Vulnerability and adaptation to climate variability: A case study of emerging farmers in the eastern Free State, South Africa

By

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ABSTRACT

A research study on vulnerability and adaptation to climate variability was conducted among emerging farmers in Tshiame Ward of Maluti-A-Phofung Municipality in the Free State Province of South Africa. The research aim was to assess the vulnerability of agricultural systems to climate variability and to identify the adaptation measures that emerging farmers use to cope with the problem. Primary data was collected by means of a semi-structured questionnaire to 19 farmers in the Ward. The data were captured and analysed using SPSS, to obtain the frequency tables. Microsoft Excel 2007 was used for statistical analysis and to plot the regression graphs while the Instat Software was used in the analysis of climate data to determine the dry spells, onset and offset of dates and the calculation of the Crop Performance Indices.

The analysis revealed that farmers regard climate variability as a phenomenon taking place in Tshiame Ward. When farmers were asked about the cause of climate variability, some were unsure about their own answers though many of them were able to relate their answers to what is happening in their immediate environment. In order to cope with the impact of climate variability, farmers in Tshiame Ward have adopted a number of practices such as the use of drought and heat tolerant seeds and mixed cropping systems. These practices are based on the already existing knowledge as well as the perceived changes in climatic conditions. The statistical analysis of climate data revealed that some of the views held by some farmers' regarding climate variability are in contrast with the results shown by the analysis.

The study concludes that the farmers who were able to perceive the change that is taking place in their environment were better able to implement effective adaptation measures and were consequently better-able to sustain their agricultural operations. The fact that farmers were aware or familiar with climate variability, as well as its associated impact can be related to the ongoing project that is being undertaken by Agricultural Research Council, where weather stations have been installed on farms in order to develop the capacity to monitor climate variability in the area.

Keywords: Climate variability, adaptation options, Crop Performance Index, Temperature, Rainfall, Emerging farmers, Agriculture, Tshiame Ward

OPSOMING

'N Navorsingstudie oor kwesbaarheid en aanpassing by klimaatsverandering veranderlikheid is gedoen onder opkomende boere in Tshiame Wyk van Maluti-a-Phofung-munisipaliteit in die Vrystaat Provinsie van Suid-Afrika. Die navorsing doel was om die kwesbaarheid van landboustelsels klimaat variasie te bepaal en om die aanpassing maatreëls wat opkomende boere gebruik om te gaan met die probleem te identifiseer. Primêre data is ingesamel deur middel van 'n semi gestruktureerde vraelys tot 19 boere in die wyk. Die data is gevange geneem en ontleed met behulp van SPSS, die frekwensietabelle te verkry. Microsoft Excel 2007 gebruik is vir statistiese analise en om die regressie grafieke te plot terwyl die INSTAT sagteware in die ontleding van die klimaat data is gebruik om die droë tye, begin bepaal en geneutraliseer van datums en die berekening van die gewas Performance indekse.

Die ontleding het getoon dat boere beskou klimaat variasie as 'n verskynsel wat plaasvind in Tshiame Wyk. Wanneer boere is gevra oor die oorsaak van die klimaat variasie, sommige was onseker oor hul eie antwoorde alhoewel daar baie van hulle in staat was om hul antwoorde betrekking het op wat gebeur in hul onmiddellike omgewing. Ten einde te gaan met die impak van klimaat variasie, het boere in Tshiame Wyk 'n aantal praktyke aangeneem soos die gebruik van droogte en hitte verdraagsaam sade en gemengde verbouing stelsels. Hierdie praktyke is gebaseer op die reeds bestaande kennis sowel as die vermeende veranderinge in klimaatstoestande. Die statistiese ontleding van klimaat data aan die lig gebring dat sommige van die standpunte wat deur sommige boere se met betrekking tot klimaat variasie is in teenstelling met die vertoon van die resultate van die analise.

Die studie tot die gevolgtrekking dat die boere wat in staat is om die verandering wat plaasvind in hul omgewing sien was, was beter in staat om effektiewe aanpassing maatreëls te implementeer en was gevolglik beter in staat is om hul landbou-bedrywighede in stand te hou. Die feit dat boere bewus of vertroud is met die klimaat variasie, sowel as die gepaardgaande impak kan verband hou met die deurlopende projek wat tans deur Landbounavorsingsraad, waar weerstasies het op plase geïnstalleer word ten einde die kapasiteit om te monitor ontwikkel onderneem was klimaat variasie in die gebied.

Sleutelwoorde: Climate variasie, Aanpassing opsies, Gewas Performance Index, Temperatuur, Reënval, Opkomende boere, Landbou, Tshiame Wyk

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LIST OF ABBREVIATIONS

MAP- Maluti-A-Phofung

ARC- Agricultural Research Council

CPI-Crop Performance Indices

Tmax-Maximum Temperature

Tmin-Minimum Temperature

Rmax-Maximum Rainfall

Rmin-Minimum Rainfall

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DECLARATION

I **Thabo Elias Matela** declare that ‘‘Vulnerability and adaptation to climate variability: A case study of emerging farmers in the eastern Free State Province of South Africa” is my own research work and has not been presented for any other degree and that all the sources that I have used have been indicated and acknowledged by means of complete references.

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CHAPTER 1:

Introduction, Aim and Rationale of the study

1. Introduction

All over the world, the impact of changing atmospheric conditions is becoming a reality. For some, climate change is just a matter of changes in environmental conditions with temperatures increasing slightly or becoming low or in general, more uncertain (Kriegier *et al*., 2012). In some regions of the world, crop production has been affected by unavailability of water, leading to drought stress, while in other places water levels are becoming excessive and causing floods. However, it is important to note that the negative impacts of climate change will not affect countries and communities equally. In Africa, victims of climate variability tend to be the poorest, who lack effective coping strategies to deal with climate induced shocks and who have had to resort to ineffective responses (Muller *et al*., 2011). This is particularly true for developing countries like South Africa, where poor households and socially marginalised groups cannot meet basic human needs (Smith and Wandel, 2006). When people are not capable of meeting their basic needs such as food, it is unlikely for them to think beyond their immediate needs, much less to implement the long term adaptation options to cope with the effects of climate change.

1.1The problem statement

In developing countries, climate change has a significant impact on the livelihoods of the rural poor. Future agricultural production is expected to decline due to changing atmospheric conditions (IPCC, 2007). According to Boko *et al*., (2007) by 2020, African countries will be characterized by high poverty levels associated with the reduced crop yields which will have fallen by as much as 50 %. Rockstrom (2009) argues that factors such as limited skills, lack of equipment for disaster management, limited financial assistance and heavy dependence on rain-fed agriculture will increase the vulnerability of farmers to climate change. In South Africa specifically, the already declining food security is expected to be worsened by an increasing population growth and limited agricultural yields due to the severe droughts that are currently affecting the country and thus increasing the vulnerability of the rural people (Funk *et al*., 2008), a situation that is expected to worsen with time. Agriculture will be forced to compete for land

and water with sprawling urban settlements. While striving to meet the essential basic human needs such as food under a changing climate, planners of agricultural sectors need to consider the issue of biodiversity protection, natural habitat preservation and at the same time the implementation of adaptation measures to overcome the stress imposed by climate change **(**Hansan and Nhemachena, 2008).

According to Moore *et al*., (2009) climate change will not affect food production in South Africa alone but on the African continent as a whole since maize crop, that forms part of more than half of the regions' diet, is mainly produced in the southern part of the continent**.** Also, some climate science studies seem to be lacking when it comes to the projection of uncertainty of climate variability and its associated effects, as well as mitigation measures that can be used to reduce its negative impacts (Wilby *et al*., 2009). Although it is not guaranteed that the Earth will continue to support life under the changing atmospheric conditions, what is obvious is that climate variability is putting more strain on both the physical and biological systems (Ronsenzweig *et al*., 2009). There is therefore a need for more detailed information on the estimated impacts of climate variability on agricultural systems, particularly for developing countries (Moore *et al*., 2009). According to Adger *et al*., (2006) and (IPCC,2007), the analysis of changing climate conditions should not be made only on its associated impacts but also in relation to effective adaptation measures that need to be taken at local and national levels.

1.2 The significance of the study

In Africa, the vulnerability of agriculture to climate variability has become an important issue because of reduced crop productivity from adverse environmental changes. In spite of the effort that has been made on the projection of impacts of climate variability on agronomic and economic sectors, it is clear that the information about the extent of the impact and mitigation options available for the continent are still limited (Wilby *et al*., 2009). However, the change in climate conditions will affect almost all the southern African economies, particularly those that depend on rain-fed agriculture, which is estimated to decrease by as much as 50% by 2050 and in turn causing a decline in both economic growth and food security (Unganai, 1994). Tadross *et al*., (2005), stated that in southern Africa, future agricultural production is expected to decline due to climate variability that is affecting the resource poor farmers, whose livelihoods depend solely on agriculture. Therefore, in developing countries increased agricultural production will be attained if the social assistance or any form of successful adaptation is directed to rural areas where farmers have experienced extreme weather conditions and where farmers lack capacity to develop effective mitigation plans (Reason *et .al*., 2005). In South Africa, food insecurity and malnutrition are expected to worsen in provinces with large rural populations such as Kwa-Zulu Natal, Limpopo, Eastern Cape and Free State (Department of Agriculture, 2007). Although there has been much recent public discussion on the effects of climate variability on developing countries, there has been little debate engaging smaller holder and subsistence farmers on how to survive under the changing climatic conditions (Jones and Thornton, 2003).

Regardless of the efforts made to control the impact of climate variability on farming, not many studies have been done in African countries, to investigate the social and economic hazards that will be brought by the changing weather conditions. Studies done in South Africa have focused on the assessment of the impact of climate variability on agricultural production using only grain crop such as maize, where the behaviour of the crop was monitored under controlled laboratory experiments (Du toit *et al.,* 2002). Again, the use of Regional Climate Models (RCM) to present the change in rainfall, temperature and precipitation patterns, extrapolated from the Global Climate Models (GCMs) show that by 2050 rain fed yields could be reduced by 50% and thus increasing the vulnerability of farmers in developing countries (IPCC, 2007). In most cases, this important information is not conveyed to subsistence farmers, particularly those challenged by poverty and lack of access to technology. It has been reported that in South Africa, physical risks that are induced by climate variability include those related to food production, water and health, all of which can be best managed if mitigation measures are employed even before the environmental disasters take place (CSAG, 2008). The African region, including the central parts of South Africa are still expected to experience extreme weather events such as increased temperatures that will give rise to droughts and desertification, worsening the already declining food production (CSAG,2008). Under these circumstances, agricultural production can be stimulated and enhanced if farmers effectively adopt appropriate strategies (Hendricks and Lyne, 2009). The identification and development of the adaptation strategies that are region specific is one of the most significant tools in improving agricultural productivity, food security, as well as livelihoods in South Africa.

1.3 Research aim

The aim of this investigation is to assess the vulnerability of agricultural systems to climate variability and to identify the adaptation options that emerging farmers use to cope with the problem in the eastern Free State Province of South Africa.

1.4 Research objectives

The study addresses the following objectives:

- To determine the impact of change in meteorological variables on crop production in Tshiame Ward, in the eastern Free State Province of South Africa
- To investigate farmers' perception about the cause and the impact of climate variability
- To investigate farmers' adaptation strategies to climate variability
- To analyze the socio-economic conditions of farmers and determine their influence on the vulnerability of agricultural production to climate variability

1.5 The scope of the study

The study was conducted in Tshiame Ward. It focused on the emerging crop farmers including both small-scale and semi-commercial.

1.6 The limitation of the study

The study was confined to Tshiame Ward, which is located in Maloti-A-Phofung Municipality of the Thabo Mofutsanyane District. Data on crop yields was not available during the course of the study, so it was not possible to check how the yields varied over the thirty year period covered in this study. Therefore, the analysis was based on the Crop Performance Indices (CPIs).

1.7 The research project is structured to cover:

Chapter 1 Provides the problem statement of the research study, the aim of the study, as well as the objectives and framework of the study. This chapter also outlines the scope and limitations of the study.

Chapter 2 Contains the literature review and discusses the theoretical frameworks that have been considered for this study

Chapter 3 Provides a description of the study area and research methodology

Chapter 4 Presents the results of the study, with primary forms of climate data

Chapter 5 Presents the results of the socio-economic data that was collected in the study

Chapter 6 Present the discussion of the results of the study

Chapter 7 Presents the conclusions and recommendations of the study

CHAPTER 2:

Literature Review and Theoretical Framework

2.1 Introduction

Literature was reviewed to assess the factors that promote the vulnerability of crop production to climate variability as well as the factors that limit mitigation measures at the farm level. Apart from the theoretical frame work of the study, this chapter discusses the existing literature on the interrelationships between climate variability, agriculture and adaptation options.

2.1.1 The relationship between climate variability and farmer vulnerability

There is a huge body of knowledge that supports the notion that the Earth has warmed since the late nineteenth century and early twenty-first century (Hansen *et al.*, 2010). As a result of the changing atmospheric conditions, extreme weather events have been documented throughout the world (IPCC, 2012). The changes of temperatures, rainfall patterns and precipitation levels, as well as rising sea levels are among the consequences that will be experienced (Endreina *et al.*, 2011). The on-going changes that are currently being detected in the environment are those that are mainly associated with human activities, especially the emission of Green-house Gases (GHGs) into the atmosphere at a relatively high rate (Lambin and Meyfroidt, 2011). These gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) which are all contributing to the warming of the atmosphere. Such undesirable changes in environmental conditions, will require humanity to develop resilient measures in order to minimise the climate hazards, while vulnerable species are likely to become extinct due to unexpected changes in their habitable zones (Parry *et al.*, 2008). However, climate variability impacts should not be considered only as a human threat but also as an opportunity for scientists to determine the possibility of human survival in the coming decades (UNDP, 2007).

There is no doubt that when communities fail to develop or to implement effective measures, they will remain vulnerable to climate variability disasters. Climate variability can be defined as the way the climate fluctuates yearly above or below a long term average value (Climate literacy, 2009). Being vulnerable means that one is susceptible to any undesirable change that is taking place or is about to happen. The concept ‘’Vulnerability’’ is used or applied in different studies for different purposes. For example, Karl *et al* (2009), defined “vulnerability” as a concept that emphasizes the need to address the changing nature of risk and variable capacity to cope with both risk and change. On the other hand, O’ Brien and Leichenko (2008) argue that vulnerability is more influential in both social and environmental studies used in early warning systems to determine the specific factors that explain how and why some groups and individuals experience negative out-comes from shocks and stressors. The concept of “vulnerability” has also been used by various sectors as a risk determining factor to estimate the extent of susceptibility to climate variability impacts, as well as in the field of disaster management when planning for risk reduction (Smithers and Smith, 2009).

Vulnerability studies are highly valued because of their importance to human wellbeing and security in this era of climate variability. In South Africa, the concept of vulnerability is applied in climate science studies as a driving tool for developmental planning, particularly in poverty stricken communities (Adger *et al*., 2009). In another study, Challinor *et al* (2009), concludes that in an agricultural context, vulnerability can be associated with those communities or populations whose essential needs, including food and water, are being threatened by environmental changes. This notion emphasizes that continuous changes that are observed in the environment by farmers are not occurring in separate forms, but rather connected to other stressors, including those linked to economic globalization (O’ Brien and Leichenko 2008). According to Wixon and Balser (2009) vulnerability depends not only on the system’s susceptibility to undesirable change but also on its ability to acclimatize to moderate environmental changes.

2.1.2 The impact of climate variability on agriculture

The African continent is going to be affected by the changing atmospheric conditions that are impacting on subsistence farming systems characterized by poor soils and lack of irrigation systems (Schlenker and Lobel, 2010). According to a report by FAO (2007), about 11 % of arable land in Africa, is expected to be lost in rural areas as a result of changing climate conditions, which in turn will give rise to food insecurity and promote malnutrition. Change in timing, frequency and intensity of rainfall events will increase the vulnerability of agricultural production to climate variability (Aliber and Hart, 2009). These envisaged changes raise concerns that climate variability will have significant adverse impacts on crop production. This is true for a country like South Africa and most of the African countries, where agricultural production is mainly rain-fed (Barrios *et al*., 2008). Global Climate Models (GCM) projections show that in South Africa rainfall will be reduced by 5-10%, while temperatures will increase by between 1º C to 3 º C, affecting the available crop water in the country caused by greater imbalance of evapotranspiration and rainfall (Kiker,2000). Similarly, Easterling (2007) argues that agriculture is climate sensitive and therefore a temperature increase of about 1º C will cause a shift in the rainfall patterns which will increase the vulnerability of crops to drought stress or flooding in some regions.

The environmental factors that are continuously changing as a result of climate vulnerability will contribute to an increase in dependence on global grain markets and threaten food security, especially in rural areas where people are challenged by increasing food prices (Pingali, 2012). According to Nelson *et al* (2009) climate variability is going to directly affect subsistence agriculture and accelerate the already increasing food insecurity**.** Subsistence agriculture is going to be affected mostly due to its reliance on traditional farming techniques that are no longer effective enough to sustain crop development (Muller *et al.,* 2011). The undesirable change in environmental conditions is also expected to bring a change in the timing of cropping seasons and in turn affecting food production, particularly where farmers are unable to purchase additional resources such as disaster management equipment and heat tolerant seeds (Knox *et al.*, 2010). Lin and Huybers (2012) state that basic agricultural resources such as available soil water, which are already in short supply, is expected to be reduced due to global warming and thus affecting the normal growth and development of dry land subsistence crops. In addition, Nelson *et al* (2009) reported that the drastic change in environmental variables such as temperature, rainfall and precipitation will transform systems of food production, especially those related to patterns of crop production in the developing world.

2.1.3 The impacts of climate variability on the food markets

According to Igram (2011), food security, as well as its existing interrelations, including access to food, as well as its availability, utilization and stability will all be severely affected by changing climatic conditions. In addition, the global human population that is expected to increase from 6 billion to 9 billion by 2050 (Lutz and Simmer, 2010), is among the factors that will result in reduced food availability in the next coming decades. Agricultural sectors will be forced to produce more food at a relatively high cost to meet the rising demand for human basic needs. At the same time, food producing institutions need not only to process more food, but also to maintain quality in food production since human nutrition is linked with health. Because of these challenges, the production of food becomes difficult, requiring more specialized goods and resources to maintain quality standards in food production (Godfray *et al.,* 2010). In order to achieve this goal, the market prices for food will rise, affecting the poor rural societies which are already stressed by poverty. In South Africa, for example, recent studies have shown that rural communities possess the farming skills that allow them to produce food in their own fields while urban communities depend on the market food for survival (Baiphethi and Jacobs, 2009). However, there has been a documented shift by rural inhabitants, who are now increasingly becoming more dependent on market products for survival (Frayne *et al.,* 2009). As a result, rural populations will be severely affected by the market prices of food since they are expected to spend the greater percentage of their total income on food (Hertel and Rosch, 2010).The increase of prices, particularly of nutrient-rich products will also lead to reduced diet diversity and continuous micro-nutrient malnutrition for many poor people (Pingali, 2012). Presently, in developing countries many people are still under or malnourished. The fact that these countries cannot produce enough food to feed all people means that there will not be enough food by 2050 (Godfray *et al.,* 2010).

Although food insecurity in rural areas can be associated with various other challenges, the main cause appears to be climate change. According to a report by Aliber and Hart (2009) in 1998 there were about 2.1 million subsistence and emerging farmers who were contributing less than 13% to the net crop production in South Africa. This percentage is expected to decline due to the large number of farmers who will be forced to leave their agricultural fields as a result of undesirable weather conditions (Aliber and Hart, 2009). However, although the human population is expected to increase, determining the success of farmers in producing sufficient food required for human survival is a complex matter (Döös, 2002). This brings further concerns that if the rising demand for food is met through current technologies and cropping practices, it is possible that some ecosystem components including air, soil and water quality will deteriorate because of the pressure resulting from human needs (Barrios *et al*., 2008). A practical example is that, using fertilizers can help to improve soil quality in order to grow more food, but the increased use of fertilizers by farmers would lead to higher greenhouse gas emissions into the atmosphere, which in turn contributes towards climate variability (Wilby *et al*., 2009). The fact that human beings participate in food production systems means that their personal expectations such as supporting their livelihoods, profit maximization and environmental maintenance will all be affected by climate variability (Vermeulen *et al*., 2012). However, although much research on the impact of climate variability on agriculture and forestry, water resources, air quality and human health has been documented in sub-Saharan Africa, only a little attention has been given to food security (Tol, 2010).

2.1.4 Farmers' perception on climate variability

In developing countries, farmer's perceptions on climate variability require evaluation since it is believed that farmers' attitudes and reactions towards the changing climate determine their success in attaining increased food production and willingness to take part in farm initiated adaptation projects (Akter and Bennet, 2011). However, farmers' perceptions about climate variability can be influenced by several factors, including their educational background, financial status, as well as previous environmental scenarios experienced by an individual (Mertz *et al*., 2009). According to Derressa *et al* (2011), in the developing world, young farmers perceive climate variability best when compared to older farmers and this is associated with the on-going current debates on climate variability, including the Kyoto Protocol and the IPCC reports made in the media (IPCC, 2007). In another study, Poortinga *et al* (2011) found that farmers who have received formal education are more likely to believe that climate variability is taking place due to the fact that in many countries, environmental studies are now being widely incorporated into the curriculum at schools and higher learning institutions. According to a report by London Central Office Information (2008), the majority of farmers in rural areas do not believe in changing atmospheric conditions. Instead they show more trust in their traditional knowledge compared to the current scientific findings on climate variability. Again, in a maize and soybean survey conducted by Gramming *et al* (2013), about 35% of the farmers who were included in the survey thought that climate variability is an ‘‘issue to scare people” while 46% supported the idea that ‘‘human actions” are the main cause of the current weather patterns.

Although it is argued that education serves as a powerful tool to improve the understanding of climate variability, Derresa *et al* (2011) argues that the perception about climate variability is driven by personal belief and the understanding of the risk that is brought by the changing weather. Furthermore, Scruggs and Benegal (2012) state that farmers’ reaction to climate issues is determined by their surrounding economic conditions. This is true for developing countries where McCarl (2010) found that subsistence farmers who live under economic recession tend to show a more positive response and acceptance of climate variability. In addition, Pryce *et al* (2011) noted that climate variability acceptability among rural farmers is driven by the fact that resource-poor farmers are the ones who are severely challenged by climate variability since they fail to shift to alternative farming systems when affected by climate variability, for example, by not affording seeds that tolerate heat or drought stress. In another study, Whitmarsh (2008) contended that climate variability and its associated risks are perceived best when individuals are able to imagine or experience the danger associated with the changing weather. The theory of personal experience is also supported by Jareman *et al* (2010) who argue that farmers who have experienced drought stress caused by global warming are more aware of changing weather patterns. In developing countries, farmers who perceive climate variability best are the ones who have experienced decreased food production associated with water stress, soil degradation and floods (Ziervogel and Erickson, 2010). However, Webber (2010) maintains that farmers’ action or inaction towards the changing weather is determined by personal experience since observation is time restricted and the memory of the past scenarios can be faulty when it comes to present experiences. Gavin and Marshall (2011) reported that the media plays a role in shaping farmers’ perceptions about climate variability. It is believed that farmers who have access to resources such as radio, television, as well as newspapers perceive climate variability better when compared to those who are unable to access such media. In addition, Bryan *et al* (2009) contend that although farmers from semi-arid regions in some parts of South Africa perceive a decrease in rainfall and increase in temperature, most of them have not taken any action to restrict the impacts that are brought by the changing environmental conditions on their agricultural production.

2.1.5 Factors that promote farmers' vulnerability to climate variability

Regardless of the efforts made to control the impact of climate variability on farming, not many studies have been done in African countries, to investigate the social and economic hazards that will be brought by the changing weather conditions. Studies done in South Africa have focused on the assessment of the impact of climate variability on agricultural production using only grain crop such as maize, where the behavior of the crop was investigated using crop modeling tools (Du toit *et al.,* 2002). In most cases, such methods tended to exclude of subsistence farming operations, particularly those farmers challenged by poverty and lack of access to technology. However, in order for farmers to reduce their levels of exposure to climate variability, they need to understand that their level of susceptibility is going to differ. For example, in South Africa, the onset or the offset of rainfall tends to be early or late and not following the usual patterns that farmers are used to, thus affecting agricultural production. In addition, areas with soils of high water holding capacity will be less affected by drought and food shortage compared to soils with low water holding capacity (Denton, 2000). It is also reported that subsistence farmers are more vulnerable to climate variability when compared to commercial farmers who have access to skilled labour, financial resources and relevant information about climate change impacts, as well as better adaptation options (Blackden and Wodon, 2006). Access to relevant information about climate variability can assist farmers in decision making regarding how to improve their management systems at the farm level. However, it is important to note that response actions and adaptation options depend not only on access to information but also on the capacity of farmers to convert the theoretical findings into functional knowledge (Karl *et al*., 2009). For example, when farming communities in Namibia and Tanzania were provided with seasonal forecasts, they were unable to make use of the supplied information due to lack of skills, equipments and draft power (O' Brien *et al.,* 2000). Eakin (2005) has shown that agricultural production can also be threatened by several other factors, including access to financial assistance, existing environmental legislation and technological developments.

Although there has been much recent public discussion on the effects of climate variability on developing countries, there has been little debate engaging the development of smaller holder and subsistence systems under the changing weather conditions. For example, findings made by Jones and Thornton (2003) show that maize production in smallholder rain fed systems in Africa and Latin American are likely to decrease by approximately 50% by 2050 and thus increase the vulnerability of famers in some regions. However, from this estimation, one can conclude that the results hide the level of the impact per region and give just the cause of concern, especially for some areas of subsistence agriculture. The Regional Climate Models (RCMs) that are used to present the change in temperature and precipitation patterns, extrapolated from the Global Climate Models (GCMs), show highly variable rainfall and temperature indices which have the potential to reduce food production and thus increasing the vulnerability of some farmers in developing countries (IPCC, 2007). It is also important to have the impact of climate variability on agricultural systems. For example, a farmer deciding on which crops to plant the following year needs to know the likelihood of drought that year rather than the likelihood of drought in a fifty year period. Farmers are therefore now more concerned about their immediate circumstances than in the past. It may be more useful for local environmental managers to identify specific, sensitive indicators of climate variability through which impacts can be observed at the local level and within a short space of time in order to minimize the impacts.

2.1.6 Factors influencing farmers' adaptation to climate variability

Perceptions about climate variability and adaptation differ among individual farmers and will also depend on personal experience. According to Derresa *et al* (2011), farmers are able to adapt to climate variability only if they are able to perceive the changes that are taking place in related environmental conditions. In addition, Sperenza (2010) noted that the determinants of action or inaction measures that are taken by farmers to gain control over climate variability are influenced by the awareness or perceptions held about the problem. The farmers' success in attaining increased food production and enhanced income to sustain their livelihoods at the farm level is determined by effective adaptation measures that are taken by farmers before and after any environmental disaster (Hansan and Nhemachena, 2008). McCarl (2010) reported that appropriate adaptation and mitigation measures in agriculture depend on the preparedness and willingness of farmers to take actions that lessen the negative impacts of climate variability. For example, farmers can prefer to use alternative measures such as the use of heat tolerant seeds or shift to multiple crop farming systems. In Africa, soil conservation, tree planting, early and late planting techniques are among the most common alternative measures that are taken by farmers (Derresa, 2008).

Smithers and Smit (2009) note that the ability of farmers to interpret the predicted results based on future global environmental changes obtained from various weather stations is among the key elements influencing the adoption of adaptation strategies. As noted by Morton (2011), farmers will only develop the interest of taking active measures towards the changing climatic conditions if they understand the negative feedback and dangers of the changing atmospheric conditions towards their livelihoods. In addition, Webber (2010) supports the view that it is not only the perception about whether climate variability is or has occurred that has an effect on effective measures adopted by farmers, but other factors as well, including resource endowments, environmental legislation as well as the indigenous knowledge that can play a significant role in decision making processes about adapting to climate variability. Farmers' perceptions about climate variability depend on the availability of the information about climate science, specifically the one addressing the need for adaptation options rather than the impacts only (McCarl, 2010). In another report, Gbetibuouo (2009) concludes that information about climate and weather received from extension services allows farmers to adapt best towards the changing atmospheric conditions.

2.1.7 Climate variability adaptation policies

It has been documented that in order for societies to effectively take control over climate variability and change, the existing interactions, including those involving the Departments of Agriculture and Finance, must be included in action plans since action involves the purchase of advanced agricultural resources and development of farming skills (Parry *et al.*, 2008). Climate variability adaptation and policy implementation should be given the highest priority, particularly at the local level where the extent of vulnerability is highest (Measham *et al.*, 2011). In addition, Ziervogel *et al* (2010) observed that effective adaptation policies in developing countries will be achieved only if adaptation is perceived as a long term response that does not encourage the need for immediate development. The implementation of effective adaptation policies will be difficult, particularly in developing countries, as a result of the existing economic and political structures that are not conducive to effective management of natural resources like water. Regardless of the challenges of climate variability, the driving agents such as UN-Habitat, WWF, Action Aid, as well as the Transition Towns campaign are among the identified key driving actors facilitating the participation of local people in climate variability policies (World Bank, 2010). Bulkely (2010) argues that local institutions that are planning how to tackle climate variability and its associated impacts are few and the majority of them are challenged by significant factors associated with institutional capacity and the prevailing political economy. Although the interest of adaptation laws is becoming a popular debate around the globe, what lacks most is the information on which steps or procedures need to be followed when drafting such laws. According to Kriegier *et al* (2012) there is a need to incorporate both socio-economic and environmental resources in the implementation of adaptation legislation since both factors are susceptible to climate variability risks.

However, Van Vuuren *et al* (2013) argues that population growth should be given special preference when implementing environmental laws because it is one of the common factors contributing to climate variability and it can also be used to test for any improvements brought by the current policies. According to Riahi *et al* (2012), environmental policies should be designed not only to protect the natural environment but also to promote participation in awareness campaigns and research to minimize the increasing statistics on uncertainties about climate change hazards on both social and ecological systems. However, not only do climate variability policies support mitigation plans but also the availability of financial resources and political willingness to address the current issues on matters relating to natural resource usage, for example, how energy is being generated and its current usage around the globe (Klein *et al.*, 2007). Adaptation policies should be designed in such a way that they are simple and region specific in order for them to be easily followed by local populations (Biesbroek, 2009). For example, governments have shown more interest in the implementation of United Nation Framework Convention on Climate Change (UNFCC) and the Kyoto Protocol, paying less attention to local and provincial issues (Barreca 2012). In addition, Burch (2010) notes that when designing adaptation policies, more emphasis should be put on how to react and respond towards the changing weather conditions rather than on the benefit that will be attained from mitigation strategies. In another study, Moser (2010) noted that environmental legislation will be more fruitful to rural societies if the resilience approach is built on the existing individual knowledge and collective adaptation actions at local, provincial and national levels. The fact that climate variability is associated with unexpected weather conditions, means that understanding the magnitude of its associated impacts remains a challenge, and therefore, it is required that adaptation policies remain transparent to incorporate personal experiences and practical steps that need to be taken to promote mitigation measures (Karl *et al.*, 2009). However, this is a challenge, particularly in developing countries, where little attention is being given to the vulnerabilities of the local people which in turn affect the implementation of direct adaptive strategies (Adger and Barnet, 2009). Furthermore, since climate variability is a complex phenomenon, it is important for policy developers to ensure that the current policies are reviewed regularly so that they remain relevant at all times (Dovers and Hezri, 2010). This shows that excluding adaptation in environmental management will accelerate vulnerability of agriculture to climate variability and, thus affect socio-economic and ecological systems across the world (Barnet, 2010).

2.1.8 Simulation models and the projection of the climate variability impacts on agriculture

Although it is difficult to explain the complex interactions existing between agricultural production and farmers' responses towards climate variability, some studies have managed to simplify the connection between them using various climate simulation models. Agricultural crop models are identified as the best tool that can be used by farmers to improve agricultural management (Rotter *et al.*, 2011). Hulme (2011) notes that quantitative information generated by crop models provide farmers with additional knowledge and guidance on which adaptation options to be used since climatic conditions keep on changing. Challinor *et al* (2009) complement the role of climate models in simplifying complex scientific projections and for their capacity to trace the regions that have insufficient information about climate variability and its associated impacts. The fact that the production of most foods is expected to decline as a result of climate variability (Battisti and Naylor, 2009) means that crop models will assist farmers in identifying the crops or varieties that are most affected in specific regions and thus allowing them to adopt new cropping systems. In addition, Reily *et al* (2013) argue that projecting the future change in environmental variables is not only beneficial to farmers but also to policy makers who are planning to implement adaptation laws that are region specific. The ability of climate science modeling procedure to present the susceptibility of the natural environment to various climatic dangers or determine whether the currently practiced ecological management systems are feasible enough to minimise future climate hazards, makes the model outputs valuable (Galic *et al*., 2010). As noted by Hillel and Rosenzweig (2010), climate models can only be practical enough when the economic risks are taken into consideration when projecting future climate impacts, since the majority of farmers in rural areas are normally challenged by financial instability before and even after the incident has occurred. Although the simulation models that are used to project future changes in environmental conditions are being appreciated for their output results (Jean *et al.,* 2010), they are still critical, since they do not include the secondary effects of climate variability such as soil erosion and imbalance of nutrients cycling (Guo *et al.,* 2010). On the other hand, Philippe *et al* (2011) argue that projecting the change in environmental conditions while presenting the variable in a form of plus or minus sign (±) is a good way of predicting the future change in environmental variables, but the method lacks consistency and increases the level of uncertainty.

However, in order to overcome the above challenges and to avoid being biased (Zhao *et al.*, 2010), it is suggest that dynamic Global Climate Models (GCM) be downscaled dynamically while Crop Models must be adjusted to meet the requirements for climate model outputs. In terms of reducing the risk of producing observations without correctly representing the processes involved, Matthew *et al* (2011) suggested the need to use a multi-model ensemble that incorporates impact studies in sample variability when presenting the output results. In one study, Tebaldi and Sanso (2009) argued that combining individual models can be a challenge since all models are being subjected to criticisms. However, it is important to evaluate each model when implementing adaptation options. Hsiang (2010) maintains that the majority of climate models present the impact of climate variability on agricultural production using common indicators such as increasing temperatures, rainfall and other forms of precipitation while the other agriculturally relevant measures such as evapotranspiration and solar radiation are rarely taken into consideration. This tends to have an effect on projected weather patterns since climatic conditions differ according to the geographical space and region (Barreca, 2012). Such challenges can also bring confusion to model users because one cannot predict whether an indicator in a particular study can be considered as the region's key problem or not. Similarly, Begert *et al* (2008) reported that the global climate models aiming to predict climate conditions in rural areas are challenged by unavailability of the weather stations, as well as archival climate data that are not meeting the recommended quality standards. The challenge is common in developing countries, where some of climate models are challenged by unavailability of climate data and historical weather information (Funk *et al.,* 2008). Such findings show that some of the climate models that are used to estimate future climate conditions are not yet in a suitable form that can be used to guide agricultural sectors. This means that there are certain measures that need to be taken before such forms of data can be meaningfully used for assessing possible impacts of climate variability and for evaluating adaptation options.

2.1.9 The role of indigenous knowledge in the adoption of adaptation measures

In the past, traditional agricultural practices have shown the possibility of farmers attaining increased food production under changing weather conditions. Farmers possess valuable indigenous adaptation strategies, including the early warning signs that enable them to recognize and respond to climate variability (Thomas *et al.*, 2007). Indigenous knowledge systems shape adaptation options that are valuable for the specific area and which can also be used as an instrument to determine if it is possible for today's farms to look different in future (Adger *et al.*, 2009). According to Erestain (2009), the zero-tillage technique adopted by farmers in Asia made a huge contribution to agriculture, where by the Gangetic plains allow about 620 000 farmers to produce increased crop yields while at the same time, conserving soil fertility using less water, which in turn reduces land degradation and production costs. The importance of indigenous knowledge systems was also observed in Ethiopia, where farmers affected by drought use small harvesting pits to collect runoff during the rainy seasons and thus increasing their production levels of potatoes and soya bean (Amede *et al.*, 2011). In another survey, Byg and Salick (2009) showed that indigenous people managed to survive floods by using adaptive measures such as riverbank retaining walls, terracing and bio-stabilization of slopes with rocks and plants. Indigenous people survive climate variability stress because of their knowledge of historical events of adaptation strategies that were used during periods of undesirable weather conditions in their surrounding environments (Nakashima *et al.,* 2012).

The use of a set of specific indicators such as plants and animals by farmers, as well as astronomical phenomena, serves as a powerful tool that allows them to detect any changes that are about to take place in their surrounding environment and in turn giving them the opportunity to prepare for any undesirable changes that might take place (Tapia *et al.*, 2012). The fact that indigenous knowledge is being constructed upon local timing and previously experienced weather conditions, makes this knowledge more applicable to local people and serve as a powerful tool to guide in the implementation of adaptation measures (Lefale, 2009). The existing local knowledge on climate variability can also play a significant role in areas with insufficient climate data (Green *et al.,* 2010). According to the IPCC (2007) indigenous knowledge has the value not only for the area where it is being practiced, but also for the scientists who are planning to make some improvements on the already existing adaptation strategies that are being practiced in other societies. However, Locatelli (2012) warned that adaptation to climate variability is a local process and therefore, there is a need to incorporate social context, including local knowledge when planning for effective adaptation policies. The success of climate variability adaptation strategies for vulnerable societies can only be achieved when the steps that are taken in shaping traditional knowledge are well understood (Agrawal *et al.,* 2009).

Although climate variability is treated as a global issue, in most incidences the quality of adaptation measures is evaluated at the local level, illustrating that local communities are the centre of adaptation planning (Funk *et al.,* 2008). Moreover, the fact those rural communities have taken their own effort to preserve the existing natural resources in their own surrounding shows that they have the capacity to overcome any challenges that will occur within their living space using existing knowledge (Draw, 2010). Furthermore, Nyong *et al* (2007) noted that traditional ecological knowledge can promote the understanding and effective communication and interpretation of reports made on climate variability and adaptation options. Also, Dekens (2007) contends that the vulnerability of communities to climate variability, particularly in developing countries, can be minimised when both indigenous and scientific knowledge are incorporated into mitigation measures. However, although the benefits of indigenous knowledge have been well documented, there is still an existing research gap on how to effectively incorporate such knowledge into scientific studies (Ford, 2012).

2.2 Theoretical framework

There are various theoretical tools that may be used to describe or quantify environmental change. In this research study, the Pressure-State-Response Model is used as a conceptual tool and as a framework to assess the impact of climate variability on agricultural systems and the feedback response action taken by farmers to address the impacts. This framework has formed the basis of the developments of the Driving-Force-State-Response (DFSR) and the Driving-Force-Pressure-State-Impact-Response (DPSIR) frameworks (OECD, 2003). There are a number of frameworks available for developing indicators, and a common challenge to establish an indicator programme is choosing the best framework by which to conceptualize potential indicators. Choosing a framework that does not integrate well within the scale and objectives can often lead to indicators that are not clearly linked to the research purpose as well as management actions (De Groen and Savenije, 2003). Therefore, the Pressure-State-Response framework is adopted in this study to create a set of indicators that provide a more comprehensive analysis and evaluation of the impact of climate variability and change on crop production.

Indicators provide a basis for conceptualizing a problem and are useful for understanding structurally diverse information, uncovering causes and effects and reviewing data sources and information gaps (Linser, 2001). Although the P-S-R approach presents various kinds of indicators including financial, poverty and health indicators, the research study uses the environmental indicators. Accordingly, the study aims to adapt the guidelines from the P-S-R set of environmental indicators to assess the natural environment and to identify any changes that have occurred within an agricultural system due to changing climatic conditions. Environmental indicators can be used to quantify the pressure resulting from climate variability on crops and to assess the responses or adaptation measures that have resulted from affected farmers. The environmental indicators that are used in the study include changes in temperature and rainfall patterns, soil degradation, drought stress as well as Crop Performance Indices. These environmental indicators are measurable and can be used to assess the impact of climate variability and change on agricultural production. These indicators can also assist farmers in decision making on which adaptation options can be used in order to limit the impact of climate variability and change in their operations.

2.2.1 The Pressure-State- Response Model

The P-S-R is a complete tool for presenting environmental issues. However, although the P-S-R approach is known to be powerful in communication and in opinion-building process, its application in the analysis of environmental change has met some criticism (OECD, 2003). Due to the shortcomings presented by the P-S-R Model, the United Nations Commission on Sustainable Development (CSD) developed the Driving Force-State-Response (DPSIR) Model to restructure and reorganize indicators in a more meaningful way (OECD, 2003). A primary modification here was to extent the concept of pressure to incorporate social, economic, institutional and natural system driving force (UNEP, 2000). Therefore, despite the criticisms that are made on the P-S-R Model, it can be practically expanded to account for greater detail or specific features, depending on the case it is to be used for. The P-S-R framework has increasingly been applied in research projects with the aim of supporting decision making processes. A number of attributes of the framework regarding structuring and communication issues in research further strengthen its original purpose of bridging the science-policy gap. Therefore, in this study, the original P-S-R approach is modified by introducing climate variability, agriculture and adaptation options to present the impact of climate change on agricultural systems based on a selected set of key indicators as shown in Figure 1**.** The output of the P-S-R model aims to assess the impact of climate variability on agricultural fields and farmers' response to limit the impacts. The Model also highlights the cause-effect relationship (Figure 1) existing between climate variability and agriculture. The P-S-R Model clearly shows the need to focus on factors influencing the change in agricultural systems and associated dangers, depicted by environmental indicators and mitigation measures adopted by farmers.

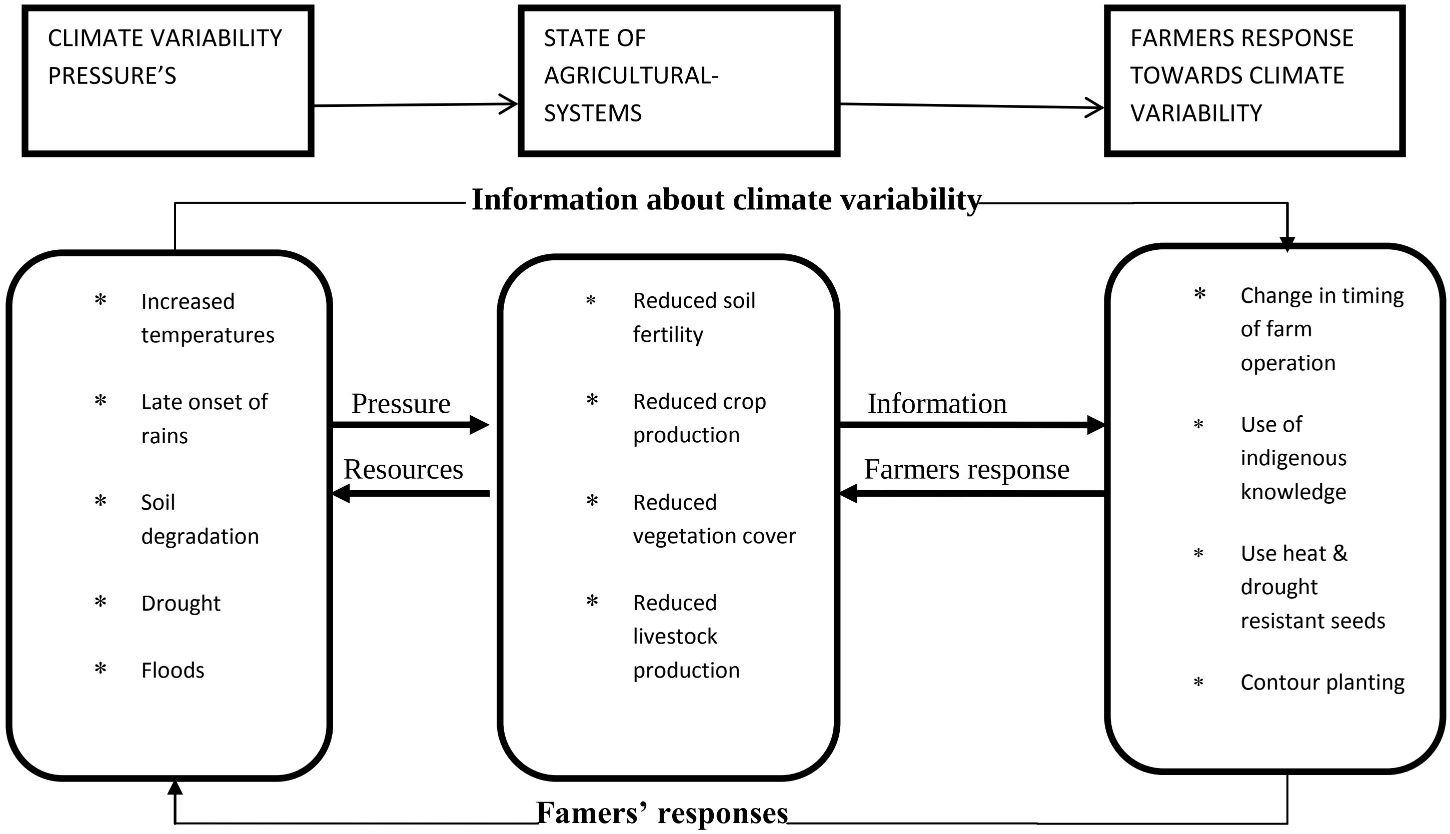

Figure 1: Pressure-State-Response model illustrating the impact of climate variability on agriculture (Adopted from OECD, 2003:21).

2.2.2 The P-S-R indicators for evaluating vulnerability of agricultural systems to climate variability at the local level

The P-S-R approach is causal one, covering the causes and effects of changing farming systems as a result of climate variability. In this case, indicators are classified into three categories including environmental pressures, environmental state and societal response indicators (OECD, 2005). Indicators of environmental pressure describe pressures on the agricultural systems originating from climate variability, including soil degradation, water scarcities and increased temperatures.

Indicators of environmental conditions (state) are designed to describe the state of agricultural systems as well as quality and quantity of resources and changes over time. For example, reduced water and soil quality reduced vegetation cover as well as reduced crop production.

Indicators of societal response are the response action taken by farmers to prevent or control the negative impacts of climate variability on agricultural systems. This could be the number and kinds of measures taken and the efforts of implementing or the effectiveness of those measures. Responses may include actions taken such as land management to address moisture deficiencies, use of heat or drought tolerant seeds and increased application of fertilizers.

2.3 Conclusion

The key focus of this chapter was the reviewed literature on climate variability. This included the definition of climate variability, the impact of climate variability on agriculture and food markets, farmers' perceptions on climate variability, factors that promote farmers' vulnerability to climate variability as well as factors that influence farmers' adaptation to climate variability. The role of indigenous knowledge in the implementation of mitigation plans and climate variability policies was also reviewed.

In conclusion, the reviewed literature shows that climate variability is going to have a severe impact on agriculture and that farmers who are highly vulnerable are resource poor farmers' who lack skills, particularly in developing countries. It was also highlighted that farmers' perceptions on climate variability can be influenced by several factors, including education, age and experience in farming. In addition, access to financial assistance, existing environmental legislation and technological developments are among the main factors that play an important role in agricultural production. The implementation of adaptation measures to combat climate variability takes different forms. These forms are based on the perceived dangers that are brought by climate variability and the majority of them are region specific.

CHAPTER 3:

Study Area and Methodology

3.1 Introduction

Chapter Three consists of a brief description of the study area which is situated in the Free State Province. It also describes the study methodology, elaborating on how data was collected, presented and analyzed. The methodology of the study involved the collection and analysis of both quantitative and qualitative data. Thus, a mixed methods approach was adopted to handle both primary and secondary data. Primary data was collected to gauge the views of farmers in relation to climate variability, while secondary data was analysed to determine the extent of vulnerability of agricultural systems in Tshiame Ward to climate variability, and the adaptation measures that have been adopted to reduce the extent of the vulnerability of crop production.

3.2 Description of the study area

The study was conducted in the Tshiame Ward of Maluti-A Phofung (MAP) Municipality, situated in the Thabo Mofutsanyana District of the Free State Province in South Africa. The Tshiame Ward is located in the upper catchment of the Vaal River, within the Wilge River sub-catchment.

The MAP includes Qwaqwa, whose administrative head office of the municipality is situated in Phuthaditjhaba, which is the only urban centre in Qwaqwa. Qwaqwa is a former homeland that was designated for the Sotho speaking people during the apartheid era. The MAP municipality comprises thirty five wards and covers an approximately 4 421 km^2 in extent, and has a total population of 400 000 (MAP, 2012b). Surrounding Phuthaditjhaba are rural villages, established on tribal land administered by Department of Land Affairs and Land Reform. Other rural land uses comprise commercial farms and biodiversity hotspot such as Qwaqwa National Park, Platberg, Sterkfontein Dam and Maluti Mountain Range. According to the Department of Social Development (2013), the Qwaqwa region has high poverty and unemployment levels. The striking poverty characterizing the area is partly a reflection of low agricultural productivity (MAP, 2012b).

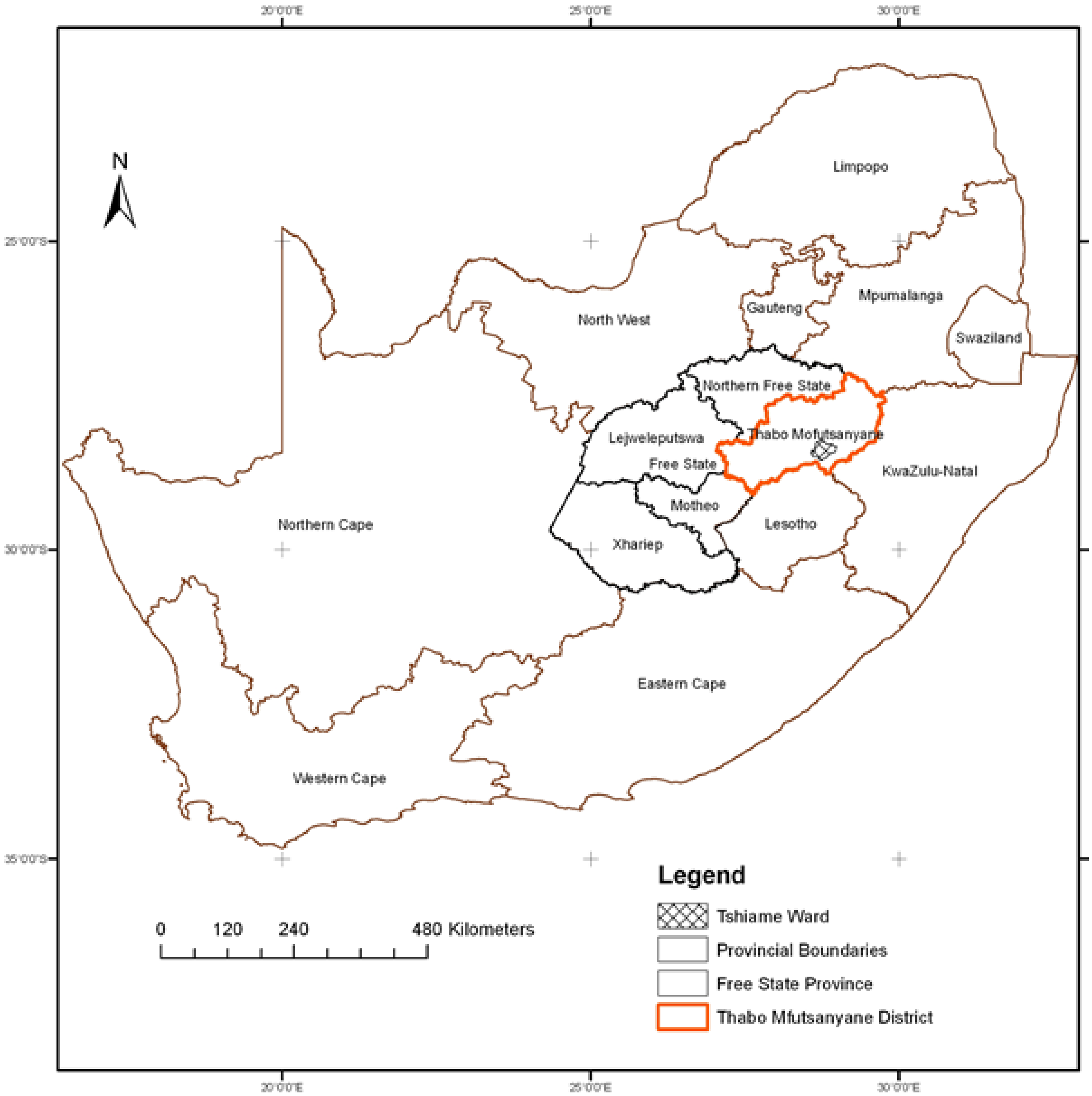

Figure 3.1 Study area

The Free State Province is situated between latitude 26.6˚ S and 30.7˚ S and between longitude 24.3˚ E and 29.8˚ E (see Figure 3.1). It is South Africa's third-largest province with an area of around 129 825 km^2 (FSP, 2005; Davis *et al*., 2006), covering 10.6 % of the country's land area (Statistic South Africa, 2007). The province has a population of 2.77 million people. The province is situated on the vast plains in the centre of South Africa and it borders six other provinces with the exception of the Limpopo Province and Western Cape. To the east, it forms a boundary with Lesotho, and the escarpment, which separates it from the Eastern Cape and KwaZulu-Natal (FSPG, 2013).

3.3 The environmental conditions in Tshiame Ward

The Tshiame Ward has a climate characterized by warm to hot summers and cool to cold winters. The total annual rainfall received in the area ranges between 632.5 mm per year and 655.1 mm per year (Extension Suite, 2014). In Tshiame Ward, the onset of rains is in October and ends in April. In Tshiame Ward, the maximum mean temperature ranges between 15°C and 26°C. The minimum mean annual temperatures in the region ranges between 5°C and -1°C. The Tshiame region is dominated by eastern Free State Sandy grasslands (Mucina and Rutherford, 2006). The majority of farmers practice crop and livestock farming. The main crops are maize, dry bean, soya bean and wheat. Animal farming is also commonly practiced in the area, and the majority of livestock farmers specialize in cattle farming. Farms range between 150 and 2196 hectares in size. However, most of the arable farms range between 40-420 hectares in size, and on most farms a portion of land is used for grazing purposes. The majority of small holder farmers are classified as semi-commercial. Most farmers do not practice irrigation and depend on rain-fed agriculture. Farmers depend on boreholes for livestock watering (Extension Suite, 2014).

3.4 Land classification

In Tshiame Ward, there are three different land classes dominating the area. These land types include class 3, class 4 and class 6 types.

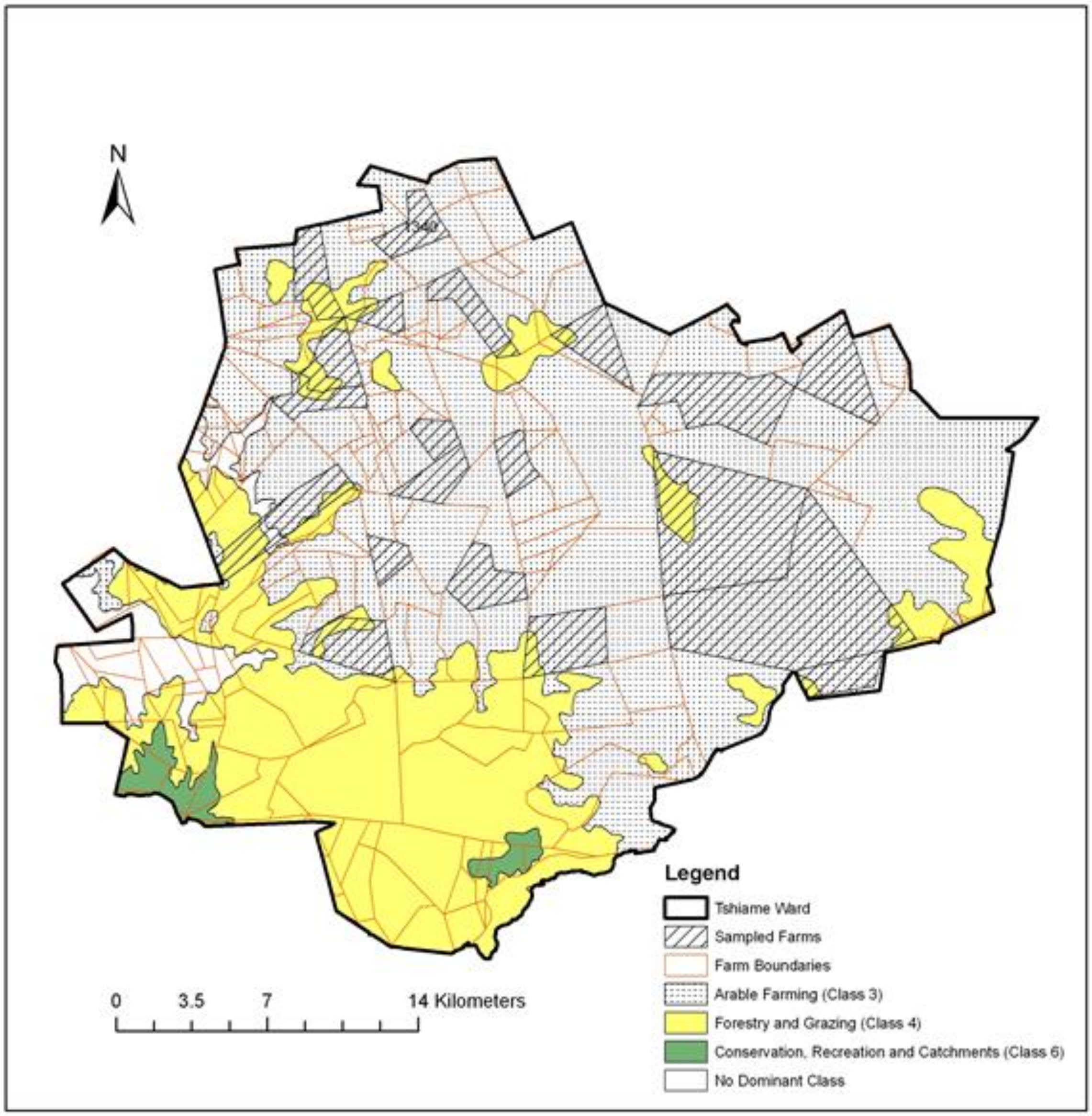

Figure 3.2 Land classes in Tshiame Ward

3.4.1 Class 3 land type

The most dominating land class in Tshiame Ward is Class 3 type. Land in class 3 imposes drastic limitations to cultivation (Extension Suite, 2014). Farmers who are occupying such type of land are required to practice special conservation techniques in order to be able to produce any kind of crop (Extension Suite, 2014). The success of farmers who own Class 3 portion of land depends on the length of the growing season, the preparation of land before growing crops, as well as the choices of the crops they cultivate. The normal growth of crops planted on such type of land is susceptible to various forms of disturbances, including erosion by water and wind. Agricultural practices undertaken on Class 3 type of land are affected by shallowness of soils, which limits the rooting zones for plants. Such land types are also characterized by soils with low water holding capacity (Extension Suite, 2014). Because of their composition, such soils also have low fertility and high levels of salinity which is difficult to correct.

3.4.2 Class 4 land type

The Class 4 land type is similar to Class 3 land type. However, the Class 4 land type accommodates a more limited number of crops and also requires the application of extensive management strategies to keep it productive (Extension Suite, 2004). Although cultivation can be practiced on Class 4 land type, conservation practices are difficult to implement because the quality of the soil is influenced by environmental conditions experienced in the region. Yields of crops produced under various farming practices are higher during the wet season than during the period of dry season. The soils are also susceptible to soil erosion.

3.4.3 The class 6 land type

Class 6 land type is largely unsuitable for crop production. One of the main factors that limit crop production on Class 6 land type is the stoniness and shallowness of the soil which make the soil prone to erosion (Extension Suite, 2014). The stoniness of Class 6 land type also affects the rooting zones for plants. Farmers tilling such land type are required to implement adaptation measures such as seeding methods, and application of liming and fertilizers. Class 6 land is only suitable for woodlands.

3.5 Soil types

Tshiame Ward is dominated by three different types of soils, including Glenrosa, Mispah and Plinthic Cantena type. Glenrosa and Mispah soils are the most common (Extension Suite, 2014).

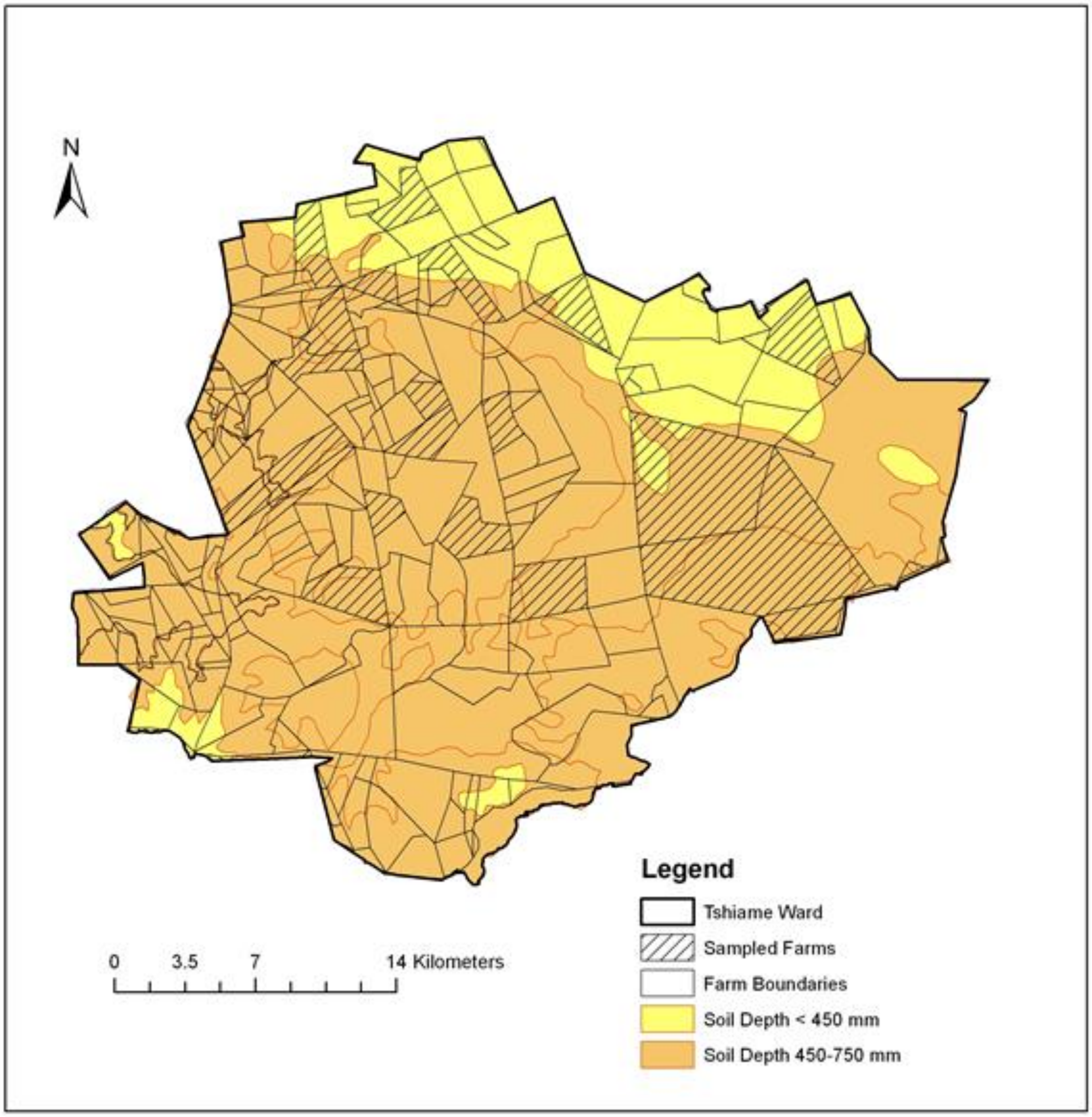

Figure 3.3 Soil depths in Tshiame Ward (Soils whose depths are less than 450 mm include the Glenrosa and Mispah soils and those whose depths range beyond 450 mm are predominantly Plinthic)

3.5.1 Glenrosa soil

The Glenrosa soil type is classified as a shallow (200 mm) soil with orthic A or lithocutanic B or saprolite horizons. The different horizons that form part of Glenrosa soil have varying colours, as well as textures. The A-horizon is brown and the B-horizon is red brown with a clayey textures. The clay content ranges between (15-25%) and (35-45%) in the A and B horizons, respectively (Land Type Survey Staff, 1976-2006). In addition, the Glenrosa soils are classified as moderately physically active and susceptible to erosion. The subsoil is sensitive to erosion and should not be exposed at all times.

Suitability

Glenrosa soils are suitable for farmers who are practicing the dry land farming (Land Type Survey, 1976-2006). However, dry land farming has severe limitations for plant available water. In addition, the dry climate of MAP municipality does not support either dry land farming or irrigation farming. This entails that those farmers occupying areas with Glenrosa soils need irrigation to sustain plant growth (Soil Classification Working Group, 1991). In their top horizons, Glenrosa soils have high levels of clay content limiting water absorption and availability for plants. Hence, areas dominated by such soils are restricted to grazing. In areas with Glenrosa soils, the production of cattle and sheep is low because the soil type does not support the growth of the natural veld, and thus affects the animal nutrition (Soil Classification Working Group, 1991).

3.5.2 The Mispah soils

Mispah soils are classified as very shallow (200 mm) and are composed of two different horizons. Both the orthic A and the saprolite horizons are brown in colour and have sandy textures (Land Type Survey Staff, 1972-2006). However, the orthic A has a (15-25%) of clay content. The Mispah soils are slightly vulnerable to erosion.

Suitability

Just like Glenrosa soils, Mispah soils are only suitable for dry land farming. However, all the crops that are produced in Tshiame Ward require the optimum supply of water in order for them to grow normally. This means that agricultural output is severely affected where Mispah soils are dominant (Soil Classification Working Group, 1991). Despite their limitation on agriculture, their role in hydrological processes is highly appreciated. In areas dominated by Mispah soil, livestock production is low since the soils do not support the plant growth or grazing. Grazing leads to open patches which accelerate soil erosion. Soil Classification Working Group (1991) documented the Mispah soils as not suitable for irrigation because of their susceptibility to erosion.

3.5.3 Plinthic Catena: upland Duplex and Margalitic soils

Plinthic soils are also classified as shallow (300 mm), containing a dark A-horizon with a durable aggregate pattern. Plinthic soils are generally highly erodible. In their composition, Plinthic soils consist of both Duplex and Margalitic soil types (Soil Classification Working Group, 1991). Duplex soil types are characterized by permeability of their top soil horizons that covers the less permeable layer of the subsoil with high levels of clay content. On the other hand Margalitic soils are classified as soils that show the presence of the A-horizon that is dark in colour and are very shallow in nature (Soil Classification Working Group, 1991). Plinthic soils are dominant in areas with the slope ranging between (2 & 8%). They can also be identified on land where the slopes ranging between 1 and (3%).

Suitability

Plinthic Catena soils are classified as unsuitable for crop production. The high levels of clay content in their composition make it difficult for water to move through the soil and underlying porous rocks (Soil Classification Working Group, 1991). The fact that Plinthic soil types are dominant in rocky areas, make them unable to anchor plants.

3.6 Socio-economic conditions in Maluti-A-Phofung Municipalityz

In MAP Municipality the arable land is estimated to be three quarters of the total land area (MAP, 2010a). Most of the tillage fields are situated in the central and northern parts of the district (Figure 3.2). Also, in the southern parts of the area, where most people live, agricultural fields are scarce. In the southern parts, agricultural development is challenged by the steepness of the land and the dominating foot hills of the Drakensburg Mountains, as well as unsuitability of soils. Commercial agriculture is extensively practiced in the central and northern parts of MAP. Commercial farming is widely practiced, especially in flat areas around Harrismith and Kestel, while the subsistence farming is largely practiced in Phuthaditjhaba and surrounding areas (MAP, 2012b). However, agriculture contributes only 2.1% of the Gross Geographic Product and employs 6.7% of the working population (MAP,2010a). Gross Geographic Product (GGP) provides a measure of the total and sectoral economic activity happening on an annual basis within the local municipalities of South Africa. In the area, emerging farmers have access to land but production is limited due to cash management issues.

According to MAP (2010a) about 23% of the people in the municipality are without secondary education. Only about 17% of the local people have completed Grade 12, while 6% have acquired higher education, though the number of people with tertiary education keeps on increasing. This is associated with the increasing number of educational institutions in the area, including the Free State University and several Further Education and Training colleges (MAP, 2010a). According to the Maluti-A-Phofung Municipality (2012), about 40% of the population in the region is employed. Most of the MAP residents rely on subsistence agriculture to survive. Some households depend on backyard gardens for survival. However, estimating the total number of employed people in the region is difficult since many people are involved in various informal activities that are contributing to the economy of the area. For example, some people are self-employed while others engage in entertainment, cultural heritage projects, bead-work, sculpting (MAP, 2010a). The estimated figure for the unemployment rate in the region requires further analysis and scrutiny (MAP, 2012b).

3.7 DATA COLLECTION

It should be noted that this area represents other surrounding communities with similar characteristics, which will provide famers from neighbouring communities with the opportunity to use the findings of the present study to cope better in their own agricultural operations.

3.7.1 Primary data

Quantitative data were collected using a structured questionnaire. The aim of using a structured questionnaire was to ensure that responses would be reliably aggregated and appropriate comparisons made, while generalizations and conclusions would be drawn on how farmers perceived climate change and which adaptation methods are used by the farmers to reduce susceptibility to climate change. The survey was conducted on farmers who specialized in crops and livestock production in the Tshiame Ward. The district Department of Agriculture was asked to provide a list of all emerging farmers in the Ward. The questionnaire consisted of both open-ended questions that required written responses and closed questions providing predetermined options. The questionnaire survey (Appendix A) consisted of five sections which include demographic characteristics of the farmers, farmers' perceptions about climate variability, impact of climate variability on crops and the mitigation measures that were used by the farmers to reduce the negative impacts of climate variability on their operations. Before its distribution to the farmers, the questionnaire was validated by agricultural extension officers and an agro-climatological expert from ARC. Reliability and validity was further increased by pre-testing of the questionnaire. The purpose and the details of the study were outlined to the farmers in a letter that was handed out along with the questionnaire. However, the actual collection of the data was done during the on farm visits. The respondents were also informed that the information that would be collected would be used only for research purpose and would be treated confidentially.

3.7.2 Sampling technique

A list of all existing farmers was collected from the district Department of Agriculture. The research study was targeting the emerging farmers' who are either practicing crop farming or mixed farming, irrespective of their backgrounds. Emerging farmers were selected because they are very vulnerable to climate variability and lack advanced agricultural resources. The sampling was drawn from a population of farmers who were taking part in the skills development programme that is run by ARC and it focused on those who were willing to take part in the study. A total of 19 farmers were interviewed from a total of 29.

The adequacy of the sample size was calculated using the following equation by Yamane (1967):

$$n = \frac{N}{1+N(e)^2}$$

Where N= number of household of farmers and e = margin of error

The primary sampling unit was the individual household. The household questionnaire survey that was used was targeting the emerging farmers. The household heads, who were the farm owners too, were the respondents in the survey. For the purpose of this study, a household is defined as a group of people in a housing unit living together as a family and sharing the same kitchen (Hillel and Rosenzweig, 2010). The household head represented his or her household members as the respondent in this survey. In this study, the head of the household is defined as a person making major economic, social and household decisions irrespective of age and gender (Hillel and Rosenzweig, 2010).

3.7.3 Secondary data

Archival rainfall and temperature data for the period between 1980 and 2007 was collected for the Kestel weather station, the station closest to Tshiame Ward. This station was purposively selected, based on the availability of records for daily rainfall, maximum and minimum temperatures and fair distribution of the station in the study area. The years (1980-2007) were selected because according to the Agricultural Research Council Officials (Personal interviews, 26 August 2014) farmers in the Maluti A Phofung were mainly affected by weather disasters during the selected periods of (1980-2007). The data were provided by the ARC. Reference evapotranspiration data that was used in the computation of Crop Performance Indices was also provided by ARC.

3.8 Data Analysis

3.8.1 Analysis of primary data

The collected data were organized and analyzed using the SPSS to determine the frequencies of farmers who held certain perceptions about geographical, socio-cultural, economic and environmental conditions prevailing in Tshiame Ward. This assisted in highlighting common understandings of climate variability and how it has affected the farmers in this area, and to identify the factors that influence farmers' perceptions and responses to this variability. The analyzed data was presented in graphical and tabular forms.

3.8.2 Analysis of secondary data

Analysis of rainfall and temperature data

To prepare the raw rainfall and temperature data for analysis, the data series of meteorological station was first stacked. This involved the use of Microsoft Excel 2007. The data were captured on an Excel spreadsheet following the day of the year (DOY) entry format. Data quality assessment was done as a preliminary step in screening and preparing data for the analysis. Data consistency was checked for both temperature and rainfall. This was done by plotting box plots in order to detect outliers (Shehadehi and Anabeh, 2013). Values of the suspected outliers were compared with the daily values and also with the values of the corresponding period from nearby stations belonging to the same physiographic zone (Basitha *et al.*, 2009). The values were discarded only when mismatch was detected, and the gaps were filled up by the normal ratio method. Graphs with trend lines were drawn in Microsoft Excel 2007 and used to determine trends in seasonal and annual means and totals. The p-values were calculated using the on line calculator (GraphPad Software, 2016). The p- values were computed from the R^2- value and degrees of freedom (DF). The r-values were determined by calculating the square root of the R^2-values using Microsoft Excel software. The DF-value was determined by subtracting 1 from the total number of years (27-1) = 26. The DF value (26) was used for all years. Time series graphs were plotted to explore long term trends in the seasonal rainfall, as well as minimum and maximum temperatures.

Dry spell characterization

In this study, the analysis of dry spells was carried out using daily rainfall data collected from the local weather station for a 27 year period (1980-2007). For the region, the analysis of dry spell is important because famers in the area are susceptible to drought. The data were examined for continuity and missing records. The use of daily time series for the local station to determine rainy season onset, cessation and dry spell lengths was carefully handled in order to prevent the missing data from significantly affecting those determinations.

Dry spells are defined as a number of consecutive days without rainfall, and consecutive days with rainfall are called wet spells. In this study, a threshold value of 5 mm was used to distinguish between a wet and a dry day (De Groen and Savenije, 2002). The simplest calculation of dry spells included the transformation of the columns of rainfall data to give dry spell lengths using the INSTAT climatic guide (Stern and Knock., 1998). Instat is a simple general statistic package that includes a range of special facilities for processing climatic data. A detailed description of the INSTAT software used in this study was documented by Stern *et al* (2006). The spell lengths were processed further to give maximum dry spells in 30 day periods, starting from the first day of each dekad. In this study, the term ‘‘dekad’’ refers to the 10 day averaging periods of each months that are commonly used in agricultural studies (Cook *et al.*, 2004). Each months was divided into 10 days starting from the 1st , 10th and 20th day of the month, which includes all the days up to the end of the month, depending on the month (with the exception of February). The choice of spell lengths reflects the need to consider shorter spell lengths for drought sensitive crops such as maize, as opposed to drought-hardy crops such as millet which can withstand longer dry spells of even 15 days. Also, for a given crop, certain growth stages are more sensitive to droughts and have a higher water requirement. For example, most grain crops are sensitive to drought at the time of flowering and grain filling (FAO, 2004).

The length of the dry spell was specifically calculated from the beginning until the end of the growing season. Officially, the growing season for maize and dry beans starts on the 1st of October and ends on the 31st of April the following year, while the growing season for winter wheat starts on 1st of May and ends on the 31st of August (Agricultural Research Council (ARC) Officer, Personal interview, 20 May 2014). The start and end of the growing season were determined looking at the onset and offset of rains in the region. Rainfall threshold used for this purpose was 5 mm. The minimum cumulative rainfall threshold of 5 mm is an insignificant amount for crop use, but it does signify the ending of dry spell. The threshold value of 5 mm was also used as a standard value based on the total amount of rainfall received in the region and the sensitivity of the crops grown there (maize, wheat, beans) to droughts.

Determination of patterns and trends in annual and seasonal rainfall

Cumulative rainfall (October to April) and cumulative winter rainfall (May to August) were computed from daily data and trends determined by the use of graphs and trend lines. Trend line linear equations of Y= aX + b were used to describe changes in rainfall, where "a", the slope shows the rate of change of ''Y'', the dependent variable (which is rainfall in this case), is a function of X, the predictor, i.e. the number of years from 1980 and "b" is a constant. Both short and long rain seasons were categorized into (i) low rainfall seasons with 400 mm of rainfall and below, (ii) average rainfall seasons having between 400-600 mm and (iii) high rainfall season with over 600 mm. The above mentioned rainfall categories for the region were determined based on classification rainfall depths by ARC.

Determination of patterns and trends in seasonal and annual temperatures

Daily minimum and maximum temperature data were used to derive monthly, seasonal and annual means. Similar linear trend line equations of the form Y= aX + b were "a", the slope shows the rate of change of ''Y'', the dependent variable (which is temperature in this case), is a function of X, the predictor, i.e. the number of years from 1980; and "b" is a constant. Both moderate and extreme temperatures were categorized into (i) Low temperature seasons with a temperature ranging between 10˚C and -5˚C, (ii) averaged temperature seasons will be classified as having the temperature range between 11˚C and 25˚C and extreme temperature seasons with 26˚C and above. The above mentioned temperature levels for the region were determined based on classification of temperature levels by ARC.

Crop Performance Indices (CPIs)

While climate data were available, the actual data on crop yields were not available for two reasons. First, most of the farmers are poor at record keeping. Second, there is a high turnover of farmers, a situation which has led to farms changing hands frequently (change of farm ownership) and thus leading to unavailability of historical data on crop yields. Therefore, in order to determine if climate change and variability had an effect on crop production CPIs had to be calculated. CPIs are used to determine the amount of moisture in the soil, starting from the minute the seed is placed in the soil until the maturity stage when the crop is ready to be harvested. In order to compute CPIs, the evaporation data for the Kestel weather station was used. Data on reference evapotranspiration rates were estimated from radiation (Rs) data using the equation by Hargreaves and Samani (1982):

$$ETo = 0.0135 (Kc) (Ra) (TD)^{1/2} (TC+17.8)$$

Where ETo = Reference evapotranspiration; Kc = crop coefficient; Ra = extra-terrestrial radiation (mm/day); TD = maximum daily temperature minus minimum daily temperature (˚C) and TC is the average daily temperature (˚C).

Table 3.1 Crop coefficient values for crops that are produced in Tshiame Ward

Crops	Initial stage	Middle stage	Final stage
Maize	0.5	1.20	0.60
Dry beans	0.4	1.15	0.35
Wheat	0.8	1.15	0.25

** Source: Food and Agriculture Organization (1998)

The CPIs were calculated from the difference between precipitation and the crop water requirements and reference evapotranspiration using the Instat Software (Stern *et al*., 2006). CPIs are known by different terms. They are referred to as Water Requirement Satisfaction Indices (WRSIs) by the FAO (1998), and as the Crop Specific Indices (CSIs) by Gizachew and Suryabhagavan (2014). The WRSI is the ratio of seasonal actual evapotranspiration (AET) to the seasonal crop water requirement (WR) and is calculated using the following equation:

WRSI = (AET/WR) *100

In current study CPIs (WRSIs) for a growing season were calculated as the ratio of seasonal actual evapotranspiration (AET) to the seasonal crop Water Requirement (WR).

The general formula used to calculate WR is as follows:

WR = PET*Kc

Where WR is the seasonal crop water requirement, PET is the reference evapotranspiration and Kc (Table 3.1) represents the crop coefficient. The WR of the crop any a given time of the growing season is calculated by multiplying the reference evapotranspiration (PET) with a crop coefficient (Kc), whose values were published by FAO (FAO, 1998**),** as noted in Table 3.1**.**

However, in the current study, CPI calculations were automated and performed in an Instat (version 3.36) environment. Instat is a type of specialized software used to analyze climate data. In these calculations, the crop coefficients for all the three stages noted in Table 3.1 were combined to generate aggregated CPI values.

For all crops, the indices were calculated from 1980-2007. CPIs were calculated for three different crops, including maize, dry beans and winter wheat. The planting dates for maize were 1^{st}, 2^{nd} and 3^{rd} dekads in October and November, maturing within 120 days. For dry beans, the sowing dates were the 1^{st}, 2^{nd} and 3^{rd} dekads of October, November and December taking 120 days to mature. The sowing dates for winter wheat were 1^{st} dekad of May, followed by 2^{nd} dekad of June and the last dekad was dekad 3^{rd} of July, taking 120 days to mature. These planting dates are recommended by Department of Agriculture, Forestry and Fisheries, South Africa (2010). For all the crops, the maximum water holding capacity was 120 mm. The index begins at 100 and decreases in two ways. First, if there is a surplus of greater than 100 mm then the index decreases by 3 units. Second, if there is a deficit, the index decreases by the percentage of that deficit in relation to the total water requirements for the season (FAO, 1998). In the study, the index less 60 was used as an indicator for crop water stress.

3.9 Conclusion

This chapter included the study area and methodology that was adopted in data collection and analysis. The study area was described in terms of its location, climate, geology, vegetation and the agricultural practices that take place in it. As noted, primary data was collected during an on farm visits using a questionnaire while secondary data was collected from ARC-Centre for Climate, Soil and Water and analyzed using computational methods. Additional secondary data was collected in the computational format from the district Department of Agriculture using the Extension Suite Software (2014). Most of the socio-economic information was obtained from the MAP (2012b) and Local Economic Development (2005).

Chapter 4:

Relationship between Climate and Crop Production

4.1 Introduction

The main purpose of this chapter is to present the results obtained from archival data on temperature and rainfall collected between 1980 and 2007. The research study was conducted in Tshiame Ward in MAP Municipality to determine the impact of climate variability on the production of four grain crops namely, maize, winter wheat and dry beans. In agriculture, environmental variables are used by farmers as primary key indicators for determining crop selection in order to implement relevant mitigation measures. When farmers are able to perceive a change in the environment they might also be able to reduce their susceptibility to the risk that is brought by that change. Therefore, the analysis was based on the need to document the rate of change in both temperature and rainfall for the study area and determine how vulnerable to climate variability crop production is in the area.

4.2 Analysis of long-term weather data to identify occurrences of risks

4.2.1 Rainfall trends

Although farmers in Tshiame Ward noticed an increase in the summer rainfall through observation, results indicate that there is actually a decrease in the total average rainfall during the summer months (October-April). In the study, the total average rainfall for summer and winter months refers to the average of all non-missing daily rainfall for a month. Figure 4.1 shows that the total summer rainfall received between 1980 and 2007 have been highly variable, reaching a maximum of 1011.9 mm / year and a minimum of 444.4 mm / year. The results also reveal that some years (1981 and 1992) were characterised by very low amounts of rainfall (below 500 mm / year), which imposed limits on agriculture. Overall, though the summer rainfall received during the 2000s is higher than the amounts received in the 1980s, as shown by the trend line (regression equation) in Figure 4.1, the difference between the amounts that were recorded during these periods is not statistically significant.

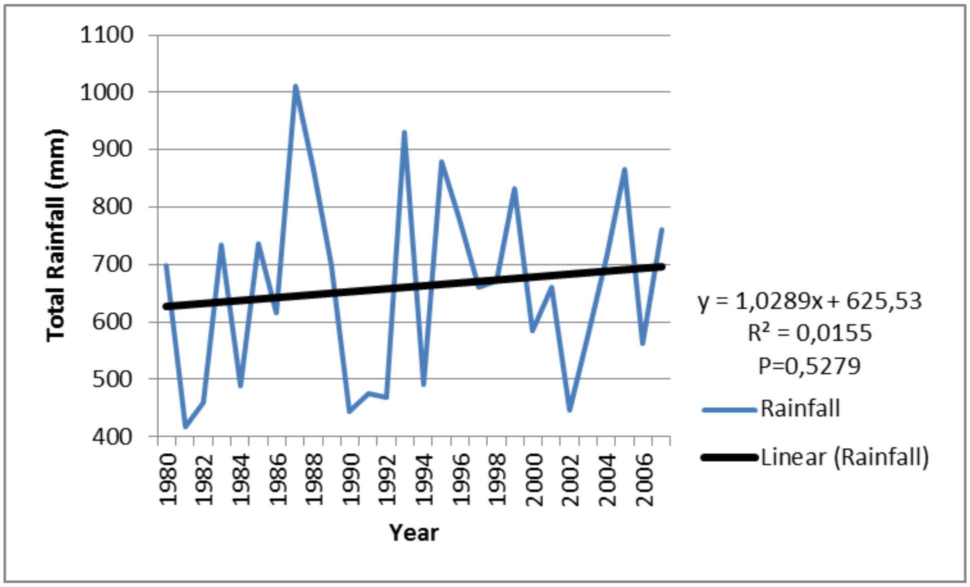

Figure 4.1 The total averaged rainfall for October-April (1980-2007)

The winter rainfall received during the study period varied, reaching a maximum of 173.6 mm in 1996 and a minimum value of 1.7 mm in 1984, as shown in Figure 4.2. However, variations in winter rainfall are not statistically significant.

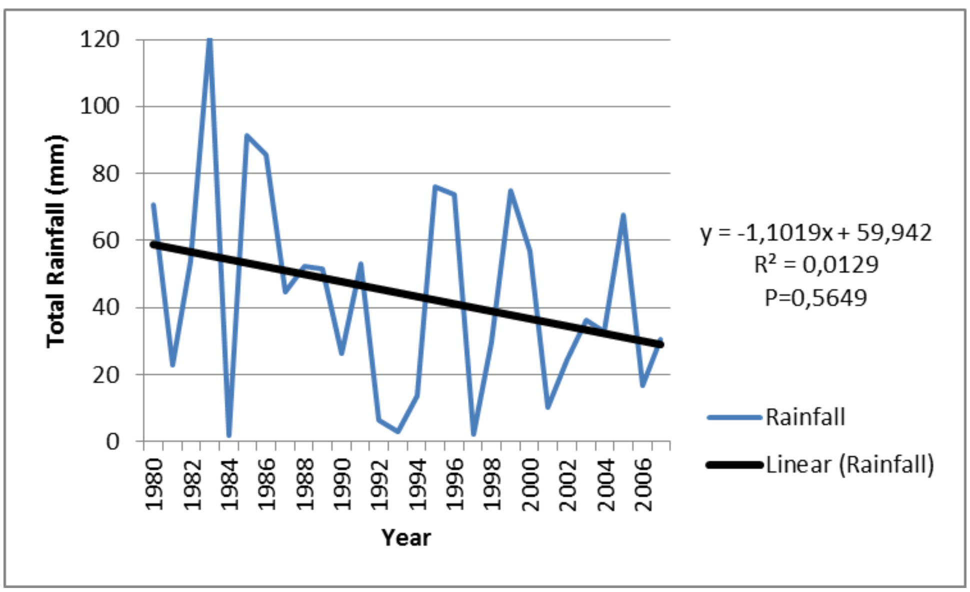

Figure 4.2 The total averaged rainfall for May-August (1980-2007)

4.3 Temperature trends

4.3.1 The average maximum temperature for summer and winter months

The average maximum summer temperature refers to the average of all non-missing daily maximum temperatures for summer months (Figure 4.3). The highest average temperature for summer months was recorded in 1990 when 26.7˚C was recorded. The lowest average temperature was recorded in1989, as shown in Figure 4.3 below.

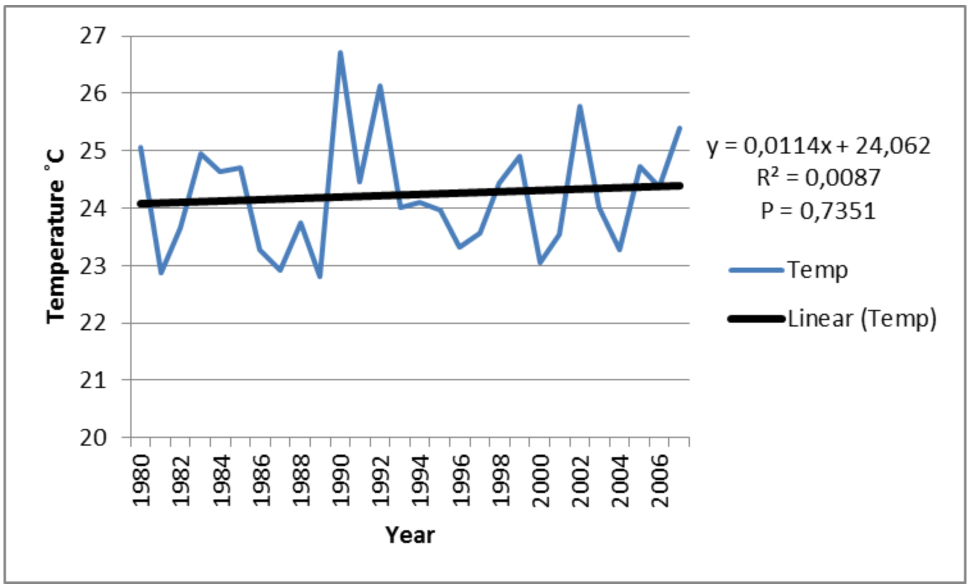

Figure 4.3 Trends in averaged maximum temperature for October-April (1980-2007)

In contrast, the average maximum temperatures for the winter months show less fluctuation (Figure 4.4). Furthermore, the variation of the average maximum temperatures for both summer and winter months is not statistically significant. In the study, the average maximum winter temperatures refer to the average of all non-missing daily maximum temperatures for winter months. The highest average maximum temperature for winter months was experienced in 2005, when a temperature of 19.6˚C was recorded while the lowest was received in 1996, when the value of 15.6˚C was recorded. In addition, the average temperatures for winter months have been showing signs of continuous decrease between 2000 (17.4˚C) and 2004 (17.2˚C).

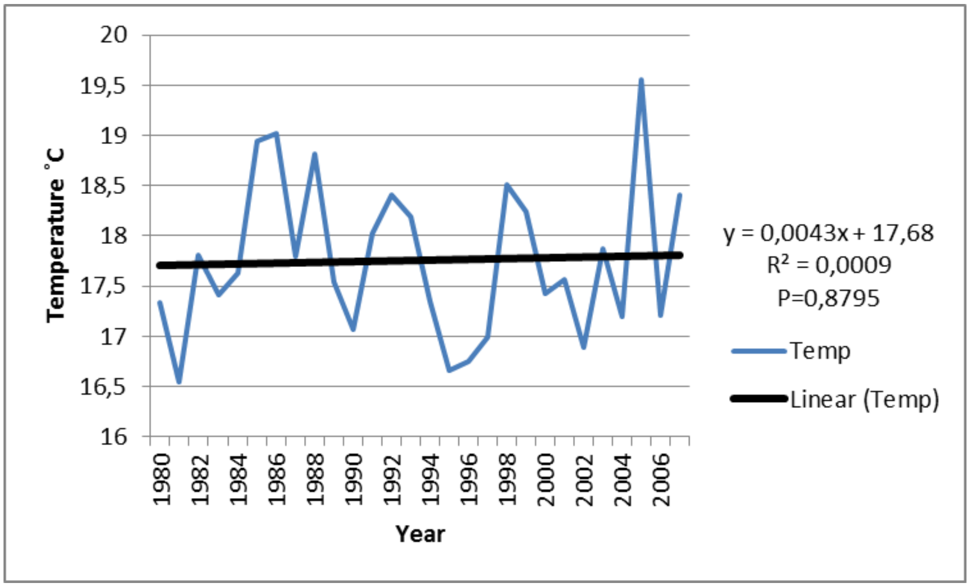

Figure 4.4 Trends in averaged maximum temperature for May-August (1980-2007)

4.3.2 The average minimum temperature for summer and winter months

As indicated in Figure 4.5, there is a high variability in the recorded average minimum temperature for summer months. The average minimum summer temperatures refer to the average of all non-missing daily minimum temperatures for summer months. The increase in average minimum temperature for summer months is observed from 1986 to 1989 and 1991 to 1993. Between the 1980s and 1990s there were fluctuations within the average temperatures for summer months, though overall these variations were not statistically significant. Consequently, the decreasing average temperature for summer months was observed in 2004 and 2007, when the average temperature ranged between 9.6˚C and 10.3˚C.

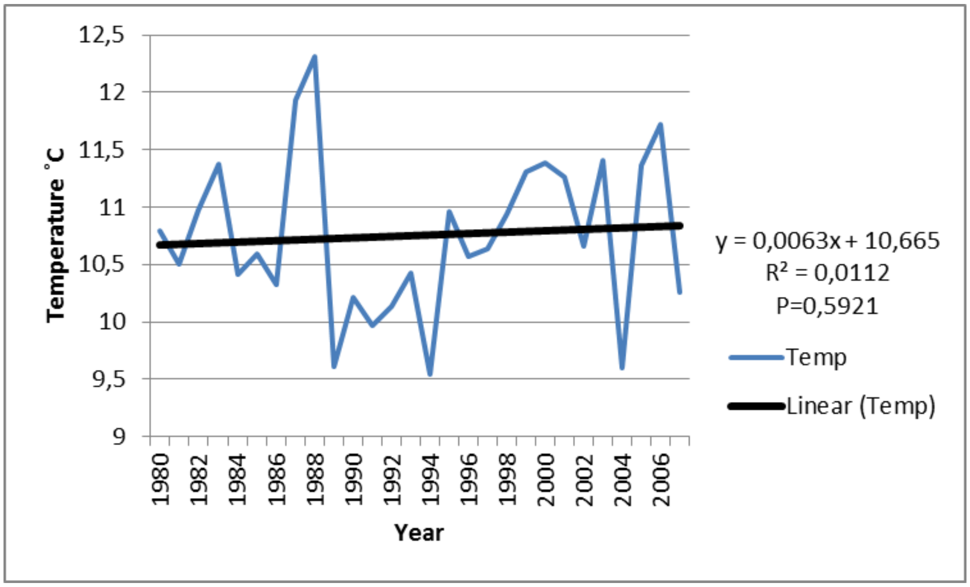

Figure 4.5 Trends in averaged minimum temperature for October-April (1980-2007)

Although the statistical analysis revealed that there is a significant change in average minimum winter temperature. The average minimum winter temperature refers to the average of all non-missing daily minimum temperatures for a month. The highest recorded average minimum temperature for winter months was experienced between the 1980s and 1990s, with the values ranging between 3.4˚C and 3.7˚C respectively. The lowest average minimum temperature of 0˚C and -1˚C were recorded in 1994 and 1995, as shown in Figure 4.6.

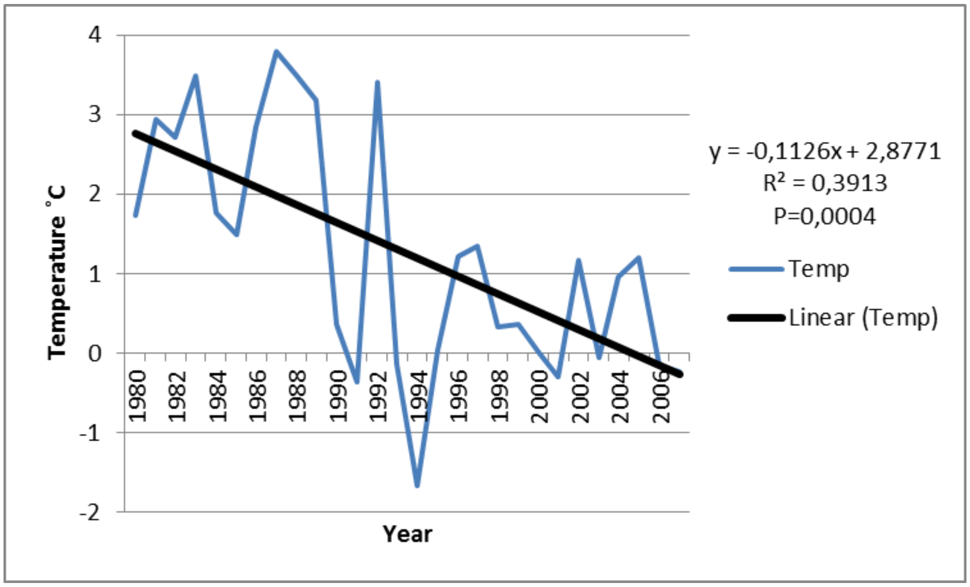

Figure 4.6 Trends in averaged minimum temperature for May-August (1980-2007)

4.4 The onset of rainy days

In Tshiame Ward, the optimal planting season for summer crops such as maize and dry beans starts in October and ends in December. Though the growing season usually ends in April, it can be concluded from Figure 4.7 that the onset of rainy days has been variable between 1980 and 2007. For this region, the onset of rains can be considered as early if it starts in September or earlier and thus can lengthen the growing season. Early onset of rain can extend the growing season, and thus have a positive effect on the production of grain crops such as maize and the beans which are the most profitable crops in the ward. However, the early cessation of rains can have a negative impact on crop production because in most cases, it can result in a shortened growing season.

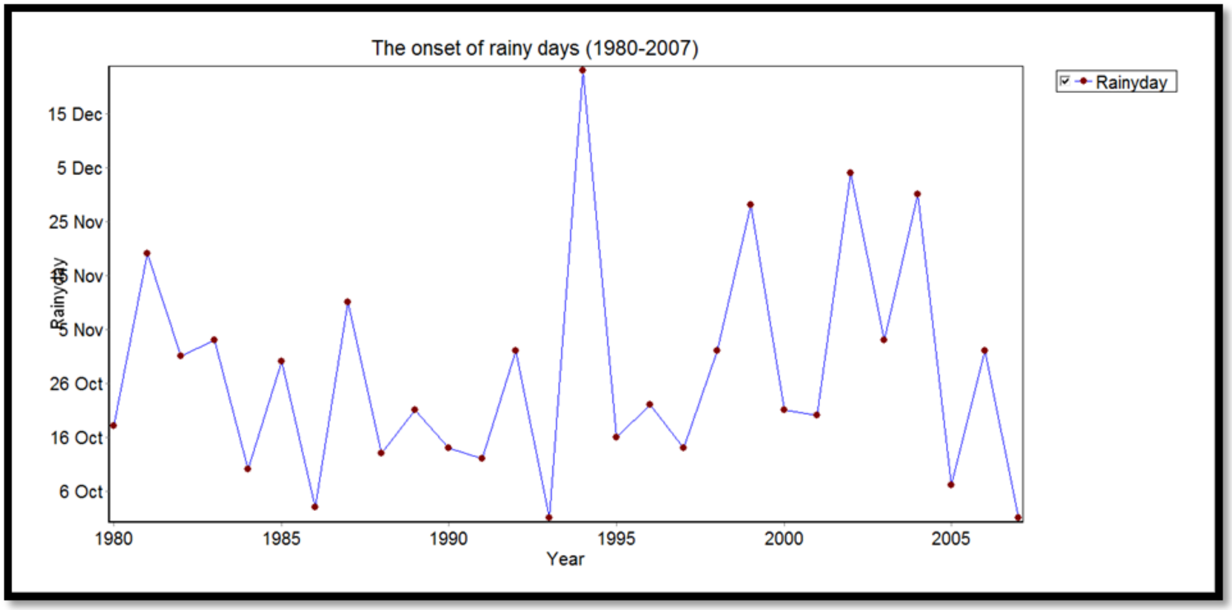

Figure 4.7 The onset of rainy days in Tshiame-Ward (1980-2007)

Table 4.1 shows that there is considerable variability on the onset and cessation of rainy days in Tshiame Ward. The variability in both onset and cessation of rains led to variation of the length of the growing season between 1980 and 2007. From Table 4.1, it can be noted that in some years, the onset of rains is experienced earlier than expected, following the agricultural calendar. The early onset can lengthen the growing period and thus promote the production of grain crops, especially maize, provided that the rainy season ends at the normal time or later than the normal dates. However, there are some years when the onset started late and when the cessation of rains occurred earlier than the expected time. The late onset of rains can lead to a shorter growing season. For example, maize is planted in October, and in order for the crop to survive, the seeds require enough moisture in the soil. Therefore, if such conditions are non-existent, production automatically declines. Therefore, it is sensible to argue that the onset and offset of rains play an important role in agricultural success in the ward.

Table 4.1 shows that the onset of rains in Tshiame Ward starts on the 1st of October and the cessation starts from the 2nd of February when the received rainfall is less than 20 mm. The cessation and onset were determined manually, following the planting days in the region (Table 4.1)

Table 4.1 The onset and cessation of rainy days in Tshiame Ward (1980-2007)

Year	Onset date	Number of rain days (on time)*[1]	Number of rain days (delay)*[2]	Offset date	Duration of the growing season	Length of rainy season (number of days)
1980	23-Sep	7		05-Feb	23Sep-5Feb	149
1981	22-Aug	69		06-Feb	22Aug-6Feb	184
1982	10-Oct		-9	03-Mar	10Oct-3Mar	168
1983	07-Oct		-6	07-Feb	07Oct-07Feb	135
1984	29-Aug	32		08-Feb	29Aug-8Feb	174
1985	30-Oct		-29	07-Feb	30Oct-7Feb	113
1986	30-Aug	31		04-Mar	30Aug-04Mar	208
1987	15-Aug	36		04-Mar	15Aug-04Mar	163
1988	15-Sep	15		02-Feb	15Sep-02Feb	132
1989	21-Oct		-20	13-Feb	21Oct-13Feb	115
1990	14-Oct		-13	03-Mar	14Oct-03Mar	163
1991	12-Oct		-11	18-Mar	12Oct-18Mar	123
1992	28-Aug	33		19-Mar	28Aug-19Mar	195
1993	01-Oct	1		19-Apr	01Oct-19April	191
1994	28-Oct		-27	04-Mar	28Oct-04Mar	149
1995	16-Oct		-17	15-Apr	16Oct-15Apr	180
1996	23-Sep	7		07-Mar	23Sep-07Mar	183
1997	08-Sep	22		15-Apr	08Sep-15Apr	188
1998	11-Oct		-10	22-Mar	11Oct-22Mar	128
1999	28-Nov		-58	20-Mar	28Nov-20Mar	102
2000	19-Sep	11		24-Mar	19Sep-24Mar	168
2001	30-Aug	31		11-Mar	30Aug-11March	171
2002	16-Dec		-76	20-Mar	16Dec-20Mar	84
2003	22-Dec		-82	19-Mar	22Dec-19Mar	79
2004	22-Nov		-52	22-Mar	22Nov-22Mar	106
2005	7-Oct		-6	27-Mar	7Oct-27Mar	147
2006	02-Nov		-9	03-Mar	10Oct-3Mar	168
2007	01-Oct		+1	26-Feb	01Oct-26Feb	93

NB: Normal onset of rains: 01 October when the received rainfall is 20 mm or more. Normal offset is when received rainfall is the less than 20 mm from the 01 February. The growing season: 01October-30 April. **(+)** Early onset. **(-)** Late onset. *[1]The number of days by which rains were received before onset. *[2]The number of days by which rains started after the onset. In this case the onset was 1 October, which is the official date when rains start in the agricultural calendar according to the ARC.

4.5 The link between crop production in Tshiame Ward and climate variables including temperature and rainfall

In the Free State (where Tshiame Ward is located), maize requires a minimum rainfall of 450 mm during the growing season (Department of Agriculture, Forestry and Fisheries, 2010). According to the Department of Agriculture, Forestry and Fisheries (2010), in addition to water supply, maize requires a maximum temperature of 25 °C (Table 4.2), while winter wheat requires a minimum rainfall of 450 mm. Dry beans are planted between October and December months. As noted in Table 4.2, the ideal temperature that is required for winter wheat ranges between 5 °C and 25°C. To the contrary, dry beans require only 300 mm and a minimum temperature of 18 °C. Therefore, if the maximum temperature increases to the levels above the optimum then the crops that are produced in the ward, except wheat, will be severely affected and thus lead to a decrease in yields (Table 4.2).

Table 4.2 Ideal and prevailing environmental conditions for crops that are produced in Tshiame Ward

	Ideal growing conditions**				**Prevailing Conditions in Tshiame**			
Crops	**Tmax**	**Tmin**	**Rmax**	**Rmin**	**Tmax**	**Tmin**	**Rmax**	**Rmin**
Maize	26°C	15°C	600mm	450mm	26°C	18°C	1000mm	417mm
Wheat	12°C	5°C	600mm	450mm	18°C	-1°C	173.9mm	1.7 mm
Soya beans	25°C	15°C	900mm	500mm	26°C	18°C	1000mm	417mm
Dry beans	24°C	18°C	600mm	450mm	26°C	18°C	1000mm	417mm

** Source: Depart of Agriculture, Forestry and Fisheries, South Africa (2010).T=Temperature, R=Rainfall, max=maximum, min=minimum

4.6 The Crop Performance Indices (CPIs)

As indicated in Chapter 3, data on crop yields was not available. This necessitated the use of CPIs, as an alternative approach for determining the link between climate change and variability on the one hand and agricultural viability on the other. As indicated in Table 4.3, in Tshiame Ward the official planting dates for maize, wheat and beans, as recommended by the ARC, vary remarkably. The recommended dates assist the farmers in knowing exactly when it is suitable to plant specific crops.

Table 4.3 The planting dates for crops that are produced in Tshiame Ward

Type of crop	**Planting Date****		**Dekad**
Maize	First planting date	10th October	1
	Second planting date	14th November	2
Beans	First planting date	10th October	1
	Second planting date	14th November	2
	Third planting date	17th December	2
Wheat	First planting date	14th May	2
	Second planting date	17th June	2
	Third planting date	20th July	2

****Official planting dates as recommended by Agricultural Research Council. Dakads refer to the number of 10 day averaging periods of each months, where each months is divided into 10 days starting from the 1st, 10th and 20th day of the month, which includes all the days up to the end of the month (with the exception of February).

4.6.1 The crop performance indices for maize

First planting period for maize crop

The analysis revealed that in the first dekad (10th October) the lowest Crop Performance Indices (CPIs) were recorded in 1981/82 when the index of (42%) was recorded and in 1990/91 when the index of (47%) was recorded. This can be explained by low cumulative rainfall of below 500 mm obtained during the growing period in 1981/82 and 1990/91 (Figure 4.8) .The maximum index of (100%) was obtained in 1988/89 and 1995/96. In addition, the analysis revealed that the year 1985/86, 1993/94, 1998/99 and 1990/2000 also had high index values, with the percentage ranging between (91%) and (94%).

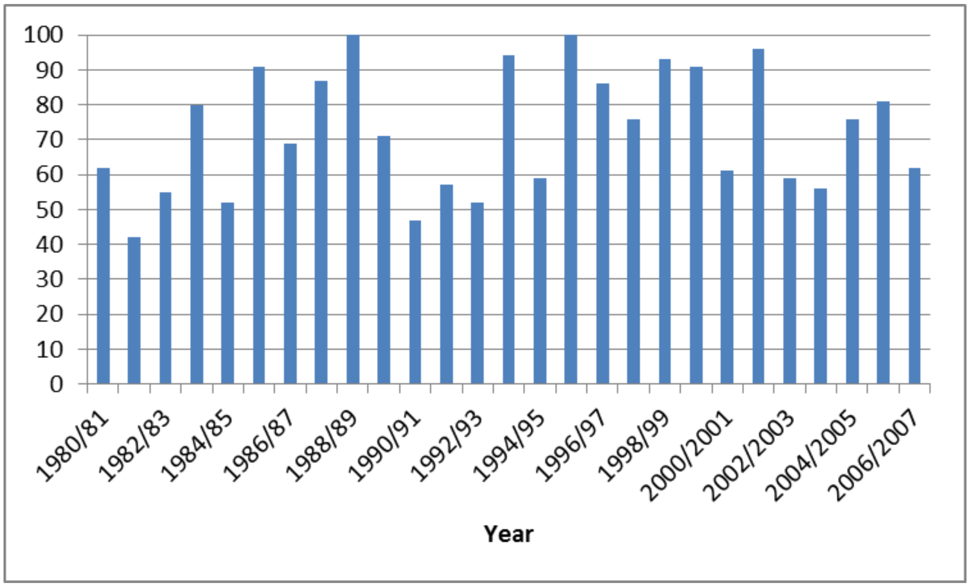

Figure 4.8 The Crop Performance Index for maize planted in October (1980-2007)

Second planting period for maize crop

Data analysis (Figure 4.9) indicates that the CPI values were generally low between 1980/81 and 1981/82 with (48%) and (45%) at the end of 2nd dekad (14h of November). This indicates that the yields for the late maize crop that was produced between 1980 and 1982 were likely to be low compared to those produced in other years due to water stress.

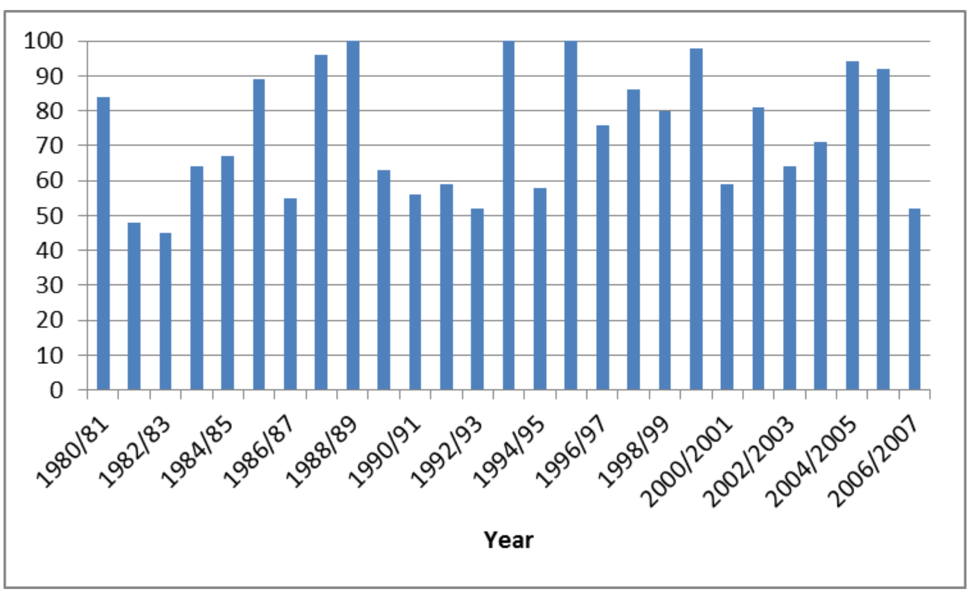

Figure 4.9 The Crop Performance for maize planted in November (1980-2007)

4.6.2 The crop performance indices for dry beans

First planting period for dry beans

Figure 4.10 shows that CPI values for dry beans planted in the 1st dekad (first ten days of October) in (1980-2007) were generally low. The lowest value was recorded in 1981/82 with the CPI value of (62%). There is a great variability of CPI value for beans, where in some years, the CPI values were below (50%) while in some years the value of (100%) was recorded.

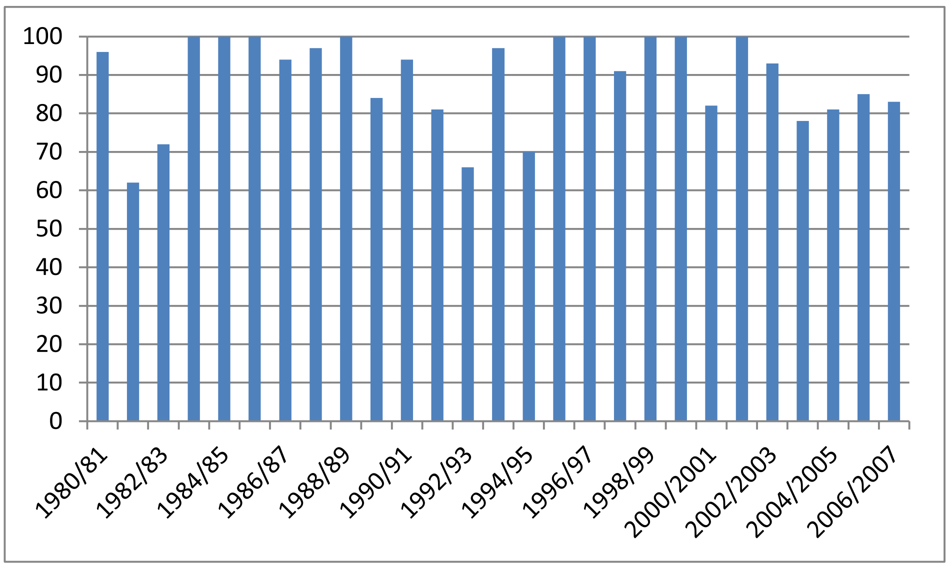

Figure 4.10 The Crop Performance Index for dry beans planted in October (1980-2007)

Second planting period for dry beans

However, the analysis (Figure 4.11) shows that there is fluctuation of CPIs for the beans planted in the 2nd dekad (20 days in November). The 2nd dekad seems to have most favourable conditions that suit the planting of dry beans since the majority of years have CPI values ranging between (90%) and (100%).

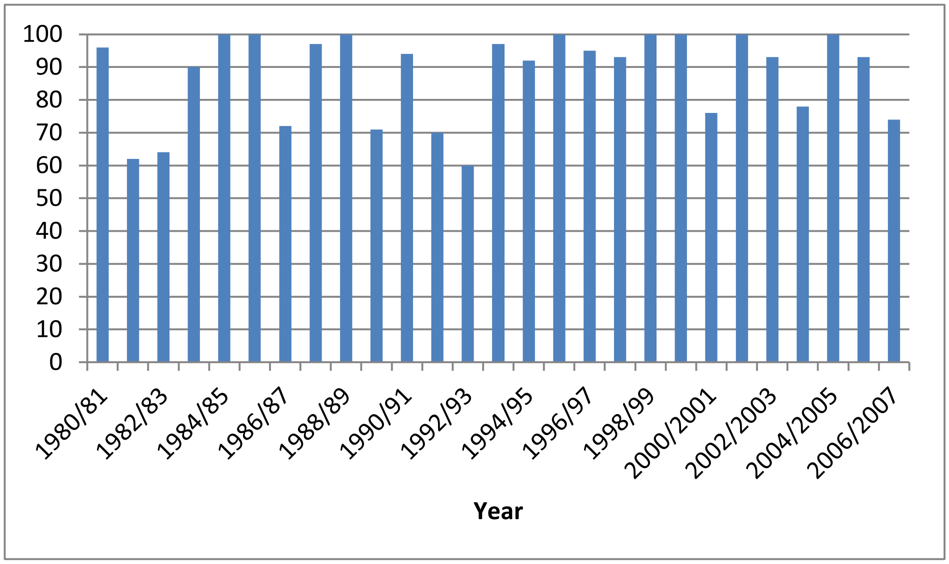

Figure 4.11 The Crop Performance Index for dry beans planted in November (1980-2007)

Third planting period for dry beans

The CPI values for crop that was planted in the 2nd dekad (17th December) as shown in Figure 4.12, ranges between 60 and 70%. These indicate that farmers can successfully grow beans as late as December.

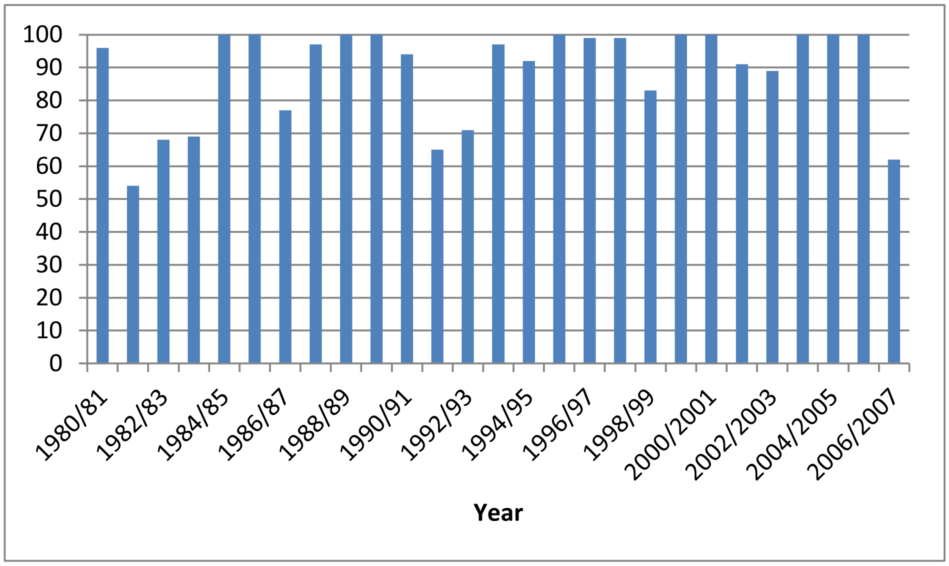

Figure 4.12 The Crop Performance Index for the dry beans planted in December (1980-2007)

4.6.3 The crop performance indices for wheat

First planting period for wheat

Although winter rainfall is very low in Tshiame Ward, the analysis (Figure 4.13) revealed that some years (1987/88 and 1998/99) obtained an index with a maximum value of (100%). This entails that farmers who were planting wheat in May had high chances of reaping good yields. This was made possible by the adequate amount of moisture that was available in the soil during the growing season.

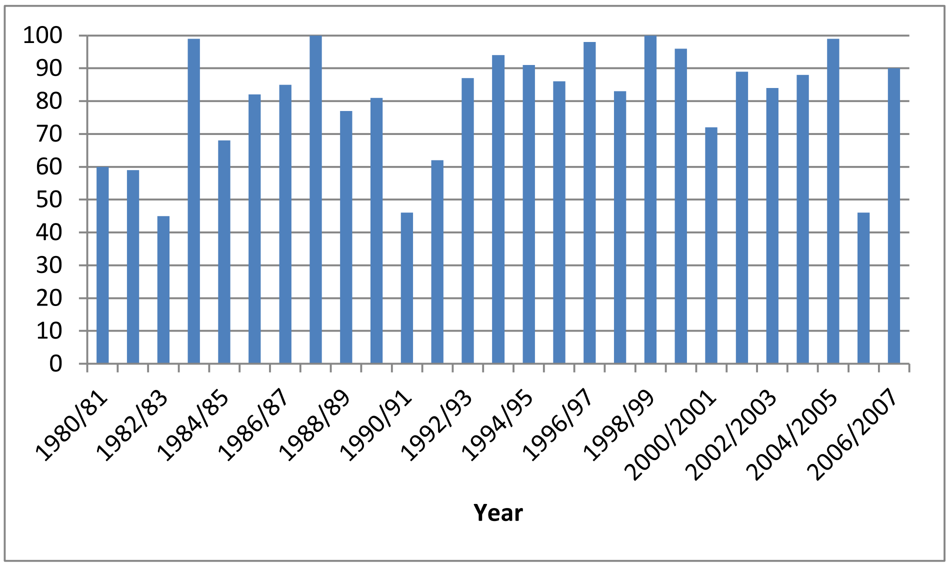

Figure 4.13 The Crop Performance Index for wheat planted in May (1980-2007)

Second planting period for wheat

The analysis (Figure 4.14) revealed that planting wheat in the second dekad (17th June) has also been suitable for good yields. However, some years (1990/91 and 2005/06) were characterized by low index values ranging between 30% and 50%. The fact that 1990/91 and 2005/06 were classified as weak La Nina years, explain the low CPIs for these years.

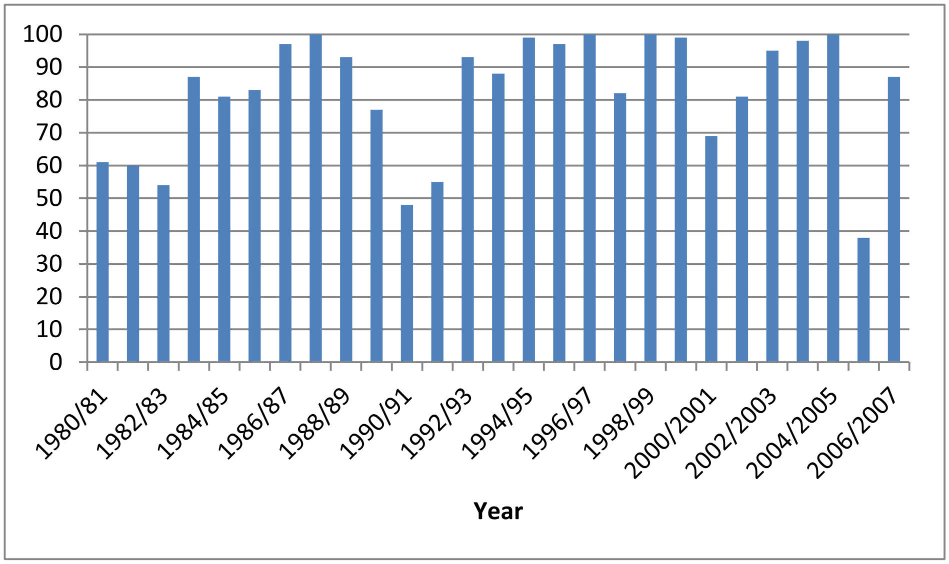

Figure 4.14 The Crop Performance Index for wheat planted in June (1980-2007)

Third planting period for wheat

The analysis revealed that while some of years had index values that were above (90%) others had values that were below (40%), as shown in Figure 4.15. This can be associated with the declining winter rainfall with some years receiving a total winter rainfall that was below was below 60 mm.

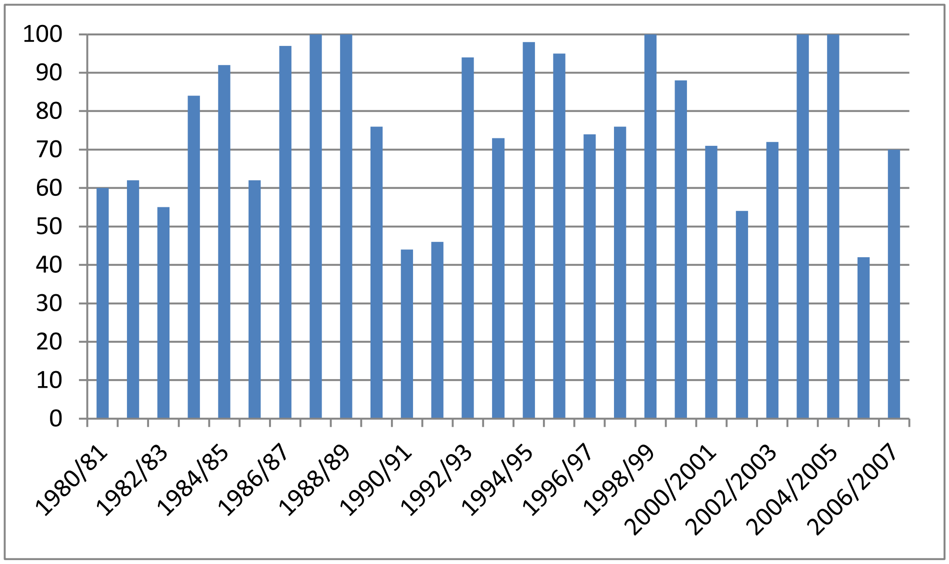

Figure 4.15 The Crop Performance Index for wheat planted in July (1980-2007)

The analysis revealed that some years had indices in excess of (60%), which is the threshold value, while in some years, the CPI were far below this value. For maize, the analysis revealed that 1988/89 and 1995/6 were favourable years since the CPIs reached (100%) implying that crop water requirements were met and high yield expected if other conditions were favourable. In contrast, the analysis revealed that for the maize crop, between 1981 and 1983 as well as 1991 and 1993, the index was below (60%), indicating higher incidences of drought stress. The statistical analysis revealed that climate conditions were generally suitable for cultivation of dry beans since the mean index value was generally above (60%). The high CPIs indicate that there were minimal chances for dry bean being affected by drought stress. Dry beans can be planted in October, November or December. In the region, wheat is planted either in May, June or July, when the amount of rainfall received is below 30 mm. Based on the findings noted above it can be argued that the changes taking place in meteorological variables are not affecting crops equally.

4.7 Conclusion

The analysis of climate data revealed that in Tshiame Ward there has been variability of rainfall and temperature recorded between 1980 and 2007. In some years, the total amount of rainfall received during the winter months was below 10 mm. This means that in those years crops that were produced in the area were likely to be susceptible to drought stress. This explains the relatively low CPIs recorded in those years. Also, in Tshiame Ward, the severity of drought stress has been promoted by the onset of rains that is generally coming late when compared to earlier years. Although the normal onset of rains is in October, rains have been starting as late as November in some years. This has been especially the case during the greater part of the last decade of the study period (Table 4.1). The fact that the first crops of maize and dry beans were planted during the start of the growing season means that the late onset of rains had a negative impact on their total outputs, as signified by low CPI values.

Overall, there has been a variation in average temperatures for winter months in Tshiame Ward, though this variation is not statistically significant. However, farmers need to be more careful when selecting crops to grow by paying attention to the length of the growing season, based on the onset and offset of rains. There is a need for farmers to implement different adaptation strategies since the variability of climate is affecting them differently. The adoption of different adaptation measures based on local conditions will assist farmers in maintaining reasonable yields.

Chapter 5:

Farmers’ Responses to Climate Variability

5.1 Introduction

The aim of this chapter is to present farmers’ perceptions about the relationship between agriculture and climate variability in Tshiame Ward. The results from the analysis of primary data derived from the questionnaire survey are presented in five subsections, including farmers’ perceptions on climate variability, its causes and associated impacts on agriculture, the extent to which climate variability has adversely affected agricultural systems in Tshiame Ward, adaptation measures used by farmers to cope with climate variability, as well as socio-economic factors that influence farmers’ choices of adaptation measures. Farmers’ perceptions on climate variability have been widely incorporated in the present study as a primary step to assess farmers’ capacity to cope with climate variability and its associated impact on agriculture. Farmers’ perceptions on climate variability assist in the evaluation of the adaptation measures used by farmers, as well as the factors that drive them. Therefore, understanding farmers’ perceptions on climate variability will also assist in explaining the views of the farmers on the causes of climate variability and how these views are influenced by demographic factors, including gender, level of education or farming experience, as noted below. In this study, adaptation is identified as an important process in minimizing the vulnerability of agricultural systems to climate variability. Therefore, including the adaptation measures of the farmers at the farm level assists in determining the success of farmers in implementing feasible options for increasing food production in Tshiame Ward.

5.2 Demographic characteristics of farmers in Tshiame Ward

The analyses revealed that in Tshiame Ward demographic characteristics including educational qualifications (Figure 5.1) and farming experiences (Figure 5.2) vary considerably across the farms. As illustrated in Figure 5.1, in Tshiame Ward, 10.5% of farmers attained tertiary education, while 26.3% completed their secondary education and 52.6% completed their primary education. About 10.5% of the farmers had no formal education at all.

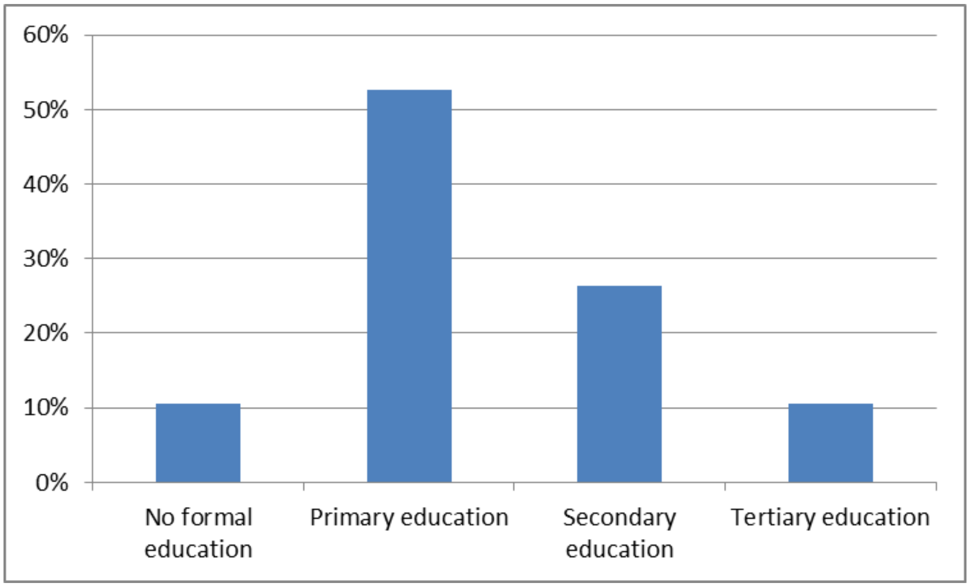

Figure 5.1 Farmers level of education

Among the farmers who were interviewed, 84.2% were male. Although some farmers were highly experienced (Figure 5.2) about 89.5% of the farmers belonged to farmers' organizations, while only 10.5% were not members of such organizations.

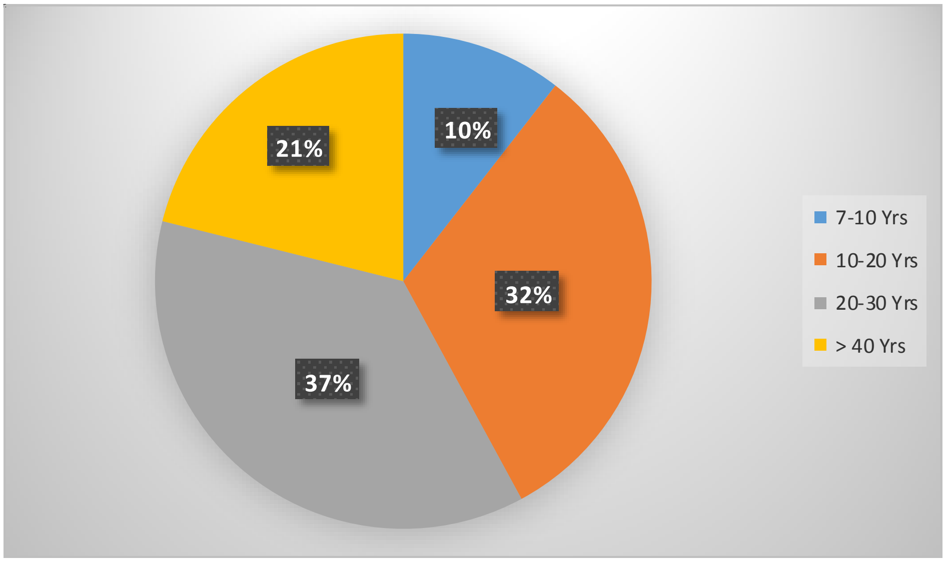

Figure 5.2 Farming experience in Tshiame Ward

The analysis also revealed that in Tshiame Ward, 53% of the farmers had ages ranging between 50 and 60 years, while 26% were aged between 40 and 50 years. The ages of nearly 16% of the farmers ranged between 30 and 40, and only 5% of the farmers were aged 60 and above (Figure 5.3).

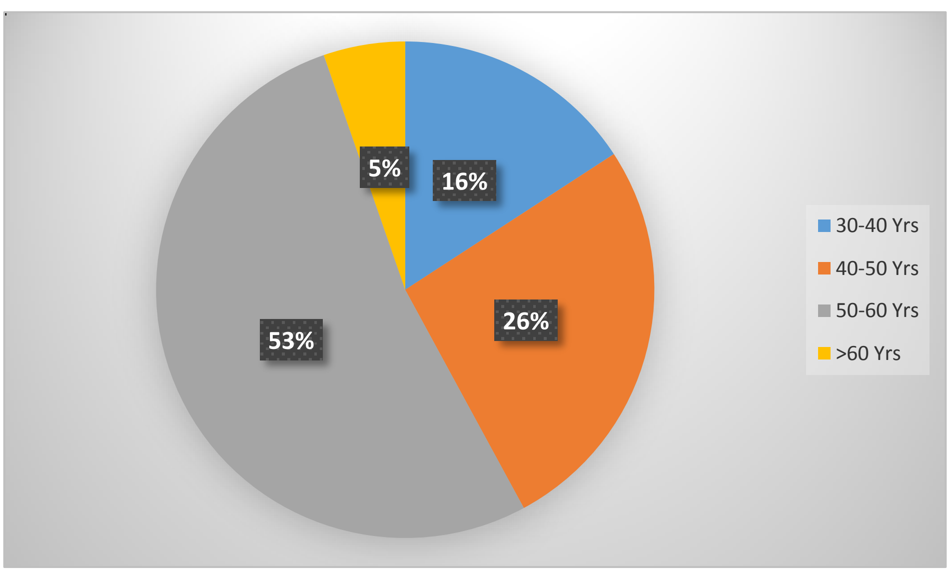

Figure 5.3 Farmers age groups in Tshiame Ward

5.3 Farmers' perceptions on climate variability

Farmers were asked whether the climate in their environment has changed over the years or whether they have perceived any unusual weather related changes in their environment. Almost all the respondents 90% agreed that climate variability was taking place. They justified their claims on changing rainfall patterns, as well as temperature variability. With respect to rainfall, the majority of the farmers reported that when recent years are compared to the past, the onset of the rain season has changed. One of the farmers who were interviewed reported:

> "When I was young, we used to receive our first rains at the beginning of August, but now, the first rains are only coming around October, which is late in terms of the agricultural calendar".

About 58 % of farmers reported that the amount of rainfall received in their area is now becoming less even compared to the past. They also noted that the rains are now more erratic and at times causing floods. Eleven percent of the farmers stated that in the past they were able to determine if they were going to get a wet or dry season using various environmental indicators such as birds, signs on the moon or stars or halos in the clouds. However, (11%) of farmers agreed that it is now becoming more difficult for them to use such indicators because of the unpredictable nature of the climate. Another farmer noted:

> " In the past, I used to get enough groundwater to supply livestock, but now, the amount of water is getting less year by year, even the small water bodies that were on the farm, have dried out."

According to emerging farmers in Tshiame Ward, change in temperature is among the factors that prove that climate variability has occurred in the ward. Some farmers (52.6%) claimed that when compared to the past, summer seasons are becoming hotter, while (47.4%) of the farmers agreed that winter seasons are becoming extremely cold. About 42.3% of farmers noted that the summer season is becoming shorter and colder, while winters are becoming longer and much colder than in before.

5.4 Farmers' perceptions on the cause of climate variability

When weather disasters, including droughts and floods strike, farmers get affected personally and financially, and agriculture becomes a risky enterprise. Therefore, in order to assist farmers to cope with periods of unexpected weather variability, it is important firstly to understand how they view environmental challenges like climate variability (Derresa *et al*., 2011).

When the farmers were asked about the cause of climate variability, some were unsure about their answers though many of them were able to relate their answers to what was happening in their surrounding environment. Relating to their annual agricultural output, most farmers agreed that climate variability is affecting their yields. Some farmers noted that the predictions made by scientists about climate variability were correct. A contrasting view was presented by one farmer who stated:

> "We black people no longer respect our traditions. We are now following western cultures and therefore our ancestors are angry with us and that is why the climate is changing. It is just the beginning, the worst is yet to come."

Another farmer reported:

> "Climate variability is a form of punishment from God, due to the things that are happening nowadays. For example, people are killing each other, children are being raped daily and widows no longer respect their mourning periods."

However, 10.5% of farmers in Tshiame Ward strongly agreed that climate variability is the result of the emissions released from cars and industries which in turn lead to increasing greenhouse gas concentrations in the atmosphere. In addition, the uncontrolled veld fires, burning of coal and wood, increasing levels of dust due to prolonged dry seasons, were among the factors that they associated with causes of climate variability. Some farmers (31%) did not believe that the climatic conditions are changing at all.

> "Climate variability is a natural process because it happens that in agriculture, sometimes we have a bad or good year. Likewise, it happens that we have a wet season this year, and an extremely dry season the following year. Therefore, there is no need for people to panic about climate variability", remarked one farmer.

A significant proportion of the farmers (42.5%) were not aware of what climate variability is. For example, one farmer said:

> "We are uncertain about what climate variability is and its causes and we don't even believe in assumptions made by scientists who even fail to predict the daily weather conditions correctly"

Similarly, about 39.5% of the farmers were more or less confused on what climate variability is because they were unable to differentiate between daily weather changes and climate variability. In general, farmers who gave relevant responses on climate variability and its causes were over the age of 50 years (Figure 5.3). This also results from the fact that most of the questions that the farmers were asked required them to compare past and present environmental conditions.

5.5 The extent to which climate variability has affected agricultural systems in Tshiame-Ward

In Tshiame Ward, 15.8% of the farmers were convinced that environmental conditions in the Ward are changing and that the changes were affecting agricultural production in many different ways, confirming that the farmers hold different views on how agriculture is affected by climate variability For instance, 39.5% of the farmers agreed that the susceptibility of agriculture to climate variability is related to changes in rainfall and temperature patterns.

5.5.1 Perceptions about the impact of changes in temperature and rainfall patterns

Farmers' opinions on both summer and winter temperatures were sought to determine whether these conditions had changed (Table 5.1). For summer, some of the farmers (52.6%) noted that temperatures have increased when compared to the past. In addition to higher temperatures, farmers reported that when temperatures increase, the evaporation rates also increase. Some farmers noted that the combined effects of increasing temperature and evaporation rates have a significant impact on agricultural production in their area. For example, some farmers associated loss of soil moisture with increasing temperatures. The majority of the respondents were mostly concerned about soils that are losing fertility and the declining yields of maize.

Table 5.1 Farmers' perceptions on temperature variability

Temperature (Summer)	**Percentage**
1.Farmers who have perceived increased summer temperatures	52.6
2.Farmers who have perceived decreased summer temperatures	31.6
3. Farmers who have perceived that summer temperature have remained the same when compared to the past	15.8
Total	**100**
Temperature (Winter)	
1. Farmers who have perceived an increase in winter temperatures when compared to the past	26.3
2. Farmers who have perceived a decrease in winter temperatures when compared to the past	47.4
3. Farmers who have perceived that winter temperature has remained the same when compared to the past	26.3
Total	**100**

N=19

About 22.8% of the farmers reported that each and every year they are forced to add more fertilizers such as urea and lime, which are costing them a lot of money. Thirty-six percent of the farmers claimed that they now use more fertilizers to keep the soils productive, particularly during these current years of unpredictable weather conditions. In addition, most farmers strongly associated the increased pest attack on crops with the increasing temperatures. One of the respondents reported:

> "In the past, I used to treat my crops for all sorts of insects, but currently I fail to do that by myself because I am no longer familiar with some of the insects that affect my crops. Therefore, I am forced to go and seek help from the Department of Agriculture since the insects are becoming more resistant to the insecticides and are attacking crops more frequently when compared to the past."

In relation to winter temperatures (Table 5.1), about (47.4%) of farmers claimed that winter temperatures are becoming extremely low when compared to past years. The intense cold winter season tends to have significant impacts on crops. One of the farmers reported:

> "Nowadays, the winter season is becoming longer compared to previous years with increasing incidence of extremely cold days. This remains a challenge because even when we plant crops on time, following the agricultural calendar, the crops are affected by frost before they reach the flowering stage. Such problems affect our monthly income during the winter months because farmers are forced to adopt frost protection methods such as early planting to protect the crops."

The overall picture that the majority of the farmers presented during interviews was that of an increase in temperature during the summer season and a decrease during the winter season while the minority claimed that these environmental conditions have remained the same (Table 5.1).

5.5.2 Perceptions about the impact of changes on rainfall distribution and intensity

During the interviews, farmers expressed different views about changes in rainfall distribution and intensity (Table 5.2).

Table 5.2 Farmers' perceptions on the intensity and distribution of rainfall

Rainfall intensity	**Percentage**
1. Farmers who perceived rainfall intensity as better than before	26.3
2.Farmers who perceived rainfall intensity as worse than before	57.9
3. Farmers who perceived rainfall intensity as The same as before	15.8%
Total	**100**
Rainfall distribution	**Percentage**
1. Farmers who perceived rainfall distribution as better than before	26.3
2. Farmers who perceived rainfall distribution as worse than before	57.9
3.Farmers who perceived rainfall distribution as the same as before	15.8
Total	**100**

N=19

The majority of the farmers (57.9%) perceived changes in both the intensity and the distribution of rainfall (Table 5.2). They stated that rainfall intensity varies significantly from one year to another. When the onset is late, it happens that it rains too much, leading to seasonal floods. Most of the farmers (42%) argued that the distribution of rainfall has changed over the years. These farmers reported that rainfall intensity has increased, especially during the growing season. However, the perceived change is associated with geographical positioning of farms in Tshiame Ward. As reported by one respondent:

> "Although at times it happens that the rainfall is evenly distributed in the region, I have experienced variations in rainfall between places that are closed to each other with some areas experiencing prolonged dry periods while others are challenged by floods during the same season."

A minority of the farmers (10.5%) strongly felt that the mountains and the strong winds prevailing in the eastern Free State region, where Tshiame Ward is situated, contribute greatly to the varying climate patterns.

5.5.3 Perceptions regarding the impact of changes on the onset and offset of rains

In Tshiame Ward, a (97.4%) of farmers (Table 5.3), perceived the onset of rains as coming late, when compared to the past. The majority of the farmers have observed that they are now more frequently affected by drought, particularly during the summer season. In the Tshiame Ward, the perceived shift in the cropping season and stunted growth in plants are associated with the late onset of rains. About (73.3%) of farmers (Table 5.3) reported that the offset of rains is now coming early as compared to the past. During interviews, farmers showed that they were more aware of changes in rainfall patterns than other environmental variables, including temperature.

Table 5.3 Farmers' perceptions on the onset and offset of rains

Farmers perception on the onset of rains	**Percentage**
1. Farmers who perceived the onset of rains as earlier than before	5.3
2. Farmers who perceived the onset of rains as later than before	94.7
Total	**100**
Farmers perception on the offset of rains	**Percentage**
1. Farmers who perceived the offset of rains as earlier than before	73.7
2. Farmers who perceived the offset of rains as later than before	26.3
Total	**100%**

N=19

A 76 years old respondent reported:

> "I am well experienced with farming, but looking at the current weather changes, I am totally confused. In the past everything was normal. Winter seasons used to start on time and end on time, but now, temperatures drop excessively, even during the middle of summer. Again, the rainfall pattern has changed. It happens that in a year, particularly during the summer season, the amount of rainfall is reduced and at the same time, coming late."

Most farmers (53.2%) in Tshiame Ward stated that when rainfall comes late, it is often erratic and it comes with hail, especially around January, after which a prolonged dry season is experienced. Therefore, since agriculture is climate sensitive, it is severely affected by such unusual weather events, thus affecting the economic viability of the farmers.

5.6 Adaptation methods

Influenced by their perceptions about climate variability, farmers in Tshiame Ward have adopted a number of adaptive practices. These practices are based on the already existing knowledge and the perceived changes in the climatic conditions.

5.6.1 Link between climate variability and adaptation methods

As shown in Figure 5.4, some farmers make various adjustments to protect their crops against unfavourable weather conditions.

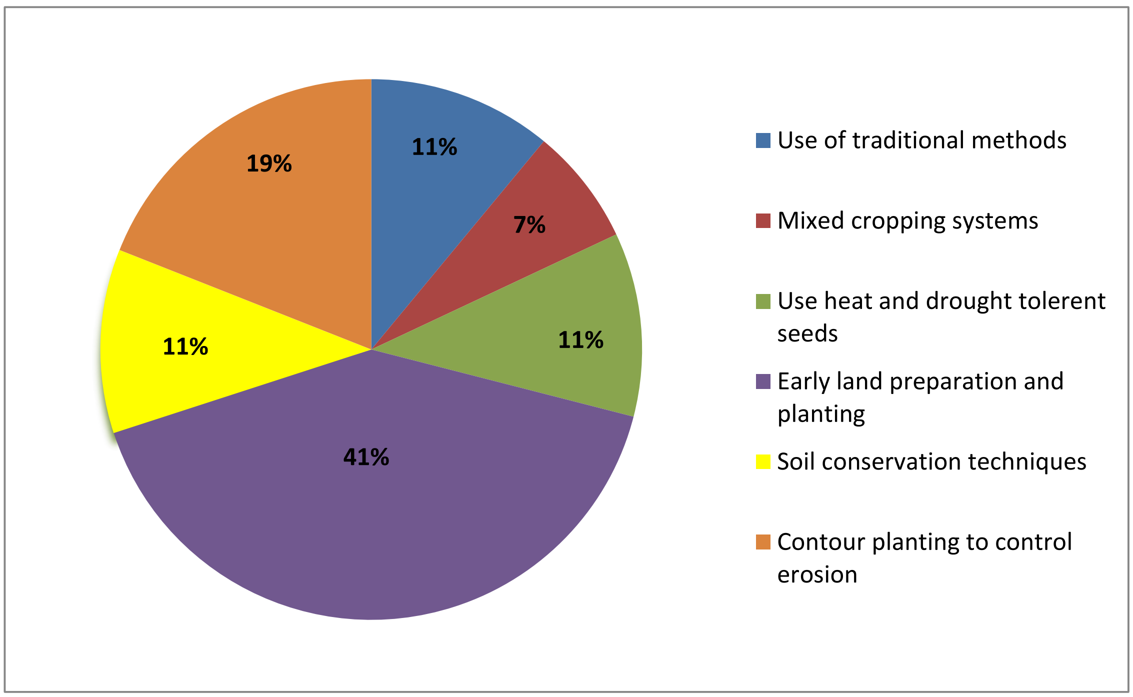

Figure 5.4 Adaptation methods employed by farmers to cope with climate variability

Descriptive statistical analysis revealed that (20%) of farmers cope by changing the cropping dates while (21%) rely on early land preparation. The farmers (21%) mentioned that these practices increase the chances of reasonable maize and beans harvests. They stressed that early land preparation and planting is a very important strategy for coping with climate variability. One of the farmers stated:

> "If you are a farmer and you are unable to plant early, you put your-self at risk since the onset and offset of rains are unpredictable. Again, it might happen that the summer season becomes short due to winter seasons that are generally becoming longer when compared to the past. Moreover, agriculture is climate sensitive and any undesirable change in weather affects crops and livestock, therefore it is also important for one to insure farming operations because weather disasters are unpredictable."

About (11%) of the farmers still believe in coping strategies that are based on indigenous knowledge. For instance, one 38 year old farmer said:

> "Although I have attended several training courses about the importance and the use of new technology in farming, I still rely in the use of indigenous knowledge. The methods that were used by our forefathers are still useful because even today, they are working for me. For example, I rely on the use of a full moon to check if we are going to get some rains during the summer season, and also the mating of some animals which indicate the change in season."

Again, during the interviews, one farmer remarked:

> "I still use the traditional *muti* provided by traditional doctors to minimise the intensity of the hail that we receive every year when we are about to harvest"

The adaptation measures adopted by the farmers in Tshiame Ward were significantly associated with the perceived changes in the weather and its associated risks on agriculture. Some farmers (21%) claimed that even when one has money and all the other necessary resources, they can only become successful farmers if they manage to cope with the current weather conditions. In addition, 43.2% of the farmers reported that unavailability of climate variability information, access to credit and availability of adequate physical resources like farm equipments will decrease the vulnerability of farming operations to climate variability. Thirty-one percent of the farmers claimed that if they get better access to climate variability information, they could determine the extent of their susceptibility and at the same time they will be able to implement the adaptation strategies that will be relevant to their level of susceptibility. One farmer remarked:

> "Even if one has access to information about climate variability risks, if he or she is not getting any financial support, it means that the farmer will be unable to adopt any form of adaptation measures since the majority of such measures require the purchase of additional resources such as tractors, organic manure, pesticides and cash to pay the farm workers."

The analysis revealed that 26.3% of farmers noted that it is important for one to have his or her own physical resources because renting farm equipment are expensive. Even if one is unexpectedly affected by environmental disasters such as floods, adapting to such events one needs to react quickly because one has to rely on borrowing resources from other farmers their responses will be late and the extent of the impact will be worse.

5.6.2 Socio-economic challenges faced by farmers regarding the implementation of adaptation options

The implementation of adaptation options by farmers is identified as the best tool to minimize the current and future adverse effects of climate variability on agriculture. However, in Tshiame Ward there are still a number of challenges faced by emerging farmers when it comes to the improvements in managing farming operations. The common set of challenges that were mentioned by farmers during the on- farm visits includes lack of access to credit facilities, lack of physical resources and lack of access to climate variability information.

Most farmers (62.3%) reported that the main causes of agricultural failure in the region are poverty and lack of financial support from financial institutions. They reported that borrowing money is becoming more difficult when compared to the past. One of the farmers reported:

> "When one borrows money from the bank, one enters into an agreement on monthly repayment installments, which are often too high in most cases, and in

> turn it happens that environmental conditions turn out not to be suitable in a particular year and one fails to make enough profit and thus fails to pay back the loan. This becomes a major challenge because the credit keeps on accumulating more interest and in most cases farmers become indebted and are sometimes forced to sell or rent their farms unintentionally."

Some respondents (42%) reported that financial problems affect not only their farming operations but the livelihood of their families as well. For example, one won't be able to support children who need money for food and school fees. Again, some farmers (72.6%) claimed that various institutions, including the Department of Agriculture, no longer assist them financially, even when they are affected by veld fires, which have become common in the Free State. For example one can report fire damage on time but will never get any assistance.

Although only a few farmers (26.3%) have reported the issue of unavailability of adequate land for farming as a challenge, one farmer stated:

> "Owning more hectares of land is not a solution because as a farmer, it forces you to get more workers which have to be paid and at the same time, we are currently not even making enough profit to properly manage the sizes of farms that we own."

Some of the interviewees (52.3%) argued that climate variability remains a challenge because farmers are still struggling to develop the farming methods that are suitable enough to cope with climate variability. This was strongly associated with the inability of most farmers to interpret or to get access to climate variability information. Figure 5.5 indicates that (45%) of farmers use radio to receive information about climate variability while (26%) depend on television. Another (10%) reported that they receive information from extension officers, while the remaining (19%) depend on other sources, including SMS on daily weather from Agricultural Research Council. The analysis also revealed that none of the farmers use newspaper, farmers union or friends and neighbours as source of information on climate variability.

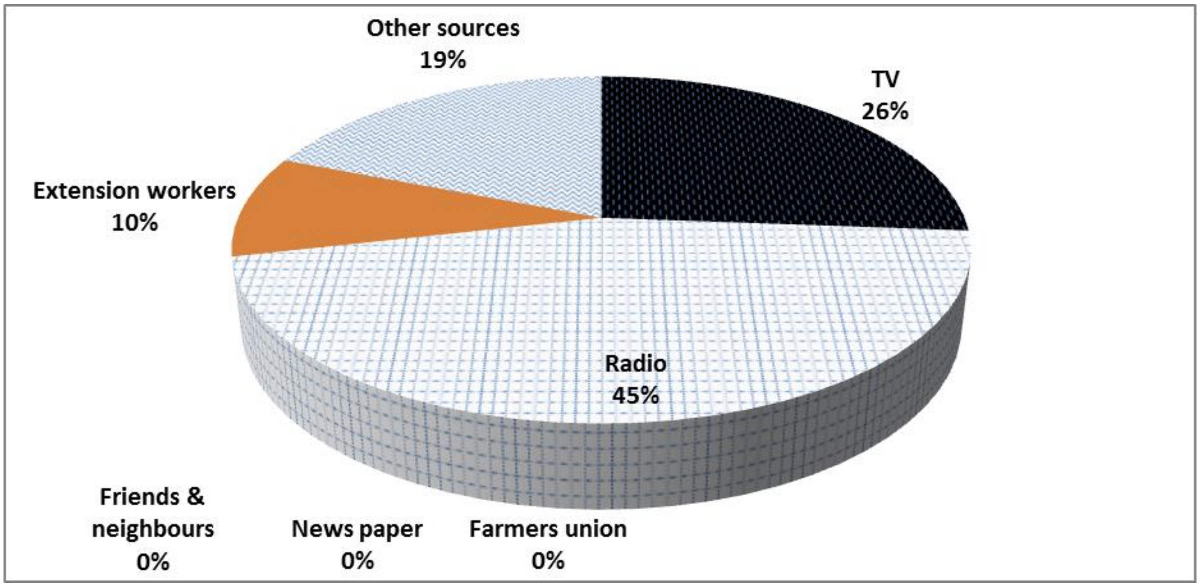

Figure 5.5 The instruments that are used by farmers as source of information for climate variability

5.7 Conclusion

As shown in this chapter, statistical analysis revealed that farmers' perceptions on climate variability and its impact on agriculture can be influenced by a variety of factors. Change in temperature and rainfall patterns greatly influence farmers' perceptions on the ongoing weather patterns. During the on farm-visits, the majority of famers (52.3%) demonstrated that they were more familiar with the concepts of climate variability than others (32.6%) and that they were clear about the impacts that result from it. This can be associated with the ongoing project by Agricultural Research Council-Centre for Soil, Climate and Water, where by weather stations are being installed on farms to enable farmers to record daily weather conditions, including both temperature and rainfall. The other important contributing factor for farmers' knowledge on climate variability can be associated with regular visits by extension officers to their farms. Farmers (62.4%) agreed that extension officers provide them with information on climate variability, as well as its associated impacts on agriculture. However, although the majority of farmers (26.3%) were relating climate variability to weather conditions, some farmers (68.3%) were relating it to social factors such as change in social mileau.

However, about (52.3%) of farmers reported that climate variability is taking place and that they have been forced to develop adaptation measures to cope with it. In addition, the majority of the farmers (65.3%) stated that adaptation is important, since weather conditions are becoming unpredictable. Although the majority of farmers (65.3%) hold the opinion that technological advancement will save agriculture during this period of unexpected weather variation, some farmers reported that they rely on the methods that were used by their fore-fathers. The use of indigenous knowledge system in the area can be strongly associated with the fact that the farmers in the area are based in a rural area, where culture and tradition are still highly valued.

Chapter 6: Discussion

6.1 Introduction

This chapter discusses the results of the research study, which have been presented in Chapter 4 and Chapter 5. As noted in Chapter 1, the objectives of this study are as follows:

- To determine the impact of change in meteorological variables on crop in Tshiame Ward, in the eastern Free State Province of South Africa
- To investigate farmers' perception about the cause and the impact of climate variability
- To investigate farmers' adaptation strategies to climate variability
- To analyze the socio-economic conditions of farmers and determine their influence on the vulnerability of agricultural production to climate variability

However, the discussion in this chapter is based on the results from the analysis of both primary and secondary data, using the P-S-R Model. The results are used to assess how vulnerable agricultural systems in Tshiame Ward are to climate variability and also to evaluate the adaptation methods that are employed by farmers to cope with undesirable changes resulting from climate variability.

6.2.1 Pressures Induced by Climate Variability in Tshiame Ward

In the context of adaptation to climate variability, the application of the P-S-R Model has revealed that the major driving forces affecting agriculture in Tshiame Ward are both environmental and social factors. Though change in meteorological variables such as temperature and rainfall is evident, it is not statistically significant. However, CPIs have been variable, depending on amount of rainfall available. Nevertheless, as indicated in the responses of farmers during interviews some farmers could not cope with these seemingly insignificant variations. There are a number of conditions that explain this situation, one of which is lack of access to credit facilities and farm equipment.

Lack of access to credit facilities and farm equipment, as well as and lack of access to weather information are among the factors hindering agricultural operations in the region. A combination of prevailing socio-economic and environmental conditions is therefore responsible for poor agricultural performance in the area. As indicated in their responses, farmers were not well adapted to cope with droughts and floods, due to lack of financial resources. Consequently, the farmers were unable to reduce the effects of such events since they have inadequate physical agricultural resources and money to purchase seeds or fertilizers needed for replanting when such events occurred. As shown by the results in the preceding chapter, this situation was worsened by lack of climate variability information among the farmers and their lack of appropriate adaptation strategies, thus leading to poor yields and low incomes.

In this study, the statistical analysis of climate data revealed that in Tshiame Ward there is great variability in both temperature and rainfall. Some famers were able to perceive the change that is taking place in their environment. The fact that farmers are able to perceive changes that are taking place in their environment using meteorological variables such as temperature and rainfall is supported by findings from a previous study by Derresa *et al* (2011). Derresa *et al* (2011) reported that farmers' perceptions on climate variability are driven by the ability of the farmers to perceive the change that is taking place in weather, by comparing current and past events, and their ability to understand the risk that is brought by such changes. In addition, the farmers' views on winter temperature were consistent with the results that were revealed by the analysis of climate data. Chapter 4 has shown that winter temperatures are decreasing, though that change is not statistically significant. However, the decrease is likely to expose crops to frost attack, especially wheat which is produced in winter. The analysis revealed that the summer rainfall received in Tshiame Ward is about 650 mm on average while the winter rainfall is around 17 mm. The crops that are produced in Tshiame Ward require a maximum rainfall of 900 mm and a minimum rainfall of 600 mm (Department of Agriculture, Forestry and Fisheries, 2010).

Although the analysis has revealed that crops in Tshiame Ward are susceptible to drought stress, trends shown by CPIs actually show an improvement in conditions that are favourable for the production of maize, beans and wheat. The CPIs values for maize range between (40%) and (100%), while the CPIs for beans range between (62%) and (100%). The CPI values for wheat range between (45%) and (100%). Such percentages indicate that there is a great variation in CPI values and such variation will affect the production of the crops grown in the Ward since some of the CPI values are below the threshold value of (60%). The other negative change that has affected crop farming is related to the recurrence of unexpected weather conditions, to which some farmers have not yet fully adjusted.

Some CPI values in Tshiame Ward reflect dekadal variations rather than change in the long term trends. The inter-annual variations in CPI indicate the possibility that soil-water moisture available during some years has been insufficient for crop growth and therefore farmers had to develop adaptation strategies to survive such change. Farmers need to develop adaptation strategies that counteract the challenge of soil moisture deficit causing reduction of plant water potentials that in turn may cause dehydration turgor loss, xylem cavitation, stomatal closure and reduction of photosynthesis (Osbahr *et al*. 2011).

6.2.2 Farmers' perceptions about the cause and impact of climate variability

Although farmers agreed that the predictions made by scientists on climate variability, such as increasing temperatures reduced rainfall and drought in some regions (IPCC, 2007) were correct, some farmers raised contrasting views. Some farmers in Tshiame Ward agreed that climate variability is the result of people who are no longer respecting tradition and causing the ancestors to become angry and thus punishing them with unfavourable weather conditions. According to a study by Mertz *et al* (2007) the majority of farmers in rural areas do not believe that climate variability is a scientific process. Rather, they believe that atmospheric conditions are changing because "God'' is angry because of human sinful nature. In Tshiame Ward, farmers who mentioned relevant response on climate variability causes and impacts were the older ones and those who are well experienced in farming, irrespective of qualification. Such farmers reported that the causes of climate variability include the smoke released from cars and industries that lead to the warming of the atmosphere. The findings of the current study are supported by Derresa *et al* (2011) who contended that emerging farmers are able to perceive climate change best due to the trending reports by (IPCC, 2007) or due to currently ongoing popular climate science debates.

In general, farmers in Tshiame Ward were convinced that environmental conditions such as temperature and rainfall are changing and undermining agricultural systems in their area.

Relating to their annual agricultural output, most farmers agreed that climate variability is affecting crop yields. Such claims strengthen research findings by Scruggs and Benegal (2012) who noted that the acceptance of climate variability by farmers is prompted by declining agricultural production. The notion of declining agricultural production due to climate variability is also supported by Ziervogel and Erickson (2010).

6.3 The State of Agriculture in Tshiame Ward

The state of agriculture in the study area, varies from year to year as perceived by the farmers, and as reflected by CPIs. Farmers in Tshiame Ward are at the mercy of the environmental conditions that affect their area. As noted above, the late onsets of rain associated with climate variability affect most farmers who fail to cope with such circumstances. This is the major challenge faced by farmers in the area, since most farmers are not practicing irrigation. Though some farmers depend on the boreholes for water supply, this does not provide a permanent solution to water shortage on the farms because the boreholes often dry up as well. The shortening of the cropping season resulting from climate variability makes the farmers vulnerable to drought, leading to loss of production due delays in crop maturity. Although climate variability is evident in Tshiame Ward, this phenomenon does not affect farmers equally. This is because farmers' respond to climate factors differently.

6.4 Responses to Climate Variability in Tshiame

Farmers in Tshiame Ward use various form of adaptation options to minimize the impact of climate variability. In relation to drought stress, farmers responded by changing the cropping dates and using heat and drought tolerant seeds. Contour planting was also another widely practiced method in the region. It is clear that in Tshiame Ward, farmers respond because they are affected. Since they are not affected equally, farmers use the different adaptation method at different times due to different pressures. In response to the early offset of rains in the region, farmers are now planting and preparing the land early. This is done to ensure that crops complete their growth cycle and thus allowing farmers to get better yields. In Tshiame Ward farmers also rely on indigenous knowledge to cope with pressures from climate variability. The use of traditional charms to protect their crops from hail storms, noted in Chapter 5, is a typical example. The flowering of certain plants, appearance of certain birds and mating of particular animals are used as important signals for change in seasons by farmers. There is no doubt that in Tshiame Ward farmers respond towards the environmental conditions they are experiencing and this makes their adaptation method region specific. In the region some of the adaption measures are adopted by farmers was influenced by the socio-economic status of the farmers. As indicated in Chapter 5, only a small number of farmers use heat and drought tolerant seeds since such seeds are too expensive to the majority. The following section discusses some of the coping strategies that have been adopted by farmers.

6.4.1 Farmers coping strategies to climate variability

In order to cope with the perceived climate variability, farmers in Tshiame Ward have adopted a number of adaptation strategies. The results of this research study revealed that some of the practices adopted by the farmers were based on the already existing knowledge. McCarl (2010) maintains that effective adaptation and mitigation measures are adopted by those farmers who perceive the danger that is brought by the changing climatic conditions. The need for adaptation measures that are region specific, especially for emerging farmers is supported by Biesbroek *et al*., (2009), who reported that climate variability is a continuous process that will not affect farmers equally. This means that the extent of the vulnerability of farmers is not uniform. One reason that explains this situation is that farmers respond differently to environmental changes. In Tshiame Ward, one form of adaptation measure that was practiced by some farmers was the use of indigenous knowledge. As noted in Chapter 5, in Tshiame Ward, reliance on indigenous knowledge system is associated with the fact that the area is based in a rural area where cultural traditions are still highly valued. Previous studies have noted that indigenous knowledge systems shape not only the adaptation options that are adopted by farmers in an area, but that can also be adopted in other rural areas where farmers are similarly challenged by poverty and lack of technological resources (Adger *et al*., 2009; Thomas *et al*., 2007; Erestain, 2009).

In Tshiame Ward, the fact that some farmers were able to perceive the change that is taking place in the environment made the farmers realize the need to adopt coping measures to combat the negative impacts of the changing weather conditions. The majority of the farmers are now becoming more aware of the planting dates that are recommended by the ARC. This shows that they are now more aware that environmental conditions are changing and in order for one to succeed in farming they need to cope with these conditions. In order for them to cope with the flooding conditions that prevail during heavy downpours of rain most farmers resort to contour planting, to reduce land susceptibility to soil erosion, especially where soils are shallow. Early land preparation, the use of liming and use of artificial fertilizers also help farmers to maintain crop yields. This is important since the area is dominated by Class 3 land type, which consists of soils of low fertility. These soils are easily affected by climate variability.

6.4.2 Maladaptation in Tshiame Ward

The fact that farmers in Tshiame Ward are confusing climate variability with climate change is a possible source of maladaptation. For example, the CPI trends showed that rainfall is still sufficient to support crop production in Tshiame Ward. However, farmers claimed that rainfall has decreased, compared to the past. This suggests that farmers are prone to making decisions based on wrong perceptions. This is similar to findings from a research study by Syukrizal *et al* (2009), who observed that risk perception is positively correlated to maladaptation. Farmers reported that they use drought tolerant seeds, which they may not actually require. Because such seeds are expensive and difficult to acquire, especially where farmers are also challenged by financial problems, this means that the farmers will remain vulnerable to climate variability. Thus, some of the responses by farmers do not address the real problems that are posed by climate variability in their area. The extent of their vulnerability will be accelerated by farmers who are spending money on expensive seeds rather than purchasing physical resources like tractors and other implements. However, according to Adger and Barnett (2009), in developing countries farmers do have intensions to implement relevant adaptation measures but they do not carry them out due to lack of objective capacity, because of lack of resources, knowledge or social support.

In Tshiame Ward, farmers were confusing unexpected weather changes with climate change due to the popularity of the concept ‘‘climate change’’ driven by the skills development programmes provided by ARC-Centre for Soil, Climate and Water causing them to underestimate the danger of the small challenges that will be brought by changing weather conditions. Therefore, maladaptation among farmers in Tshiame Ward is caused by inability of the farmers to understand the actual stressors and factors that determine the risk they face. The Department of

Agriculture could provide more support to farmers so that the problem of maladaptation is lessened. This lessens the chances of farmers relying on inappropriate farming techniques, especially where farmers are short of resources and depend and equipment hired from other farmers. In most rural areas farmers face challenges such as poor infrastructure, unstable or weak institutions and inadequate access to resources, making them highly vulnerable (Hulme, 2011).

6.4.3 The relationship between socio-economic characteristics of farmers and vulnerability to climate variability

The analysis of the socio-economic data indicates that the challenges faced by farmers will accelerate the extent of the vulnerability of their agricultural operations to climate variability. The common set of challenges that were mentioned by farmers include lack of access to credit, lack of physical resources, as well as lack of access to information about climate variability. The inability of farmers to purchase physical resources such as tractors, as well as other disaster management equipments were identified by Knox *et al* (2010) as some of the major factors that undermine farmers ability to cope with climate variability. The fact that farmers depend on borrowing or exchanging resources means that they are delayed when implementing some adaptation strategies. A case in point is where farmers have to replant, and those from whom implements have to be sought require the same resources for their operations. Also, due to financial constraints farmers are unable to hire enough workers to perform some operations. This means that they are affected by time losses and in most cases they end up recording poor yields.

In Tshiame Ward, the poor dissemination of information on climate variability will remain a challenge since some farmers are illiterate. Similar challenges were highlighted in a study by Blackdon and Wodon (2006), who observed that lack of farming skills, resources and inability of farmers to access climate information are among the common barriers that worsen the susceptibility of agricultural operations to climate variability. However, another research study by Karl *et al* (2009) concluded that it is not only access to information that is important, but also the ability of farmers to use climate information to produce functional knowledge which can assist them to gain control over climate variability.

6.5 Conclusion

From the results obtained in Chapter 4 and 5, it is clear that there are several factors that affect agricultural production besides the changing weather conditions. Such factors include poverty, unavailability of physical resources such as tractors and climate science information. However, farmers' perceptions on climate variability also determine the success or the failure of farmers in agriculture. Where farmers are unable to perceive the risks brought by climate variability, their vulnerability is worsened, especially where maladaptation is prevalent. In the case of Tshiame Ward, there is a need for the Department of Agriculture and other related stakeholders to support farmers, not only financially but also with the relevant skills and information, since crop production is complicated by unexpected weather conditions associated with climate variability.

Chapter 7:

Conclusion and Recommendations

The current study has managed to gauge farmers' understanding of the causes of climate variability, in the context of their perceptions and the available historical climate data. Farmers' views on the implementation of adaptation measures were also assessed in this study. The conclusions of the study are outlined in this chapter and recommendations made in order to reduce the extent of the vulnerability of agricultural systems to unexpected weather conditions associated with climate variability. The conclusion and recommendations drawn from this study are discussed below.

7.1 Conclusion

This research study revealed that in Tshiame Ward, temperatures and rainfall amounts are changing. However, these changes are not significant. As shown in the preceding discussion, the responses of the farmers to environmental pressures induced by climate variability, are the coping strategies that they adopt, even though some of which exhibit elements of maladaptation. The responses do not match the pressures, leaving agriculture in in a relatively unsatisfactory state. However, the change is not statistically significant, as shown in the results in Chapter 4. The CPI results have revealed that the available soil moisture is sufficient to support the production of maize, beans and wheat in the area. Although the existing variability in temperature is not significant, temperature fluctuations may accelerate the vulnerability of agricultural systems to climate variability. The soils dominating the area, include low fertility soils such as Glenrosa, Mispah and Plinthic Catena, which are susceptible to erosion. Poor soil fertility may be worsened by climate variability. Accordingly, the land use types, including the Class 3, Class 4 and Class 6 dominating the area impose drastic limitations to cultivation since they are characterized by shallow soils that are susceptible to water erosion restrict rooting zones for plants. Such challenges are limiting crop production in the area.

The fact that farmers were implementing adaptation strategies based on conditions prevailing in the immediate environment helps some farmers to cope better with risks of climate variability. However, there are several factors that have prevented some farmers from developing effective adaptation measures in Tshiame Ward. Some of the common factors that hamper farmers' adaptation include lack of access to credit facilities, lack of physical resources and lack of access to climate variability information. Therefore, support from the Department of Agriculture and other relevant stakeholders could assist in minimizing the vulnerability of agricultural systems to weather in the ward. The kind of support that farmers would need includes financial assistance, physical resources, inputs and extensive training by extension officers through workshops and the on farm visits. The availability of weather information on time will also be helpful since it is difficult for the majority of farmers to access such information through newspapers and radio, as well as their inability to convert such information into practice.

7.2 Recommendations

7.2.1 Recommendations in terms of farmers' preparedness

The majority of the farmers in Tshiame Ward are vulnerable to climate variability. Therefore, in order for them to maintain high crop production, it is important for the Department of Agriculture to assist them with the resources that can cushion them from climate variability. This form of assistance can include the provision of agricultural equipment or implements which will enable the farmers to respond in time, in the events that they have to adjust their agricultural calendars. NGOs, as well as government departments can also provide the farmers with skills development support through training so that they can cope better with unexpected weather variations associated with climate variability. In the ward, extension officers could organize outreach programmes so that farmers will get more information about weather conditions. This is important because it will address the problem of maladaptation. Therefore, the dissemination of weather information through workshops and on farm visit by extension officers will be of great importance in addressing this problem. The Department of Agriculture and other relevant stakeholders such as NGOs and community-based organizations could play an important role in disseminating weather information to the farmers. The information could be presented in form of flyers, posters, calendars or any other reader friendly forms that can easily be understood by the farmers. There is therefore need to engage well trained extension officers to work with the farmers in order to provide them with all necessary skills including the ability to interpret the results revealed by climate science simulation models.

It is important for farmers to be taught about climate variability as well as its associated impacts on agriculture. This is necessary because some of the farmers were unable to differentiate between climate variability and climate change. The inability to develop adaptation measures that are region specific for the farmers may lead to an increase in the vulnerability of their agriculture operations to climate variability. There is also a need for farmers to develop the adaptation strategies that are region specific since climate variability will not affect regions equally. In addition, there is a need for adaptation policy developers to incorporate indigenous knowledge when designing the mitigation measures. This is important since the majority of the farmers rely on environment indicators based on indigenous knowledge systems to interpret the changes that are taking place in the environment.

7.2.2 Recommendations for evaluation of adaptation measures employed by farmers

If farmers decide to adapt to any form of change, there is a need to ensure that the coping strategies that they adopt are appropriate. Again, farmers have to be informed that they need to consult the current adaptation policies in order for one to implement adaptation measures that are effective. This will guide farmers to always adapt effectively to existing risks. The effective soil conservation techniques must also be taken into consideration when implementing mitigation measures since soil plays the significant role in agriculture. However, farmers need to be made aware that it is not only the soil that is supposed to be considered when implementing adaptation measures but other environmental risks as well. The potential effects of climate variability such as prevalence of pests and weeds need to be taken into consideration when designing mitigation measures. Government should ensure that appropriate policies are developed to enable farmers to cope better with climate variability. These policies could spell out the kind of support that farmers can access from government in the event of weather calamities or could relate to how water resources should be managed.

7.2.3 Recommendations on farm management

Farmers need to be trained on general farm management, for example, effective water usage, but in this case, it will be of great importance for farmers to be trained on how to harvest water in preparation for drought periods. Farmers need to be assisted with record keeping. This is important because when farmers are keep records on crop yields, climate data, fertilizers used and planting methods it will be possible to plan better for climate variability.

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APPENDIX SECTION

APPENDIX A

Questionnaire

The purpose of this questionnaire survey is to assess how farmers view climate variability and its impact on agricultural systems in the eastern Free State. The results of the survey will assist in identifying the adaptation methods that are used by farmers to reduce the negative impact of climate variability on crop production. Any information provided by the farmers will be used for research purposes only and will be treated confidentially. When completing the questionnaire indicate your response by ticking the appropriate box with "X'' or by filling the blank spaces provided, where necessary.

GENERAL INFORMATION

QUESTIONNARE NO:

Farm details

Farm name:	
Size of the farm (hectares)	
District	
Location (GPS coordinates)	
Number of workers	

SECTION A: DEMOGRAPHIC CHARACTERISTICS OF THE FARMERS

1. Gender

MALE		FEMALE	

2. Age

<20	25-35	35-45	45-55	65-75	>75

3. Level of education

1. No formal education	
2. Primary education	
3. Secondary education	
4. Tertiary education	

4. Marital status

1. Single	
2. Married	
3. Divorced	
4. Widowed	

5. Type of farming activity

1. Livestock	
2. Crop farming	
3. Mixed farming	

6. Farming experience (years)

1. 1-3	
2. 4-6	
3. 7-10	
4. > 10	

SECTION B: FARMERS PERCEPTIONS ON CLIMATE VARIABILITY

8. What do you understand by the term climate variability?

....
....
....
....

9. In your own opinion, do you believe that the climate variability is taking place in the region?

YES		NO		NOT SURE	

10. Have you encountered any climate variability related risks on your farm?

YES		NO		NOT SURE	

11. If yes, explain

....
....
....
....

12. How do you receive information about climate variability?

1. TV	
2 Radio	
3. News paper	
4. Farmers union	
5. Friends and neighbours	
6. Extension workers	
7. Other sources?	

13. Is the information practically useful enough to assist you in carrying out your farming operations?

YES		NO	

14. If yes, in what way is the information helpful? Explain.

....
....
....
....

15. What do you think is the main cause of climate variability?

....
....
....

SECTION C: CLIMATE VARIABILITY IMPACTS ON CROPS

16. Do you notice any changes on crop yields in relation to the size when compared to previous years?

YES		NO	

17. Where does the water you use for agriculture come from?

1. Dam	
3. River	
4. Tap	
5. Rain	
6. Other	

18. Do you have water all year round?

1. Almost never we have sufficient water	
2. Sufficient water in three months in the year	
3. Sufficient water in six months in a year	
4. Sufficient water all year round	
5. Plenty of water all year round	

19. Has scarcity of water been affecting your agricultural operations?

YES		NO	

20. If yes, explain?

………
………
………
………

21. What cropping system are you using under changing climatic conditions?

1. Mixed	
2. Wide spacing	
3. Shifting to quick maturing crops	
4. Cultivation of vast area in different direction	
5. Crop rotation	
6. mono cropping	
Others	

SECTION D: FARMERS STRATEGIES IN RESPONSE TO CLIMATE VARIABILITY DISTURBANCES

22. Have you noticed any persistent changes in the mean temperatures?

Summer season	**Winter season**
1. Increased	1. Increased
2. Decreased	2. Decreased
3. The same	2. The same

23. Have you noticed any persistent changes in the total rainfall?

Summer season	**Winter season**
1. Increase	1. Increased
2. Decrease	2. Decrease
3. The same	3. The same

24. Have you noticed any persistent changes on the onset of rains?

Summer season
1. Earlier than before
2. Later than before
3. The same

25. Have you noticed any persistent changes on the cessation of rains?

Summer season
1. Earlier than before
2. later than before
3. The same

26. Have you noticed any persistent change on rainfall intensity?

Summer season
1. Increase
2. Decrease
3. The same

27. Have you noticed any persistent changes on rainfall distribution?

Summer season
1. Better
2. Worse
3. The same

28. Have you noticed any persistent changes in the occurrence of the dry season?

1. Increased	
2. Decreased	
3. The same	

29. Have you noticed any persistent changes on the onset of frost?

1. Earlier than before
2. later than before
3. The same

30. Have you noticed any persistent changes on the cessation of frost?

1. Earlier than before
2. later than before
3. The same

31. When do you experience the hail?

1. Increased
2. Decreased
3. The same

32. Which adaptation options have you employed to reduce the negative impacts arising from climate variability in relation to **crop**s?

1. Mixed cropping systems	
2. Use heat or drought tolerant seeds	
3. Changing the cropping dates	
4. Early land preparation and planting	
5. Application of soil conservation techniques	
6. Contour planting to control erosion	
7. Use of traditional methods	

33. Can you conclude that the coping mechanisms you adopted helped to ease the effect of climate variability?

YES		NO	

34. Give your reasons

……
……
…………………………………………………………………………………………

35. Did you and your family receive any form of support from government departments or any other agencies regarding adaptation options for coping with climate variability?

YES		NO	

36. If yes, specify.

………
………
………
…….

37. If yes, how did you find out about the organization you received help from?

1. Friends and families?	
2. Farmers union	
3. Community association	
4. New media	
5. Others	

38. Which of the following factors do you think are likely to decrease the vulnerability of your operations to climate variability?

1. Availability of information	
2. Access to credit	
3. Adequate of labour	
4. Adequate land	
5. Potential for irrigation	
6. Availability of appropriate seeds	
7. Availability of physical resources (e.g. Tractors, planters)	

Appendix B

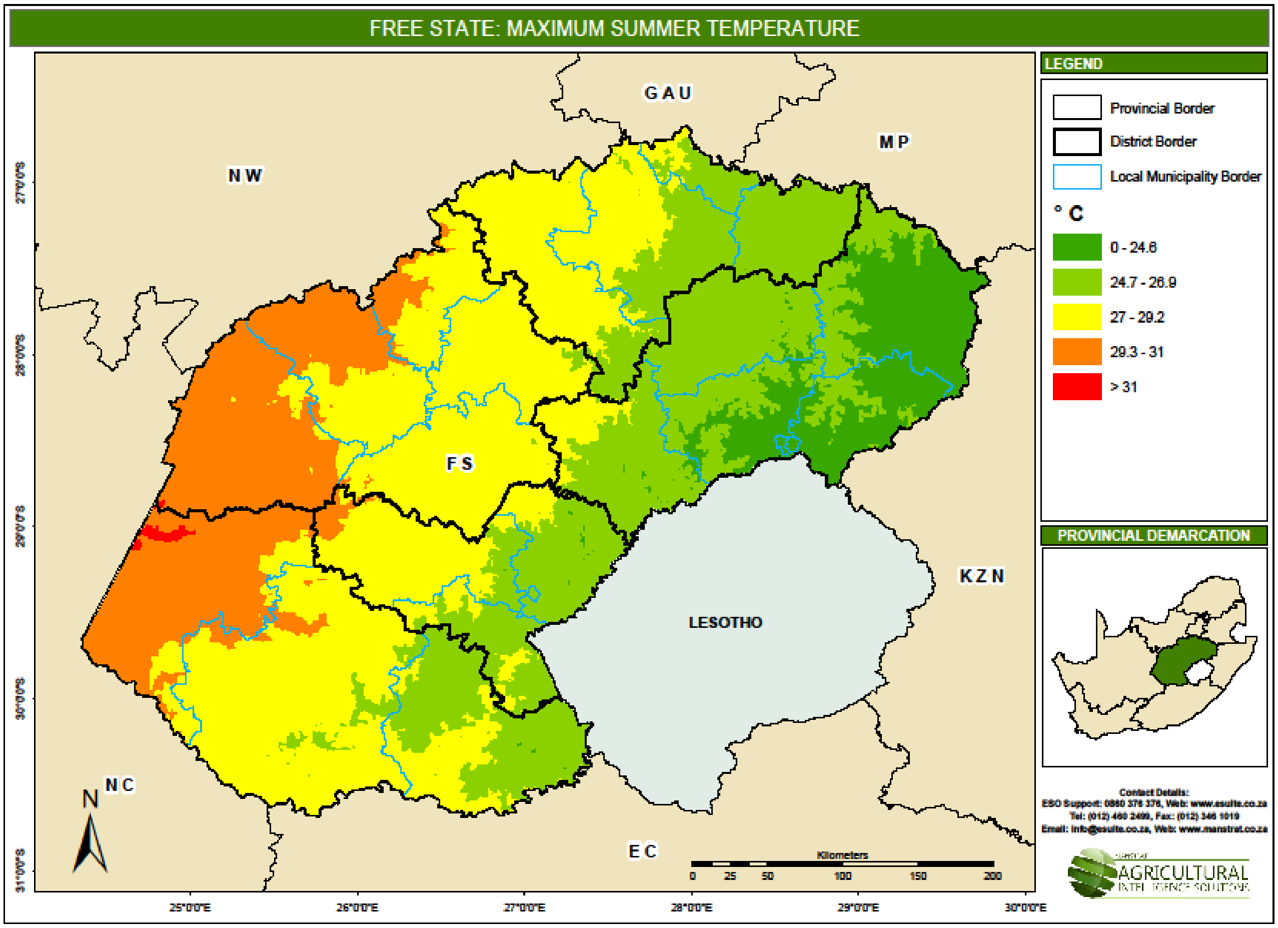

Figure 3.4 The maximum summer temperature for Free State Province. Source: Extension Suite (2014)

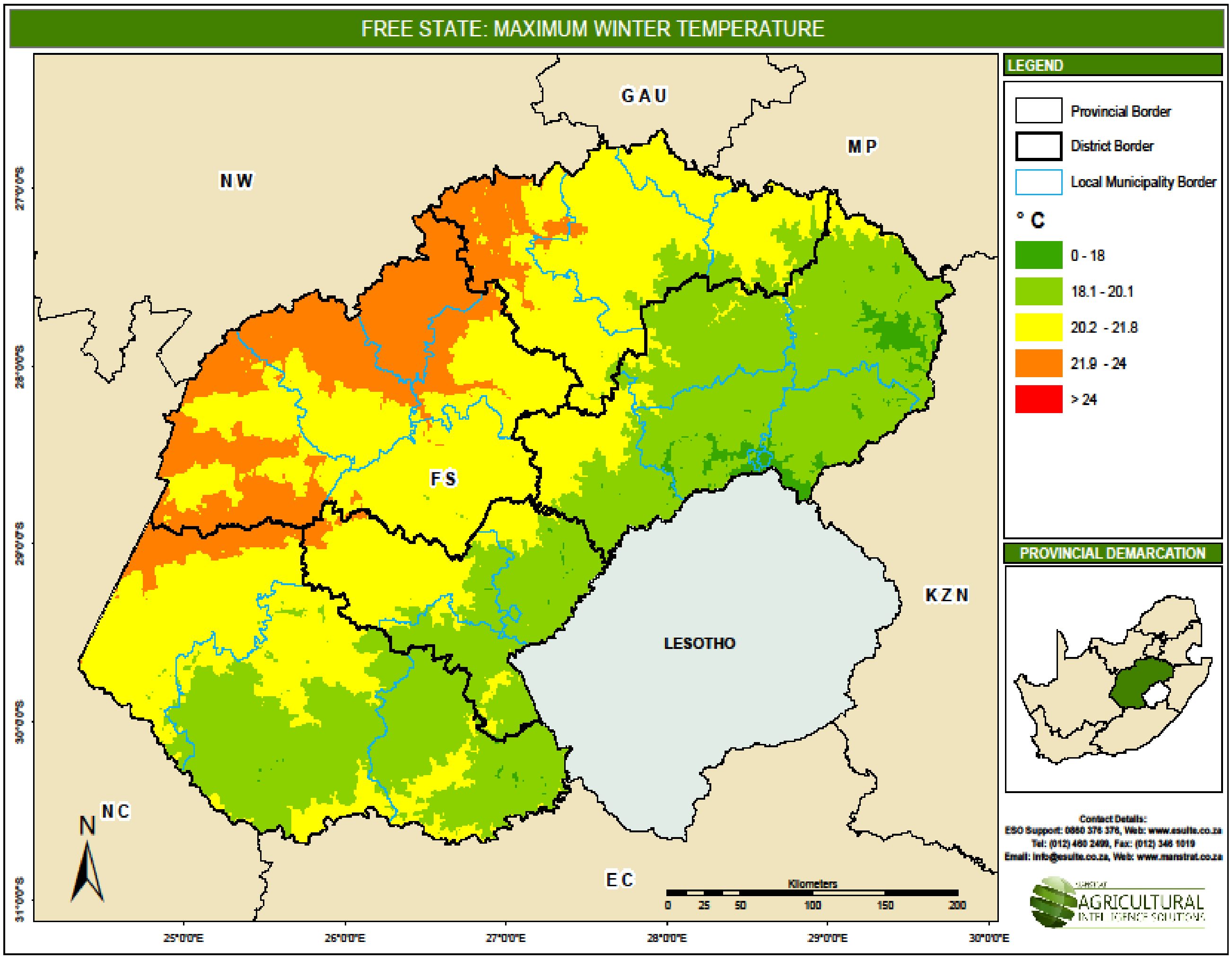

Figure 3.5 The maximum winter temperature for Free State Province. Source: Extension Suite (2014)

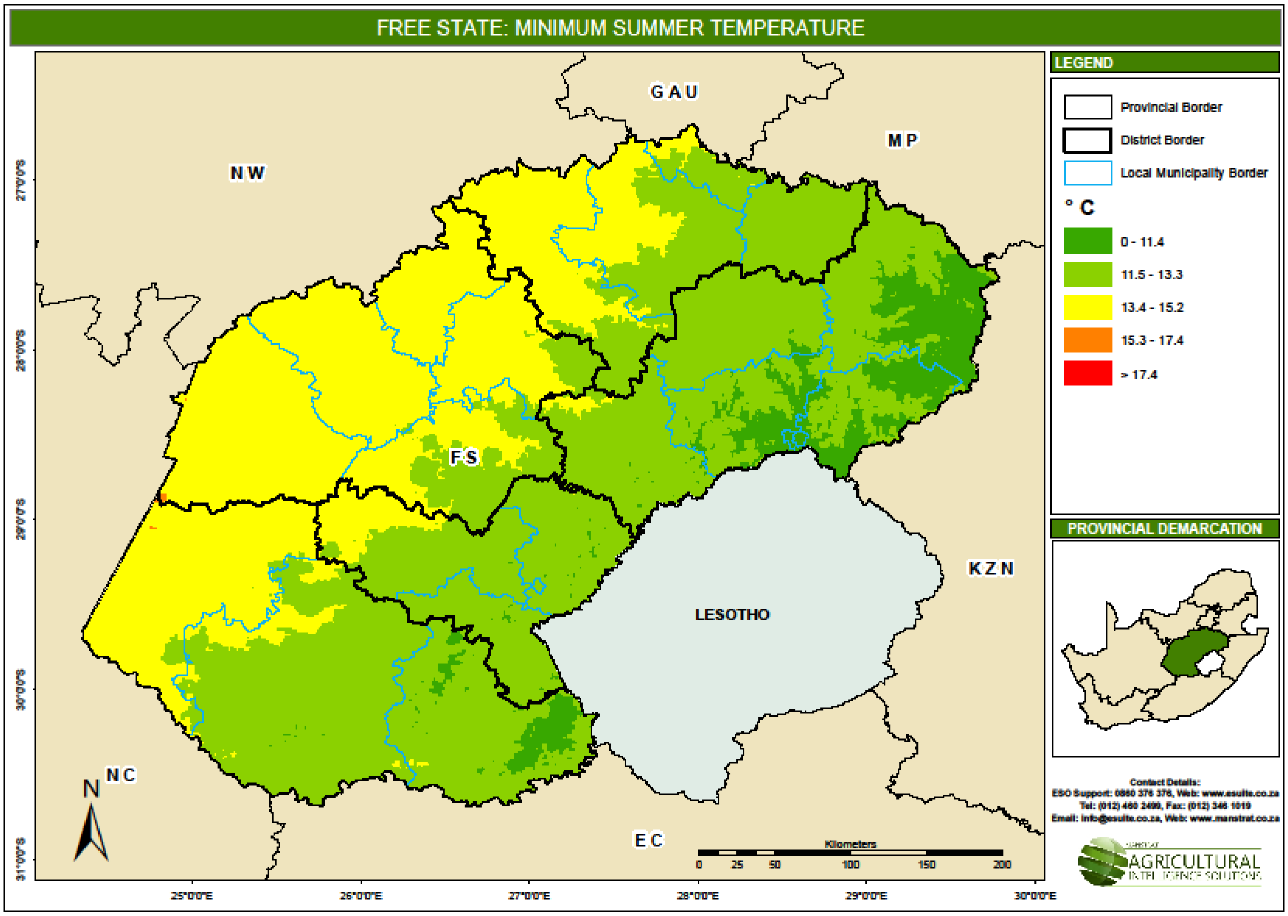

Figure 3.6 The minimum summer temperature for Free State Province. Source: Extension Suite (2014)

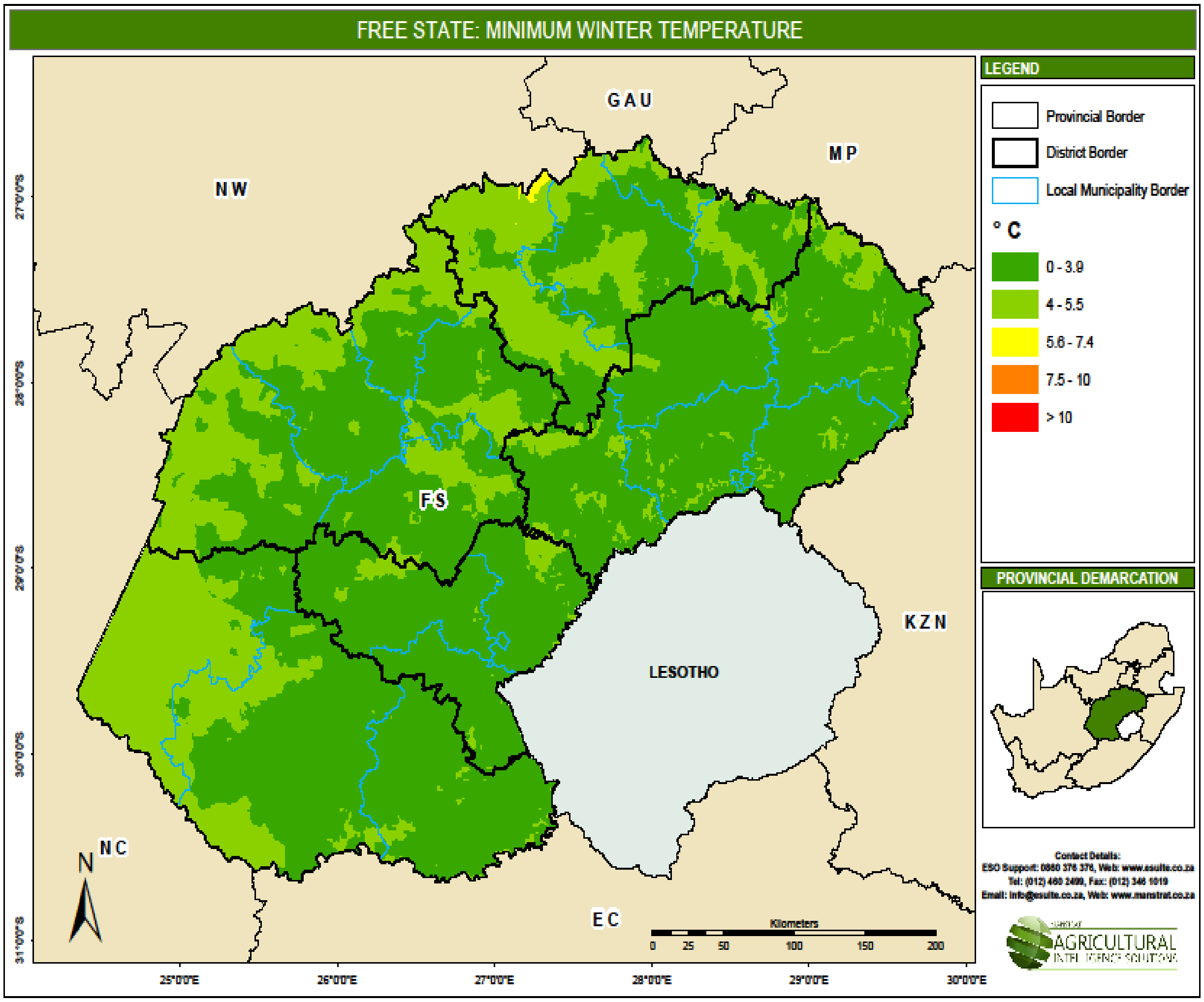

Figure 3.7 The minimum summer temperature for Free State Province. Source: Extension Suite (2014)

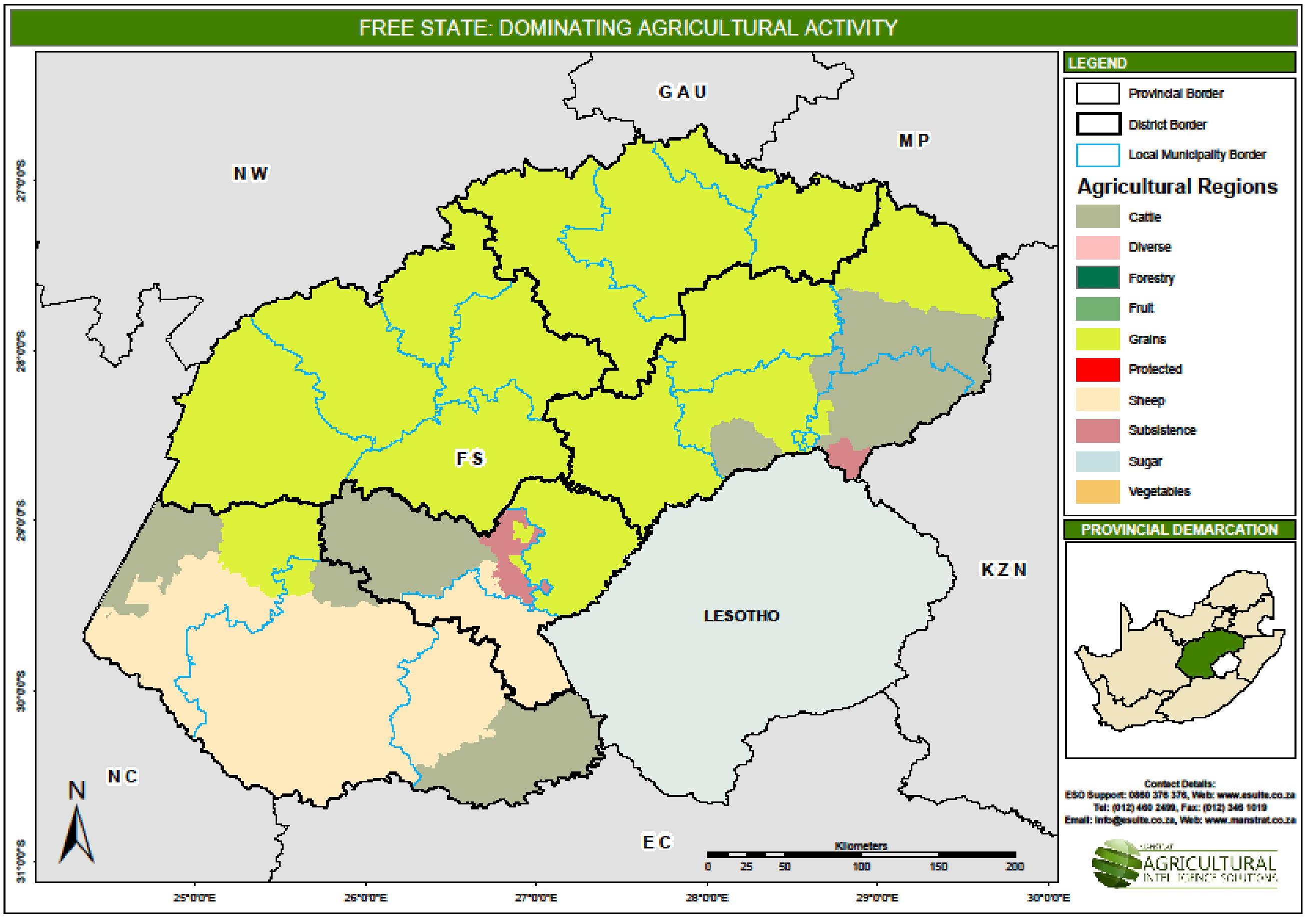

Figure 3.8 The dominating agricultural activities in the Free State Province. Source: Extension Suite (2014)

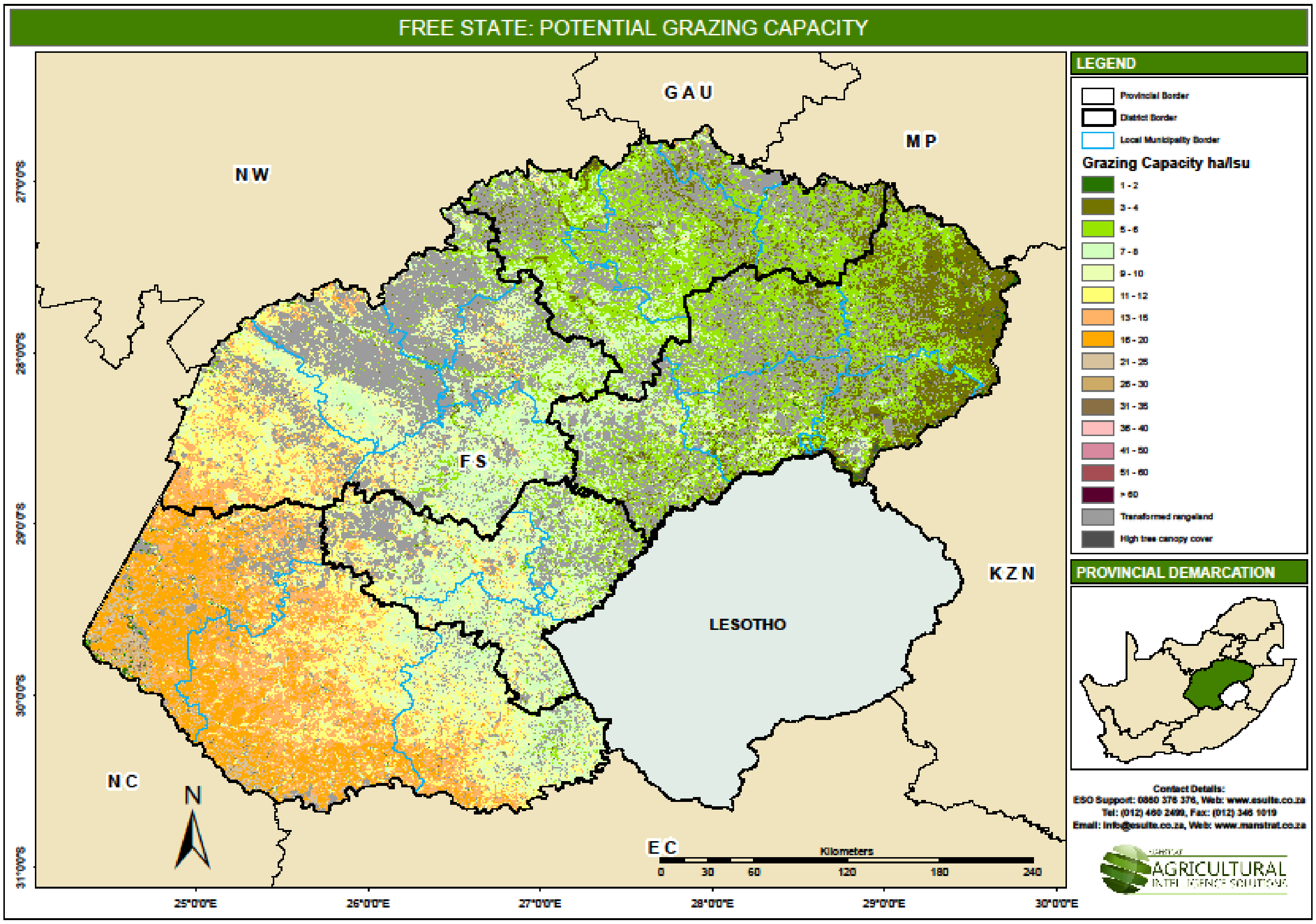

Figure 3.9 The potential grazing capacity in the Free State Province. Source: Extension Suite (2014)