levels can increase yields. The yields for some crops, like wheat and soybeans, could increase by 30% or more under a doubling of CO<sub>2</sub> concentrations. The yields for other crops, such as corn, exhibit a much smaller response (less than 10% increase). However, some factors may counteract these potential increases in yield. For example, if temperature exceeds a crop's

optimal level or if sufficient water and nutrients are not available, yield increases may be reduced or reversed

Knox *et al.*, (2011) indicated that warmer growing season temperatures can directly reduce yields in two important ways. First, for crops such as maize, higher temperatures have a bad effect because it speeds up crop growth and development. This reduces the time for plant and grain development, limiting the attainment of yield potential. Second, if extreme heat occurs during flowering, such as the maize ‘silk-tasseling’ phase, pollination may be inhibited and the development of grain may be prevented entirely. Additionally, temperature increases could accelerate plant development enough that the reproductive period, the development stage requiring the most water, would shift away from the typical wettest time of the cropping season a problem for rain fed maize production systems. Lovejoy (2008) also agreed that the effect of temperature in reducing the length of the growth cycle, especially the grain filling phase, is the most important factor in explaining reduced yields at warmer temperatures.

Climate change has an impact on crop growth and development processes. For example, an increase in CO<sub>2</sub> will simulate photosynthesis rates and sometimes result in higher yields (Adlakha, 2011). Changes in temperature and precipitation may also affect crop photosynthesis, and plant development rates, as well as water and nutrient budgets in the field. Rosenzweig *et al.*, (2004) also emphasized that an increase in temperature due to climate change has both positive and negative impacts on crop production. For example, in the middle and higher latitudes, global warming will extend the length of the potential growing season, allowing earlier planting of crops in the spring, earlier maturation and harvesting, and the possibility of completing two or more cropping cycles during the same season. In warmer, lower latitude regions, increased temperatures may increase the rate at which plants release CO<sub>2</sub> in the process of respiration, resulting in less than optimal conditions for net growth. High temperature reduces yield by accelerating physiological development (hastening maturation), not allowing the crop to progress slowly through the season so as to maximize time for the capture of resources and for assimilate partitioning to reproductive structures (Ramados, 2006). Therefore, under warming conditions, yields are expected to decrease.

Mendelsohn and Dinar (2009) did a study in America looking at the impact of climate change in agriculture and the study indicated that each crop species has a given set of temperature thresholds that define the upper and lower boundaries for growth and reproduction, along with optimum temperatures for each developmental phase. Plants are currently grown in areas in which they are exposed to temperatures that match their threshold values. As temperatures increase over the next century, shifts may occur in crop production areas because temperatures will no longer occur within the range, or during the critical time period for optimal growth and yield of grain or fruit. The study also indicated that increasing temperatures cause plants to mature and complete their stages of development faster, which may alter the feasibility and profitability of regional crop rotations and field management options, including double-cropping and use of cover crops. Faster growth may create smaller plants, because soil may not be able to supply water or nutrients at required rates, thereby reducing grain, forage, and fruit production.

According to FAO (2009) changes in temperature and precipitation will bring changes in land suitability and in crop growth. The projected net effect will be an increase in the area of land in higher latitudes suitable for crop production, because of milder and shorter winters, but a decrease in land suitability in arid and semi-arid areas. In the East African highlands, higher temperatures may result in land becoming unsuitable for crop production. The effects on potential yields will follow the same pattern as land suitability, with yield gains in middle to higher latitudes and losses in the lower latitudes. There may be some gains in tropical highlands where at present there are cold temperature constraints.

Kurukulasuriya (2003) further stipulated that changes in temperature and precipitation will change the distribution of agro-ecological zones. changes in the climate variables will have the different effects on the different agro-ecological conditions like for example in semi-arid area decrease in precipitation will leads to changes in soil moisture and content and the timing and length of growing seasons. Deressa *et al.*, (2009) stated that in middle and higher latitudes, higher temperatures will lengthen growing seasons and expand crop producing areas pole-ward, thus benefiting countries in these regions.

Plants have become specialized to optimize yields at particular temperature and humidity settings (Knox *et al.*, 2011). The level of CO<sub>2</sub> and temperature in the atmosphere affect the rate at which

a plant develops. With the increasing of temperatures and the concentration of CO<sub>2</sub> rising, the rate of development in plants changes, in turn affecting the growing period of the plant or crop (Mendelsohn & Dinar, 2009). Apata *et al.*, (2009) further stipulated that in lower latitudes, higher temperatures as a result of climate change will adversely affect growing conditions, of the crops especially in areas where temperatures are close to or at the optimal level for crop growth to begin with.

The report by IPCC (2007) indicates that any changes in climate will have implications for climate-sensitive systems such as agriculture, forestry, and some other natural resources. The study indicated that with respect to agriculture, changes in solar radiation, temperature, and precipitation will produce changes in crop yields, crop mix, cropping systems, scheduling of field operations, grain moisture content at harvest, and hence, on the economics of agriculture including changes in farm profitability. This study will assess the impact of the changes in climate variables (precipitation and temperature and CO<sub>2</sub>) which will affect or reduce profitability of maize production thus affecting the net revenue.

## **2.5 The impact of climate change on livestock**

The study done by Mandleni, (2011) in Eastern Cape (E.C), province of South Africa indicated that livestock are key assets for the poor, they provide a cushion against shocks of multiple economic, social, and risk management functions. Examples of livestock kept are cattle, buffalo, sheep, goats, pigs and poultry. In rural areas they are kept for various reasons such as income, manure, ploughing, status and savings. Climate change climate influences livestock production by affecting the conditions governing animal production, fodder crop production and animal health. According to the study done by Knox *et al.*, (2011) in Uruguay, livestock production and climate change have a complex and multi-directional link, because animal production has an influence on climate change, with mainly ruminants generating emissions of greenhouse gases, which causes climate change.

Livestock production is of high importance not only in South Africa but globally. According to Montshwe (2006), livestock contributes 40 percent to agricultural GDP and employs more than a million people. It also creates livelihoods for more than 1 million poor people. Research also shows that livestock production is the world's dominant land use, covering about 45 per cent of

the earth's land surface, much of it in harsh and variable environments that are unsuitable for other uses. It is believed that climate change can impact the amount and quality of produce, reliability of production and the natural resource base on which agriculture depends.

Morgan and Wall (2009) did a study in North West province of South Africa which was looking at climate change and parasitic diseases the study indicated that an increasing temperature as a result of climate change can have varying effects, depending on when they occur. Warmer conditions in the summer can lead to stress on range and housed livestock since dry pastures, poor hay and feed production and shortages of water all leads to worse conditions for cattle. On the other hand, increased temperatures during the winter months can reduce the cold stress experienced by livestock remaining outside, as well as reduce the energy requirements to heat the facilities of those animals inside.

According to FAO (2010) climate change can also affect livestock by changing species composition in rangelands and some managed grasslands while species composition is an important determinant of livestock productivity. As temperature and carbon dioxide levels change due to climate change, the optimal growth ranges for different species also change resulting in changes in species composition and their competition dynamics. Small changes in temperature alter this balance significantly and often result in changes in livestock productivity; an implication of this is that significant changes in management of the grazing system may be required to attain the production levels desired.

A study done by Mandleni (2011) in Eastern Cape province of South Africa indicated that grazing livestock is expected to be negatively affected by climate change. It reduces rainfall and thereby reduces fodder production while increasing marginal costs of ranching. The reduced amount of rainfall is also expected to affect fodder production and lead to proportionately less animal production. The study further indicated that climate change has an indirect impact on livestock production because it leads to the changes in the ecosystem. Ecosystem changes resulting from climate change were seen relevant for livestock production because of the land dependency of most production systems and the close interaction of livestock genetic resources with other agricultural biodiversity. Water, feed and forage were the most important inputs for

livestock production. Their overall and relative availability may be affected by the ecosystem changes, which were accelerated by climate change.

Climate change also leads to temperature changes, the expected 2°C increase in temperatures is expected to increase average savannah fires by 7 percent and with the increase in grass fuel load of 15percent, fire intensities are expected to increase by about 20 percent (Madzwamuse, 2010).Higher carbon dioxide is expected to lead to less protein in the grass, which will reduce any benefit resulting from increased plant growth. Climate change also affects livestock because it leads to the increase of the frequency and spatial spread of livestock disease outbreaks such as foot and mouth disease.

Dinar *et al.*, (2008) did a study in Tunisia which indicated that climate change represents a special “feedback loop”, in which livestock production both contributes to the problem and suffers from the consequences. Livestock contribute to climate change by emitting greenhouse gases, either directly (e.g. from enteric fermentation) or indirectly (e.g. from feed-production activities, deforestation, overgrazing, etc.). Greenhouse gas emissions can emanate from all the main steps of the livestock production cycle. Emissions from feed-crop production and pastures are linked to the wide use of chemical fertilizers and pesticides, to soil organic-matter losses and to transport (use of fossil fuels). The study also indicated that climate change will have tremendous consequences for dairy, meat and wool production, mainly arising from its impact on grassland and rangeland productivity. Heat distress suffered by animals will reduce the rate of animal feed intake and result in poor growth performance (Meza *et al.*, 2008). This study will concentrate on the economic impact of climate change on crop production specifically maize.

A similar study was done in America by Soe and Mendelsohn (2008) which indicated that livestock production systems are vulnerable to temperature stresses. An animal’s ability to adjust its metabolic rate to cope with temperature extremes can lead to reduced productivity and in extreme cases death. Prolonged exposure to extreme temperatures will also further increase production costs and productivity losses associated with all animal products, e.g., meat, eggs, and milk. There are four ways in which livestock is affected by livestock and those ways are explained in the next section.

According to Valtorta (2009) climate change affects animal production in four ways firstly, it has an impact on livestock feed-grain availability and price, impacts on livestock pastures and forage crop production and quality, changes in the distribution of livestock diseases and pests and the direct effects of weather and extreme events on animal health, growth and reproduction. Alterations of temperature and precipitation regimes may result in a spread of disease and parasites into new regions or produce an increase in the incidence of disease, which, in turn, would reduce animal productivity and possibly increase animal mortality.

According to Hoffman and Vogel (2008) animals are less sensitive to climate change than crops because they can move to seek for consumable vegetation and can access to feed. Changes in the primary productivity of crops, forages and rangelands could be observed in areas affected by climate change. Increased temperatures coupled with water scarcity and irregular rainfall patterns would affect the optimal growth rates of many forage and range species. The impact that climate change will bring about is expected to increase the vulnerability of livestock systems and to reinforce existing factors that are simultaneously affecting livestock production systems such as rapid population and economic growth, increased demand for food (including livestock) and products (FAO, 2009).

According to Schiere *et al.*, (2011) livestock also provide the key inputs to crop production. Most farms in rural areas are too small to justify owning or using a tractor so farmers use livestock for draught power. Livestock also create a crucial link in nutrient cycles, returning nutrients to the soil in forms that plants can readily use. Few smallholder farmers can afford mineral fertilizer, so livestock provide nutrients through manure and urine. If climate change affects livestock production, a smallholder farmer that depends on livestock for crop production will also be affected.

## **2.6 The impact of climate change on water resources**

According to ARC (2002), South Africa's average rainfall is estimated at 450mm per year, which is far below the world's average of 860mm, while evaporation is comparatively high. In addition, surface and underground water resources are limited. According to Blignaut *et al.*, (2009), South Africa in general has been approximately 2% hotter and at least 6% drier over the ten years between 1997 and 2006 compared to the 1970s. Within the same period there was also

an increase in the use of water. By the year 2000, 98.6% of that year's surface water yield and 41% of the annual utilisable potential of groundwater was allocated to use. Irrigation agriculture, comprising 60% of total consumption, is by far the largest single consumer of water (Meza, *et al.*, 2008). Climate change, that brings about changes in climate variable may make temperatures to climb above the normal temperatures and reduce rains and change their timing, and therefore put more pressure on the country's scarce water resources, with implications for agriculture, employment and food.

According to DWAF (2004) climate change will significantly impact agriculture by increasing water demand, limiting crop productivity and reducing water availability in areas where irrigation is most needed or has comparative advantage. Global atmospheric temperature is predicted to rise by approximately 4°C by 2080, consistent with a doubling of atmospheric CO<sub>2</sub> concentration. Mean temperatures are expected to rise at a faster rate in the upper latitudes, with slower rates in equatorial regions. Mean temperature rise at altitude is expected to be higher than at sea level, resulting in intensification of convective precipitation and acceleration of snowmelt and glacier retreat. In response to global warming, the hydrological cycle is expected to accelerate as rising temperatures increase the rate of evaporation from land and sea. Thus rainfall is predicted to rise in the tropics and in higher latitudes, but decrease in the already dry semi-arid to arid mid-latitudes and in the interior of large continents.

Rivers and lakes supply drinking water for people and animals, as well as being vital for agriculture and industries. South Africa is a water scarce country and the demand for water is always in excess of natural water availability in several river basins (ARC, 2007). According to Department of Water Affairs Forestry (DWAF) (2005) climate change will affect two key parameters: firstly, temperatures will increase and, secondly, rainfall will decrease and be distributed more erratically. A recent estimate of the effects of climate change on water resources suggests that South Africa may experience a reduction of 10% on average rainfall reducing surface water runoff up to 50-75% by 2025. The effects of variable rainfall patterns and different climatic regimes are compounded by high evaporation rates across the country.

Herden and Stevens (2010) did a study in South Africa which was looking at the impact of climate change on irrigation water management; the study indicated that although climate change

is expected to affect many sectors of natural and built environments, water is considered to be the most critical. The study further indicated that because of the general aridity of South Africa it is vulnerable to climate change. Stream flow is relatively low for most of the year and due to the high water demand by the industries, forestry and urban development, the requirement for water already exceeds the natural availability of water in several of the river basins. Water is therefore considered as the limiting resource in South Africa and a change in available water supply together with climate change could have severe implications on the majority of sectors of the economy especially on irrigated agricultural sector.

According to the study climate change affects hydrological resources in South Africa because as the temperature increases, that increases the variability of climate and decreases rainfall. Agriculture is affected in that manner because crop water requirements increase leading to the increase in irrigation water requirement. Climate change leads to the increase as a result of the change in precipitation, since a relatively small fraction of rainfall in South Africa will be converted to runoff.

Another study was carried out by Zhu and Ringler (2010) in Limpopo province of South Africa the study was looking at climate change implications for water resources in the Limpopo river basin the results indicated that climate change is expected to alter present hydrological resources in Limpopo and add pressure on the adaptability of future water resources. It also has the potential to impact very significantly on both the availability and the requirements for water in Limpopo. Change in rainfall can affect soil erosion rates and soil moisture, both which are important for crop yield. The increase in temperature along with the reduced precipitation will likely result in the loss of arable land in the region due to decreased soil moisture, increased aridity, increased salinity and groundwater depletion. Water shortages could lead to water rationing and higher water costs and limit opportunities to maintain or extend cultivated agricultural land through the use of irrigation.

A similar study was done by Walker and Schulze (2006) which was looking at the impact of climate change on irrigation industry, the study indicated that there are agronomic strategies that should be adopted by farmers like choosing crops that are adapted to the soil, climate and the environment that fit into the production system of a farm, decide on the optimum crop are taking

into account irrigation water availability (water allocation) and also select crops that will give an income level at a lower yield that will ensure long term economic viability and lastly grow crop that is efficient and can be managed by a farmer.

## **2.7 Maize production in South Africa**

Maize is considered as a major grain crop, in South Africa being both the major feed grain and the staple food of the majority of the South African population (Adams, 2006). It is used in more ways than any other grain crops as human food, as feed grain, fodder crop, and for industrial purposes. It is grown throughout the whole country on approximately 3.1 million hectares of land under diverse environmental conditions and approximately 8.0 million tons are produced annually (Agricultural Statistics, 2010), other things being equal. Climate change could have a significant impact on South African maize production. According to Akpalu *et al.*, (2008) maize plant is quite hardy and sometimes adapts to harsh conditions, but a drier and warmer climate can have negative effects on crop yield, and might make its cultivation unviable in marginal and exposed regions. However, improved crop cultivars, biotechnology, the fertilization effect from elevated CO<sub>2</sub> levels *inter alia* have the potential to assist agriculture in adapting to a changing environment.

According to Stern (2006) it is important to better understand the link between maize physiology and its optimum management strategies. Suitable hybrids, optimum plant population, planting dates, plant nutrition and timely weeding are crop management factors that are important to achieve optimum crop yields (Deressa *et al.*, 2009). Du Toit, 2003) summarized the state of maize production on the high veld of South Africa. According to Akpalu *et al.*, (2008), the average production of maize on a commercial scale yields between 1 000 and 3 000 kg ha<sup>-1</sup> in the drier western half of the country. The breakeven yields for commercial farmers in the western Highveld are just above 2 000 kg ha<sup>-1</sup>. Maize production is also influenced by different factors like the type of soil, fertilizer application rate, climate, plant population density and planting date and these factors are discussed below.

## **2.8 Factors influencing maize production in South Africa**

Maize production depends on the correct application of management practices ensuring both environmental and agricultural sustainability. According to Du Plessis (2003) it is important for a farmer to understand the link between maize physiology and its optimum management strategies. The study by Abraha and Savage (2006) in KZN indicated that suitable hybrids, optimum plant population, planting dates, plant nutrition and timely weeding are crop management factors that are important to achieve optimum crop yields. The average production of maize on a commercial scale yields between 1 000 and 3 000 kg ha<sup>-1</sup> in the drier western half of the country.

The low productivity of dryland (rainfed) maize could be attributed to a combination of factors such as low soil fertility, unfavourable climatic conditions and poor farm management during the growing season (Lotsh, 2009). Mati (2004) stated that inputs such as fertilisers, seed quality and cultural management activities are all important factors for rain fed maize production in semi-arid regions.

### **2.8.1 Climate**

The daily temperatures, seasonal rainfall, day length, solar radiation and humidity are major climatic factors affecting maize production in semi-arid regions. Furthermore, global warming has already led to changes in the local climate and its variability and will ultimately impact on grain yield (Dogan *et al.*, 2004). Climatic conditions could also raise issues of sustainability of maize production at a regional and national level in South Africa. Uncertainty of maize yield scenarios could be influenced by the sensitivity of the crop to climate variability which affects farming practices (Beiragi *et al.*, 2011).

The distribution of global solar radiation such as photosynthetic active radiation and net all-wave radiation influences the growth and development of maize plants. Solar radiation provides the free energy required by plants for growth and maintenance through the process of photosynthesis (Mati, 2004). Fanadzo *et al.*, (2009) found that solar radiation can be used to identify the management decisions that allow maximising crop growth in an environment. Solar radiation can be transformed into grain production, while the duration of day length also influences the flowering and growth of shoots of crop plants.

Most processes in plants that relate to growth and yield are highly dependent on temperature, since the optimum temperature for photosynthesis frequently corresponds to the optimum growth temperature. Crop yields can be affected positively or negatively by temperature increases. Maize is a warm weather grain crop, since the plants develop optimally at temperatures around 30°C. At temperatures below 6°C and above 45°C the process of photosynthesis does not continue. High temperatures shorten the life cycles of grain crops, resulting in a shorter grain filing period. High temperatures could also produce smaller and lighter grains, culminating in lower crop yield and poor grain quality (Azam *et al.*, 2007).

Rainfall is the most important climatic factor that influences the pattern and productivity of rainfed maize in sub-Saharan Africa, since rainfall replaces soil water used by crops (Abraha and Savage, 2006). A number of climatic factors such as low and erratic rainfall, constant low humidity levels and high temperatures during the growing season have influenced crop growth conditions (Du Plessis, 2003). Mati (2004) stated that erratic rainfall and drought are more difficult to manage, since their occurrence is less predictable, while the response of maize to climate depends on the physiological make-up of a variety/cultivar being grown.

The variability of seasonal rainfall total and climate change increases the vulnerability of maize production. The final maize yield is affected by the amount and distribution of rainfall and the amount of water transpired by the crop canopy. Maize requires between 450 and 600 mm of rain per season, which is mainly acquired from the soil moisture reserves (Du Plessis, 2003). Maize plants can easily reach the soil moisture reserves, since the total root length of maize extends to an estimated 2 metres for a mature crop (Du Plessis, 2003). Maize production under rainfed conditions could be affected by the timeliness, adequacy and reliability of seasonal rainfall (Walker & Schulze, 2006). Under rainfed conditions an annual rainfall of 350 to 450 mm is required to produce a maize yield of 3 tonnes per hectare (Du Plessis, 2003). Ramadoss (2006) found that rain fed maize production was severely impeded by water stress and high temperatures even if the soil water profile was full at the beginning of the growing season. Akpalu *et al.*, (2008) found that a 10% reduction in mean rainfall reduced the mean maize yield by approximately 4% in South Africa.

### 2.8.2 Soil

Maize production requires suitable soil that has sufficient and balanced quantities of plant nutrients and chemical properties, effective depth, favourable morphological properties, good internal drainage, and an optimal moisture regime (Du Plessis, 2003). The interaction of soil physical, chemical and biological properties in various soils could prompt the occurrence of soil degradation which affects maize yields. This could be results in the form of erosion, losses of nutrients or soil compaction which is extreme alarm to agricultural production (Beiragi *et al.*, 2011). Dogan *et al.*, (2004) also highlighted that the degradation of agricultural soils threatened sustained production, are consequences of decreases of loss of soil structure and organic matter. Bryan *et al.*, (2009) also pointed out that the loss of organic matter and stored nutrients, as a result of cultivation, causes a loss in crop productivity. In order to maximise maize production it is important to assess the soil nutrient status frequently (every second year) to determine how much fertiliser should be applied.

The effect of water shortages on production will vary with crops, the soil characteristics, the root system, and the severity and timing of moisture stress during the growing cycle. Mati (2004) found that to maximise maize yield, the soil water profile throughout the growing season should be around or above 50% of the available water capacity in the rooting zone. Soil water stress usually hampers the growth and development stages of maize such as flowering, pollination and grain filling, which is critical in determining crop yield (Lotsh, 2006). Soil compaction is another factor that directly or indirectly affects the growth and yield of crops, especially maize. This decreases plant root penetration, movement of water and nutrients through factors such as bulk density, porosity and penetration resistance of soil. Soil compaction can be reduced through soil preparation at planting using deep tillage systems to improve water infiltration and nutrient movement in the soil (Du Plessis, 2003).

A study by Abraha and Salvage (2006) indicated that soil acidity is the main cause of soil degradation in South Africa, where it reduces crop production drastically for small and large-scale agriculture. Extremes in soil pH (acid or alkaline) could result in poor biomass production and in reduced additions of organic matter to the soil due to poor growing conditions for micro-organisms in the soil. This will result in low levels of biological oxidation of organic matter,

which affects the availability of plant nutrients and thus indirectly biomass production. The study further indicated that the solution to soil acidity is liming, which reduces the toxic concentration of aluminium and manganese and increases the soil pH. Most importantly, liming improves the solubility and availability of plant nutrients and makes production to increase. This study will also look at the factors that will influence productivity of maize and thus influencing gross margin of the farmer.

### **2.8.3 Planting date**

Planting date plays a significant role in influencing the growth and yield of maize (Azam *et al.*, 2007). Maize growers have a challenge in finding the planting window that is neither too early nor too late. Selection of planting date is the most important management tool under rain fed production in South Africa (Du Plessis, 2003). Planting date is mainly linked to the long-term climatic conditions of the region (Abraha and Salvage, 2006). Since planting date affect the timing and duration of the vegetative and reproductive stages, small-scale farmers tend to use multiple planting dates over extended periods of time to ensure that at least part of the crop is successful, but as result of climate change farmers end up changing planting dates. Therefore, small-scale farmers select early maturing varieties that offer flexibility in planting dates. The late planting of early maturing varieties helps during a delayed onset of rainfall to avoid terminal drought during the cropping season (Morton, 2007). Changing planting date is one of the adaptation strategies to climate change (Abraha and Salvage, 2006). This study will also look at the adaptation strategies smallholder farmers' use in the face of climate change.

In temperate and subtropical regions of the world, maize is planted early with a high plant density to maximise grain yield. Under these conditions the pattern of development of early planted maize is slower due to low soil and air temperatures (Ngaira, 2008). In South Africa, the potential plant dates for rain fed production in the summer rainfall region is from October (east) to December (west) (Walker & Schulze, 2006). This could lead to a risk of yield reduction when using early or late planting dates for rainfed maize production. Delaying planting dates could affect the growth and development of maize during later stages of the season due to frost occurrence. Beiragi *et al.*, (2011) found that different planting dates have an effect on the growth

and development of maize plants, modified by environmental changes such as solar radiation and temperature.

In a field experiment in central South Africa, it was found that greater leaf area index and dry matter accompanied by higher plant heights were achieved using early planting dates (Ngaira, 2008). The experiment also indicated that early planting dates resulted in higher grain yield and yield components such as cob number, cob length and cob mass. In contradiction to Adams (2006) findings, early hybrids in the tropics produced shorter plants with, fewer leaves and lower leaf areas, resulting in fewer self-shading plants than late hybrids. This means that the crop cannot utilise maximum interception of solar radiation in order to maximise grain yield (Mendelsohn and Dinar, 2009). The probability exists that unfavourable climatic condition that occurs after planting or during the growing season could drastically lower maize yield or cause crop failure regardless of the planting date (Beiragi *et al.*, 2011). Due to unanticipated climatic conditions during the growth and development of maize, farmers could utilise multiple planting dates to avoid crop failure or unprofitable maize yield.

#### **2.8.4 Plant population density**

Maize is the agronomic grass species most sensitive to variations in plant population density. Du Plessis (2003) emphasised that maize plant population density would differ on account of soil fertility, varying climatic conditions, row spacing and cultivar type. Climatic conditions and cultivar types could be used to modify the optimum plant population density. Under Southern African conditions plant population density is generally low (15 000 to 35 000 plants ha<sup>-1</sup>) (Walker and Schulze, 2006). Under cooler, temperate and warmer regions the plant population densities required to produce maize yields of 3 000 kg ha<sup>-1</sup> are 19 000 plants ha<sup>-1</sup>, 16 000 plants ha<sup>-1</sup> and 14 000 plants ha<sup>-1</sup>, respectively. For a yield of 6 000 kg ha<sup>-1</sup> under cooler, temperate and warmer regions the plant population densities are 37 000 plants ha<sup>-1</sup>, 31 000 plants ha<sup>-1</sup> and 28 000 plants ha<sup>-1</sup>, respectively (Du Plessis, 2003). The use of plant population density to increase maize yield gained popularity.

Maize plants respond well to high plant populations up to a critical optimum number of plants per unit area. This is due to the fact that maize plants have a small capacity to develop new reproductive structures in response to an increase in the available resources per plant (ARC,

2007). Climate change affects plant population density because Jozini receives a low rainfall so higher population density will lead to many plants competing for water, nutrients and space and leading to lower yield and affect the farmers' net revenue. This study will assess the economic impact of climate change on maize production under irrigation and dryland looking also at the factors that affect maize yield and reducing the farmers' net revenue

Maize yield could fall drastically by increasing plant population, since too high plant densities result in limited availability of resources (e.g. solar radiation, nutrients and water) per plant during the period of silking. Light penetration in the crop canopy can be reduced by high plant population densities, which could displease the crop net photosynthesis process which may reduce grain yield (Azam *et al.*, 2007). Yield may also be reduced as a result of a decline in harvest index and increased stem lodging caused by plant population density beyond the optimum level. The optimum plant density for maize grain yield could also be affected heavily by uncontrollable factors such as water availability when farming operations occur under rainfed conditions.

The interaction between soil water, plant population and rainfall could influence vegetative crop growth up to silking. High air temperatures and erratic rainfall that leads to drought stress as a result of climate change could also affect maize yield due to interplant competition for water. Under such conditions it is advisable to use lower plant population densities. Using high plant population densities does not guarantee mean higher grain yields even if water supply is increased, since small deficiencies in water supply during critical growth stages, such as flowering and kernel set could drastically reduce grain yield (ARC, 2007).

### **2.8.5 Fertiliser application rate**

The application of fertilisers to improve or maintain soil fertility is essential for crop growth, development and also required to sustain profitable yields. Soil fertility declined over southern and eastern Africa, causing a dominant limitation to yield improvement and sustainability of maize production system (Azam *et al.*, 2007). Balanced nutrient management can improve fertiliser use and crop growth (Knox *et al.*, 2006). Optimum fertiliser application rate is required, since poor growth and low yield could be prompted by shortages in nutrients, while too much fertiliser could lead to insignificant increases in grain yield (Walker and Schulze, 2006). The

solution to nutrient shortages could be the application of micronutrients (e.g. calcium, magnesium and baron manganese) without neglecting the macronutrients (nitrogen, phosphorus and potassium). Integrated nutrient management could stimulate sustainable agriculture using soil micro-organisms. This regulates the dynamics of organic matter decomposition and the availability of plant nutrients (ARC, 2007).

Nitrogen stress reduces photosynthesis by reducing leaf area and accelerates leaf senescence. Inadequate nitrogen is the second biggest constraint after drought in tropical maize production, since maize has a strong positive response to nitrogen supply. Crops can uptake nitrogen from biological nitrogen fixation or microbial mineralisation in the form of nitrate ( $\text{NO}_3$ ) and ammonium ( $\text{NH}_4^+$ ). The soil nitrogen will vary between season and location. This may influence the soil nitrogen status, water availability, and plant population density of maize, while factors such as soil temperature and water will affect the application of nitrogen. Interactions between environmental factors could cause a variation in soil characteristics which leads to a variation in the optimum rate of nitrogen application required for maize. At the beginning of the season, nitrogen supply usually exceeds nitrogen demand by the crop, but as the season progresses nitrogen in the soil will start to deplete, causing a nitrogen scarcity and nitrogen stress (Le Roux, 2009).

Timing of plant nitrogen stress in the growing season could affect grain filling and kernel weight. Effective use of starter fertiliser will improve early growth and maize yield due to increased early season dry matter production. The study done by Maddison (2007) indicated that climate change will affect fertiliser application because if there is more rainfall that will leads to leaching of fertiliser form the soil and reduce productivity. That could force the farmer to apply more fertiliser after it has been washed away by rainfall and that leads to extra costs and affecting the farmer's net revenue. This study will look at how climate change will affect the farmer's net revenue.

## **2.9 Impact of climate change on maize production**

Maize yield is a function of number of grains (kernels) and grain weight. Full potential grain weight is achieved when the rate of grain filling and the duration of the filling period are both at maximum. Over moderately high temperatures (25 to 32°C) the maximum grain filling rate is

achieved. However, the high temperatures also accelerate plant development, causing the duration of the filling period to shorten. Because the enhanced filling rate cannot compensate for this temporal limitation, kernels cannot attain potential weight. At temperatures above 32°C, starch production is impaired, slowing the filling rate. The most substantial impacts to grain weight occur when the beginning of the reproductive period is exposed to temperatures above 32°C. Heat or drought stress during the maize silk-tasseling phase (flowering and pollination) have been observed to reduce yields by as much as 7% per day of stress, a greater yield reduction than for all other potential climatic stresses. This study will assess how the change in climatic variables which is temperature and rainfall will affect maize profitability and thus affecting the farmers' net revenue in Jozini municipality.

According to Knox *et al.*, (2006), most processes in plants that relate to growth and yield are highly dependent on temperature, since the optimum temperature for photosynthesis frequently corresponds to the optimum growth temperature. Crop yields can be affected positively or negatively by temperature increases. Maize is a warm weather grain crop, since the plants develop optimally at temperatures around 30°C. At temperatures below 6°C and above 45°C the process of photosynthesis comes to a standstill (Adams, 2004). High temperatures shorten the life cycles of grain crops, resulting in a shorter grain filling period. High temperatures could also produce smaller and lighter grains, culminating in lower crop yield and poor grain quality (Apatha *et al.*, 2009). Extremely low temperatures will cause frost conditions which can damage maize at all growth stages. To prevent frost damage to crops, a 120 to 140 day frost-free period is required (Du plessis, 2003). Climate change will lead to the changes in temperature that is required for growth and development of maize crop and that will affect maize yield and reduce the farmers net revenue.

According to the Bureau for Food and Agricultural Policy (2004) maize requires a minimum daily temperature of 19°C or, alternatively, it requires that the mean temperature in summer months is less than 23°C. For germination to proceed normally, a minimum air temperature of between 10°C and 15°C is required for seven successive days. The ideal germination temperature is between 16°C and 18°C. At 20°C, maize should emerge within 5-6 days, but if the temperature rises above 32°C it may affect maize production detrimentally. Frost is the main cause of damage

to maize and a frost free period of at least 120 to 140 days is required in order to prevent permanent damage (Du Plessis, 2003). Changes in climate variables below or above the required threshold will affect growth and development of maize crop and reduce maize yield and leads to lower productivity which will end up affecting the farmer's gross margin.

Rainfall is the most important climatic factor that influences the pattern and productivity of rain fed maize in sub-Saharan Africa, since rainfall replenishes soil water used by crops (Watson, 2010). A number of climatic factors such as low and erratic rainfall, constant low humidity levels and high temperatures during the growing season have influenced crop growth conditions. According to Du Toit(2003) erratic rainfall and drought are more difficult to manage, since their occurrence is less predictable, while the response of maize to climate depends on the physiological make-up of a variety/cultivar being grown. Adams (2006) indicated that low temperature affects maize production in the sense that it causes germination inhibition leading to growth and yield depression at the same higher temperature decreases growth and reduces yield. High intensity of rainfall can increase erosion, while the absence of rainfall or long period of dry period causes a delay in germination and reduced growth or growth failure.

Adams (2006) further indicated that variability of seasonal rainfall total and climate change affects maize production by increasing vulnerability in maize production. Amount and distribution of rainfall and the amount of water transpired by the canopy affects the final yield for example if there is less rainfall during the stage of canopy formation that affects maize yield. Maize requires between 450 and 600 mm of rain per season, which is mainly acquired from the soil moisture reserves (Du Toit, 2003). Maize production under rain fed conditions could be affected by the timeliness, adequacy and reliability of seasonal rainfall (Walker & Schulze, 2006). Under rain fed conditions an annual rainfall of 350 to 450 mm is required to produce a maize yield of 3 tonnes per hectare (Du Toit 2003).

Similar study by Ramadoss *et al.*, (2004) discovered that rain-fed maize production was severely hampered by water stress and high temperatures even if the soil water profile was full at the beginning of the growing season. Akpalu *et al.*, (2008) found that a 10% reduction in mean rainfall reduced the mean maize yield by approximately 4% in South Africa. This study will assess the economic impact of climate variables on maize production on both dryland and

irrigation farming systems in Jozini municipality, looking at how this climate variable affects maize productivity and also farmers' revenue.

According to Blinguat *et al.*, (2009) the effect of water shortages on production as a result of changes in precipitation will vary with crops, the soil characteristics, the root system, and the severity and timing of moisture stress during the growing cycle. Makadho (2006) found that to maximise maize yield, the soil water profile throughout the growing season should be around or above 50% of the available water capacity in the rooting zone. Soil water stress usually hampers the growth and development stages of maize such as flowering, pollination and grain filling, which is critical in determining crop yield (Adlakha, 2011).

A study by Knox *et al.*, (2011) in Bulgaria investigating impact of climate change on maize showed that maize yields could be reduced by between 5% and 10%. The authors deduced that this is the result of a reduction of the growing period. Brooks *et al.*, (1999) in Romania reported similar values, where maize showed yield reductions of 10%. Jones and Thornton (2003) studied the performance of maize in several locations of Latin America. They came to the conclusion that maize yield is expected to be reduced by 10% for the region, with higher impacts on dry lowland tropical areas. Similarly, Du Toit(2003) carried out a study on the effects of water and high-temperature stress on maize production in Australia.

Makadho (2006), using Global Circulation Models (GCMs) and the CERES Maize model to assess the potential effects of climate change on maize in Zimbabwe, reported that maize productivity in Zimbabwe will decrease in the range of 11 to 17% under irrigated conditions in some regions of agricultural production. The reductions in maize yields were primarily attributed to the increased temperature, which shortened the crop growth period, particularly the grain-filling period. Bancy (2000) reported an increase in maize yield in Kenya in regions with altitudes between 1150 and 1580 m.a.s.l. by 2030 using CCCM and GFDL models. This increase depended on the planting date of the crop. Makadho (2006) further explained that in order to counter the adverse effects of climate change in maize production, it might be necessary to use early-maturing cultivars and practice early planting.

Oseni and Masarirambi (2011) carried out the study in Swaziland which was looking at the effect of climate change on maize production and food security in Swaziland. The study indicated that

reduction in both the mean annual and planting season's precipitation have impacts on maize production and which may pose a serious threat to household food security since maize is a staple food for most of Swazi people. Apata *et al.*, (2009) did a study in Southern Africa which was looking at the impact of climate change on maize yield the study indicated that climate change sometimes leads to the increase in precipitation which encourages the prevalence of the disease in maize. The study indicated that for a disease to occur a virulent pathogen, susceptible host and favourable environment are essential all of these components are strongly coupled with environmental conditions. A climate change has the potential to adjust host physiology and resistance, and alter both stages and rates of pathogen development.

## **2.10 Conclusion**

The chapter indicated that agriculture both animal and crop production depends on climate variables, so climate change which leads to the change in precipitation and temperature affects agriculture and also water resources which provides water for agricultural purposes. Maize is very important in South Africa it is used as a staple food. It is the second largest crop produced after sugarcane, so the effects of climate change on maize production will leads to food insecurity.

## **CHAPTER THREE**

### **DESCRIPTION OF THE STUDY AREA AND METHODOLOGY**

#### **3.0 Introduction**

This chapter outlines a brief description of the study area including location, municipality, population size, climate and agricultural potential in the study area. The section also explains sampling procedure and how data was collected and analysed.

#### **3.1 Selection and description of the study area**

The study was carried out in Jozini which is in the North Eastern part of KwaZulu Natal (KZN) province of South Africa. The area was purposively selected because of its agricultural potential, cropping history, geo-climatic and soil characteristics. The study area is one of the areas that are known to produce maize throughout the year in KZN, and farmers make a living out of maize production (DARD, 2013). In Jozini farmers that are producing maize under dryland produce maize only during the planting season of maize which is between October and March. Farmers that are producing under irrigation produce maize throughout the year because they have access to irrigation infrastructure (DARD, 2013).

Jozini area falls under Jozini Municipality which forms part of UMkhanyakude district Municipality. It is located in the Northern portion of KwaZulu Natal, and is bordered by Mozambique to the North, Swaziland to the West, Umhlabuyalingana to the east and Hlabisa to the south. Jozini covers 32% (3057 square kilometres of the total area of 13859 square kilometres of uMkhanyakude District Municipality (DARD, 2013). The study was carried out in three villages which are, Ndumo, Mjindi and Zinashe as indicated on (Figure 3.1).

These villages were selected because they are known to be the leading maize producing villages in Jozini (Zungu, 2013). Ndumo and Mjindi have irrigation schemes, so maize is produced all year round on this village, while at Zinashe they produce under dryland and rely on rainfall for maize production. This study will assess the economic impact of climate change on different farming systems to see which farmers are being affected most. Ndumo is situated on the North of the Municipality and it is adjacent to Mozambican border, and it is approximately 70km away

from Jozini town. Mjindi is located 39 km away from Jozini town, and Zinashe is situated 45 km away from Jozini town. Farmers in Mjindi and Ndumo are producing under the irrigation scheme, and they obtain water from Jozini dam. Farmers in Zinashe village are producing under dry land.

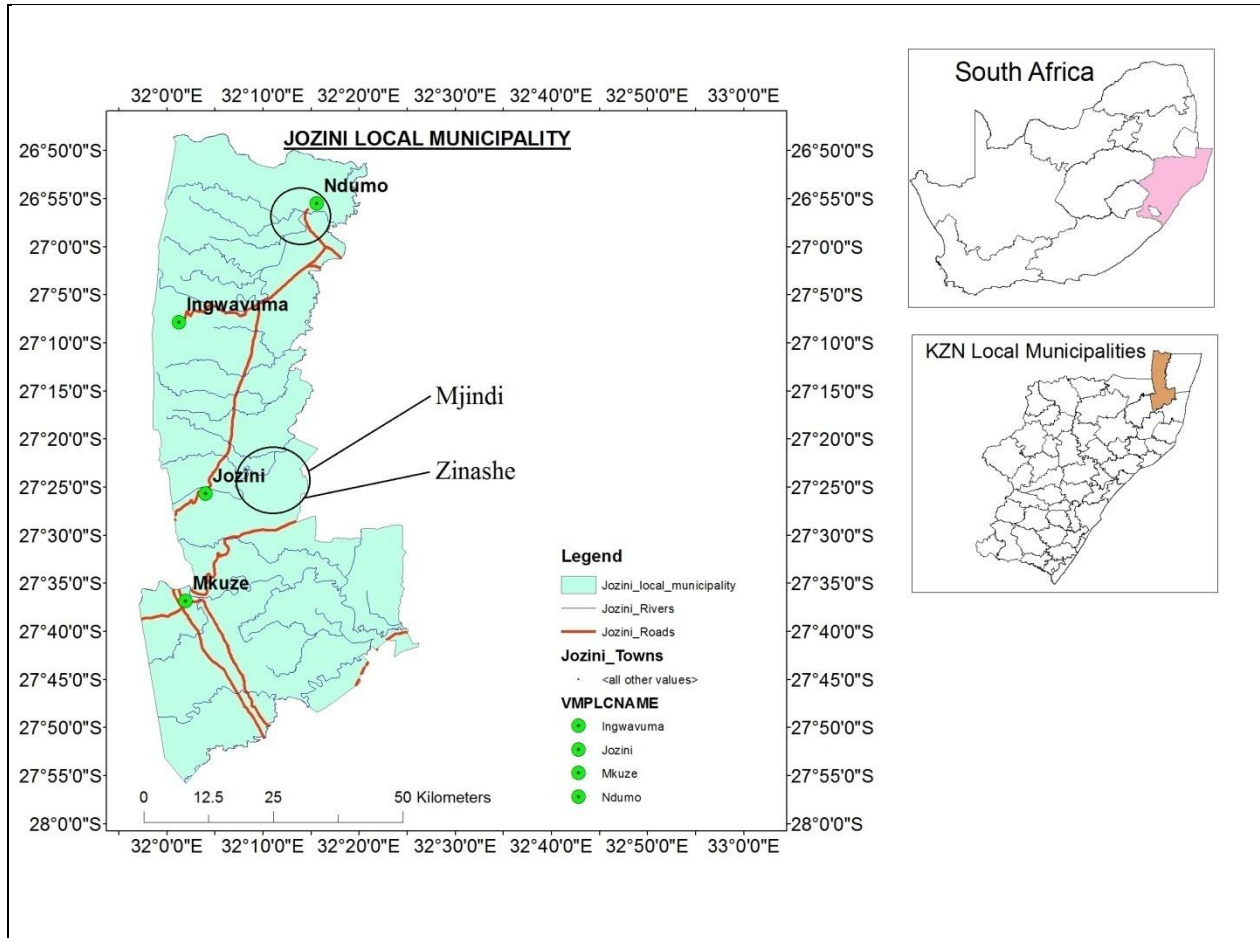


Figure 3.1: GIS Mapping (2013)

### 3.2.1 Population

Jozini is the most populated municipality within Umkhanyakude district. It has a population of 207 250 citizens and 38530 households (Stat 2012). There are 200 farmers who are producing maize, using the irrigation schemes and there are 30 farmers who are producing maize on dry land (Department of Agriculture and Environmental Affairs (DAEA), 2012). The study will assess the productivity or profitability of maize production under different farming system,

which are dry land and irrigation and assess the economic impact of climate change since there are many farmers that are producing maize under irrigation so the study will assess which farming system is being affected by climate change. The majority of the population in Jozini they are not employed, they rely on agriculture for a living, meaning that they produce different crops and sell to get income for a living (DARD, 2013). Climate change will affect population in the study area because maize is also used as a staple food in Jozini. Climate change will lead to the extreme events like floods and drought which will both affect maize productivity and thus affect the farmers' gross margin and net revenue.

### **3.2.2 Climate**

Jozini has a tropical climate. It normally receives about 569 mm of rain per year, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall (9mm) in June and the highest (90mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Jozini range from 23.5°C in June to 30.3°C in January. The region is the coldest during June when the mercury drops to 9.1°C on average during the night (DWAF 2009).

The study done by Moeletsi (2004) in Lesotho indicated that the rate of growth and development of maize from planting to maturity is dependent mainly upon temperature. Maize is a crop with a rapid growth rate that yields best under moderate to warm temperatures. Cool temperatures slow down the progress to maturity and high temperatures hasten maturity. Each plant has its own specific optimum temperature for growth and a temperature range in which it thrives. Once temperatures outside this range are encountered, Maize suffers and growth slows. Temperature (soil and air) during the growing period is the single most important environmental factor controlling maize development.

The study further indicated that rainfall also has an influence on the growth and development of maize. Water stress occurring during different development stages of maize may reduce final grain yield to different degrees. The extent of yield reduction depends not only on the severity of the stress, but also on the stage of the plant development. Maize appears to be relatively tolerant to water deficits during the vegetative and ripening periods, and that the greatest decrease in

grain yields is caused by water deficit in the soil profile during the flowering period. For potential yields, adequate water should be available during the growing season.

A similar study by Mqadi (2005) indicated that maize production has different growth stages which influences maize yield. Each stage requires a certain amount of temperature and also rainfall. If climate change leads to the change in climate variables (rainfall and temperature). The growth and development of maize will be affected and thus affect the yield. The study will look at the economic impact of climate change on maize production in Jozini Municipality under irrigation and also under dry land. Jozini annual rainfall and annual temperature are discussed on the figures 3.2.

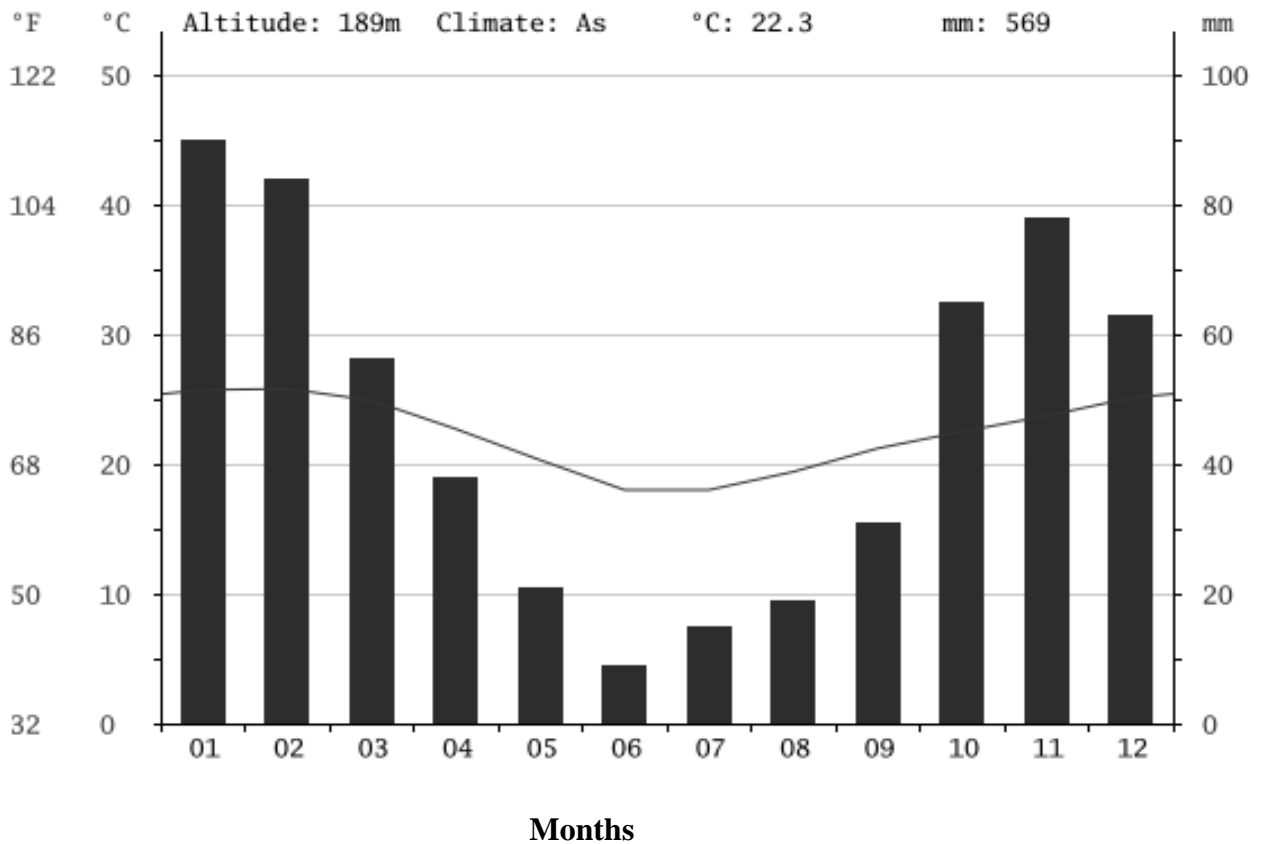


Figure 3.2: Annual rainfall in Jozini, Source: South African Weather Services (SAWS) (2013).

Figure 3.2 indicates the annual rainfall in Jozini. Jozini receives a higher rainfall in the summer months from November to February. Most precipitation falls in January, with an average of 90 mm. The driest month is June with 9 mm. Dry land farmers depend on rainfall for the production

of maize. According to Mati (2004) climate change will either increase or decrease rainfall and alter temperatures, and that will affect maize production and lower the yield. Maize is an efficient user of water in terms of total dry matter production and among cereals it is potentially the highest yielding grain crop (Le Roux, 2009). For maximum production a medium maturity grain crop requires between 500 and 800 mm of water depending on climate (Adams, 2006). Therefore the study will look at the economic impact of climate change on maize production under dry land and under irrigation in Jozini Municipality. This study will check whether climate change will result in more or less rainfall than the amount that is enough or required for maize production.

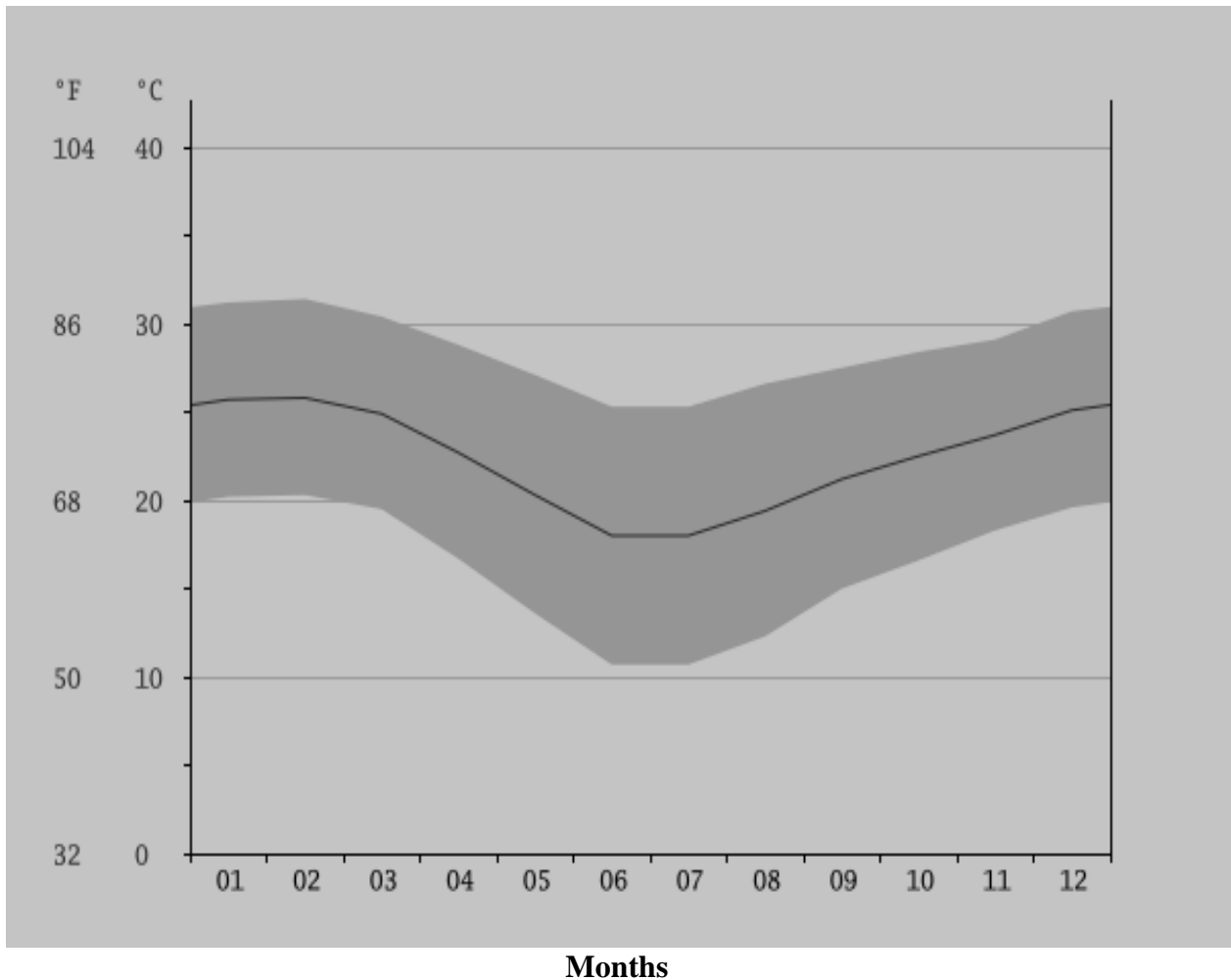


Figure 3.3: Annual Temperature in Jozini, Source: SAWS (2013)

Figure 3.3 above indicates annual temperature in which the warmest month of the year is February with an average temperature of 25.8 °C. In June, the average temperature is 19.0 °C. It is the lowest average temperature of the whole year. Maize is a warm weather crop and is not grown in areas where the mean daily temperature is less than 19 °C or where the mean of the summer months is less than 23 °C. Climate change alters temperature and that affects maize production, so the study will assess the economic impact of climate on maize production looking at how climate change affects the farmers gross margin and net revenue.

### **3.3 Infrastructure**

The notable agricultural infrastructure is Jozini Dam which supplies water for irrigation and drinking water to the surrounding villages. There are two irrigation schemes which is Mjindi irrigation scheme situated next to Makhathini research station and Ndumo irrigation scheme. Both of these schemes get irrigation water from Jozini dam (DWAF, 2009). Mjindi irrigation scheme operates an irrigation scheme of over 2,000 hectares on the Makhathini flats. The irrigation scheme is a state owned scheme with over 1,000 farmers farming on plots ranging between 2 hectares and 10 hectares under 26 primary co-operatives and one secondary co-operative.

Jozini has the main national road (N2) which joins it with the nearby towns (Pongola and Mkuze). Road conditions in town and to the field where maize is produced are poor. Farmers in Jozini are using cell phones as their medium of communicating with the nearby farmers and also the extension officers.

#### **3.3.1 Markets and storage facilities**

There is an input market called Mjindi Farming which is a provincial government business enterprise which serves to repair and upgrade the existing irrigation scheme. It also sells the agricultural inputs to the local farmers. Jozini farmers also purchase their inputs at Pongola which is the town after Jozini. Most of the farmers they do not buy their inputs in Mjindi because they sometimes do not find the inputs at Mjindi, so they prefer to go to Pongola which is 73km away from Jozini. That leads to the increase in transaction costs of production. There is no stable market for maize output: farmers sell their produce at the point of production and to the local

consumers. In Jozini there is no local storage facility for perishable agricultural products. The storage facility available is for cotton since most of the farmers are producing cotton.

### **3.4 Agricultural potential**

Jozini Municipality has all the necessary ingredients for massive and diverse agricultural practice, given the climate, soil types and conditions, water availability and stable weather throughout the year. It is the only area in the whole district in which two to three crop cycles can be harvested. Jozini generally represents low rainfall patterns but the soils are favourable for crop farming. The main agricultural activities include the cultivation of mangoes, vegetables (cabbage, green pepper, butternut, and maize) cotton and sugarcane (DARD, 2013).

### **3.5 Other economic activities**

The dominating economic activities in Jozini are tourism and agriculture. There are three close by game reserves which attract tourists and contributes to economic growth in Jozini and also forms part of tourism. The game reserves are Pongolapoort game reserve, Mkuze and Ndumo game reserve. There is also Tiger Lodge which is closer to Jozini dam and also attracts tourists that want to have a good view of Jozini dam. These areas contribute to the employment of the local communities and boost the economy of Jozini. There are many agricultural activities that are taking place in Jozini. Farmers keep livestock (cattle, horses, goats and chicken) which they sell to the local consumers and also sometimes sell at the livestock auction. There is also Makhathini research station which specialises in production of different crops like mango, macadamia nuts and maize. The research station also provides help to the local farmers who are producing crops like sugarcane, sugar beans, cabbage, spinach and butternut.

### **3.6 Conclusion**

The chapter has presented a description on the study sites. It has outlined and explained the population distribution in the areas, infrastructure and economic activities in the study areas. Socio-economic and agricultural potential of the study areas have been indicated in this chapter. This has provided an understanding of the characteristics of the study areas that are important in the interpretations of the research outcomes from this study.

## **CHAPTER FOUR RESEARCH METHODOLOGY**

### **4.0 Introduction**

This chapter presents the research methodologies applied in the assessment of the economic impact of climate change on maize production and under dry land and under irrigation in Jozini. It also describes the research design, sampling method used in selecting the sample, data collection, and data analysis. The study was using the subset (sample of maize farmers) as the unit of analysis. The following section will look at the research design and the method of data collection and analysis.

### **4.1 Research design**

The research design refers to the overall strategy that a researcher chooses to integrate the different components of the study in a coherent and logical way. The research design ensures that the researcher will effectively address the research problem (Bless *et al.*, 2006). Cross sectional design was used to obtain data. It was collected at one point in time on several variables such as demographics, household socio-economic factors, production of maize, market potential, and climate awareness of farmers. A subset was selected to represent the population. Both qualitative and quantitative data was gathered on demographics, household socio-economic factors, market potential and farmers' awareness about climate change. The unit of analysis will be discussed in the next section.

### **4.2 Unit of analysis**

Unit of analysis is the major entity that is analyzed in a study (Trochim, 2006). It could be any of the following: groups, individuals, artifacts (books, photos, newspapers), geographical units (town, census tract, state), and social interactions. In this study, individual maize smallholder farmers are the major unit of analysis in getting primary data. Farmers from three villages (Ndumo, Zinashe and Mjindi) which are producing maize were interviewed.

### **4.3 Sampling Procedure**

Sampling is a process of selecting units from a population of interest, so that by studying the sample, the results obtained from the sample may be generalized to the population from which the sample had been chosen (Jari, 2009). Hence, the purpose of sampling is to reduce the cost of collecting data about a population by gathering information from a subset instead of the entire population (Bless & Higson, 1995).

Jozini Municipality has 17 wards, which has 10 villages, some of the villages are not active in agriculture. Three villages were selected for the study (Zinashe, Mjindi and Ndumo) because they produce more maize compared to the other villages in Jozini Municipality (Zungu, 2013). Ndumo and Mjindi have a lot of farmers that are producing different vegetables under the irrigation scheme. Zinashe village has farmers that are producing maize under dryland. The sample for the study was selected from the three villages using the different sampling methods which are discussed below.

The sampling method used was cluster sampling. Maize farmers were first divided into clusters, indicating farmers that are producing under irrigation and farmers that are producing under dry land. Random sampling was then used to select 40 farmers that are producing on dry land. With the irrigating farmers the random sampling method was used to select a group of 60 irrigating farmers for the survey.

### **4.4 Sample frame**

Bless et al., (2006) defined a sampling frame as a list of all units from which a sample is to be drawn. In this research, farmers were selected based on their willingness to participate. Not all smallholder farmers in the study areas were selected for the study, but a sample was drawn. For the sample to best represent the total population, a complete frame was used. Table 3.1 represents the sample frame in the sample for the study was chosen from. A total of 100 farmers were selected from three villages under study.

**Table 4.1: Sample frame**

| Municipality | No of maize farmers | Dryland | Irrigation | Sample size |
|--------------|---------------------|---------|------------|-------------|
| Jozini       | 270                 | 100     | 170        | 100         |

Source: Zungu (2013)

Table 4.1 indicates the sample frame from which the sample for the study will be drawn from. Not all smallholder maize farmers in the study areas were selected for the study; but a sample was drawn. For the sample to best represent the total population of all maize farmers in Jozini, a complete frame was used. In this research, farmers were selected based on their willingness to participate.

#### **4.5 Sample size**

Bless *et al.*, (2006) indicated that it is important to deal with an adequate sample size in order to collect accurate information about a group when sampling. A large sample is more representative but very costly; while a small sample is less accurate but more convenient (Bless & Higson, 1995). The sample size selected was 100 respondents (maize farmers), 60 maize farmers producing under irrigation and 40 maize farmers producing under dry land.

**Table 4.2 Maize farmers' distribution according to the study villages**

| Villages | Irrigators | Dryland | Total |
|----------|------------|---------|-------|
| Zinashe  | 0          | 60      | 60    |
| Ndumo    | 100        | 0       | 100   |
| Mjindi   | 70         | 0       | 70    |

Source: (Zungu, 2013)

Table 4.2 indicates the distribution pattern of maize farmers across the study area, and also indicates why the sample has a higher number of population from the farmers that are irrigating. At Ndumo and Mjindi there are more farmers that are producing maize than in Zinashe. This is

because the two villages has irrigation scheme which helps the farmers with irrigation so it becomes easy for the farmers to produce all year round.

#### **4.6 Data collection**

A questionnaire was designed as a tool for data collection. It was administered to respondents through face-to-face interviews. According to Bless *et al.*, (2006) an interviewer-administered questionnaire is an important tool of data collection because it reduces the omission of difficult questions by respondents. In addition, it reduces the problem of word or question misinterpretation by respondents and can be administered to participants that can neither read nor write. In addition, the presence of the interviewer increases the quality of the responses since the interviewer can probe for more specific answers.

The questionnaire was designed to capture data on the demographic information, socio-economic, institutional and climatic data. The questionnaires were interviewer-administered so as to alleviate the problem of misinterpretations or misunderstandings of words or questions. The questionnaire consisted of both open ended and closed questions. Open ended questions are important as they allow respondents to freely express their views. Most of the questions had closed ends to make the coding of the responses easier and to extract as much information as possible from the respondents without taking too much of their time. Data collection process took place in different stages which are discussed below.

##### **4.6.1 Orientation stage**

This is the first stage where the researcher was introduced in the community leadership and also to the extension officers that are working around the research villages. The orientation stage involved a visit to the study area in 2013. During this phase, informal discussions with project local farmers that are producing maize were done. The main objectives of the research project were outlined to the farmers through agricultural extension officials.

##### **4.6.2 The survey**

The second stage was the actual survey being conducted whereby data was collected. This was done in August 2013. An interview schedule (questionnaire) was used as the data collection

instrument. A structured questionnaire was used to interview maize farmers for the study so as to standardise the order in which questions were asked to the farmers, and to ensure that questions were answered within the same context. Both primary and secondary data was collected.

#### **4.6.3 Primary Data**

Primary data was obtained from the farmers that are producing maize through the questionnaire and also extension officers that are working around the research areas. Data was collected in three villages which are, Ndumo, Mjindi and Zinashe as indicated on (Figure 3.1). Information on socio-economic factors like farmers 'age, educational status, market access, farming experience and arable land size was collected using the questionnaire.

#### **4.6.4 Secondary data**

Data for climate variables (rainfall and temperature) for the previous 20 years was obtained from the South African Weather Services. Additionally, library based research was conducted in order to explore what other researchers have done in the same field. Sources of such information include journals, books, internet, and government documents. Data for analysis was collected on variables outlined in the next section.

#### **4.7 Variables for data collection**

These are the variables that were used in obtaining the information that will help to achieve the research objectives. These variables are discussed in table 3.2.

- Demographic and socio-economic information
- Crops produced
- Planting area in hectares
- Prices of maize input used in rands
- Prices of maize output in rands
- Maize farming methods
- Fertilizer used for maize production in kilograms (kg)
- Maize yield in different areas of research
- Maize Gross margin per hectare in rands

- Access to financial institutions
- Access to maize market/Marketing channel
- Access to extension services
- Knowledge on climate change

#### **4.8 Previous related studies**

Sibanda, (2012) did a research in the Eastern Cape province of South Africa, which was looking at the market potential and profitability of improved maize open pollinate varieties (OPV) in the Eastern Cape. The objective of the study was to assess the profitability of growing improved maize OPV when compared to hybrids in the Eastern Cape province of South Africa. Data was collected on the market share of OPV, crop budgets for all varieties, land and farm size, yield, crop income and the proportion of the land under hybrid and under landraces. Gross margin and analysis was used to analyse data. The results suggest that, the production of hybrid maize by smallholder farmers in the Eastern Cape Province remains profitable. Gross margin analysis was adopted for this study to be used for objective two.

Another study was done by Laube *et al.*, (2012) in Nigeria looked at the Gross Margin Analysis on maize-yam based cropping system. According to the study there were different cropping systems which were soya bean cropping system and maize cassava cropping. The objective of the study was to look at the benefit of engaging in the maize-yam cropping system only. Data on demographic information for each household, directly allocable variable costs and the gross production of the land was collected to be used in gross margin analysis. The results indicated that engaging on maize-yam only has the higher gross margin than the other cropping system. Therefore in this study gross margin analysis was used for objective two because it is a good measure of assessing the profitability of a farm or company's core activity excluding the fixed costs. Gross margin is the difference between revenue and costs before accounting for certain other costs like directly allocable variable costs (Lovejoy, 2008). It measures what proportion of revenue is converted into the gross profit (Mqadi, 2005).

Gbetibouo and Hassan (2005) carried out a study which was measuring the economic impact of climate change on major South African field crops using the Ricardian approach. The objective

of the research was to develop and apply the empirical methods and procedures to assess the economic impact of climate change on South African field crops (maize, wheat, sorghum, sugarcane, groundnut, sunflower and soya bean) data on the input costs, output prices and production costs for each of the field crops, data on the climate variables such as precipitation, temperature was collected and lastly data on soils and water flows on those specific areas was collected. Ricardian model was used for data analysis.

Another study was done by Benhin (2006) which looked at the crop farming in South Africa and climate change. The objective of the research was to assess the impact of climate change in crop farming in South Africa using the Ricardian model. Data that was collected included the household data, climate variables and hydrology or water flow. Data was analyzed using the Ricardian model. The results indicated that climate change leads to change in climate variables (rainfall and temperature) affects crop farming and thus affects the farmer's revenue.

In this study the Ricardian model will be used for data analysis for the third objective because, the model addresses or compares net farm revenue against various climates, soil, hydrological and socio-economic variables to help determine the factors that influence variability in net farm revenues. Further this model measures the sensitivity of land value per hectare to climate change and climate variability.

Mqadi (2005) also did a research looking at the production function analysis of the sensitivity of maize production to climate change in South Africa. The objective of the study was to develop and apply the production function model to assess the sensitivity of maize production to climate change in the nineteen main producing sites in South Africa. Data was collected on the yield of maize produced (kg/ha), fertilizer used, labour, machine used, soil drainage rate, soil mineralization, rainfall in different stages of growth and temperature also in different stages of growth. The multiple regression model was used to analyze data. In this study multiple regression was adopted and it was be used for the second objective.

## 4.9 Data analysis

After collecting data, it was captured and encoded in the form of spreadsheets in Microsoft Excel and exported to SPSS software. Descriptive statistics was used to measure objective one. The results from the descriptive statistics were indicated using figures and tables.

Gross margin analysis was used for the second objective in which gross margin was calculated for each farmer. Multiple regression model was used to determine whether different systems (irrigation and dryland) had an influence on gross margin. The Ricardian model was used for the third objective to measure the economic impact of climate change on maize production. Net farm revenue was calculated for each farmer. It was then used as the measure of the economic impact of climate change on maize production in Jozini. Gross margin analysis for objective two is discussed below.

### 4.9.1 Gross Margin analysis

Gross margin for a crop is the sales revenue obtained from the crop sold minus the direct costs of producing it (Sibanda, 2012). The direct costs are variable costs that increase or decrease based upon the quantity produced. Figure 4.1 is an illustration of how the gross margin of an enterprise is determined. Gross margin was calculated for each and every farmer under study. Figure 4.1 indicates gross margin components used in calculating gross margin and the formula used in calculating gross margin.

#### 4.9.1.1 Gross Margin components

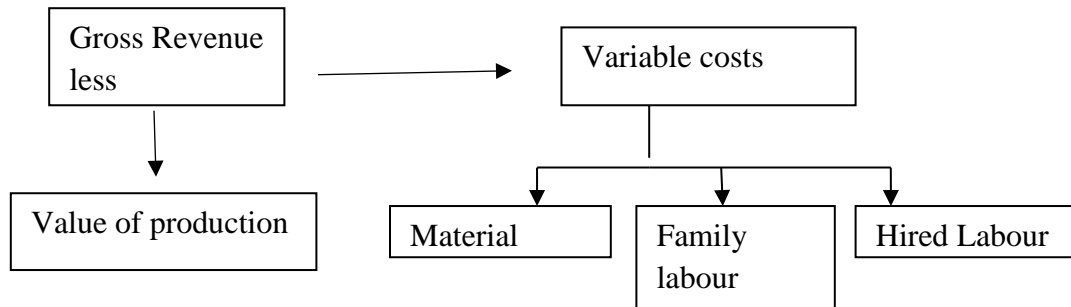


Figure 4.1: Gross Margin components

Source: Sibanda (2012)

Equation 1 indicates a simple mathematical expression of gross margin for an enterprise:

$$GM = GI - TVC \dots\dots\dots (1)$$

GM is gross margin. GI gross income which is a product of physical production measured in tones and current market price. Total variable costs are mainly a summation of operational costs that vary with changes in scale of operation, to include most of the inputs like fertilizers, seed, chemicals, transport, labour and land preparation.

#### 4.9.2 Multiple regression model

The multiple regression model was used to test the factors that have an influence on gross margin on both systems. The multiple regression model is a statistical tool that allows the examination on how the multiple independent variables are related to the dependent variable. It can be used to predict a dependent variable, based on continuous and/or categorical independent variables, where the dependent variable takes more than two forms (Gujarati, 2002). Furthermore, it is used to determine the percent of variance in the dependent variable explained by the independent variables and to rank the relative importance of independent variables. Y is gross income which is the dependent variable which was regressed against the socio-economic factors, production factors and the type of soil to see factors that have influence on maize gross margin.

The regression model is as follows

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \dots\beta_nX_n + U \dots\dots\dots (2)$$

Where Y is the gross margin obtained from value of maize output, it is the dependant variable.  $\beta_0$  is the intercept and  $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$  and  $\beta_6$ , are partial regression coefficients. U is an error term.

The variables that were used for regression analysis are indicated in Table 4.3

**Table 4.3: Variables used for multiple regression analysis**

| <b>Variable</b>    | <b>Description</b>                | <b>Type of measurement</b> | <b>Expected sign</b> |
|--------------------|-----------------------------------|----------------------------|----------------------|
| <b>Dependant</b>   | <b>Gross Margin</b>               | <b>Continuous</b>          | <b>+/-</b>           |
| <b>Independent</b> |                                   |                            |                      |
| AGE                | Age of the farmer                 | Categorical                | +/-                  |
| LVLED              | Level of education                | Categorical                | +/-                  |
| ACCTCR             | Access to credit                  | Categorical                | +/-                  |
| LSZ                | Land size                         | Continuous                 | +/-                  |
| FMREXP             | Farmers experience                | Categorical                | +                    |
| TYPSL              | Type of soil                      | Dummy                      | +/-                  |
| USOFIRR            | Use of irrigation                 | Categorical                | +                    |
| USOFFRT            | Use of fertilizer                 | Categorical                | +                    |
| YLD                | Yield obtained in the last season | Continuous                 | +/-                  |

### **4.9.3 Ricardian model**

The Ricardian model is an empirical approach developed by Mendelson *et al.*, (1994) to measure the value of climate in the United States of America's agriculture. The technique has been named the Ricardian method because it is based on the observation made by Ricardo (1817), that land values would reflect land productivity at a site under perfect competition. It is possible to account for the direct impact of climate on yields of different crops as well as the indirect substitution among different inputs including the introduction of different activities, and other potential adaptations to different climates by directly measuring farm prices or revenues by using the Ricardian model.

The value of land reflects the sum of discounted future profits, which may be derived from its use. Any factor, which influences the productivity of land, will consequently affect land values or net revenue. Therefore the value of land or net revenue contains information on the value of climate as one attribute of land productivity. By regressing land values (or net revenue) on environmental and other factors, one can then determine the marginal contribution of each input to farm income.

Ricardian approach by Mendelsohn and Dinar (2003) was used to measure the third objective, which measure the economic impact of climate change on the net farm revenue of smallholder farmers producing maize in Jozini (KZN). Cross sectional data and econometric analysis to estimate the economic impact of climate variable, hydrological and socio-economic factors on net farm revenue. According to Mendelsohn and Dinar (2003) Net revenue for maize ( $R$ ) is assumed to reflect the present value of future net productivity of each maize farmer. The Ricardian method used is a cross-sectional approach studying the agriculture production. It accounts on how changes in climate variables affect the net farm revenues. The principle is explained in the following equation.

$$R = \sum P_i Q_i(X, C, Z, G, W) - \sum P_x X \dots\dots\dots (3)$$

Where  $R$  is net revenue per hectare,  $P_i$  the market price of the crop is,  $Q_i$  is the output of crop  $i$ ,  $X$  is the vector of purchased inputs (other than land), such as seeds, fertilizer, and pesticides.  $C$  is a vector of climate variables,  $Z$  is a vector of soil variables,  $G$  is a vector of economic variables such as market access and  $P_x$  is a vector of input prices (used in the calculation of net revenue). The farmer is assumed to choose  $X$  to maximize net revenues given the characteristics of the farm and market prices.  $W$  is the available water for irrigation. The Ricardian model is a reduced form model that examines how several exogenous variables,  $F$ ,  $Z$  and  $G$ , affect net revenues.

The standard Ricardian model relies on a quadratic formulation of climate:

$$R = B_0 + B_1 F + B_2 F^2 + B_3 Z + B_4 G + \mu \dots\dots (4)$$

$\mu$  is an error term, while  $F$  and  $F^2$  show level and quadratic terms for temperature and precipitation. The quadratic terms of temperature and precipitation reflects the non-linear relationship between net revenues and climate. It is non-linear because up to a specific range of

temperature and precipitation, there is increase in yield but beyond that threshold, there may be decrease in crop yield. These non-linear relationships provided us with best definitions of the extent of climate variable affecting net revenues. When the quadratic term is positive there will be a U-shaped net revenue function and when the quadratic term is negative there will be a hill-shaped function net revenue function (Mendelsohn *et al.*, 1994) Variables to be used for the Ricardian model are indicated in Table 4.3.

**Table 4.4: Variables to be used in the Ricardian model**

| Variable              | Description                          | Type of measurement | Expected sign |
|-----------------------|--------------------------------------|---------------------|---------------|
| <i>Dependant</i>      |                                      |                     |               |
| <b>CNR</b>            | <b>Crop net revenue</b>              | <b>Continuous</b>   |               |
| <i>Independent</i>    |                                      |                     |               |
| <b>AGE</b>            | Age of the farmer                    | Categorical         | +             |
| <b>GEN</b>            | Gender                               | Dummy               | -             |
| <b>FEDUC</b>          | Farmers Education level              | Categorical         | +             |
| <b>INCF</b>           | Farmers Income                       | Categorical         | +             |
| <b>FAREX</b>          | Farmers experience measured in years | Continuous          | +             |
| <b>FERTUS</b>         | Farmer uses the fertilizer           | Dummy               | +             |
| <b>PURHMSE</b>        | Farmer purchase some seeds           | Dummy               | +             |
| <b>USEOFIRRIG</b>     | Farmers use of irrigation            | Dummy               | +             |
| <b>SMTMP</b>          | Summer temperature in °C             | Continuous          | +/-           |
| <b>SMTMPSQRD</b>      | Summer temperature squared in °C     | Continuous          | +/-           |
| <b>SPRNGTEMP</b>      | Spring temperature in °C             | Continuous          | +/-           |
| <b>SPRNGTEMPSQRD</b>  | Spring temperature squared in °C     | Continuous          | +/-           |
| <b>WNTMP</b>          | Winter temperature in °C             | Continuous          | +/-           |
| <b>WNTMPSQRD</b>      | Winter temperature squared in °C     | Continuous          | +/-           |
| <b>AUTMNTTEMP</b>     | Autumn temperature in °C             | Continuous          | +/-           |
| <b>AUTMNTTEMPSQRD</b> | Autumn temperature squared in °C     | Continuous          | +/-           |
| <b>SMPREC</b>         | Summer precipitation in mm           | Continuous          | +/-           |
| <b>SMPRECSQRD</b>     | Summer precipitation squared in mm   | Continuous          | +/-           |
| <b>SPRNGPREC</b>      | Spring precipitation in mm           | Continuous          | +/-           |
| <b>SPRNGPRECSQRD</b>  | Spring precipitation squared in mm   | Continuous          | +/-           |
| <b>WNTPREC</b>        | Winter precipitation in mm           | Continuous          | +/-           |
| <b>WNTPRECSQRD</b>    | Winter precipitation squared in mm   | Continuous          | +/-           |
| <b>SOILTYP</b>        | Type of soil                         | Dummy               | +             |
| <b>LNDS</b>           | Land size                            | Categorical         | +             |
| <b>ACCCR</b>          | Access to credit                     | Dummy               | +             |
| <b>ACCEXT</b>         | Access to extension                  | Dummy               | +             |
| <b>MBRSHORG</b>       | Member of any farming organisation   | Dummy               | +             |

The Ricardian Econometric model statistically analyses the relationship between farms inputs and outputs (agricultural production) through regressing a set of climate variables (rainfall and temperature) and other socioeconomic variables with revenue from agricultural productions. In doing so, the model measures the contribution of each independent factor to the outcome of maize production and impact of climate change on maize production (Mendelsohn and Dinar, 2003). Net farm income was calculated for each respondent and was regressed against socioeconomic factors, climate variables and production factors. The method used to come up with the Net farm income is explained.

#### **4.9.3.1 Net farm income**

It is the amount of money that is left after all costs, expenses and taxes are subtracted from the total sales of the form the total sales of the company (Gujarati, 2002). Net farm income was calculated for each farmer. Equation 5 shows a simple mathematical expression of net farm for an enterprise:

$$\text{NFI} = \text{Total Revenue} - \text{Total expenses}$$

Whereby NFI is a Net farm income, Total Revenue this is the total income from the sale of the product. Total expenses in a business are all the expenses including variable costs and fixed costs. In the study fixed costs is only available for farmers that are producing under irrigation because they pay rent.

#### **4.10 Conclusion**

This chapter provided a description of the research design, sampling method employed for data collection. The chapter also explained how data was obtained and the analytical methods used to obtain results. The chapter also explained the use of primary data in the analysis and the empirical model used. Table 4.4 summarizes the research objectives and analytical tools used.

## **CHAPTER FIVE**

### **RESULTS AND DISCUSSION OF DESCRIPTIVE STATISTICS**

#### **5.0 Introduction**

This chapter presents the results of the analysis of the survey data. The chapter presents an analysis of the demographic and socio-economic characteristics of the smallholder maize farmers of Jozini. Figures and tables given in this chapter are the results derived from data collected through the survey. The demographic results are going to be discussed below.

#### **5.1 Demographic characteristics of sampled farmers**

In this section, demographic characteristics such as gender, age, household size and highest educational levels of the respondents (maize farmers) are discussed. These aspects are important because the main household activities are coordinated by the household head and the household head's decisions are most likely to be influenced by such demographic aspects (Bembridge, 1998). Demographic characteristics of households are essential when analysing economic data because such factors influence the households' economic behaviour.

##### **5.1.1 Gender of the farmer**

Figure 5.1 indicates gender of the respondents and how does gender distribution has an influence on the effect of climate change on maize production.

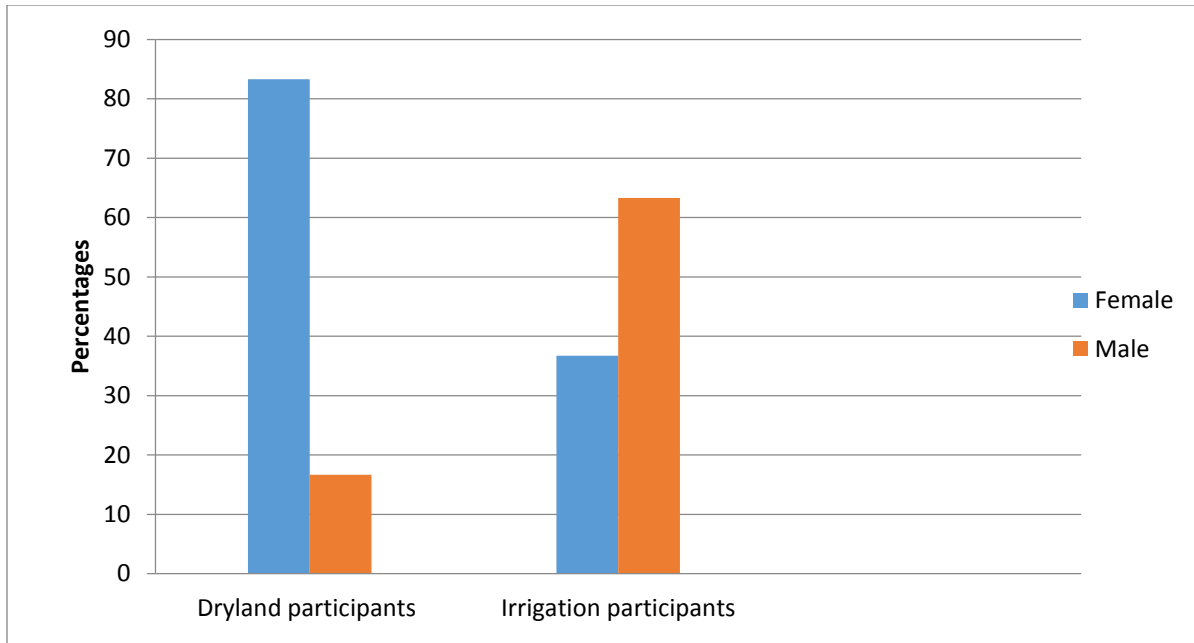


Figure 5.1: Gender of the respondents:

Source: Survey data (2013)

Figure 5.1 indicates gender distribution for the sample of 100 respondents (farmers) producing under irrigation and under dry-land. The sample had 40 respondents producing under dry land and 60 respondents producing under irrigation. On dry-land participants, the majority of the respondents were female farmers and smaller percentages were males. On irrigating participants it was the opposite as there were more males than females.

### 5.1.2 Age of the farmer

According to Sibanda (2012) the age of the farmer is a very important aspect in agricultural productivity as it determines farming experience and also the ability of carrying out the farming activities. Furthermore, the age of a farmer always determines the ability of the farmer to acquire the outside knowledge about production. From the survey, there were four age categories 25-35, 36-46, 47-57 and 58 and above. Figure 5.2 indicates that with the dry land participants majority of them were between the age of 47-57 and about 16% of the respondents were between the age of 36-46, 4% of the farmers were between the age 25-35, and lastly a smaller percentage were in the age category of 58 and above. With farmers participating in irrigation a larger percentage

(63.3%) of the farmers were between the ages of 36-46, 23.3% were between the ages of 47-57. Lastly there were smaller percentages from the other age categories.

The results of this study indicate that farmers that are producing on both farming systems (under irrigation and dryland farmers) are dominated by middle aged farmers who are able to easily adopt new technology that leads to the increase in maize production. Older and experienced farmers even if they are affected by climate change but they can easily adapt to the new technologies because of the experience that they have with farming. This is in line with the study done by Abdulai and Huffman (2005) which agreed that older farmers have a higher possibility to adopt a technology because of their accumulated knowledge, capital and experience. The study indicates that a less percentage of farmers are in the last category which is 58 and above which is regarded as the older person who cannot be active in terms of agricultural activities. This is indicated in the Figure 5.2.

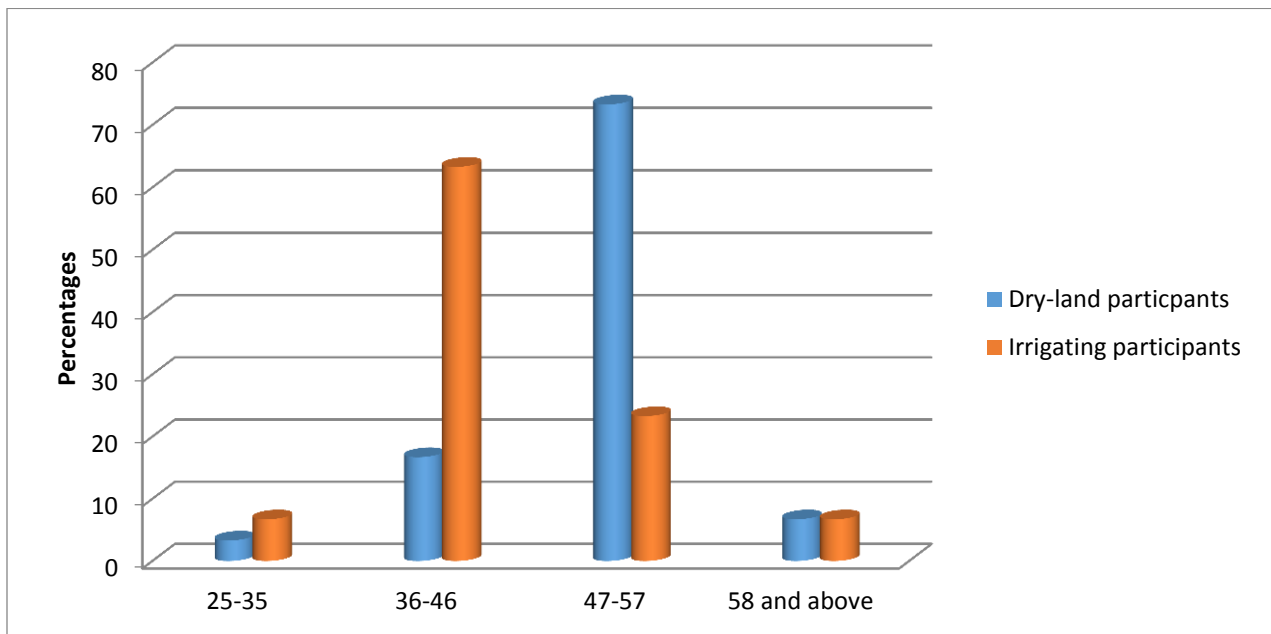


Figure 5.2: Age of the farmer: Source

Survey data (2013)

### 5.1.3 Level of education

Ngemntu (2010) indicated that small-scale farmers especially in rural areas of South Africa have little or no formal education, which makes them to be unable to make informed choices

regarding farming. Usually they produce to bring food on the table for their families. Figure 5.3 indicated that with the dry-land farmers the majority had no formal education, while majority of irrigating farmers had formal education because they are dominated by farmers who have high school level of education. Less percentage of the farmers that are producing on irrigation had no formal education.

This study indicate that farmers producing under irrigation can be able to understand new technology that is brought about reducing the effect of climate change and also increase their productivity because they are educated. Farmers that are producing under dryland have higher chances of being affected by climate change because they are not educated. If technology can be available they will not easily adapt to the use of that kind of technology, and that affects their productivity. This is also in line with the study by the Department of Agriculture Forestry and Fisheries (DAFF) (2012) which indicated that smallholder farmers lacks the human capital and have poor technological skills in which education is one of human capital.

This also indicates that farmers that are producing under irrigation are likely to interpret the agricultural information. They can be able to understand and interpret information about climate change. Also be able to interpret information on the adaptation strategies that can help them to overcome the effect of climate change. Also farmers that are producing under irrigation they can be able to use fertilizer correctly so that they increase their production. Farmers producing under irrigation are also likely to be able to use the correct measurements of fertilizer because they are educated which might have a positive influence on production and increase the net revenue also.

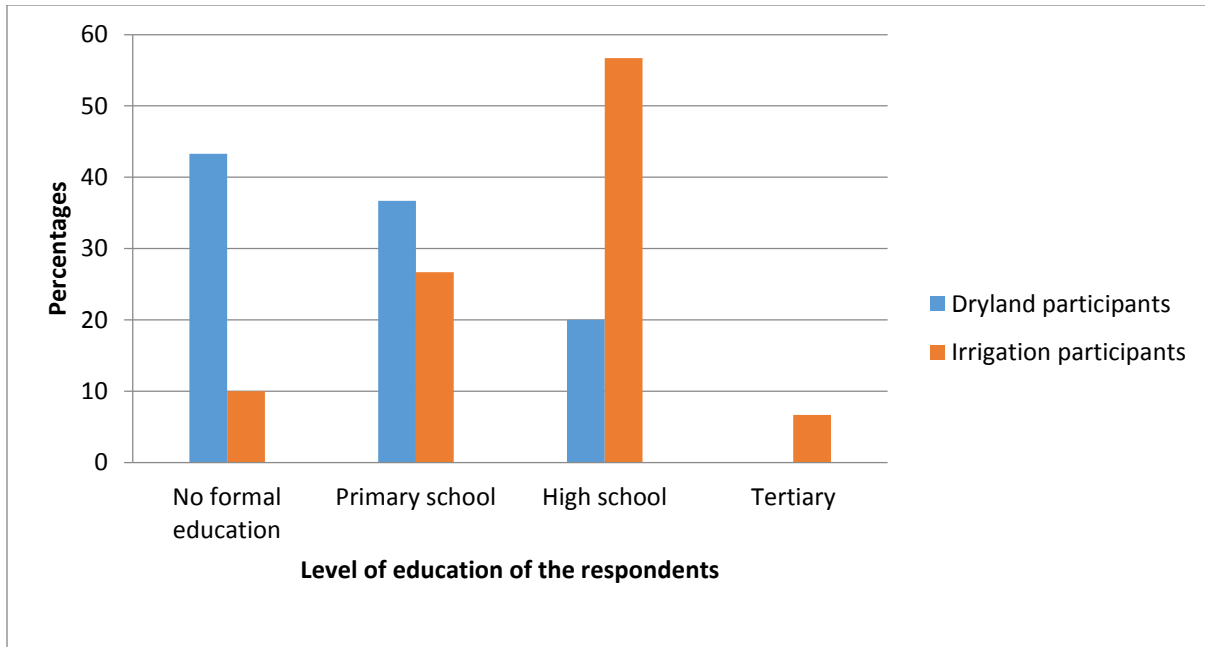


Figure 5.3: Level of education:

Source Survey data (2013)

### 5.1.3 Occupation of the farmer

Figure 5.4 indicates that the majority of farmers that are producing under dry land are full time farmers, and lower percentage is doing petty businesses. This is in line with the research done by Morton (2007) who indicated that most farming households are characterized by poor remuneration, under-employment as well as unemployment, and that limits them from creating and sustaining the economic growth. For the irrigating farmers the survey indicated that all the respondents are full time farmers. Fulltime farmers will be affected by climate change since they are dependent on farming for their livelihood. In both farming systems (dry-land and irrigation) climate change will affect maize production and thus affect the farmers' net revenue, especially for full time farmers.



Figure 5.4: Occupation of the farmer: Source: Survey (2013)

#### 5.1.4 Farmers income per month

The study indicates that about half of the respondents that are producing under dry-land are getting income between R1600-R2500 per month. About 36.7% of the respondents are getting income between R1501- R1599 per month. Small percentages are getting the income which is less than R1500 per month. From the respondents that are producing under irrigation 36.7% they are getting monthly income which is between R1600-R2500, and 20% are getting monthly income which is between R2501-R3500. About 26% of the respondents are getting income which is above R3500, 13% are getting income which is between R1501-R1599, and lastly small percentage of the farmers is getting monthly income less than R1500.

The results also indicated that most of the respondents both in dry-land and in irrigation are getting monthly income between R1600-R2500 for their survival. Farmers that are producing maize under dry land cannot be able to adapt to the changes in climate because adaptation comes with costs, hence they cannot take the small income that they are getting for their living and divert it to adaptation strategies. As a result, farmers that are producing on dry land cannot be able to increase their productivity because climate change affects rainfall which they rely on for maize production. Climate change will also affect the net revenue that they are getting.

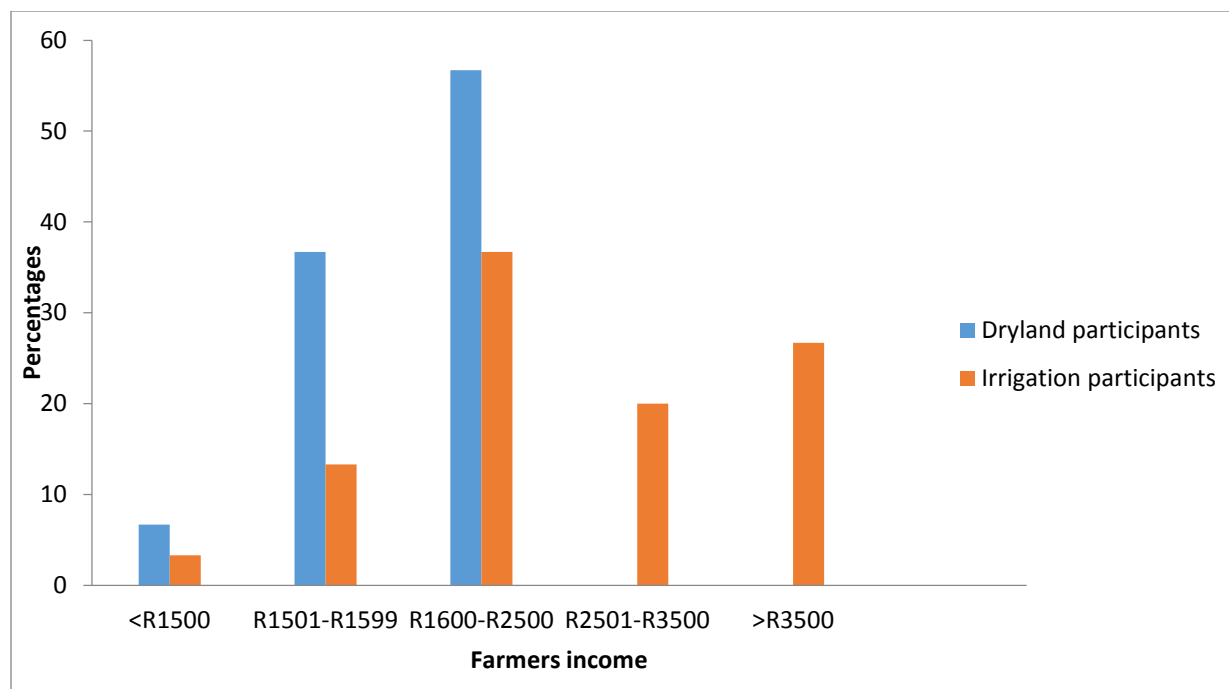


Figure 5.5: Farmers income per month: Source: Survey (2013).

### 5.1.5 Source of income

The study shows that farmers are getting their income from three main sources which are farming, pension and also different kinds of child grants. This study indicates that most farmers are getting the income mainly from farming and also get income from the other sources like pension and child support grants, meaning that climate change can have a negative effect on income since most of the farmers rely on farming for their income. Figure 5.6 indicates that the majority farmers in both farming systems (dry land and irrigation) are getting their monthly income from farming less percentage of the farmers are getting their monthly income from pension and child support grants to add to the income that they are getting from farming. The results also indicate that climate change negatively affects both farmers that are producing under irrigation. A larger percentage of farmers are getting their income from farming, so climate change will affect their productivity which will end up affecting the farmers' net revenue. Farmers that are producing under irrigation are better off because they use irrigation which is one of the adaptation strategies to climate change and can also increase their productivity. Irrigating and dry land farmers operate on different land sizes some produce maize on a bigger land size while others plant on the smaller land size.

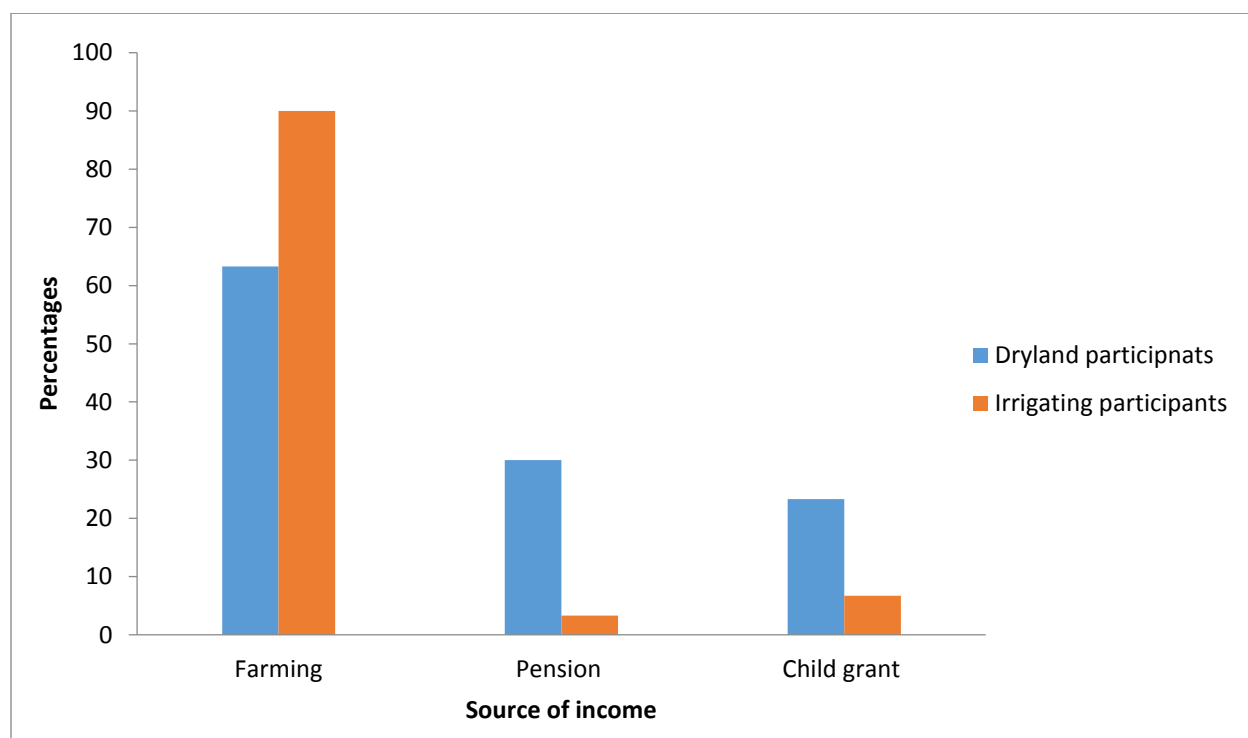


Figure 5.6: Source of income  
Source: Survey data (2013)

**Table 5.1 Farmers land size**

| Land size (ha)     | Dry land farmers | Irrigating farmers |
|--------------------|------------------|--------------------|
| Min                | 0.5              | 0.5                |
| Max                | 5                | 10                 |
| Mean               | 1.8              | 2.7                |
| Standard deviation | 1.16             | 2.9                |

The study by Ngoma (2008) indicated that land size cultivated is believed to have a positive influence on the efficiency and development of smallholder farming system. The results of this study indicate that farmers from dry-land production owned a minimum land of 0.5 hectares (ha) and a maximum of 5 hectares. Farmers from the irrigation side owned the minimum land of 0.5

ha and a maximum land size of 10 hectares. The study also indicated that farmers producing under dry-land had a smaller land size with the mean of 1.8ha. Farmers that are producing under irrigation have the mean land size of 2.7ha. Smaller land size for the farmers that are producing under dry-land indicates that if they can be affected by climate change this can affect their revenue because they are producing on a small piece of land and also using low technology methods of production. Farmers under irrigation have bigger land sizes and also using irrigation to support the small amount of rainfall received in Jozini. Therefore the effect of climate change is not expected to be severe with farmers producing under irrigation.

#### **5.1.6 Land utilization for maize production**

The study indicated that farmers were not using the land they have for planting maize only, but farmers were also planting different crops like (cabbage, tomatoes, butternut) and sugarcane. A certain portion of land was used for maize plantation although they were practicing crop rotation. Table 5.2 indicates that dryland farmers were planting on a small piece of land compared to farmers that are producing under irrigation. The majority of farmers under dryland planted maize on an area that is between 0.5-1 ha. The majority of farmers producing under dryland produced maize on an area that is between 1.5 and 2.0 ha. Farmers that are producing under irrigation are expected to be more productive and have a higher gross margin compared to the farmers that are producing under dryland. Climate change will affect both groups of farmers. Farmers that are producing under irrigation are better off because they are more educated they are able to use the information that they get from the extension officers about climate change and be able to adapt to strategies to help them to continue with production while there is climate change.

Table 5.2 indicates that 86.5% of farmers that are producing under dryland produce maize on a land size that is between 0.5 and 1 hectare. Less percentage (13.5) of the farmers are producing under dryland produce maize on a land are producing maize on a land size between 1.5 to 2.0. Majority of the irrigating farmers are producing on a land that is between 1.5-2.0. Less percentage of farmers is producing under irrigation plant maize on area that is about 5hectares and above. Irrigating farmers uses bigger land sizes for maize plantation so climate change will affect both groups of farmers but irrigating farmers will be more affected because the majority of produce maize of bigger land sizes.

**Table 1.0: Land size under maize production**

| <b>Land size</b> | <b>Dryland Percentage</b> | <b>Irrigation Percentage</b> |
|------------------|---------------------------|------------------------------|
| 0.5-1.0          | 86.5                      | 18                           |
| 1.5-2.0          | 13.5                      | 78.3                         |
| 5.0 and above    | 0                         | 3.7                          |

### **5.1.7 Individuals farmers' experience**

The study indicates that the respondents from dry land production had a minimum experience of 1 year and a maximum of 14 years of maize production. Irrigating farmers had minimum experience of 1 year and the maximum of 15 years of maize production. The results from Table 5.3 indicate that farmers that are producing under dry-land have more years of experience but because a larger percentage has low levels of education they could not acquire information that would make them adapt to climate change. Irrigating farmers had the mean experience of 6 years, but most of them are educated up to a high school level meaning that they can be able to acquire more information about changes in climate. They can also be able to choose the type of seed to be used in order to increase productivity and also increasing the farm net revenue.

**Table 5.3: Individual's farmer's experience**

| <b>Farmers experience</b> | <b>Dry land farmers</b> | <b>Irrigating farmers</b> |
|---------------------------|-------------------------|---------------------------|
| Min                       | 1                       | 1                         |
| Max                       | 14                      | 15                        |
| Mean                      | 8.9                     | 6.0                       |

Source: Survey 2013

### 5.1.8 Use of hybrid seeds

According to Smale and Mason (2013) hybrid seeds possess certain characteristics which include characteristics like vigor, high yielding, drought, pests and disease tolerance and uniform in colour. Figure 5.8 indicates that with farmers that are producing under dry land a smaller percentage of those farmers are planting maize using the hybrid seeds. The studies also showed that majority of maize farmers under dry-land are not using the hybrid seed. These farmers only plant with the seeds from the previous harvest and they are not getting the benefits of the hybrid seeds since they are not using the hybrid seeds.

The majority of the respondents that are producing under irrigation are producing using the hybrid seeds. According to Ngaira (2008) using hybrid seeds is one of the adaptation strategies for climate change. Producing maize under dryland means that farmers are producing maize with the seeds that cannot withstand harsh conditions that occur as result of climate change. Farmers that are producing under irrigation are better off because they use hybrid seeds which can withstand harsh conditions caused by climate change and also increase productivity while there is climate change.

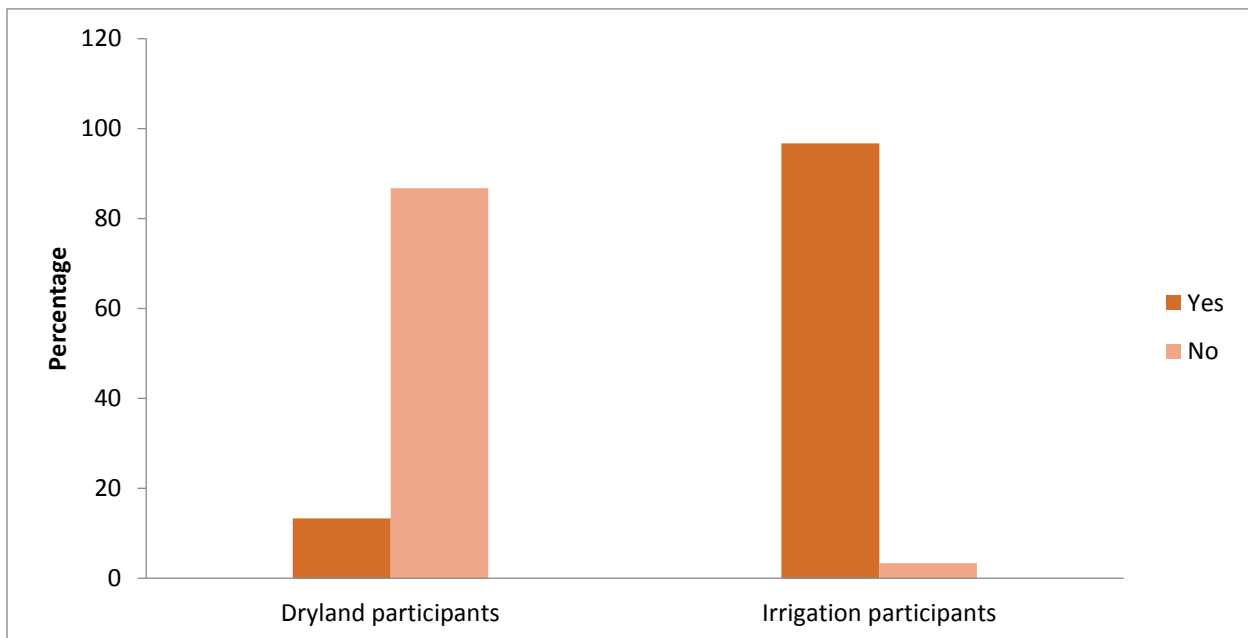


Figure 5.7: Use of hybrid seeds:

Source: Survey data (2013)

### 5.1.9 Farmers use of fertiliser

Minde *et al.*, (2008), indicated that fertiliser refers to plant nutrients that exist in the soil that occurs naturally or added as grains to be used by the plants so that they can grow to their maximum potential. Figure 4.10 shows that the majority of maize farmers producing under dryland are not using fertiliser as they sometimes use the kraal manure and sometimes plant without using any fertilizer. A smaller percentage of those farmers are using fertilizer. Almost all maize farmers producing maize under irrigation are using fertiliser for maize production. Only a smaller percentage of farmers producing under irrigation are not using fertiliser.

The study indicates that farmers that producing under dryland will have lower productivity because maize plants are using the readily available nutrients on the soil. They are not adding more nutrients in the soil by means of fertiliser, which will lower productivity and thus affecting the farmers' gross margin and net revenue. Farmers that are producing under irrigation are using fertiliser which adds nutrients to the soil and increase farmers' productivity and again because they are educated so they can be able to use the correct quantities of fertiliser required and that increases their productivity and also increases their net revenue. Irrigating farmers are educated means they can be able to easily interact with the extension officers for the technical advice on the use of fertiliser.

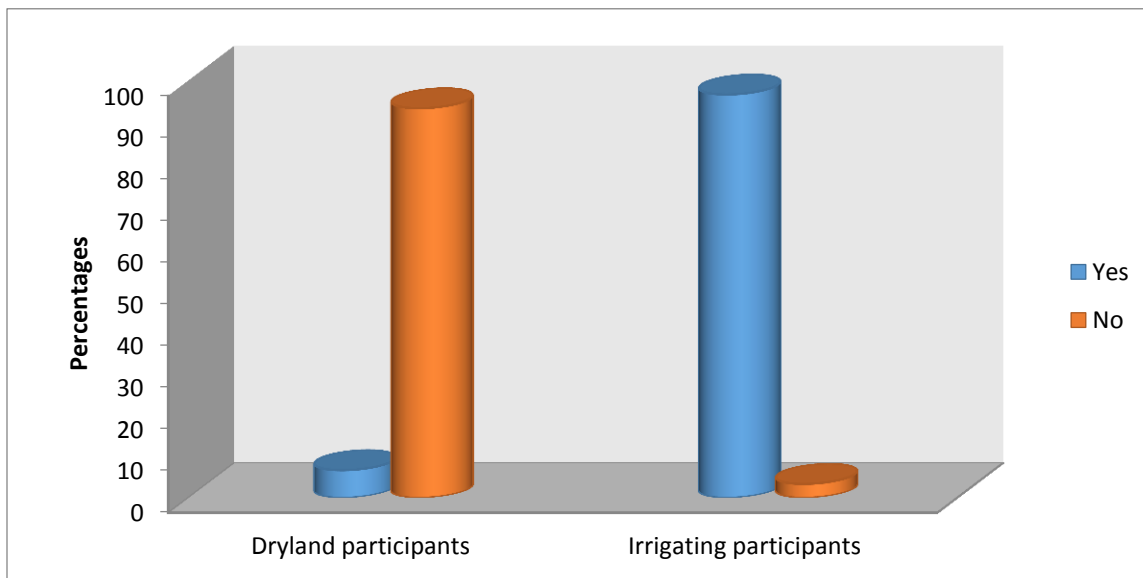


Figure 5.8: Farmers use of fertiliser.

Source: Survey data (2013)

### 5.1.10 Farmers access to extension services

From the study farmers were asked whether or not they have contacts with the extension officers and the responses are given in Figure 5.9. The study by Hosu (2012) indicated that extension services are very important to smallholder farmers' agricultural development and productivity. The study also indicated that an extension service received by the smallholder farmers has a positive influence on the adoption of new technologies by the smallholder farmers. This study shows that the respondents from both farming systems have access to extension services. Figure 5.9 indicate that the majority of participants from dryland have access to extension services a smaller percentage of dry land farmers do not have access to extension services. All participants (100%) that are producing under irrigation have access to extension services. The result of the study indicates that it will be easy for the farmers to obtain more information about climate change from the extension officers and also the adaptation strategies to help them continue with maize production and increase productivity and their net revenue under changing climate.

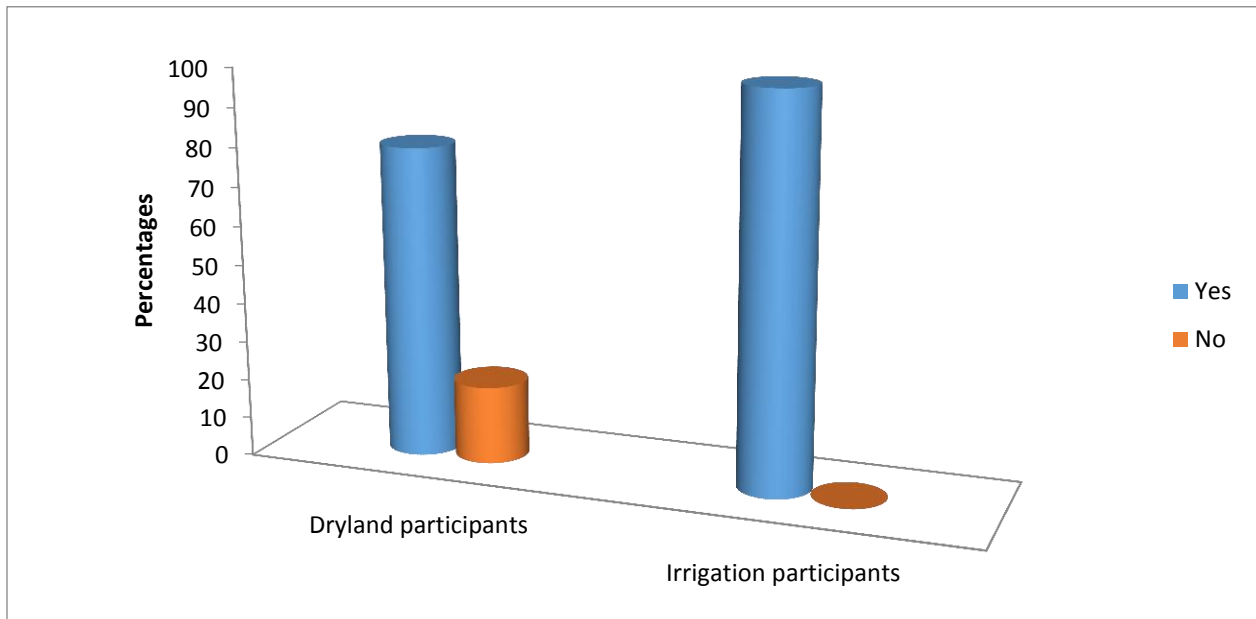


Figure 5.9: Access to extension

Source: Survey data (2013)

### 5.1.11 Frequency of extension officers visit

A study by Ngemuntu (2010) indicated that agricultural extension officers work directly with farmers and companies related to agriculture to take new technologies to the farmers. The more the extension officers visit the farmers the more the farmers will be exposed to the new technologies that can increase their production. Figure 5.10 showed that with the dry land participants 43.3% of the respondents interact with the extension officer once in two weeks, 26,7 % interact the extension officer once in a month and 10% see the extension officer once a week. The majority of irrigation farmers consult with the extension officer once in month, 30% interact with the extension officer once in two weeks and 23.3% interact with the extension officer once in a week.

Some farmers from the irrigation side are educated up to a tertiary level that they could easily understand the information that is provided by the extension officers through extension education. They could also be able to get the information on the effects of climate change on maize production from the extension officers. According to Nhundu (2010) farmers with frequent contacts with extension services can regularly upgrade their knowledge and also learn more about problems like climate change. Extension officers can also encourage farmers to work as an organisation which will provide benefits to the farmers.

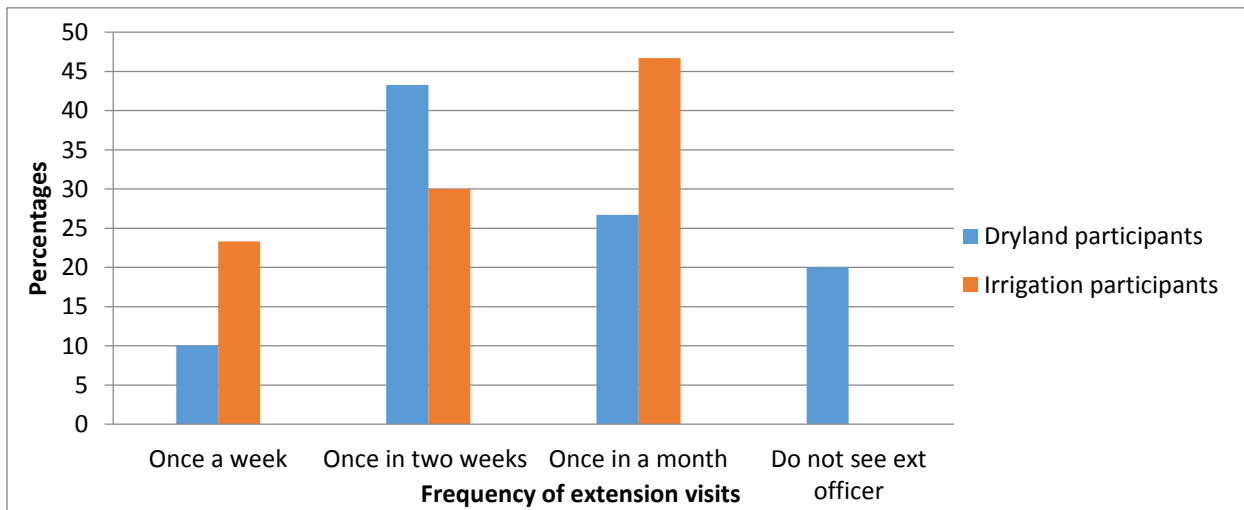


Figure 5.10: Frequency of extension visits .Source

Survey data (2013)

### 5.1.12 Membership to farmers' organization

Randela (2005), indicated that farmer organisations are important means of linking producers with markets, where an individual producer cannot individually enjoy economies of scale. Ngemntu (2010) indicated that a farmers' organisation helps farmers by overcoming transaction costs. The results of the survey as indicated on Figure 5.11 show that the majority of dry land farmers do not belong to any farmers' organization. Farmers indicated that they prefer to work as individuals than to work as a group. With the irrigation participants the majority of farmers belonged to an organization. Farmers that are working as an organisation get the benefits because they can sell their products together and reduce the transaction costs.

Farmers that are producing under irrigation can be able to overcome the impact of climate change because even if one farmer within the organisation is not aware of climate change, but the farmer can get information from other members of the organisation and be aware of climate change that affects the farmer's net revenue. This is in line with the research done by Jari (2009) which indicates that farmers working in an organization are getting the benefits like financial support, marketing information and the moral support from other group members.

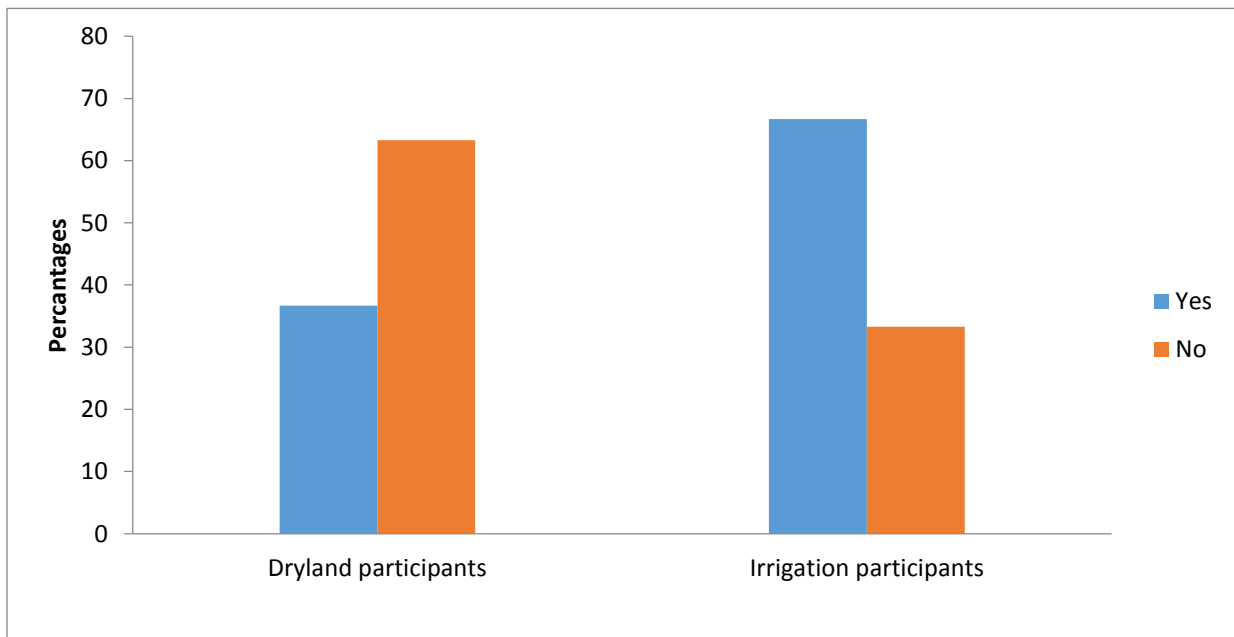


Figure 5.11: Membership to farmers' organization

Source: Survey data (2013)

### 5.1.13 Access to credit

The study by Parry *et al.*, (2007) indicated that credit is one of the most major bases of capital accumulation. Figure 5.11 above indicates the results from the study in which the majority of smallholder farmers producing under dry-land had no access to credit, while 10% have access to credit. The majority of smallholder farmers producing under irrigation had no access to credit and 3.3% had access to credit. Some of the respondents under irrigation had access to credit that is being provided by the government specifically for the smallholder farmers as a support service but they lacked information about their accessibility to credit they thought they do not have access to credit. Montshwe (2006) submits that there is lack of timely and reliable information, particularly in the communal areas. This study indicate that smallholder farmers on both farming systems do not have access to credit that can help them to increase their productivity, since credit is a major way of capital accumulation and can also help them in buying the inputs that can help improve their productivity such as fertilisers and chemicals. Failure by farmers to access to credit affect their revenue base, because as the study showed if they have access to credit that can help them to easily adopt to climate change and their productivity will increase.

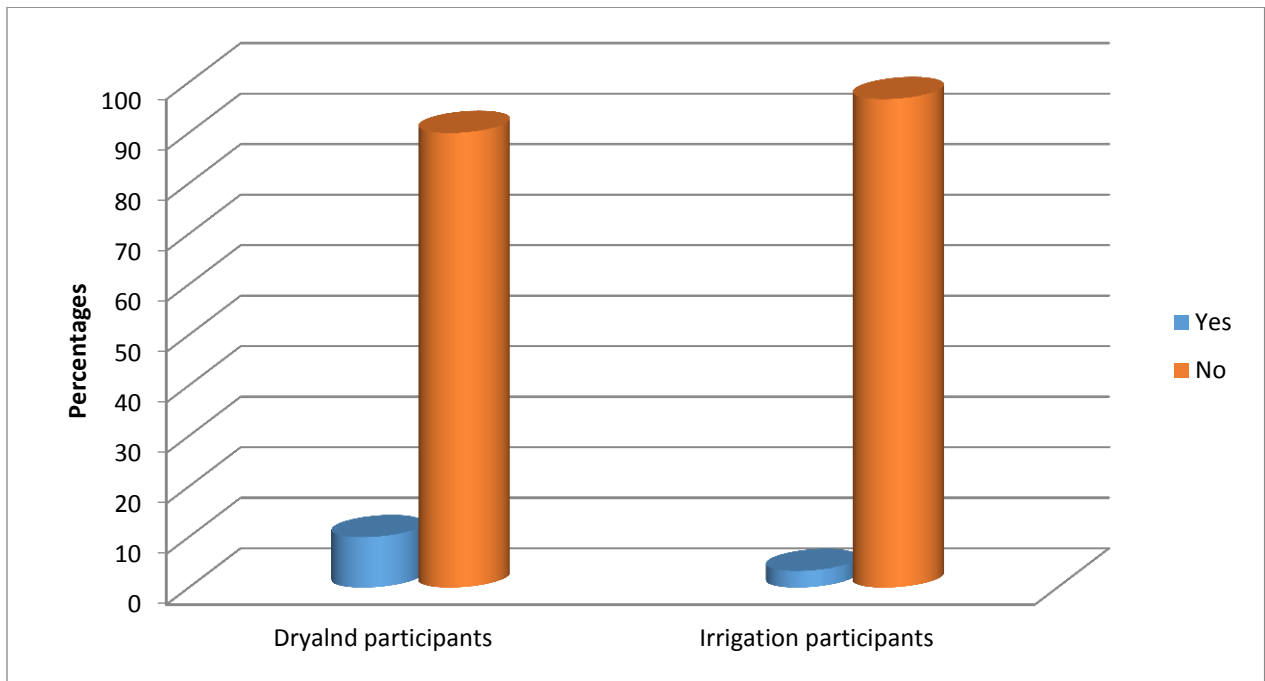


Figure 5.12: Farmers access to credit

Source: Survey data (2013)

### 5.2.14 Farmers' access to market

According to Kirsten and Sartorius (2002) market is a place where buyers and sellers interact to trade in goods and exchange information. The study indicates that smallholder farmers under survey were using the farm gate as their marketing channel since they were selling at the point of production. Figure 5.13 indicates the results of the farmers' access to market. From irrigating farmers 100 % confirmed that they have access to the market. Majority also of the dryland farmers have access to the market.

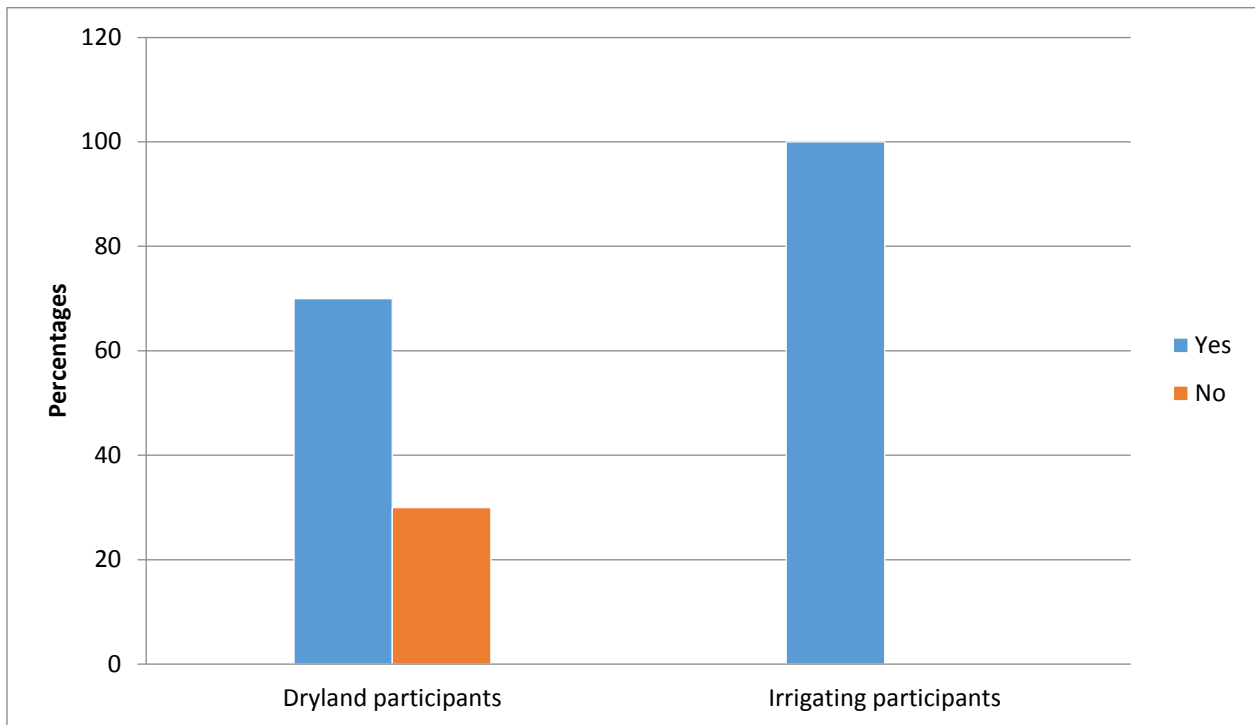


Figure 5.13: Farmers access to market  
Source Survey data (2013)

### 5.2.15 Type of soil

According to Kurukulasuriya and Mendelson (2006) suitability of the soil for a certain crop determines the productivity of the crop, if the soil is not suitable for the production of a certain crop that can affect the crop growth and development. Figure 5.13 indicates the type of soils that was dominant in the area of production in Jozini. There were three soil types that were dominant which are clay soil, sandy loam and loam soil. The study indicates that majority of the farmers

producing under irrigation are producing on loam soil and fewer farmers are producing on sandy loam. Majority of smallholder farmers producing under dry-land most are producing on loam soil. Climate change will leads to the more or less water in the soil that will affect productivity because more water encourage the presence of diseases which will affect maize productivity and lower the farmers net revenue. For farmers that are producing under dryland the increase in rainfall as a result of climate change will leads to the increase in productivity because loam soil will retain water to be used during growth of maize. According to Tingem *et al.*, (2009) loam soil is a good soil and suitable for maize production..

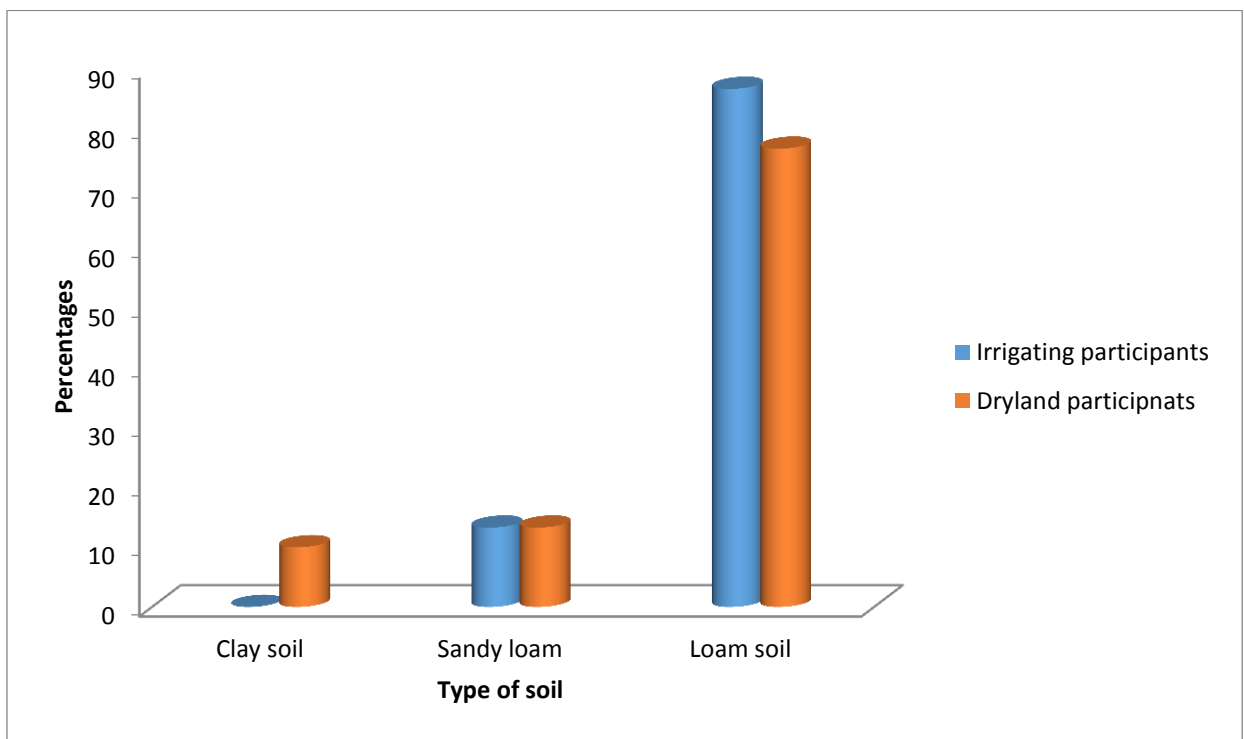


Figure 5.14: Type of soil

Source: Survey data (2013)

### 5.1.16 Farmers' awareness of climate change

The result of the study indicates that the majority of farmers that are producing under irrigation and dryland are aware of climate, as indicated in Figure 5.15. The study also indicates that they do not have the details of what is climate change but they are able to identify the signs of climate change. The study further noted that farmers are getting information from the media (radio) and

are also getting information from other local farmers. This indicates that farmers will be able to adopt to climate change strategies because adaptation process starts with awareness of the threat which is climate change in this case. This indicates that if farmers can get more information about climate change they can be able to adapt to the strategies that will help farmers to increase their productivity while there is climate change. This is in line with the study by Kgakatsi *et al.*, (2006) which indicated that the adaptation process starts with the awareness of the threat whereby farmers must have information about the threat and also how to overcome or to prevent such a threat.

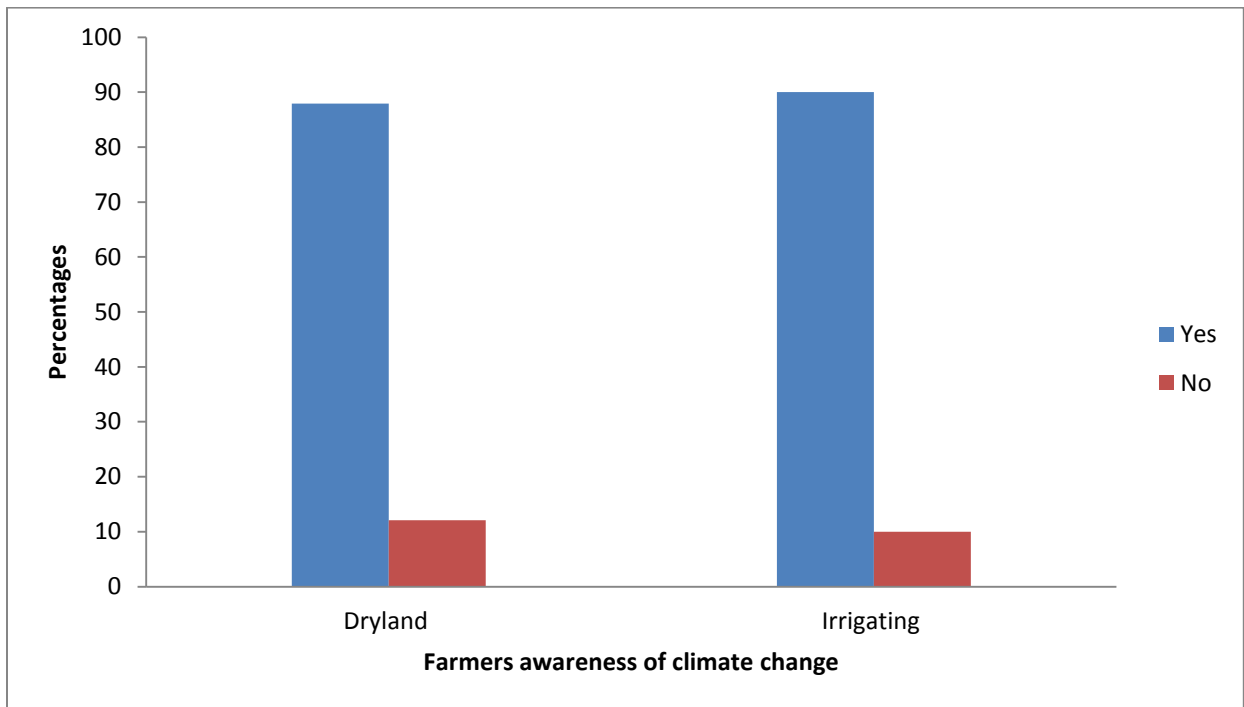


Figure 5.15: Farmers awareness of climate change

Source: Survey data (2013)

### 5.2.17 Marketing channels pursued by farmers

According to Montshwe (2006) marketing channel is a set of practices or activities necessary to transfer ownership of goods from the point of production to the point of consumption or it is the way the product gets to the end user of the product. Figure 5.16 indicates marketing channels mostly used by the farmers in this study, which are local consumers and hawkers. The study indicates that the majority of irrigating farmers are using hawkers as their main markets but

hawkers come to buy at the point of production (in the field), and also they sell to the local consumers who also come to buy in the field. Irrigation farmers sell maize as cobs in which the buyers come from different towns like Durban, Richards’s bay and from other areas which are not producing maize in KZN. They do not have high transaction costs for marketing their product (maize).

The majority of dryland farmers are using local consumers as their marketing channel in which these farmers sell their product to the local consumers who are not producing maize. In most cases dryland farmers sell maize as grain rather than to sell as cobs. The study indicates that climate change will not only affect the producers of maize it will also affect consumers of maize (Hawkers and local consumers) because productivity climate change will affect farmer’s productivity, and net revenue will be reduced as well.

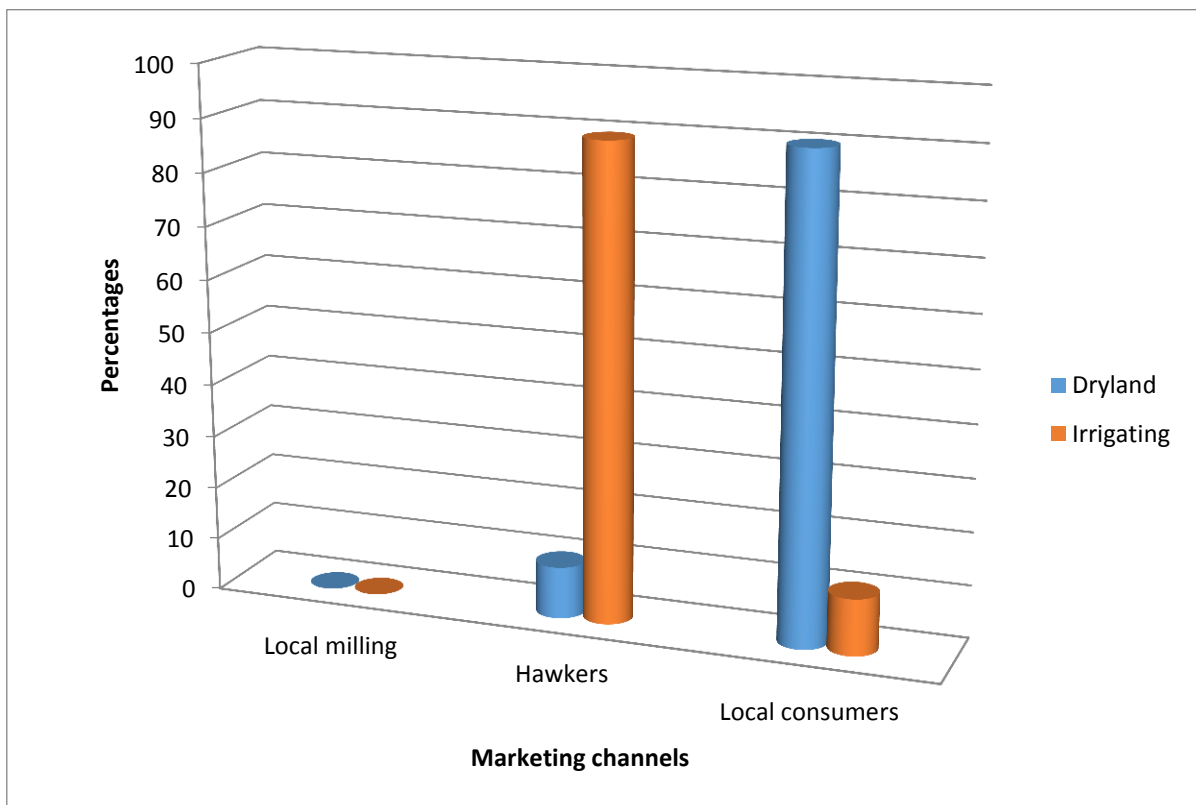


Figure 5.16: Marketing channels pursued by farmers

Source: Survey data (2013)

### **5.2.18 Adaptation strategies pursued by farmers**

The study done by Mekonen (2012) indicates that adaptation at the farm level requires detecting a shift in one's external environment, determining that it would favour a change in behaviour, and undertaking that change. Mekonen (2012) also indicated that farmers must adapt to climate change so that they will continue with production even in the presence of climate change. The study indicated that both groups of farmers that are producing under irrigation and under dryland are aware of climate change. They are pursuing the adaptation strategies although they do not know that it is the way of adapting to climate change. Figure 5.16 indicates that the majority of farmers producing under irrigation are changing planting dates, use resistant cultivars and irrigation as an adaptation strategy.

Majority of farmers that are producing under dryland are changing their planting dates as adaptation to climate change. The study indicates that farmers that are producing under irrigation are better off because they are using more than one adaptation strategy at the same time that increases their productivity and leads to the higher gross margin and reducing the chances of being affected by climate change. The study also indicates that farmers that are producing under dryland have adopted one adaptation strategy to climate change which is changing planting dates because farmers rely on natural rainfall. They wait for rainfall till they start planting, so that affects their productivity and also their net revenue.

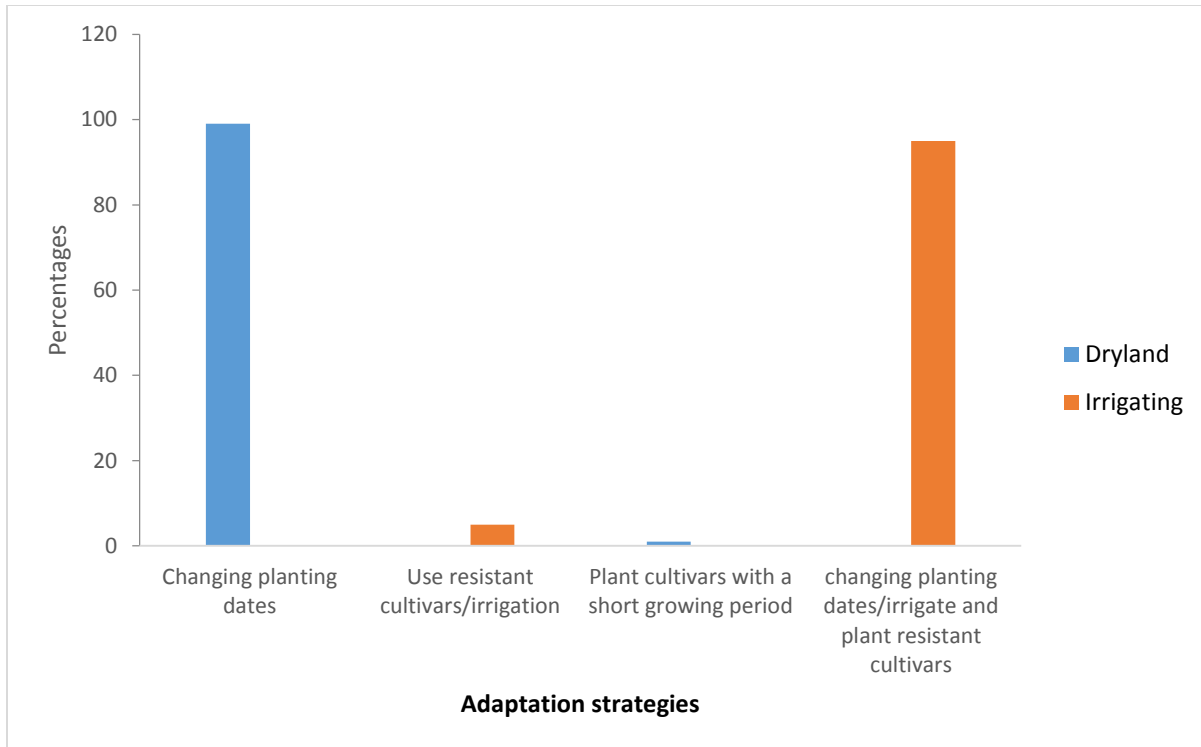


Figure 5.17: Adaptation strategy pursued by farmers

Source: Survey data (2013)

### 5.3 Conclusion

This chapter has shown that most of the respondents are fulltime maize farmers, who obtain their income from maize production. Male farmers are dominating under irrigation and the female farmers are dominating under dry land. The level of education is higher with the farmers that are producing under irrigation as most of them went up to the high school level meaning that they can be able to interpret the information that is provided to them by the extension officers or the local farmers. The results show that both farmers that are producing under dry-land and irrigation are affected by climate change, but respondents producing under irrigation are better off because they have adopted more adaptation strategies which makes them stand a better chance of reducing the effects of climate change. Gross margin and net revenue was calculated for each of the farmers with the empirical results which indicate the factors that are affecting the farmer's profitability and the impact of climate change on maize farmers' net revenue being presented in the next chapter.

## **CHAPTER SIX**

### **RESULTS AND DISCUSSION OF THE EMPIRICAL ANALYSIS**

#### **6.0 Introduction**

This chapter presents the empirical results of the multiple regression analysis which was formulated and explained in Chapter 4. Gross margin was calculated for each respondent under study, the mean gross margin from the farmers producing under irrigation was compared to the mean gross margin producing under dryland. For multiple regression analysis the dependant variable was gross margin which was regressed against socio-economic, production and soil variables to indicate the variables that have an influence on the changes of gross margin. This chapter also presents the empirical results of the Ricardian model that was formulated and explained in Chapter 4. For the Ricardian model, the net revenue for each respondent was calculated which was used as the dependant variable on the analysis. The independent variables are tested for their significance and conclusions are drawn based on the results. Significant variables in the model are explained in detail. The explanatory variables used in the models were seasonal climate variables, soils and socio-economic factors.

#### **6.1 Results of Gross margin analysis**

Gross margin was calculated for each and every farmer under study. In calculating gross margin rent for land was only included for farmers that are producing under irrigation. Farmers that are producing under dry land were not paying rent because they own the land. The mean gross margin was obtained for each group to indicate which group of farmers is getting a higher gross margin. The formulae for Gross margin was used as explained in chapter 4. Table 6.1 indicates the minimum Gross margin and the maximum Gross for farmers that are producing under irrigation and also for dryland farmers. Dryland farmers are getting less minimum and maximum gross margin compared to the irrigating farmers. This study indicated that irrigating farmers are getting a higher average gross margin compared to the farmers that are producing under dryland.

This study is in line with the results obtained on descriptive statistics results. The results indicated that farmers that are producing under irrigation are educated and use fertilizer and also irrigation which contributes to the increase in yield.

Farmers that are producing under dry land have a lower mean gross margin because they are still using the low input technology which affects their gross margin.

**Table 2.1: Gross Margin for maize (R)**

| Gross margin (R) | Dry land farmers | Irrigating farmers |
|------------------|------------------|--------------------|
| Min              | R357.00          | R5547.00           |
| Max              | R550.00          | R6238.00           |
| Mean             | R448.00          | R5892.00           |

Source: Survey (2013)

## 6.2 Factors affecting profitability of maize production in Jozini Municipality

Multi regression analysis was used to test factors that have an influence on gross margin on tow farming systems or factors that are affecting profitability of maize in the study area. Gross margin was used as the dependant variable which was regressed against socio-economic factors, production factors and the type of soil. Out of 10 variables that were considered 8 of them were significant. These are indicated on Table 6.2 and discussed in the following section.

According to Gujarati (2002) the coefficient values measure the expected change in the dependant variable for a unit change in each independent variable, all other independent variables being equal. The positive or negative (+/-) sign of the coefficient shows the direction of influence of the variable on the dependant variable. If it follows a positive value, it indicates that an increase in the independent variable will also lead to an increase in the dependant variable. A negative value shows the increase in the independent variable will lead to the decrease in the dependant variable. In this study, the variables were tested at 1%, 5% and 10 % significance levels. Thus, if the significance value is greater than 0.01, 0.05 or 0.10 then it shows that there is insufficient evidence to support that the independent variable influences a change in the gross margin of the dependant variable. If the significance value is less or equal to 0.01, 0.05 or 0.10, then there is enough evidence to support a claim presented by the co-efficient value.

**Table 6.2: The empirical results of the factors affecting maize profitability in Jozini Municipality.**

| <b>Variable</b>                   | <b>Beta (<math>\beta</math>)</b> | <b>Significance</b> |
|-----------------------------------|----------------------------------|---------------------|
| Age of the farmer                 | -.089                            | .239                |
| Level of education                | .211                             | .005**              |
| Access to extension services      | .010                             | .862                |
| Access to credit                  | .281                             | .065*               |
| Land size (ha)                    | .125                             | .052**              |
| Years involved in farming         | .163                             | .018**              |
| Type of soil                      | .039                             | .026**              |
| Using irrigation                  | .733                             | .000***             |
| Use of fertiliser                 | .083                             | .088*               |
| Yield obtained in the last season | .328                             | .001***             |

**No of respondents = 100  $R^2 = 85\%$  \*\*\* Significant at 1% \*\* Significance at 5%, \* Significance at 10%**

Table 6.2 indicates that the level of education is significant at 5% and shows a positive relationship with the gross margin. This indicates that farmers with a higher level of education are capable of understanding most of the things that are required for production thus the production increase and leads to a higher gross margin. According to the literature use of new resistant cultivars with short growing season is one of the adaptation strategies. From the descriptive statistics, the majority of farmers that are producing on dry land are not educated and their gross margin is lesser than the gross margin obtained by the farmers that are producing under irrigation. Farmers that are producing under dryland are less educated and they are resistant to accepting the new varieties which can increase productivity and increases their gross margin.

Access to credit was found to be significant at 10% and has a positive relationship with gross margin. Both groups of farmers (irrigating and non-irrigating farmers) do not have access to credit because they do not qualify to get credit as a result of not having collateral. Ngemuntu (2010) indicated that credit enables the smallholder farmers to acquire more efficient production

assets: hence it contributes to the productivity and income of rural households. The study by Ngoma (2008) indicated that the Department of Agriculture Forestry and Fisheries came up with a new initiative called Micro Agricultural Financial Institution of South Africa (MAFISA) to enhance agricultural activities especially to smallholder farmers, but farmers in the study area lacked information about such initiatives. If they had access to credit that was going to have a positive impact on their gross margin because they would be able to buy more inputs like fertiliser and improve their productivity and also increase gross margin.

Land size was found to be significant at 5% and has a positive relationship with the gross margin. The study was dealing with the smallholder farmers in which the maximum land size was 10 hectares but most of the farmers that are producing under irrigation rent the land that is about 3 hectares which they use for maize production. The bigger the land sizes for maize plantation, the higher the gross margin under good management. The study indicated that farmers that were producing under dry land owned the land, while farmers that produced maize under irrigation did not own the land but were renting the land of and that has an influence on their gross margin. According to Mati (2004) the land size influences gross margin in the sense that farmers that are producing on a larger area obtain a higher gross margin than the farmers that are producing on a smaller piece of land. The study indicated that farmers that are producing under dryland have smaller piece of land as compared to the farmers that are producing under irrigation. Farmers under dryland also use low technology methods of production like they don't apply fertiliser which can increase productivity on a small piece of land that they have.

Years involved in farming was found to be significant at 5% and had a positive relationship with gross margin. These indicate that the more years the farmer is involved in farming the better the chances of having a higher gross margin. The descriptive results of these study indicated that farmers that are producing under dry land had experience in farming but then they were using the low technology methods since they started farming. Although farmers that are producing under dryland have more experience, but they are less educated they cannot easily adopt the adaptation strategies to climate change. Climate change will affect maize productivity on dryland and reduces maize gross margin. Farmers that are producing maize under irrigation also have experience in farming and that the majority of farmers are educated and they can be able to share

the production information amongst themselves and help each other to increase their gross margin.

Use of irrigation was significant at 1%, and had a positive relationship with gross margin. This means that the use of irrigation to supplement natural water provided by rainfall leads to an increase in production and generates a higher gross margin. According to Ngaira (2008) use of irrigation to supplement natural rainfall increases productivity. Shortage of water on certain development stages of the crop like flowering or tasseling in the case of maize will lower the yield and farmers' gross margin. The study was based on farmers that are producing under irrigation and those that are producing under dry land. Farmers that are producing under dry land are more affected by climate change as compared to the farmers that are irrigating because they are supplementing the natural water. The study indicates farmers that are producing under irrigation are also being affected by climate change because according to the literature climate change also affects water resources in which is the source of irrigation water. Farmers under irrigation are better off because use of irrigation is one of the adaptation strategies to climate change.

Use of fertiliser was found to be significant at 10% and had a positive relationship with the gross margin as expected. The study indicated that majority of maize farmers that were producing under dry land were not using fertiliser at all, and not even the organic fertiliser. Majority of farmers that were producing under irrigation were applying fertilisers. This indicates that farmers that are producing under irrigation have a higher gross margin because applying fertiliser increases maize productivity and thus increasing the farmers gross margin. This is because during harvesting nutrients are removed from the soil by the crop and need to be replaced by applying fertiliser to increase productivity of the crop and thereby increasing gross margin and the net revenue.

Type of soil and yield obtained in the last season was found to be significant at 1% and 5% respectively. Type of soil had a positive relationship with gross margin, meaning if the soil is suitable for maize plantation there are higher chances of obtaining a higher gross margin. The study indicates that both groups of farmers are planting on a soil that is suitable for maize plantation. Climate change will affect factors (temperature and rainfall) that are important for maize production and lower farmers productivity and gross margin. The descriptive results

indicated that both groups of farmers are planting on loam soil that is suitable and good for plant production. Farmers sometimes do not use the right quantity of inputs and that will lower the yield and affect gross margin. When climate change affects the climate variables both groups of farmers are affected and that lowers the farmers' gross margin.

The next section will present the empirical results of the economic impact of climate change on the farmer's net revenue which was formulated and explained in chapter 4.

### **6.3 The empirical results of the economic impact of climate change on farmer's net revenue**

Net farm revenue is the amount of revenue left over after subtracting all costs of doing business (Ngaira, 2008). The net revenue was calculated for each farmer and was used as the dependant variable on the Ricardian model. The model was used to estimates the economic impacts of climate change on the farmer's net revenues). Net revenue was regressed against socio-economic, climate variables and soil variable to see variables that influence the net revenue of the farmer. On the Ricardian model, temperature and precipitation data was grouped into three-month average seasons; summer, autumn, winter and spring as indicated in Appendix 2. Table 6.3 show the estimated coefficients ( $\beta$  values) and significance values of the independent variables in the model. Nineteen variables was used, eight out of those variables were significant and are discussed below.

**Table 6.3: Empirical results of the economic impact of climate change on farmers' net revenue.**

| <b>Variable</b>                  | <b>Beta (<math>\beta</math>)</b> | <b>Significance</b> |
|----------------------------------|----------------------------------|---------------------|
| Age of the farmer                | 0.021                            | .912                |
| Use of irrigation                | 0.323                            | .082*               |
| Purchase of hybrid seeds         | 0.572                            | .001* *             |
| Land size                        | 0.454                            | .052*               |
| Market outlet                    | -0.075                           | .695                |
| Main input suppliers             | -0.035                           | .853                |
| Summer temperature squared       | 0.221                            | .241                |
| Autumn temperature squared       | -0.386                           | .035**              |
| Summer rainfall squared          | 0.201                            | .028**              |
| Gender of the farmer             | 0.207                            | .273                |
| Level of education of the farmer | 0.021                            | .912                |
| Income of the household head     | 0.061                            | .749                |
| Access to credit                 | -0.548                           | .002**              |
| Access to extension              | -0.035                           | .853                |
| Years involved in farming        | 0.035                            | .853                |
| Type of soil                     | 0.409                            | .025**              |
| Summer temperature               | -0.286                           | .042**              |
| Autumn temperature               | -0.050                           | .794                |
| Winter temperature               | 0.299                            | .109                |

**No of respondents = 100  $R^2 = 0.455$  \*\* Significant at 5% \* Significant at 10%**

Estimates of the Ricardian model are presented in table 6.3. Use of irrigation, purchase of hybrid seeds, autumn temperature squared, summer rainfall squared, access to credit, type of soil and summer temperature were found to be significant. Each significant variable was explained to indicate whether it is positively or negatively influencing the net revenue.

Use of irrigation was statistically significant at 10% significance level. The model indicates that the use of irrigation by the maize farmers had a positive relationship with the farmers' net revenue. This indicates that unit increase in the use of irrigation increases the net revenue by 0.03

units. The study by Durand (2009) indicated that irrigation ensures a constant supply of water which is essential not only for growth of the crop, but also for the quality of the crop which will leads to a higher yield and also leads to the higher net revenue. The study by Zhu and Ringler (2010) indicated that climate change leads to the changes in rainfall pattern. It leads to either increase or decrease in the amount of rainfall which will affect soil moisture and soil erosion and thus affects the farmer's net revenue. Jozini is a relatively dry place, rainfall is low so the decrease in rainfall as result of climate change will worsen the situation.

Purchase of hybrid seeds was also found to be statistically significant at 5% significance level. The model indicates that the use of hybrid seeds is positively related with the farmer's net revenue. From the study farmers that are producing under dry land were not using hybrid seeds for maize production but used the retained seeds from harvest to plant in the following season. The model shows that if they could adopt the use of hybrid seeds, it could have a positive impact on their net revenue.

The study by Apata *et al.*, (2009) indicated that planting hybrid seeds will produce similar plants while the seeds of the next generation from those hybrids will not consistently have the desired characteristics. The study further indicated that planting hybrid seed is one of the adaptation strategies to climate change. Farmers that are producing under irrigation are better off because they are producing maize using the hybrid seeds which can be able to resist against the effect of climate change and thus increase productivity and also increase the net revenue. Net revenue for farmers that are producing under dry land will be affected by climate change because they are not using hybrid seeds that will lower their productivity as a result of climate change and thus lower their net revenue.

Land size was also found to be statistically significant at 10% significance level, and had a positive relationship with the farmer's net revenue. This indicates that the farmers' net revenue sometimes depends on the size of the land, the smaller size may have a lower net value and may need the farmer to use expensive technology to obtain a higher net value. The big land size will have a higher net value. The results of this study also indicate that 1 % increase in the land size results in 0.5% increase in the net revenue. This is in line with the study by Seo and Mendelsohn (2006) who indicated that farm sizes appear to have strong positive influence on net farm

revenue across all farm types suggesting that more land allows farmers to diversify crop and livestock enterprises per farm leading to more income. Similar studies found contrasting results of the impact of farm size on net revenue. For example, Nhemachena (2008) found a similar result on the combined African analysis and Kurukulasuriya and Mendelsohn (2008) found that farm area reduces the value per hectare of farms at a decreasing rate implying that they are more productive on a per hectare basis.

Summer temperature and autumn temperature squared was statistically significant at 5% significance level. This study indicates that both the summer temperature and autumn temperature have a negative relationship with the farmers' net revenue. This means that the increase in summer and autumn temperature will lead to a decrease in the farmer's net revenue. Summer temperature has a negative relationship with the farmers' net revenue. This is because an increase in summer temperature as a result of climate change will lead to higher evaporation, pollination will not take properly and then maize crop will suffer stress and the output will be reduced leading to the lower net revenue. The descriptive statistics indicates that farmers are planting late or changing the planting dates in trying to adapt to climate change but by autumn maize will be, maturing and higher temperatures will affect maturing of maize and lowers the output leading to a lower net revenue. For example maize will dry up quickly in the field and that will reduce the farmers' net revenue especial for farmers that are selling the green cobs.

The results of this study are in line with the study done by Kurukulasuriya and Mendelson (2006) which also used a Ricardian model to estimate the impact of climate change on net farm revenues in African agriculture using farm-level data collected for African climate project coordinated by CEEPA. The study measured the total of 102 net farm revenue of rain-fed dry land crops, irrigated crops that depend at least on some irrigated water and livestock enterprises. The results showed that dry land crops and livestock will experience more adverse impact from increases in temperature and decreases in precipitation, compared to irrigated crops which will benefit from warming in terms of irrigation.

Nemachema (2008) indicated that warmer growing season temperatures can directly reduce yields in two important ways. First, for crops such as maize higher temperatures have a bad effect because it speeds up crop growth and development. This reduces the time for plant and grain development, limiting the attainment of yield potential. Second, if extreme heat occurs

during flowering, such as the maize 'silk-tasseling' phase, pollination may be inhibited and the development of grain may be prevented entirely. The study indicated that the climate change will negatively affect maize in yield and thus affect a farmers' net revenue.

Summer rainfall squared was also found to be statistically significant at 5% significance level in the model. The study indicates that summer rainfall has a positive relationship with the farmer's net revenue. The increase in summer rainfall will leads to an increase in the farmers net revenue. This is more applicable with the farmers that are producing under dry-land because they rely on rainfall. Dry land farmers also plant maize in summer, so increase in summer rainfall leads to an increase in productivity and thus increasing the farmers' net revenue. Jozini is a dry area and is a low rainfall area, so if climate change reduces rainfall that will affect the farmers net revenue especial for farmers that rely on rainfall for maize production. Farmers that are producing under dryland will be affected by climate change if there is less rainfall because there will no water in the dams for irrigation. More than necessary rainfall will also affect maize production because maize crop required a certain amount of water for different stages of maize. More than the required amount of water will leads to lower output, and thus affecting the farmers net revenue.

According to Meza *et al.*, (2008) crops require a certain amount of water for different stages of growth. If climate change can leads to the increase in rainfall more than the required amount of water that will negatively affect productivity and reduce the farmers' net revenue. For farmers that are producing under irrigation this have a negative relationship because the level of rainfall in the country during this summer is already high so any further increasing precipitation results in flooding and damage to field crops and then affects the farmers' net revenue.

Type of soil was also found to be statistically significant at 5% significance level in the model. Type of soil indicated to have a positive relationship with the farmer's net revenue meaning that the more suitable the soil for growth of maize, the greater the likelihood that will leads to an increase in the farmer's net revenue. Descriptive results indicated that majority of farmers in both groups are planting maize on loam soil. According to Ngoma (2008) loam soil is good for crop production because it has a good aeration, good water holding capacity and good infiltration rate. If climate change leads to less rainfall loam soil will play a good role it retains water to be

used by crops while there is no water, but if the situation continues for a longer period the output will decrease and the net revenue will also decrease.

Access to credit was also found to be statistically significant at 5% significance level in the Ricardian model. The study indicated access to credit to have a negative relationship with the farmer's revenue, but hypothetically access to credit was expected to have a positive relationship with the farmer's revenue because farmer's access to credit means that the farmer will be able to buy more inputs. In this study access to credit was found to have a negative relationship with the net revenue because, credit was not enough to increase their output. Farmers also need education or training on how to use the credit and what inputs do they need to buy on credit.

The results of the study indicated that a small percentage of farmers had access to borrowing. The amount of money that they borrowed was not enough to make a difference in the net farm revenue. According to the study done by Pote (2008), smallholder farmers' access to credit means that farmers will be able to buy more inputs, increase productivity and get a higher gross margin and also be able to repay the credit back. This study also indicated that smallholder farmers had no experience on how to manage the credit and also they did not have the information on how to obtain the credit.

#### **6.4 Conclusion**

The results of the study indicated that farmers that are producing under irrigation obtain higher gross margins compared to the farmers that are producing under dry land. The empirical results of the factors that are productivity of farmers also indicated that gross margin is positively influenced by many factors such as the level of education, farmers experience land size and yield obtained on the previous season. Type of soil was found to be significant but it had a negative relationship with the gross margin meaning that if the soil is not suitable for planting a certain crop it will lead to a loss in gross margin. This study also indicated that climate change has a negative impact on maize farmers especially with the farmers that planted maize under dry-land, although farmers that are producing under irrigation are also affected by climate change.

According to the study farmers producing under irrigation are already using the adaptation strategies which include the use of the hybrid seeds which can withstand harsh conditions and

also use irrigation for maize production. Changes in precipitation and temperature affects farmers net revenue in different ways. This study indicated that an increase in temperature especially the autumn temperature squared will leads to the reduction in the output thus affecting the farmers net revenue. Increase in summer rainfall as a result of climate change will affect production of maize because maize requires a certain amount of water for growth and development. Increase in summer rainfall leads to more water which will sometimes lead to floods and lowers the output and farmers net revenue.

## **CHAPTER SEVEN**

### **SUMMARY, CONCLUSION AND RECOMMENDATIONS**

#### **7.0 Introduction**

The purpose of the study was to assess the economic impact of climate change on maize production under dry-land and irrigation by smallholder farmers in Jozini Municipality (KZN). This chapter outlines the summary of the research findings, conclusion and recommendation.

#### **7.1 Summary of the study**

Climate change is a long-term shift in the climate of a specific location, region or planet. The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation. These changes occur when the climate of a specific area or planet is altered between two different periods of time. These changes can be caused by natural processes like volcanic eruptions, variations in the sun's intensity, or very slow changes in ocean circulation or land surfaces which occur on time scales of decades, centuries or longer (IPCC, 2014).

Mendelsohn and Dinar (2009) further explained that causation for climate change is ascribed largely to the increased levels of atmospheric carbon dioxide produced by the human activity of burning fossil fuels. The burning of fossil fuels releases gases known as greenhouse gases into the atmosphere. These are gases in the Earth's atmosphere which absorb heat energy radiated by the earth and return most of this energy back towards the surface. This process is known as the greenhouse effect. Burning of fossil fuels leads to an increase in the concentration of greenhouse gases, trapping increasing amounts of heat in the earth's atmosphere and resulting in an increase of the earth's temperature over time.

Climate change will significantly impact agriculture by increasing water demand, limiting crop productivity and reducing water availability in areas where irrigation is most needed or has a comparative advantage. It will also affect crop production temperature and precipitation which are some of the factors that determine the crop yield. Climate change is not only affecting crop production but also livestock production is also affected by climate change. Climate change reduces the amount of rainfall thereby affecting fodder production. It also leads to the spread of

diseases and parasites into the new regions or produces an increase in the incidence of diseases, which in turn will reduce animal productivity and possibly increase animal mortality.

The study had three objectives, and they were measured using the different methods. The first objective was to determine the level of maize production per hectare by the smallholder farmers under different farming systems (irrigation and dry land) in Jozini Municipality. Descriptive statistics were used for the first objective, where graphs and tables were used to analyze data. The second objective was to assess profitability of maize produced by the smallholder farmers under irrigation and under dry land. The third objective was to determine the economic impact of climate change on maize production under different farming systems looking at the farmers that are producing under dry-land and also farmers that are producing under irrigation. Gross margin analysis was used for the second objective whereby gross margin was calculated for each farmers and the mean gross margin was also determined to indicate which group of farmers is obtaining a higher gross margin. Multiple regression analysis was used to determine the factors that contribute to the decrease or increase in gross margin. The dependent variable was gross margin which was regressed against socio-economic factors, factors of production and soil variables.

Most of the independent variables were found to be significant and had a positive relationship with the gross margin meaning that they contributed to the increase in gross margin. Type of soil is the only variable that was found to be significant and had a negative relationship with the gross margin.

The Ricardian model was used for the third objective, where the dependent variable was the farmer's net revenue. The independent variables included the linear and quadratic temperature and precipitation terms for the four seasons (winter, spring, summer and fall), household variables and soil types collected from different various sources. The regression results indicated that climatic, household and soil variables have a significant impact on net revenue per hectare for smallholder maize farmers.

On the climate variables, seasonal temperature had a negative impact on the farmer's net revenue. Especially for the smallholder farmers that are producing maize under dry-land the increase in seasonal temperature affected their net revenue more compared to the farmers that are producing under irrigation. Summer rainfall on the model was found to be significant and had a

positive impact on the farmer's net revenue. Use of hybrid seeds was also found to be significant in the model and showed the positive relationship with the farmer's net revenue and that implies that if the farmers can use hybrid seeds, their net revenue is expected to increase. Use of irrigation was found to be significant and had a positive relationship with farmers' net revenue. Irrigation is used as one of the adaptation strategy to climate change so producing under irrigation helps and even during the periods of higher temperatures.

Type of soil was also found to be significant and had a positive relationship with the farmer's net revenue, meaning that if the soil is suitable or is good for maize plantation it is also expected to increase the farmer's revenue. The results indicated that net revenue sensitive to both seasonal temperature changes and changes in precipitation.

From the results farmers that are producing under dry land are getting less tons (0.5 tons) of maize as compared to the farmers that are producing under irrigation (5 tons). This is also indicated by the gross margin obtained by the farmers on dry land which is lower than the gross margin obtained by the farmers that are producing under irrigation. The study accepts the first hypothesis that maize productivity is higher under rainfall than under dry land. The results also indicate that the average gross margin obtained by farmers producing under dry land is R448.00, while farmers that are producing under irrigation obtained the average of R5892.00. This indicates that the study accept the hypothesis that maize farmers obtain a higher gross margin as compared to maize farmers under dry land in Jozini.

The study also indicated that changes in climate variables (precipitation and temperature) affects farmers net revenue in different ways. For example an increase in temperature especially the autumn temperature squared will leads to the reduction in the output thus affecting the farmers net revenue. Increase in summer rainfall as a result of climate change will affect production of maize because maize requires a certain amount of water for growth and development. Increase in summer rainfall leads to more water which will sometimes lead to floods and lowers the output and farmers net revenue. Decrease in summer rainfall can leads to drought also affects maize farmers under dry land because they rely on rainfall, and lowers the productivity, and thus affects the yield and the farmer's net revenue. The study accepts the last hypothesis which states that climate change has an economic impact on maize production and under dry land conditions.

## 7.2 Conclusion

Climate change is a reality, although its projections are over a long time horizon, there is more than enough reason to believe that it is a reality and is likely to create an even harsher environment for us as human beings and for agriculture in particular. It is also a natural disaster that affects every individual on earth. Farmers cannot stop climate change but they need to adapt to it which is referred to as an adjustment in natural and human systems in response to actual or expected climatic stimuli or their effects, which moderates the harm (IPCC, 2001). Crop adaptation includes planting the hybrid seeds which include the characteristics that will make the crop to withstand the climate change.

Gross margin was calculated for each farmer, which was then used as a proxy to measure profitability. The results of the study indicated that farmers' gross margin is influenced by different factors like level of education meaning that an educated farmers can be able to adopt adaptation strategies to climate change and continue with production while there is climate change. Access to credit also had a positive relationship with gross margin because credit allows the farmer to buy more inputs that are required to increase productivity and also increase gross margin.

The results of the study indicated that climate change affects maize production in the study area (Jozini). Changes in climate variables (precipitation and temperature) affect maize production and thus affecting the farmers' net revenue. Autumn temperature squared and summer temperature has the negative relationship with the farmers' revenue, meaning that a decrease or an increase in this variable lowers maize productivity and thus affecting the farmers' revenue. Land size and also the type of soil also affects that famers' net revenue. This study indicated that farmers that are producing under irrigation are dominated by males who are educated and they are middle aged meaning that they easily adapt to climate change adaptation strategies. Dryland farmers are dominated by female farmers who are not educated and also in the middle age.

In conclusion climate change affects maize production both under irrigation and under dryland, but farmers that are producing under irrigation are better off because they use irrigation as the

adaptation strategy. Farmers need to be taught about climate change so that they will use the adaptation strategies to continue with production while there is climate change.

### **7.3 Recommendations and policy implementations**

Government must consider designing and implementing adaptation policies to counteract the harmful impacts of climate change. Governments need to integrate adaptation into national economic policies as well as strengthening community based adaptations to help farmers reduce the potential damages from climate change. Government should increase programs that will ensure that farmers are aware of climate change in order for them to accept or easily adapt the adaptation strategies. Much research should be done in the area of climate change which will open the minds of people (and the government) to what is expected in the country and later on help farmers plan on how to handle the expected problems.

There is need for the South African government to take concrete steps to ensure that appropriate policies on climate change adaptations and mitigations are adopted. Building adaptive responses to climate change is not a one-time affair. Concrete steps should be placed on the ground to ensure that the indigenous people are carried along in the design and formulation of policies on climate change.

Adaptation options include investment in technologies such as irrigation, because even if the farmers want to grow maize under irrigation they will not be able to do so because irrigation equipment is very expensive. Also helping smallholder farmers to choose the irrigation system that will be suitable for the level of water availability, soil type, topography, climate, and crop type as well as management skills for the farmer will be necessary. Although choosing the appropriate irrigation system for small-scale farmer is a significant challenge, since very often irrigation technology that is available is either too expensive and out of reach for many small-scale farmers or does not match the needs or managerial skills of the farmer, so it is important for government to work with the private sectors in giving the information to the smallholder farmers that are involved in farming so that they will choose the appropriate or suitable irrigation system in which they are producing in. Planting drought tolerant and early maturing crop varieties, strengthening institutional set-ups working in research, and educating farmers and encouraging

ownership of livestock, as owning livestock may cushion the effects of crop failure or low yields during harsh climatic conditions.

Adaptation at the farmer level requires three basic steps. The first step is detecting a shift in one's external environment, determining that it would favor a change in behavior, and undertaking that change (Chen and Rasaily, 2010). Thus the first step in adapting to climate change requires detecting the signal of climate change. Have the information about climate change and lastly come up with the measures of adapting to climate change. Government should have the programs that will educate the development officers like extension officers more about climate change. Development officers will design the extension programs that will help in educating smallholder farmers about climate change and its effects. The government should also increase the funds for research because the extension officers work as the mediator between farmers and the researchers, so that the extension officers will disseminate the current information from the ongoing research about climate change.

Awareness and knowledge of the impacts of climate change are essential to make the agricultural sector less vulnerable, to encourage the sector to adapt to climate change and, most importantly, adopt a soil protection ethos and practices conducive to soil and water conservation, minimum greenhouse gas emissions, and carbon sequestration. Many within the farming community are either not aware of climate change and its impacts, or regard climate change as normal climate variability. A means of adaptation, targeted especially towards smallholder and subsistence farmers, would be to disseminate knowledge on and make finance available to use already established practices (e.g. soil sampling, conservation tillage), to embrace new technologies and to purchase appropriate equipment. Government can play a role in helping the farmers through forecasting which can help farmers in the planning process. The study indicated that farmers are aware of climate but they are not aware of the adaptation strategies so farmers need more knowledge on the adaptation strategies. Farmers also need to be trained about climate change in a language that they will understand, because the study indicated that farmers that are producing under dryland are less educated

Extension officers work as the mediator between the researchers and the farmers so if government can increase the funding in helping the researchers to carry out more research on

climate change. Extension officers or community development officers must encourage farmers to practice crop diversification because diversifying crop production can greatly contribute to building both biophysical and socio-economic resilience of farming systems and communities.

Diversification should take into account the existing differences in agro-ecologies and exploit the complementariness among systems. With improved water management and cropping techniques, farmers will be able to reduce the areas cultivated to food crops and invest more resources in legumes and high value crops. Agricultural diversification can have the triple advantage of improving food/nutritional security, boosting household income and reducing risks of total crop failure. Extension officers must also encourage farmers to practice conservation agriculture, which is an approach to farming that seeks to increase food security, alleviate poverty, conserve biodiversity and safeguard ecosystem services. Conservation agriculture practices can also contribute to making agricultural systems more resilient to climate change. In many cases, conservation agriculture has been proven to reduce farming systems' greenhouse gas emissions and enhance their role as carbon sinks (Morton, 2007).

One of the reasons why smallholder farmers have often been by-passed by new technologies is their inability to access credit. The agricultural banks that exist usually target big commercial farms and are reluctant to lend to smallholder farmers because they often consider them 'unbankable'. Permitting farmers, and particularly women, to own land through title deeds could perhaps allow them to have the collateral needed to secure loans from financial facilities. But, one proven way of enhancing the rural communities' chance of attracting loans is to organize them into some kind of groupings. The major advantage of group lending is that: (1) it allows the poorest members who cannot secure loans individually to do so under joint collateral; and (2) it greatly reduces the transaction costs associated with individual lending. Although in South Africa there are farmer support programs like Micro Agricultural Financial Institution of South Africa (MAFISA) which is helping the farmers with credit with lower interest but the information is not readily available to the farmers. This kind of information can be disseminated to the farmers through media (radio and TV) and also through information days and farmers' days arranged by the extension officers.

Information delivery is critical in the process of enhancing the adaptive capacities of the rural areas to climate change. Information on weather or new technologies can be transmitted to the farmers using rural radios and other media such as churches. The rapid development of mobile telephone is opening up new opportunities and should be exploited fully to reach the otherwise remote and unreachable areas. Encouraging farmers' field days has also proven effective for the rapid spread of new technologies. Climate forecast is another method which is helping farmers in terms of planning and be prepared for the events like drought and floods but such information does not reach the smallholder farmers so if government together with the private sectors can improve the flow of information from the researchers (SAWS) to the farmers so that they can be able to take the adaptive strategies for climate change.

Government with the help of ARC must promote the technique of rain water harvesting that will help in retention of water to be used for irrigation during drought, and to supplement rainfall. This can be done by retention of basins or boring of shallow wells can help to provide supplemental irrigation for rain-fed crops in the occurrence of dry spells and contribute to the development of off -season gardening. However, bearing in mind that global warming could exacerbate the scarcity of water resources through reduced rainfall/runoff and higher evaporation regime, technologies such as micro irrigation that allow the economical use of water should be given priority.

Climate change leads to the increase in pests and diseases on crops, which constitute a major threat to food security in southern Africa. Climate change may also aggravate the situation since a warmer climate could shorten the developmental cycle of many pests and disease agents. An integrated management approach combining biological and non-biological methods will be the best option to deal with an increased pest and disease pressure.

## LIST OF REFERENCES

- Abraha, M.G. and Savage, M.J., 2006. Potential impacts of climate change on the grain yield of maize for the midlands of KwaZulu-Natal, South Africa. *Agric. Ecosys. Environ.*, 115 (1-4): 150-160.
- Abdulai, A., & Huffman, W.E. 2005. The diffusion of new agricultural technologies: the case of crossbred-cow technology in Tanzania. *Am. J. Agric. Econ.*, 87: 645-659.
- Adlakha E.S., 2011. Impact of climate change on Agriculture in Nova Scotia, Unpublished Mscthesis. Acadia University.
- Adams RM, 2006. Global climate change and agriculture: An economic perspective. *American Journal of Agricultural Economics* 71(5): 1272–79.
- Agricultural Research Council (ARC).(2007). Climate change – A critical emerging issue. Climate change research group, Natural resources and the environment, CSIR, Pretoria, South Africa.
- Agricultural statistics. 2007. Maize production per province. Agricultural statistics committee report. Pretoria. National Department of Agriculture.
- Akpalu W., Hassan R.M, Ringler C., 2008. Climate variability and maize yield in South Africa. International food policy Research. Centre for Environmental Economics and Policy in South Africa.
- Apata, T.G., Samuel, K.D and Adeola, A.O. 2009. Analysis of climate change perception and adaptation among arable food crop farmers in South West Nigeria. Contributed paper prepared for presentation at International Association of Agricultural Economists' 2009 conference, Beijing, China.
- Azam, S., Ali, M., Amin, M., Bidi, S. and Arif, M., 2007. Effect of plant population on maize hybrids. *J. Agric. Biol. Sci.*, 2(1): 13-20.

Barnard R.O.2007.Agricultural Research Council (ARC)..Climate change and agricultural sector in South Africa.published by the Department of agriculture.

Bancy, M.M., 2000. The influence of climate change on maize production in semi-humid and semi-arid assessment mission to Swaziland.*Journal of Arid. Environ.*, 46: 333-334.

Beiragi, M.A., Khorasani, S.K., Shojaei, S.H., Dadresan, M., Khodadad, Mostafavi, K. and Golbashy, M., 2011.A study on effects of planting dates on growth and Yield of 18 Corn Hybrids (*Zea mays L.*). *Am. J. Experimen. Agric.*, 1(3): 110-120.

Bembridge, T.J. 1998. A systems approach study of development problems in Transkei. Unpublished PhD Agric thesis, University of Stellenbosch, Stellenbosch.

Benhin, J.K.A. 2006.Climate change and South African Agriculture: Impacts and adaptation options. CEEPA Discussion paper No. 21, 3 July, 2006.

Bless C., and Higson, S.C., 1995. Fundamentals of Social research methods: An African perspective. Kenwyn: Juta.

Bless, C., Higson-smith, C. &Kagee, A., 2006. Fundamentals of social research methods.(4th edition).Juta& Company Ltd., Cape Town, South Africa.

Blignaut, J., Ueckermann, L. and Aronson, J. 2009. Agriculture production's sensitivity to changes in climate in South Africa. *South African Journal of Science*, 105: 61-72.

Brooks N, Adger, W. N. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation.*Global Environmental Change*, 15:151-163.

Bryan, E., Deressa, T.T., Gbetibouo, G.A. and Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science and Policy*, 12:413-426

Bureau for Food and Agricultural Policy, (BFAP) 2007. Modeling the impact of climate changes on the South African Maize industry. Available on [www.bfap.co.za](http://www.bfap.co.za) [Accessed on 13 May 2013]

Chamuka, T. 2011. Possible Short to Long-Term Impacts of the January 2011 Floods to South African and Some of Her SADC Trading Partners. [Available from: <http://www.sangonet.org.za>] [Accessed on 20 June 2013].

Centre for Environmental Economics and policy in Africa (CEEPA). 2006. Vulnerability of maize production to climate change and adaptation assessment in South Africa. Available on [www.ceepa.co.za](http://www.ceepa.co.za). [Accessed on 13 October 2013].

Chen, L. Z. T. and Rasaily, R.G. (2010). Farmers' adaptation to climate risk in the context of China. A research on Jiangnan Plain of Yangste River Basin. *Agriculture and Agricultural Science Procedia*, **1**: 116 – 125.

Dawood G. 2013. Maize production and climate change in KZN, Department of Agriculture and rural development newsletter. KZN Cedara.

De La Roque S. 2008. Introduction. In: Climate change: impact on the epidemiology and control of animal diseases. *Journal of animal science*. *27* (2), 303-304.

Department of Agriculture Forestry and Fisheries, 2004 South Africa's yearbook on Agriculture and climate change. ARC document. Pretoria.

Department of Agriculture Forestry and Fisheries, 2005. Climate change sector plan 2005-2010. Available on [www.daff.gov.za](http://www.daff.gov.za) . [Accessed on 27 September 2013].

Department of Agriculture Forestry and Fisheries. 2010. Monitoring climate change and environmental impact of genetically modified organisms. DAFF document available on [www.daff.gov.za](http://www.daff.gov.za). [Accessed on 10 September 2014].

Department of Agriculture Forestry and Fisheries, 2012. Constraints faced by the smallholder farmers in rural areas of South Africa. Available on [www.daff.org.za](http://www.daff.org.za) .[Accessed on 15 October 2013].

Department of Agriculture and Environmental Affairs. 2012. Demarcation of the municipalities. Available on [www.daea.org.za](http://www.daea.org.za) .[Accessed on 10 July 2013].

Department of Environmental Affairs and Tourism (DEAT). 2004. United Nations Framework Convention on Climate Change (UNFCCC) – South Africa’s Initial National Communication, Pretoria.

Department of Agriculture and environmental affairs. 2012. Full technical report on the implications of climate change for the agricultural sector in South Africa. Climate change conference paper. Durban.

Department of Water Affairs & Forestry (DWAF). 2005. Directorate of Water Conservation and Demand Management. Implementation guidelines for water conservation and water demand management in agriculture. Development of irrigation water management plans (draft for testing in the pilot phase) Available on <http://www.dwaf.gov.za/waterconservation/worddownloads/guidelines.doc> [Accessed 10 September 2003].

Department of Water Affairs & Forestry.(DWAF) 2009. Intergration of climate change into the National Forest programs in South Africa. World Watch Report. Pretoria.

Deressa, T. 2007. Analysis of perception and adaptation to climate change in the Nile Basin of Ethiopia. *Review of Development Economics*, 7 (1): 58-70.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T., and Yesuf, M. 2009. Determinants of farmer’s choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* 19: 248-255.

Dinar, A., Mendelsohn, R., Hassan, R. and Benhin, J., 2008. Climate Change and Agriculture in Africa: Impacts Assessment and Adaptation Strategies. Earthscan. London.

Dogan, M.N., Unay, A., Boz, D. and Albay, F., 2004. Determination of optimum weeds control timing in maize (*Zea mays* L.). *Turk. J. of Agric Economics*. 28: 349-354.

Durand, W., 2009. Assessing the impact of climate change on crop water use in South Africa, ARC Grain Crop institute.

Du Plessis, J. 2003. Maize production. Directorate Agricultural Information Services, Department of Agriculture in cooperation with ARC-Grain Crops Institute, Potchefstroom.

Du Toit, W., 2003. Guide for the production of maize in the summer rainfall area. ARC grain crops institute Publication. Available on [www.nda.agrc.za/publications](http://www.nda.agrc.za/publications). [Accessed on 01 November 2013].

Fanadzo, M., Chiduzo, C., Mnkeni, P. N. S., 2009. Investigation of agronomic factors constraining productivity of grain maize (*Zea mays* L.) at Zanyokwe Irrigation Scheme, Eastern Cape, South Africa. *Journal of Applied Bioscience*. 17:948-958.

Fatti C.E., Patel Z., 2013. Perceptions and responses to urban flood risk: implications for climate change in South Africa. *Agrekon* 36:13–22

FAO. 2009. Impact of Climate change phenomena by sector How to mainstream climate change adaptation and mitigation into agriculture policies, Report 4 of June 2009, FAO, Rome.

FAO, 2010. Climate change adaptation and mitigation: New initiatives and update on Agriculture, Forestry and Fisheries. Proceedings: Thirtieth FAO Regional Conference for the Near East: December 4-8, 2010, Khartoum, the Republic of the Sudan.

Gbetibouo, G. and Hassan, R. 2005. Economic impact of climate change on major South African field crops: A Ricardian approach. *Global and Planetary Change*, 47: 143-152.

Gujarati, D., 2002. Basic Econometrics, 5th Edition. New York: McGraw-Hill.

Hoffman, M.T. & Vogel, C. 2008. Climate change impacts on African rangelands. *Rangelands*, 30: 12–17.

Herden B. Stevens C.R., 2010. Implications of climate change for agricultural sector performance in Africa: policy challenges and research agenda. *Journal of African Economies*, 19: 77-105.

Hosu Y.S., 2012. Agro-ecological conditions and constraints to optimal productivity of smallholder intergrated crop-livestock farmers in E.C. province of South Africa. Unpublished Phd thesis.University of Fort hare.

Intergovernmental Panel on Climate Change (IPCC). (2006). *Impacts, Adaptation, and Vulnerability*. Second Assessment Report, Cambridge University Press, Cambridge, UK.

Intergovernmental Panel on Climate Change. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge, United Kingdom.c

Intergovernmental Panel on Climate Change (IPCC) 2014. Summary for Policymakers, In: *Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jari, B. 2009.Institutional and technical factors influencing agricultural marketing channel choices amongst smallholder and emerging farmers in the Kat river valley.UnpublishedMscthesis.University of Fort Hare.

Jones, P. G. and Thornton, P. K. (2003). The potential impacts of climate change in tropical agriculture: the case of maize in Africa and Latin America in 2055. *Global Environmental Change*, 13: 51-59.

Kabubo-Mariara, J. 2008. Climate change adaptation and livestock activity choices in Kenya: An economic analysis. *Natural Resource Forum*, 32: 131-141.

Kirsten, J. and Sartorius K. 2002. "Linking agribusiness and small-scale farmers in developing countries: is there a new role for contract farming?" *Development Southern Africa* 19(4): 503-529.

Knox J., Hess T., Dacache A., Webner T., 2011. Climate change impacts on crop productivity in Africa and South Asia. *Environmental Research letters*.

Kurukulasuriya P., 2003. Will African agriculture survive climate change? *World Bank Econ. Rev.* (20) 367.

Kurukulasuriya P., and Rosenthal S., 2003. Climate change and agriculture : A review of impacts and adaptation : the World bank climate series paper no 91.

Kurukulasuriya, P. and Mendelsohn, R. 2006. Crop selection: adaptation to climate change in Africa. CEEPA Discussion Paper No. 26, Centre for Environmental Economics and Policy in Africa, University of Pretoria, Pretoria.

Laube W, B. Schraven and M. Awo 2012. Smallholder adaptation to climate change: dynamics and limits in Northern Ghana. *Climatic Change* (2012) 111: 753 – 774

Le Roux N., 2009. Seasonal maize yield simulations for South Africa using a multi model Ensemble system. Unpublished Msc thesis. University of Pretoria.

Lotsch, A. 2006. Weather and climate risks in Africa. CRMG, The World Bank ITF Meeting, May 15-17, Pretoria.

Lovejoy T. 2008. Climate change and biodiversity. *Rev. Sc. Tech. Off. int. Epiz.*, 27, 331-338

Madzwamuse, M. 2010. Climate Governance in Africa: Adaptation Strategy and Institutions. A synthesis report submitted to Heinrich Böll Stiftung.

Makadho J.M., and Mwamuka F.C., 1993. Zimbabwe Climate change Impacts on maize production and adaptative measures for the Agricsector. Interim reports on climate change.

Mandleni, B., 2011., Impact of climate change and adaptation on cattle and sheep farming in the Eastern Cape Province of South Africa. Unpublished thesis, University of South Africa.

Maddison, D. 2007. The perception of and adaptation to climate change in Africa. Policy research working paper 4308, Washington.

Makadho J.M., 2006. Zimbabwe Climate change Impacts on maize production and adaptative measures for the Agric sector. Interim reports on climate change.

Mandleni, B., 2011., Impact of climate change and adaptation on cattle and sheep farming in the Eastern Cape Province of South Africa. Unpublished thesis, University of South Africa.

Matarira, C.H., Makadho J.M. and Mwamuka F.C., 2010. Zimbabwe: Climate change impacts on maize production and adaptive measures for agricultural sector. Available on <http://www.gcrio.org/CSP/IR/IRZimbabwe>. [Accessed 29 September 2013].

Mati, B.M., 2004. The influence of climate change on maize production in the semi-humid-semi-arid areas of Kenya. *J. Arid Environ*, 46: 333-344.

Mekonen A. B. 2012. Analysis of climate variability and its economic impact on agricultural crops: The case of ARSI Negele District, Central Rift of Ethiopia. Unpublished Mscthesis. Hawassa University.

Mendelsohn, R., W. Nordhaus, and D. Shaw. 1994. The impact of global warming on agriculture: A Ricardian analysis. *Am. Econ. Rev.* 84:753-771.

Mendelsohn, R., and Dinar A. 2009. Climate change impacts on African agriculture. Centre for environmental economics and policy in Africa. [http://www.ceepa.co.za/Climate change /pd/ \(5-22-01\) afrbckgrnd-impact.pdf](http://www.ceepa.co.za/Climate%20change%20impact.pdf). [Accessed November 7 2013].

Meza FJ, Silva D, Vigil H., 2008. Climate change impacts on irrigated maize in Mediterranean climates. Evaluation of double cropping as an emerging adaptation alternative. *AgricSyst* 98:21–30.

Minde I, Pedzisa T., and Dimes J., 2008. Improving access and utilization of fertiliser by smallholder farmers in Limpopo province of South Africa. International crops Research Institute for semi-arid tropics (ICRISAT) .report no 3.

Montshwe, B.D., 2006, Factors affecting participation in mainstream cattle markets by small-scale cattle farmers in South Africa. Unpublished master's thesis. University of Free State, Bloemfontein.

Moeletsi M.K., 2004. Agroclimatic characterization of Lesotho for dryland maize production. Unpublished Mscthesi University of Free State. Bloemfontein.

Morgan, E. R. & Wall, R. 2009. Climate change and parasitic disease: farmer mitigation? *Trends in Parasitology*. 25, 308-313.

Morton, J.F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences (PNAS)*, 104 (50): 19680-19685.

Mqadi L., 2005. Production function analysis of the sensitivity of maize production to climate change in South Africa. Unpublished Mscthesi. University of Pretoria.

Nhemachena, C., 2008. Determinants of African farmers' strategies for adaptation to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, 2 (1):83-104.

Ngaira, J.K.W., 2008. Impact of climate change on Agriculture in Africa by 2030. *Scientific Research and Essay academic journals*. Vol 2(7) 238-243.

Ngemuntu S.T., 2010. An investigation of production and marketing challenges faced by the smallholder farmers in Amahlathi Municipality: A case of Zanyokwe irrigation scheme and Silwindlala women's project. Unpublished Mscthesi. University of Fort Hare.

Ngoma J., 2008. Effects of climate change on maize production in Zambia production in Zambia. Unpublished Mscthesi. Linkopics University.

Nhundu K., 2010. Determinants of farmer participation in irrigation development posts fast track land reform: A case of Mashonaland East Province of Zimbabwe. University of Fort Hare.

Nxumalo, B., and Nkoliso C., 2013. Location of the study sites in Jozini Municipality. Department of GIS. University of Fort Hare, Alice.

Oseni B., and Masarirambi, 2011. Effects of climate change on maize production and food security on maize production in Swaziland. Unpublished Msc thesis, University of Swaziland.

Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.). 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press. <http://www.ipcc.ch> [Accessed November 11, 2013].

Pote, P., 2008. Technical Constraints to Smallholder Agriculture: Case study of Nkonkobe Municipality, Eastern Cape, South Africa. Available online <<http://ufh.netd.ac.za/bitstream/10353/84/1/Dissertation%20final%20POTE.pdf>> [Accessed on 17 October 2013].

Ramadoss M, Birch CJ, Carberry PS and Robertson M (2004) 'Water and high temperature stress effects on maize production. [www.cropsscience.org.au/icsc\\_2004/poster/1/3/3/1037](http://www.cropsscience.org.au/icsc_2004/poster/1/3/3/1037). [Accessed 10 November 2013].

Ramados M., (2006). Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute, Washington, D.C.

Randela, R. (2005), Integration of emerging cotton farmers into the commercial agricultural economy. Unpublished PhD thesis, University of the Free State, Bloemfontein.

Roberts D. 2008. Thinking globally, acting locally, institutionalizing climate change at the local government level in Durban, South Africa. *Environ Urban*, 20:521–537

Rosegrant, M.W., Ringler, C., Msangi, S., Cline, S.A. & Sulser, T.B. (2005). International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACTWATER).

Rosenzweig, C., Major, D.C., Demong, K., Stanton, C., Horton, R., and Stults, M., 2007, Managing climate change risks in New York City's water system: *Assessment and adaptation planning, Mitigation and Adaptation Strategies for Global Change*, v. 12, p. 1,391–1,409.

Schiere, J.B., Ibrahim M.N.M, Van Kuelen H., 2011. The role of livestock for sustainability in mixed farming: criteria and scenario studies under varying resource allocation. *Journal of Agriculture, ecosystem and environment*. 90 (2).139-153.

Scholes, R. J., and Biggs R., 2004. Ecosystem services in southern Africa: a regional assessment. Council for Scientific and Industrial Research, Pretoria.

Stern, N. (2006). What is the Economics of Climate Change? *World economics*, 7 (2):1-10.

Smalle B., and Mason N., 2013. Hybrid seeds, income and inequality among maize smallholder farmers in Zambia. Indaba Agricultural policy research Institution. Working paper 12.

Seo, N. S-O., and Mendelsohn R., 2006, The impact of climate change on livestock management in Africa: a structural Ricardian analysis', CEEPA Discussion Paper # 23, Centre for Environmental Economics and Policy in Africa -CEEPA, University of Pretoria, S.A.

Seo S.N., and Mendelsohn R., 2008. A Ricardian analysis of the impact of climate change on South American Farms. *Journal of agricultural research*. 68 (1), 69-79

Seo, S., and Mendelsohn, R., 2008. Animal Husbandry in Africa. *African Journal of Agricultural and Resource Economics*, 10 (2): 65-82.

Sibanda, M., 2012. Market potential and profitability of improved maize open pollinate varieties in the Eastern Cape. Unpublished Msc thesis. University of Fort hare.

Stern, N. (2006). What is the Economics of Climate Change? *World economics*, 7 (2):1-10.

Thornton, P. Kruska, R. Henninger, N. Kristjanson, P. Reid, R. Atieno, F., Odero, A., & Ndegwa, T., 2002. Mapping Poverty and Livestock in the Developing World. International Livestock Research Institute (ILRI), Nairobi, Kenya

Tingem, M., M. Rivington, and G. Bellocchi. 2009. Adaptation assessments for crop production in response to climate change in Cameroon. *Agronomy for Sustainable Development* 29:247-256.

Thornton, P. K., Jones, P. G., Alagarswamy, A. and Andresen, J. 2009. Spatial variation crop yield responses to climate change in East Africa. *Global Environmental Change* 19, 54-65.

Valtora S.E., 2009. Animal production in a changing climate :*Journal of Animal Science* 23, 65-75.

Vetter S. 2009 .Drought, change and resilience in SouthAfrica's arid and semi-arid rangelands. *SA for J Sci*, 105:29-33.

Walker, N.J., & Schulze, R.E, 2006.An assessment of sustainable maize production under different management and climate scenarios for smallholder agro-ecosystems in KwaZulu-Natal, South Africa.*Phys. Chem. Earth, Parts A/B/C*, 31 (15–16) (2006), pp. 995–1002.

Winkler H., Marquard A., Tyler E., Visser M., 2010. Economics of climate change: context and concept related to mitigation. Unpublished Msc thesis. University of Cape Town

World Bank.(2010). Africa rainfall and temperature evaluation system (ARTES).World Bank, Washington DC.

Zhu M.&Ringler B., (2010). The impact of climate change on smallholder and subsistence agriculture.*Proceedings of the National Academy of Sciences (PNAS)*, **104** (50): 19680-19685.

Zungu P.K. 2013. Department of Agriculture and Rural development (Jozini). Personal communication.

**APPENDIX 1  
QUESTIONNAIRE  
UNIVERSITY OF FORT HARE  
FACULTY OF SCIENCE AND AGRICULTURE**

**DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION**

**TITLE: ECONOMIC IMPACT OF CLIMATE CHANGE ON MAIZE PRODUCTION  
UNDER DIFFERENT FARMING SYSTEMS: A CASE STUDY OF THE SMALLHODER  
FARMERS IN JOZINI**

**NB: The information captured by this instrument will be treated with high level of privacy and confidentiality**

Village.....

Name of Interviewer..... Date of Interview: .....

**SECTION A: DEMOGRAPHIC INFORMATION (FARMER VARIABLES)**

**A1 Name (Optional).....Telephone/Cell phone/.....**

*Please tick the appropriate box*

|                       |       |       |       |     |
|-----------------------|-------|-------|-------|-----|
| <b>A2 Age (Years)</b> | 20-29 | 30-40 | 41-59 | ≥60 |
|                       | 1     | 2     | 3     | 4   |

|                  |        |      |
|------------------|--------|------|
| <b>A3 Gender</b> | Female | Male |
|                  | 1      | 2    |

**A4 Highest level of education**

|                     |                |             |                |   |
|---------------------|----------------|-------------|----------------|---|
| No formal education | Primary School | High School | Tertiary Level | Other( <i>please specify</i> )<br>..... |
| 1                   | 2              | 3           | 4              | 5                                       |

**A5 Age of household head**

|       |       |       |     |
|-------|-------|-------|-----|
| 20-29 | 30-40 | 41-59 | ≥60 |
| 1     | 2     | 3     | 4   |

**SECTION B: SOCIO-ECONOMIC CHARACTERISTICS**

**B1 Occupation**

|                 |          |               |                      |
|-----------------|----------|---------------|----------------------|
| Fulltime farmer | Trader   | Civil servant | <i>Other specify</i> |
| <b>1</b>        | <b>2</b> | <b>3</b>      | <b>4</b>             |

**B2 What is the income of the household head per month?**

|          |             |             |          |
|----------|-------------|-------------|----------|
| < R1500  | R1600-R2500 | R2600-R3500 | >R3500   |
| <b>1</b> | <b>2</b>    | <b>3</b>    | <b>4</b> |

**B3. Source of income**

|          |          |          |             |
|----------|----------|----------|-------------|
| Salary   | Farming  | Pension  | Child grant |
| <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b>    |

**B4What are other sources of off-farm income?**

| Source | Amount (R) | Code     |
|--------|------------|----------|
|        |            | <b>1</b> |
|        |            | <b>2</b> |
|        |            | <b>3</b> |

**B5. Do you have access to credit from the financial institutions?**

|          |          |
|----------|----------|
| Yes      | No       |
| <b>1</b> | <b>2</b> |

**B6 If yes how do you use that money? .....**  
 .....  
 .....

**B7 Do you have access to extension services**

|          |          |
|----------|----------|
| Yes      | No       |
| <b>1</b> | <b>2</b> |

B 7 How many times in a week do you see the extension officer

.....

**C. PRODUCTION CHARACTERISTICS**

C1 How long, in terms of years, have you been involved in farming (years)?.....

.....

.....

C2 What is the size of the land that you are planting in terms of hectares (ha)

.....

.....

C4 How many hectares do you use for planting maize.....

.....

C4 What type of soil do you have in the area?.....

|            |           |             |           |
|------------|-----------|-------------|-----------|
| Sandy Soil | Clay soil | Sandy loamy | Loam soil |
| 1          | 2         | 3           | 4         |

C5 Do you own the land which you use for ploughing/cultivation?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

C6 If (yes), how did you get the land?

|                       |       |        |           |       |
|-----------------------|-------|--------|-----------|-------|
| Traditional Authority | Lease | Bought | Inherited | Other |
| 1                     | 2     | 3      | 4         | 5     |

C7 When did you start planting maize?.....

.....

.....

C8 Do you use irrigation for maize production?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

C 8.1 If (yes) what is the source of irrigation water?

.....

.....

C8.2 Which irrigation scheme do you belong to? .....

.....

C9 Did you apply fertilizer for the maize production in the last season?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

C10 If (yes), how many kilogram's do you apply per hectare?

.....

.....

C11 If you do not buy fertilizer, how do you compensate for it?.....

.....

.....

C12 When do you use fertilizer?

|          |                           |      |
|----------|---------------------------|------|
| Planting | Topdressing/Side-dressing | Both |
| 1        | 2                         | 3    |

C13 How much do you spend on fertilizer per year in the last season?

.....

C14 Did you use any type of pesticides/herbicides for maize?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

C15 If (yes), how much was the cost of pesticides per hectare?

.....

.....

C16 If (No) how do you compensate .....

.....

C17. Did you purchase hybrid maize seed in the last season ?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

C18. If (yes), how much does it cost per kg?

.....

C19. How many kilogram's of seeds do you normally use per hectare of maize?

.....

.....

C20. How much does it cost?

.....

C21 How many bags of maize (in kg's) did you get in the last season?

.....

.....

C22.Has producing maize become profitable to you?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

C23. If (yes), explain in details?

.....

.....

.....

C24. What problems/ Challenges do you have with maize production in the area?

.....

.....

.....

.....

.....

C25 Do you belong to any farmersorganisation?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

C26 If (Yes), which organisations do you belongs to?

.....

.....

C27 How long have you been a member of the organisation?

.....

C28 What benefits do you derive from being a member of the organisation?.....

.....

.....

#### **D. MARKETING INFORMATION**

D1Do you have access to markets?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

D2. What are your main market outlets?

| Hawkers | Local milling | Shops | Local Consumers |
|---------|---------------|-------|-----------------|
| 1       | 2             | 3     | 4               |

D3 How many bags of maize do you sell last season?.....  
 .....  
 .....

D4 How many kilogram's of maize do you consume last season?  
 .....  
 .....

D5 At how much do you sell per bag?  
 .....  
 .....  
 .....

D6 How much does it cost to market your product in terms of transport cost packaging and other expenditure?.....  
 .....  
 .....

D6 (i) How much does it cost in terms of packaging .....  
 .....  
 .....

D7 Who are your main inputs suppliers?

| Local shops | Stores in town | Cooperatives | Friends/ family relatives |
|-------------|----------------|--------------|---------------------------|
| 1           | 2              | 3            | 4                         |

D8. How much does it cost to reach the inputs market?  
 .....  
 .....  
 .....

D9. What problems do you have about inputs supplier?  
 .....  
 .....  
 .....

D10 Do you own any large farming equipment?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

D11. If (yes), which one?

|             |         |            |       |
|-------------|---------|------------|-------|
| Wheelbarrow | Tractor | Implements | Other |
| 1           | 2       | 3          | 4     |

D12. Do you hire any farming equipment?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

D13 If (yes), at what price do you hire them out?

.....  
 .....

**E.AWARENESS ABOUT CLIMATE CHANGE**

E1 Do you know what climate change is?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

E2 If yes how do you describe such climate change indicators?.....

.....  
 .....

E3 Do you receive any information about climate change?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

E4 If yes from where?

|                    |       |               |               |
|--------------------|-------|---------------|---------------|
| Extension officers | Media | Local farmers | Organizations |
| 1                  | 2     | 3             | 4             |

E5 Do you see any impact from the climate change on your agricultural production?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

E4 If (Yes) how does climate change impacts maize production? Explain

.....  
 .....

E5 Is you're sowing date changing due to change in the start of rain?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

E6 Is the amount of precipitation sufficient for full cropping during short rainfall?

|     |    |
|-----|----|
| Yes | No |
| 1   | 2  |

E7 What local adaptation strategies are you adopting to minimize the impact of climate change?

.....  
.....  
E8 What is the perceived constraints in adapting to climate change?

|   |                                     |  |
|---|-------------------------------------|--|
| 1 | Lack of information                 |  |
| 2 | Lack of money                       |  |
| 3 | Shortage of labor                   |  |
| 4 | Shortage of land                    |  |
| 5 | Poor potential for irrigation       |  |
| 6 | There is no hindrance to adaptation |  |

**THANK YOU FOR YOUR CO-OPERATION!!!!!!!!!!!!**

**SIYABONGA KAKHULU NGESIKHATHI SAKHO**

**APPENDIX 2: RAINFALL IN JOZINI FOR THE PREVIOUS 20 YEARS**

| <b>Year</b>           | <b>Summer (Nov-March)</b> | <b>Autumn (April-May)</b> | <b>Winter (June August )</b> | <b>Spring (Sept-Oct)</b> |
|-----------------------|---------------------------|---------------------------|------------------------------|--------------------------|
| 1993                  | 82.1                      | 9                         | 9.1                          | 70.6                     |
| 1994                  | 36.7                      | 6.6                       | 5                            | 11.5                     |
| 1995                  | 71.2                      | 3                         | 2.7                          | 27.5                     |
| 1996                  | 104.5                     | 27                        | 9.5                          | 50.9                     |
| 1997                  | 121.1                     | 63.4                      | 31.2                         | 70.5                     |
| 1998                  | 100.4                     | 45.7                      | 4                            | 44.5                     |
| 1999                  | 53.0                      | 21.2                      | 10.7                         | 0                        |
| 2000                  | 73.9                      | 28.2                      | 1.7                          | 49                       |
| 2001                  | 37.4                      | 50.9                      | 2.5                          | 38.5                     |
| 2002                  | 48.8                      | 6.8                       | 3                            | 10.7                     |
| 2003                  | 30.2                      | 3.6                       | 12.1                         | 9.7                      |
| 2004                  | 34.2                      | 12.8                      | 14.2                         | 20.7                     |
| 2005                  | 47.3                      | 4.2                       | 17.8                         | 4.1                      |
| 2006                  | 63                        | 1.8                       | 19.5                         | 39.7                     |
| 2007                  | 69.6                      | 20.6                      | 25.6                         | 89.6                     |
| 2008                  | 52.3                      | 35                        | 8                            | 14.6                     |
| 2009                  | 66.9                      | 28                        | 3.5                          | 0                        |
| 2010                  | 62.1                      | 27                        | 3.1                          | 0                        |
| 2011                  | 33.1                      | 20.6                      | 15.3                         | 42.8                     |
| 2012                  | 35.7                      | 3                         | 1.73                         | 121                      |
| 2013                  | 124.2                     | 48                        | 3                            | 15.3                     |
| <b>Average</b>        | <b>67.4</b>               | <b>20.8</b>               | <b>10.1</b>                  | <b>36.7</b>              |
| <b>Season squared</b> | <b>4542.8</b>             | <b>432.6</b>              | <b>102</b>                   | <b>1346.9</b>            |

Source : South African Weather Service (2013)

**APPENDIX 3: TEMPERATURE FOR THE PREVIOUS 20 YEARS IN JOZINI**

| <b>Year</b>           | <b>Summer (Nov-March)</b> | <b>Autumn (April-May)</b> | <b>Winter (June-August)</b> | <b>Spring(Oct-Spring)</b> |
|-----------------------|---------------------------|---------------------------|-----------------------------|---------------------------|
| 1993                  | 24.7                      | 21.3                      | 17.6                        | 21.8                      |
| 1994                  | 24.2                      | 20.3                      | 17.1                        | 20.4                      |
| 1995                  | 24.1                      | 19.9                      | 17.6                        | 22.5                      |
| 1996                  | 23.9                      | 19.9                      | 16.3                        | 21.9                      |
| 1997                  | 23.9                      | 19.7                      | 15.6                        | 20.6                      |
| 1998                  | 24.3                      | 18.9                      | 17.6                        | 21.0                      |
| 1999                  | 25.1                      | 21.2                      | 18.1                        | 20.6                      |
| 2000                  | 24.7                      | 21.2                      | 18.1                        | 21.8                      |
| 2001                  | 24.7                      | 20.5                      | 17.8                        | 21.1                      |
| 2002                  | 24.8                      | 22.1                      | 17.3                        | 20.9                      |
| 2003                  | 24.0                      | 20.9                      | 16.6                        | 21.2                      |
| 2004                  | 24.4                      | 20.7                      | 16.5                        | 19.7                      |
| 2005                  | 23.9                      | 19.7                      | 18.0                        | 21.7                      |
| 2006                  | 24.2                      | 20.4                      | 17                          | 20.9                      |
| 2007                  | 24.1                      | 19.3                      | 16.7                        | 20.9                      |
| 2008                  | 24.7                      | 19.9                      | 18.7                        | 21.4                      |
| 2009                  | 24.1                      | 20.6                      | 17.6                        | 21.7                      |
| 2010                  | 23.6                      | 21.5                      | 17.4                        | 21.5                      |
| 2011                  | 24.4                      | 20.2                      | 16.7                        | 21.9                      |
| 2012                  | 24.7                      | 21.1                      | 18.2                        | 20.9                      |
| 2013                  | 25.2                      | 20.1                      | 17.6                        | 20.5                      |
| <b>Average</b>        | <b>26.7</b>               | <b>20.5</b>               | <b>19.0</b>                 | <b>23.4</b>               |
| <b>Season Squared</b> | <b>712.9</b>              | <b>420.1</b>              | <b>361</b>                  | <b>547.6</b>              |

Source: South African Weather Services (2013)

#### **APPENDIX FOUR: LIST OF PRICES USED IN COMPUTATION OF GROSS MARGIN**

Selling price of a cob = R30 per dozen (12 cobs)

Selling price of a 50kg bag = R200

The average price for hiring a tractor per hectare= R700

The seed costs different varieties as obtained on the purchasing slip

PAN 701 =R300/ 25 kg

The price of fertiliser taken from a receipt

LAN 28%= R200 per 50kg

Compound 2:3:4= R300 per 50kg

Chemicals prices taken from a receipt

Herbicide pre-emergence : Roundup = R112 per litre

Post emergence :Basagram= R65.19 per litre

#### **Insecticides (Price taken from the receipt)**

Cutworm (dusban)=R78.80 per liter

Maize stalk borer (dusban)=R78.80 per liter

Gramaxone =R47.25 per liter

Fastac =R189.00 per liter

Contract work –Planting, herbicides and insecticide application, irrigation, weeding, harvesting, shading and bird fearing each R50 per worker per day for 8 labor days per hectare.

**APPENDIX FIVE: GROSS MARGIN BUDGET TEMPLATE FOR COMPUTATION OF GROSS MARGIN**

**Annual Cash Crop Income and Costs Budget**

|   |       |          |                |                   |
|---|-------|----------|----------------|-------------------|
| Enterprise name   |       |          |                |                   |
| Quality expected to be harvested                                  |       |          |                |                   |
| Ecotope/Soils   |       |          |                |                   |
|   | Unit  | Quantity | Price per unit | Amount R per unit |
| Sale of maize in dozens or 50kg bags                              |       |          |                |                   |
| Maize stored for livestock  |       |          |                |                   |
| Maize consumed  |       |          |                |                   |
|   |       |          |                |                   |
| <b>GROSS INCOME</b>   |       |          |                |                   |
| Variable costs  | Unit  | Quantity | Price R/unit   | Amount R/unit     |
| Pre harvest   |       |          |                |                   |
| Seeds   |       |          |                |                   |
| PAN 701   | kg    |          |                |                   |
|   |       |          |                |                   |
|   |       |          |                |                   |
| Fertiliser LAN 28% Compound 2:3:4                                 |       |          |                |                   |
| <b>Chemicals</b>  | kg    |          |                |                   |
| Chemicals: Herbicides-  | kg    |          |                |                   |
| Insecticides-Dusban<br>Stalk borer –Dusban<br>Gramaxone<br>Fastac | litre |          |                |                   |
| <b>Contract work</b>  |       |          |                |                   |
| Planting  | 2     |          |                |                   |
| Herbicide application   | 2     |          |                |                   |
| Irrigation  | 2     |          |                |                   |
| Fertiliser application  | 2     |          |                |                   |
| Removing suckers  | 2     |          |                |                   |
| Harvesting  | 2     |          |                |                   |
| Transport fertiliser from Pongola to the farm                     |       |          |                |                   |
| <b>Total variable costs</b>                                       | R     |          |                |                   |
| <b>Crop Gross Margin</b>  | R     |          |                |                   |

