An exploration of commercial and subsistence farmers climate change adaption strategies in the Ditsobotla-local municipality, North-West Province, South Africa

A Pienaar

orcid.org 0000-0001-9792-6050

Dissertation accepted in fulfilment of the requirements for the degree *Master of Science in Environmental Sciences with Disaster Risk Science* at the North-West University

Supervisor: Dr C Coetzee

Co-supervisor: Dr LD Nemakonde

Graduation October 2020

25017624

ACKNOWLEDGEMENTS

"It is not the most intellectual of the species that survives; it is not the strongest that survives; but the species that survives is the one that is able best to adapt and adjust to the changing environment in which it finds itself"

– Leon C Megginson

At the very outset of this study, I would like to extend my sincere and heartfelt appreciation to the many people who have assisted and supported me in this endeavour. Without their active help, guidance and encouragement this would not have been possible.

I am indebted to my primary supervisor, Dr. Christo Coetzee, who has the substance of a genius. Your conscientious guidance and encouragement throughout were monumental towards the success of this study.

I wish to thank my co-supervisor, Dr. Livhuwani Nemakonde whose valuable assistance and suggestions were a milestone in the completion of this research.

I am whole-heartedly grateful to all the farmers I've had the honour of working with during this journey, who so generously and passionately gave of their time and experience. Thank you for entrusting me with your stories, you give me hope for our beautiful country's future.

I would like to recognize the invaluable assistance of Ennice Motlhaolwa, whose translation eliminated any language barrier during the course of this study.

I also acknowledge with a deep sense of reverence, my heartfelt gratitude towards my amazing parents and my beloved Johan, for their sacrifices, unconditional support and persistent encouragement.

Finally, I give honour to my Heavenly Father, who has never forsaken me and has been my faithful Saviour throughout my life:
"When you go through deep waters, I will be with you"
Isaiah 43:2.

ABSTRACT

Climate change is one of the greatest threats facing the agricultural sectors of developing countries during the 21st century. The vulnerability of South African farmers, and more specifically those located in the Ditsobotla Local Municipality of the North West Province, will increase in direct correlation with the occurrence of extreme weather events and unexpected variations in climate. In the Ditsobotla Local Municipality, the manifestation of climate change is already evident in the form of increased temperatures, longer periods of drought and irregular rainfall patterns. Adaptation is a key component of resilience among farmers as they encounter challenges caused by climate change.

Previous research has revealed that a differentiation in the ability of commercial and subsistence farmers to respond efficiently to climate change could further exacerbate the vulnerability of farming communities, and lack of livelihood security in agricultural areas. This study aimed to explore various aspects pertaining to the topic of climate change adaption that are relevant to the study, and whether a difference in adaptive capacity could be observed between commercial and subsistence farming groups within the context of the Ditsobotla Local Municipality.

An exploratory sequential mixed method design was used for this undertaking, as it made room for the use of both qualitative and quantitative methods in a single study. Themes derived from the initial theoretical phase of the research permitted the development of an appropriate measuring instrument. A questionnaire was administered to twenty-five farmers from each of the commercial and subsistence farming groups during the latter part of the research.

An analysis of the responses to the questionnaire showed different adaptation strategies implemented by the commercial and subsistence farming groups in an effort to cope with the steadily declining state of agriculture due to the manifestation of climate change. Commercial farmers opted for adaptation methods aimed at ensuring maximum yield, such as the application of recommended chemicals and fertilizers. Subsistence farmers favoured operational adjustments, for example tactically distributing their agricultural activities throughout the season for optimized production and use of their land. Unique indigenous methods of adaptation, such as the grass shelters, that have emerged from the study were testimony to the belief, shared by most of the commercial and subsistence respondents, that indigenous knowledge could add great value to modern climate adaptation strategies. The study also established that some of the most prominent factors constraining the adaptive capacity of the farmers (both commercial and subsistence) are related to their physical environment, lack of market access, financial constraints and limited access to established social networks (such as farmers associations). Crucially, the results revealed that the constraining factors identified should not be seen as a means of deciding which farming group (commercial or subsistence) should receive priority for support with climate change adaptation. Rather, they should all be considered in the formulation of holistic climate change adaptation strategies that will benefit all farmers and ensure the sustainability of all agricultural systems.

Keywords: agricultural adaptation strategies; climate change adaptation; coping capacity; disaster risk reduction; resilience; sustainable agriculture; vulnerability

OPSOMMING

Klimaatsverandering is een van die grootste bedreigings vir die landbousektore van ontwikkelende lande in die 21ste eeu. Die kwesbaarheid van Suid-Afrikaanse boere, spesifiek diegene wat geleë is in die Ditsobotla plaaslike munisipaliteit van die NWP, sal waarskynlik ook toeneem in direkte korrelasie met die voorkoms van ekstreme weergebeurtenisse en onverwagse variasies in klimaat. Die effek van klimaatsverandering in die Ditsobotla plaaslike munisipaliteit kan reeds waargeneem word in die vorm van hoër temperature, langer periodes van droogte en onreëlmatige reënvalpatrone. Aanpassing by dié omstandighede is 'n sleutelkomponent van boere se veerkragtigheid. Vorige studies het aangedui dat daar teenstrydighede is in die vermoë van kommersiële en bestaansboere om effektief te reageer op klimaatsverandering. Dit kan lei tot 'n hoër kwesbaarheid onder landbougemeenskappe, en onsekerheid oor bestaansvoering in landbougebiede. Die doel van die studie was om al die aspekte wat verband hou met die onderwerp van aanpassing by klimaatsverandering te verken. Die ondersoek het ten doel gehad om vas te stel of daar moontlike verskille is in die aanpassingskapasiteit van kommersiële en bestaansboere van die Ditsobotla plaaslike munisipaliteit.

'n Gemengde kwalitatiewe-kwantitatiewe metode is gebruik om die studie se doelwit en doelstellings te bereik. Dit het voorsiening gemaak vir die gebruik van beide kwalitatiewe en kwantitatiewe metodes in 'n enkele studie. Temas wat geïdentifiseer is gedurende die aanvanklike teoretiese fase van die navorsing is gebruik tydens die ontwikkeling van 'n toepaslike meetinstrument. 'n Vraelys is deur vyf-en-twintig boere van elke groep, dit wil sê kommersiële en bestaansboere, beantwoord tydens die tweede gedeelte van die studie.

Die analise van die antwoorde op die vrae in die vraelys het aangedui dat die twee groepe boere verskillende motiewe het vir die aanpassingstrategieë wat hulle toepas in 'n poging om die agteruitgang in landbou weens die impak van klimaatsverandering the hanteer. Kommersiële boere mik hulle aanpassingstrategieë op die maksimum opbrengste, byvoorbeeld deur die toediening van nuutontwikkelde gif en kunsmis. Bestaansboere het operasionele aanpassings verkies, soos die verspreiding van boeredery aktiwiteite oor verskillende seisoene vir optimale produksie en volle benutting van hulle grond. Verskeie unieke aanpassingsmetodes wat gedurende die studie waargeneem was het gedui daarop dat die siening heers onder meeste van die kommersiële en bestaansboere dat inheemse kennis waarde toe kan voeg tot moderne klimaatsaanpassingstrategieë.

Die studie het verder bevestig dat van die mees prominente faktore wat die aanpassingskapasiteit van die boere beperk verwant is aan hulle fisiese omgewing, 'n tekort aan toegang tot markte, finansiële beperkings en beperkte toegang tot gevestigde sosiale netwerke (soos boereverenigings). Wat van groot belang is, is dat die studie vasgestel het dat hierdie faktore nie gebruik moet word om te besluit watter groep boere (kommersiële boere of bestaansboere) die prioriteit moet wees by die ontvangs van ondersteuning vir aanpassing op klimaatsverandering nie. Die faktore moet eerder in ag geneem word om holistiese klimaatsveranderingstrategieë te ontwikkel wat alle boere sal bevoordeel en die volhoubaarheid van alle landbousisteme sal verseker.

Sleutelwoorde: landbou aanpassingstrategieë; aanpassing by klimaatsverandering; hanteringskapasiteit; risikobestuur; veerkragtigheid; volhoubare landbou; kwesbaarheid

LIST OF ABBREVIATIONS AND ACRONYMS

CCA	Climate Change Adaptation
CEEPA	Centre of Environmental Economics and Policy in Africa
CO_2	Carbon dioxide
COP	Conference of the Parties
CRED	Centre for Research on the Epidemiology of Disasters
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DoA	Department of Agriculture
DRDLR	Department of Rural Development and Land Reform
DRR	Disaster Risk Reduction
FAO	Food and Agricultural Organization
GHG	Greenhouse gasses
HFA	Hyogo Framework for Action
IK	Indigenous Knowledge
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
NMMDM	Ngaka Modiri Molema District Municipality
NWP	North West province
SFDRR	Sendai Framework for Disaster Risk Reduction
Stats SA	Department of Statistics South Africa
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION AND ORIENTATION

1.1 Introduction

As the world's climate changes, society is presented with considerable challenges with regard to vulnerability reduction and sustainable development. Climate variability and climate-related extremes accompany these climatic changes (IPCC, 2012a). Arguments for not facilitating and prioritising the implementation of adaptation strategies within the climate change community are based on the assumption that climate change will happen at a gradual pace in correlation with social development rates. However, the Intergovernmental Panel on Climate Change (IPCC) suggests that future changes in climate could occur more abruptly compared to the environmental shifts observed in the past due to a rapidly changing nonlinear system (IPCC, 2012a; IPCC, 2013; Mayowa, 2019). Despite increased awareness and the probability of rapid and extreme climatic events, many societies, especially those in developing countries, do not have the capacity to cope with these events, which greatly threatens their livelihood (Lalego *et al.,* 2019; Nhamo *et al.,* 2019; Zwane, 2019).By virtue of the ever-changing and unpredictable nature of extreme climatic events, the focus is no longer on post-disaster damage control, but rather on addressing the root causes of society's vulnerability to disasters by means of adaptation methods (Solecki *et al.*, 2011). In order to cope with these extreme climatic events, there is now a great emphasis on protecting vulnerable communities, such as farmers, and their ability to adapt efficiently.

Climate change has become an ever-present challenge in the agricultural sector, and even more so for vulnerable farming communities in developing regions such as Africa (Awojobi & Tetteh, 2017; Lalego *et al.,* 2019). The IPCC asserts that some regions are likely to experience more extreme climatic events, such as droughts, floods and heatwaves (IPCC, 2018b). While farmers in some regions or countries may have the opportunity to benefit from climatic conditions caused by climate change, others are faced with increased vulnerability, especially in developing countries such as South Africa (Mitchell *et al*., 2010; Quinn *et al.,* 2011; Schulze, 2016; Nhamo *et al*., 2019). Considering that the study region has a history of frequent and prevailing droughts that pose a significant threat to the agricultural community, it is important to understand the vulnerabilities of both the commercial and subsistence farmers of the Ditsobotla Local Municipality in the NWP to climate change and their current adaptation strategies (Department of Rural Development and Land Reform (see South Africa), 2016).

Climate change adaptation (CCA) plays a crucial role in combating the potential effect of climate-induced disaster on agriculture. In the context of this study, climate change adaptation relates to adjustments to the established processes of farming systems to cope with current or foreseeable external climate stresses (Bryan *et al.,* 2013; Schulze, 2016; Oduniyi, 2018). The main purpose of adaptation is to enable farmers to mitigate the detrimental effects of climate change while they also use new opportunities that may arise, especially for vulnerable groups such as subsistence farmers (Elum *et al.,* 2017). Adaptation is an important factor that could be used to decrease both subsistence and commercial farmers' vulnerability to short term variations in climate and longer-term climate change (Bryan *et al.*, 2009). However, this study argues that there could currently be a difference in the adaptive capacity of commercial and subsistence farmers driven by factors such as lack of access to resources, financing and insufficient government support. These differences in adaptive capacity could mean that certain groups such as subsistence farmers could be more exposed to the ravages of future climate change and climate related disasters, thereby threatening their lives and livelihoods. In order to address this perceived problem of a difference in adaptive capacity, the chapter first looks at the study region to establish the importance of agriculture for the livelihood of the members of the community. This is followed by the overall problem statement and the research questions and objectives. The latter part of the chapter gives a brief description of several limitations of the study, which is followed by the dissertation’s outline.

1.2 Study Orientation

The focus region of this study is the Ditsobotla Local Municipality, situated in the North West Province and forms part of the Ngaka Modiri Molema District Municipality, South Africa.

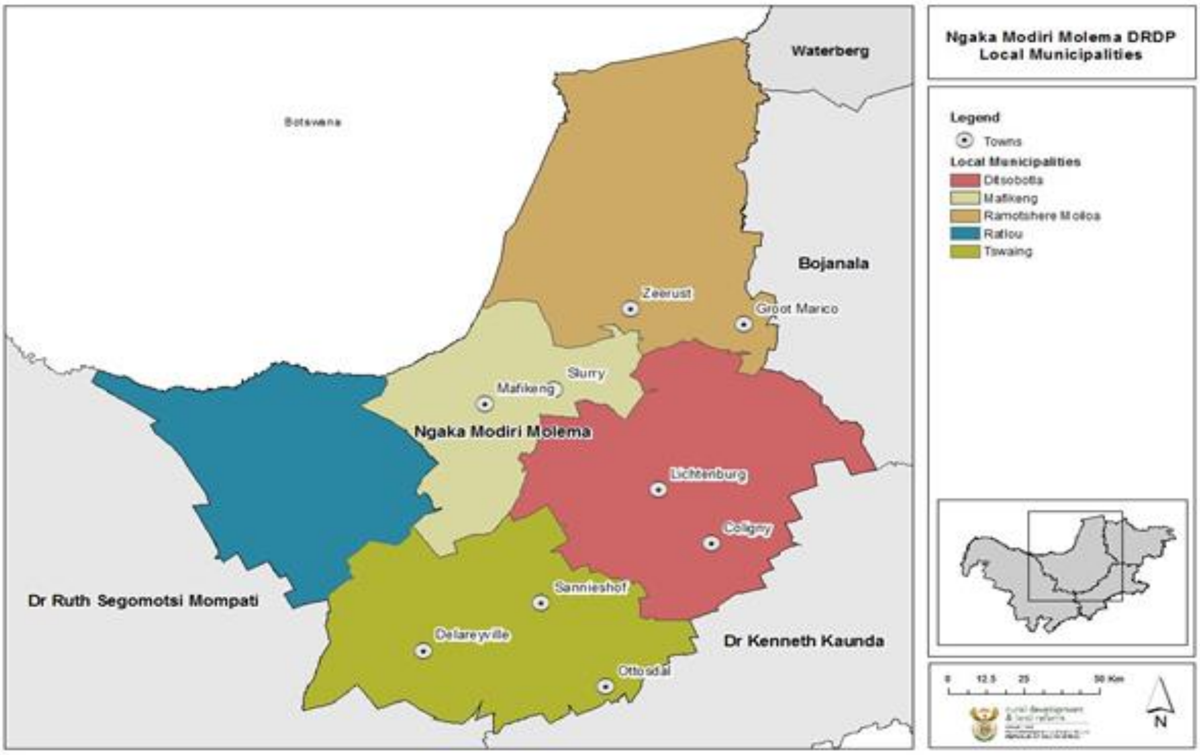

Figure 1.1 NMMDM Local Municipalities Map (Source: Department of Rural Development and Land Reform, 2016).

The North West Province includes areas that formed part of the now defunct homeland of Bophuthatswana. A great number of Bophuthatswana's inhabitants were originally agro-pastoral communities who, during its existence, depended on agriculture as their primary source of food and income (Stacey *et al*., 1994). Agriculture is woven into the history of the province and continues to play an important part in the livelihoods of various communities. In 2016, roughly 7 730 or 81% of the area's agricultural households had an income of R0–R38 400 (DRDLR, 2016). According to the Department of Rural Development and Land Reform (2016), most of these households practice subsistence farming (definition of the term is given in section 2.3.1) and are greatly dependent on agricultural activities and production for their livelihoods.

The North West Province plays a pivotal role in national agricultural production. Specifically, the NWP is deemed one of the largest maize producing regions in South Africa and forms part of South Africa's maize triangle (Mayowa, 2019; Oduniyi *et al*., 2019). During the 2017-2018 production year the NWP was the third largest maize producing province, accounting for 1 789 000 tons of the country's 12 223 000 total maze production (DAFF, 2018). This region is intensively cultivated with a high capacity for sunflower, sorghum, groundnuts and maize production. The NWP is also well known for its cattle farming throughout the province (Department of Agriculture (DoA), 2005; Kotze & Rose, 2015). The agricultural activities in the NWP also account for about 18% of the province's employment, making it the highest source of employment in the province (DoA, 2007; DRDLR, 2016).

The topography of the Ditsobotla Local Municipality could be described as primarily flat with only limited mountainous areas (Savannah Environmental, 2018; Oduniyi *et al.,* 2019). This characteristic is directly linked to land use for agricultural activities and it contributes to the region's high potential for crop production. The climate in the Ditsobotla Local Municipality is generally dry with a mean annual rainfall within the range of 400mm–600mm. Due to sporadic rainfall accompanied by heatwaves, the district has a history of prevailing and regular droughts.

1.3 Problem Statement

According to Oduniyi *et al.* (2019), the North West Province (NWP) and the Ditsobotla Local Municipality specifically are some of South Africa's most important agricultural areas. Along with being central to the country's overall agricultural production, both the NWP in general and the locality of interest specifically are important for the livelihoods of commercial and subsistence farmers (DRDLR, 2016; Savannah Environmental, 2018). Unfortunately, the use of intensive farming practices over extended time periods, such as overstocking of land or the overuse of synthetic fertilizers, has caused the agricultural production of the country and the NWP to decrease immensely as a result of the degradation of agricultural land (Lotter, 2017; Oduniyi & Tekana, 2019).

Climate change poses a great threat to the agricultural sectors of developing countries such as South Africa. Chambers *et al.* (1989) and Downing *et al.* (1997) predicted this threat by labelling farming in developing countries as "complex, diverse and risk-prone". Altieri and Nicholls (2017) and Lalego *et al.* (2019) attribute developing countries' vulnerability to the centrality of agricultural activities in their economies and the lack of available and sufficient capital for implementing some adaptation strategies such as the application of chemicals and fertilizers to boost soil fertility and production. Predicted effects of climate change in South Africa include CO_2 enrichment; increased temperature; rise in sea levels; changes in wind patterns; temporal and intensity changes in drought and flood hazards; and changes in seasonal precipitation (Wiid & Ziervogel, 2012; Department of Environmental Affairs (DEA), 2013b; Oduniyi, 2018). The observed impacts of climate change in the area are identified and further elaborated on in section 2.2.4. Each of these effects could have a direct impact on the agricultural production and water resources of South Africa. As crop production is highly dependent on water resources, there is an emphasis on the effect climate change could have on groundwater resources and precipitation patterns. Predictions suggest that contrary to the possible global increase in rainfall, a decrease is suspected for South Africa of about 9.5% by 2080 (DEA, 2017a).

As stated by Elum *et al.* (2017), weather-related disasters, specifically droughts and floods, have had a long history in the NWP (historic droughts are discussed in section 2.2.5). This especially affects areas that are known to be highly dependent on agricultural activities for people's livelihoods, such as the Ditsobotla Local Municipality. On average, serious droughts could potentially occur every two to seven years in South Africa due to the recurring El Niño phenomenon (Schulze, 2016; Lotter, 2017). Damages caused by such disasters often leave the farmers with severe livestock deaths and harvest failure (Elum *et al.,* 2017). Despite being highly important for agricultural production, the NWP has an average annual rainfall of between 400-600mm and has the lowest long-term average rainfall per month in comparison with other provinces in South Africa (DRDLR, 2016; Mayowa, 2019). Worryingly, the Department of Environmental Affairs states that any effects of climate change in the province will have a negative influence on the agricultural productivity in the province, with the Ditsobotla Local Municipality being an region of great concern (DEA, 2015). The susceptibility of the NWP's agricultural productivity to climate change could be attributed to the sensitive nature of the natural resources on which the region depends for agricultural production and the history of long-lasting droughts in the area.

South African farmers are highly vulnerable to the adverse consequences of climate change and tend to have a low adaptive capacity towards the manifestations of climate change, for a variety of reasons including environmental and economic factors (Schulze, 2016; Mambo, 2017). In addition, there are differences in the adaptive capacity of commercial and subsistence farmers for a variety of reasons, including access to technology and finances to support adaptation (Bryan *et al.,* 2009; Yaro, 2013). These differences could be amplified in a developing country such as South Africa where climate change is likely to affect farming groups, including commercial and subsistence farmers, and individuals differently (Oduniyi, 2018). Though it will most likely affect commercial and subsistence farmers differently, the successful adaptation of both groups is of great importance, especially in an agriculturally intensive area such as Ditsobotla. The decision to apply methods of adaptation depends on various factors, including cultural and socio-economic factors. According to Bryan *et al.* (2009) and Buchmann *et al.* (2010), farmers' perceptions of climate change and traditional ecological knowledge (indigenous knowledge are discussed in section 3.4) is an important factor influencing their decision to implement adaptation methods. The rich agricultural background and indigenous knowledge of the Ditsobotla Local Municipality's farmers may therefore serve as an advantage for the subsistence farmers of the area, but a lack of credit and market access could adversely affect their response to climate change (Bryan *et al.*, 2009; Yaro, 2013; Mashizha, 2019). For commercial farmers, failure to adapt successfully would entail loss of financial resources, loss of production and crop yield and loss of employment for farm labourers, while for subsistence farmers failure to adapt could destroy their livelihoods, cause food insecurity and force them into poverty (Benhin, 2006; Morton, 2007; Yaro, 2013; Altieri & Nicholls, 2017). Therefore, if a low adaptive ability prevails for both commercial and subsistence farmers, social disruption, economic loss and loss of livelihoods will ensue. The study problem as outlined in this section will further be address by addressing the research objectives as outlined in the section below.

1.4 Research Questions and Objectives of the study

1.4.1 Research Questions

The following research questions were formulated to give broad guidance to the study:

1. What is the impact of climate change on agriculture within the context of Africa, Southern Africa, South Africa and the Ditsobotla Local Municipality?
2. What are the perceptions and extent of knowledge of the farmers within the Ditsobotla Local Municipality of climate change?
3. What methods of CCA do commercial and subsistence farmers of the region implement?
4. What hinders or promotes farmers application of their chosen methods of adaptation?
5. How could factors hindering the application of CCA methods be eliminated to promote the effective adaptation of both commercial and subsistence farmers?

From these broad questions primary and specific research objectives were formulated. These are discussed below.

1.4.2 Primary Objective

This purpose of this study is to explore the difference in adaptation strategies implemented by the commercial and subsistence farmers of the Ditsobotla Local Municipality, and to critically assess the factors causing a possible differentiation in their adaptive capacity and vulnerability towards climate change. This would ultimately result in recommendations for addressing these differences.

1.4.3 Specific Objectives

In the course of this research, specific objectives were used to achieve the research aims. These specific objectives were used to emphasize the importance of Ditsobotla's farmers' successful adaptation to climate change and ultimately to evaluate the differences in adaptation between this region's commercial and subsistence farmers.

The following specific objectives drove the research:

- To establish the impact of climate change on agriculture in the context of Africa, Southern Africa, South Africa and the Ditsobotla Local Municipality.
- To explore the perceptions the farmers of the Ditsobotla Local Municipality have of climate change.
- To identify the methods of CCA the commercial and subsistence farmers in the NWP and the Ditsobotla Local Municipality implement in their agricultural activities.
- To determine the factors, including indigenous knowledge, that could hinder or promote the implementation of CCA strategies among commercial and subsistence farmers of the study region.
- To propose realistic methods for improving commercial and subsistence farmer's ability to adapt to climate change.

1.5 Methodology

An exploratory sequential approach was implemented to conduct the research and was accepted as the method best suited for this specific study. This entailed the exploration and analysis of qualitative data, followed by the use of the qualitative findings in a second quantitative phase (Creswell, 2014). The aim with using this approach was to develop an accurate measurement for comparison between the commercial and subsistence farmers of the Ditsobotla Local Municipality. This section to follow elaborates on aspects of the research methodology, with specific reference to data collection, sample selection and the analysis of the information used to achieve the research objectives.

1.5.1 Methodological Order of Data Collection and Analysis

Data collection and analysis were completed in a phase-based manner as proposed by Onwuegbuzie and Combs (2011) in their study on data analysis in mixed research.

Qualitative data were collected by exploring relevant literature relating to the topic during the first phase of data collection. Following the qualitative data collection, the information was analysed following a thematic analysis approach. Themes that emerged during the first phase analysis were exploited for the development of a relevant quantitative instrument for further exploration of the research problem (Berman, 2017; Creswell & Plano Clark, 2011).

The second phase of data collection involved the collection of quantitative data by means of a questionnaire. The specific questions were formulated based on the information gained from the qualitative analysis.

This phase-based analysis therefore occurred in the following manner:

Phase 1: The data collected during this phase was analysed using a thematic analysis method. This method was best suited for phase one as the purpose of this phase was to identify, analyse, organize and describe themes found in the qualitative data that had been collected (Nowell *et al.,* 2017). The emergent themes served as a basis for the creation of a questionnaire. The questionnaire was used for the second, or rather quantitative phase, and served as an instrument of evaluation.

Phase 2: The data obtained and analysed during phase one were used to create a questionnaire relevant to the respondents and the study area. The purpose was to gain more insight regarding the adaptation methods the commercial and subsistence farmers of the Ditsobotla Local Municipality use. During this phase, 25 farmers from each group (50 farmers in total) were identified through purposive homogenous sampling and were given the questionnaire consisting of semi-structured and structured questions. The number of respondents was deemed sufficient for the study as it allowed the researcher to thoroughly analyse the questionnaires while still collecting information-rich data. Semi-structured questions were included in the questionnaire with the intent of collecting information regarding the farmers' current knowledge of climate change, the methods they use to adapt, where they learned these methods and what prohibits them from using other methods of adaptation. Semi-structured questions were particularly useful in this study as it allowed the respondents to elaborate on their views and methods of CCA (Cohen & Crabtree, 2006). Quantitative structured questions were asked using the checkbox format and a Likert scale. This method was best suited for the quantitative questions as this part of the questionnaire only aimed to identify what adaptation methods the commercial and subsistence farmers of the Ditsobotla Local Municipality use in their agricultural practices.

The questionnaire data was then analysed using deductive content analysis. According to Rose *et al.* (2015), content analysis is a systematic analysis that involves the classification of text by means of a systematic coding scheme to ultimately form knowledgeable conclusions of the message content. This method was best suited for the analysis of the data gathered by means of the questionnaires as it allowed for the interpretation of complex social data; it is flexible and applicable to both qualitative and quantitative data; while also promoting reliability and validity (Bengtsson, 2016; Songsore & Buzzelli, 2016). After analysing the data in both a qualitative and quantitative manner, the data were ultimately used to create charts. Visual illustrations of the results facilitated the comparison of the commercial and subsistence farmers' questionnaire data sets. This made the differences in their adaptation more visible.

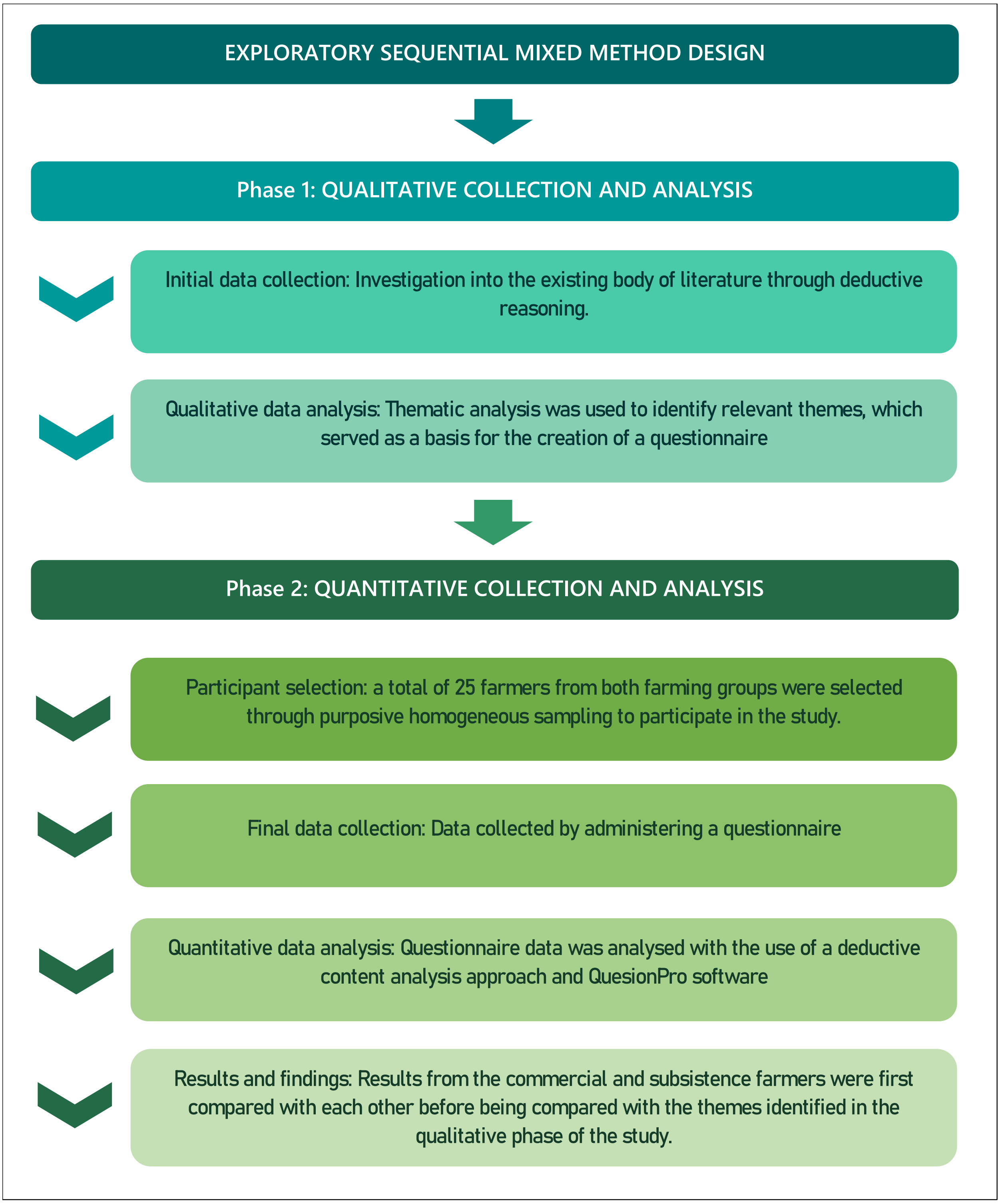

Figure 1.2 Methodological order followed to complete the study

1.5.2 Literature Review

A literature review was conducted in the initial stage of the research for the purpose of exploring the unfavourable circumstances climate change could potentially create for agriculture in South Africa, and more specifically in the NWP. The literature review involved a discussion of relevant existing scholarly work. The purpose of investigating this body of work was to identify how CCA strategies vary between commercial and subsistence farmers; their applicability to the farmers in the study area; and to describe emerging themes found in the literature. Literature was identified using a desktop research approach through the use of internet search engines and resources. This included Google, Google Scholar, Science Direct and ResearchGate. Qualitative information was obtained from books, journal articles relating to the subject and available academic dissertations and theses. Key authors who provided the researcher with invaluable insight during the qualitative phase included the work of William Neil Adger; Hans-Martin Füssel; Rashid Hassan and Charles Nhemachena; Laura Pereira; Katharine Vincent; and Joseph Awetori Yaro, among others

1.6 Limitations of the Study

The research aims to provide a significant contribution to knowledge, in both theory and practice, about the differentiation of climate change adaptation methods implemented by the commercial and subsistence farmers of the Ditsobotla Local Municipality in the North West Province. The information collected could serve as a comparative reference point for facilitating the improved adaptive capacity of agricultural communities. However, the study has potential limitations. The research is mainly confined to the Ditsobotla Local Municipality context. Therefor it is not assumed that all findings, including the climate change adaptation methods implemented by these farmers and the challenges they face, could be generalized to other regions and farming groups within the country or to other countries. However, the study might provide insights into the factors leading to a differential in CCA methods chosen by commercial and subsistence farmers, as well as the importance of improving agricultural communities' ability to respond to effectively to climate change. Lack of access to a list of the population being studied, in this case subsistence farmers, eliminated the application of probability sampling. In turn the application of a non-probability sampling method restricted the generalizability of the findings. Nevertheless, non-probability sampling methods are useful in exploratory mixed methods research, especially for developing a complete understanding of the complex issues relating to human behaviour such as adaptation to climate change.

1.7 Dissertation Outline

This dissertation has been organized into six chapters. Chapter one gives a brief overview of the problem statement, research questions and objectives and study limitations. The significance of adaptation within an agricultural context are explored from various aspects in chapter two. Chapter three focuses on CCA, its various components, the differences and correlations between CCA and mitigation, and the connection between CCA and disaster risk. The chapter then investigates the CCA methods commercial and subsistence farmers in the NWP use to adapt. The methodology used to meet the research objectives are identified and discussed in the fourth chapter. This includes identifying and giving an overview of the research design, the research tools and the sample size. It also includes the validity, reliability and ethical implications of the study. In chapter five the questionnaire data are analysed, along with key findings that can be derived from the results. The final chapter comprises of a brief discussion of the findings, recommendations for reducing the adaptation differences between commercial and subsistence farmers, recommendations for increasing the adaptative capacity of farmers, as well as recommendations for further relevant studies on the topic.

1.8 Conclusion

Adaptation allows societies to cope better with the unpredictable circumstances as a result of climate change (Bryan *et al.*, 2009; Awojobi & Tetteh, 2017; Oduniyi, 2018). With the implementation of appropriate measures and adjusting to these abrupt changes, communities could minimize the possible negative effects (Elum *et al.,* 2017). Though all societies have the ability to adapt, some groups and communities can be more vulnerable to climate change, for example women in subsistence agriculture as emphasized by Pereira (2017). The need to investigate the adaptation ability of this region’s farmers becomes evident when considering NWP’s vulnerability to the threat of climate change, the probability of extreme weather events, high dependency on natural resources and economical and social limitations (DEA, 2015; Oduniyi & Tekana, 2019). Therefore, proactive action should be taken to assess the differences in adaptation strategies between different farming communities. As part of such an undertaking, this study takes into consideration the background of both types of farmers, the influences that prompt them to choose the adaptation methods they implement, and their indigenous knowledge of adaptation.

The chapter also outlined contextual and methodological issues relevant to the study, especially the study area of the Ditsobotla Local Municipality. This was followed by a consideration of the possible impacts climate change could have on the area. The study’s research questions and objectives were determined, with an explanation of the methods used to achieve them. Literature suggests that the agricultural systems of developing countries, including South Africa, are highly vulnerable to the continual manifestation of climate change (Oduniyi, 2018). The next chapter therefore explores the effects of climate change on agricultural systems in general and in the study area, as well as the fundamental differences between commercial and subsistence farmers that result in differences in their adaptive capacities.

CHAPTER 2 CLIMATE CHANGE AND AGRICULTURE: AN EXPLORATION OF THE LITERATURE

2.1 Introduction

As defined by the IPCC (2012a), climate change refers to deviations in the state of the climate that can be observed through changes in the overall variability or the mean of its properties and is prevalent for an extended time, such as decades and longer. The prominent reliance on natural resources causes the agricultural sector to be highly sensitive to variations in climate (Buchmann *et al.,* 2010; Marshall *et al.,* 2013). Societies who built their livelihood around agriculture are becoming increasingly vulnerable during the 21st century as climate change is expected to have significant and pervasive effects through the manifestation of extreme climatic events (Mutekwa, 2009; Awojobi & Tetteh, 2017; Mayowa, 2019).

Research suggests that even though some regions may benefit from the effects of climate change, specifically temperate regions, other regions are faced with increased vulnerability (FAO, 2010b; Yaro, 2013). Therefore, due to the geographical location and warmer average baseline climates of developing countries, their agricultural sectors are the most likely to be adversely affected by climate change as opposed to developed countries located in temperate regions (Altieri & Nicholls, 2017; Mayowa, 2019). Factors contributing to the increased vulnerability of a country relate to the extent of their dependency on natural resources, economic stability and wellbeing, institutional stability and their perceptions of environmental changes (Vincent, 2007; Berman *et al.,* 2012; Elum *et al.,* 2017). Unfortunately, most of the countries predicted to experience a severe decrease in agricultural production are greatly dependent on it for export and economic growth. The projected impact of climate change and high levels of vulnerability threaten the livelihood of these populations.

This chapter makes a special effort to understand the potential effects of climate change on agriculture in general, as well as the agricultural sector of South Africa and the Ditsobotla Local Municipality. This would help confirm the importance of successful adaptation. The latter part of this chapter focuses on the fundamental differences between commercial and subsistence farmers and their respective perceptions of climate change. This serves as the background to the exploration of how their adaptation compares.

2.2 The Impact of Climate Change on Agriculture

Challenges created by climate change, such as the increased intensity and frequency of extreme weather events, along with globalization, are exposing farmers to conditions unfamiliar to them and to the broader agricultural community (Quinn *et al*., 2011; Nhemachena *et al*., 2014; Oduniyi *et al.,* 2019). The various effects and challenges climate change might hold for agriculture is discussed in the following section.

2.2.1 Projected Impact of Climate Change on Agriculture Globally

The effect of climate change will continue to have a significant impact on agriculture in the 21st century as it exerts an influence on both animal and plant health (Pereira, 2017). Arguments have been made for both opposites of the climate change spectrum, debating whether or not future climate change projections will be beneficial or detrimental to agricultural systems. Great uncertainty about future projections confronted society when the first IPCC report was released in 1990. The anticipation of increased carbon dioxide (CO_2) levels in the atmosphere as climate change continues gave rise to the beneficial line of reasoning, such as the proposed fertilization effect. According to McGrath and Lobell (2013) and Govere *et al.,* (2018), the CO_2 fertilization effect is the phenomenon of increased photosynthesis in plants as a consequence of excess CO_2 in the atmosphere, which has the potential to promote plant growth. Along with increased photosynthesis, this effect leads to reduced transpiration in plants, which might supplement the water use efficiency of crops (Schlenker & Lobell, 2010). However, not all groups of plants are expected to reap the same benefits. Degener (2015) and Cawthra (2019) suggest that plants with a C3 photosynthetic pathway (such as potatoes and wheat) are more likely to benefit from this effect, as opposed to those with a C4 pathway, such as maize and sorghum (which are crops produced in the Ditsobotla Local Municipality). Though not as well adapted to higher temperatures, the photosynthesis of C3 plants are more responsive to carbon dioxide than C4 plants (Streck, 2005; Ahmad *et al.,* 2019). Therefore, research has found a correlation between elevated levels of CO_2 and the growth of C3 plants, but varying responses between regions and species of those with a C4 pathway. However, if global warming continues to bring the other proposed effects of climate change on agriculture, for instance drastic changes in precipitation patterns and prolonged droughts, the detrimental effects of climate change are likely to exceed the potential benefits (Streck, 2005; Pereira, 2017; Nhamo *et al.,* 2019).

The greatest climatic parameters challenging agriculture relates to changes in temperature, water resources and precipitation patterns (Keane *et al.,* 2009; Maponya & Mpandeli, 2012; Calzadilla *et al*., 2013; Altieri & Nicholls, 2017). Extensive studies on the relationship between agriculture and climate change predicts a highly probable increase in mean temperatures, which would have a negative consequence for the overall production and yield of crops in semi-arid and arid environments (Yaro, 2013; IPCC, 2018a; Mashizha, 2019). Increased temperature causes faster plant growth with shorter growing phases and increased transpiration in crops. Shorter growing seasons could lead to a decline in yield quality, a metric that represents the amount of deficit free units produced (Calzadilla *et al.,* 2013; Nhamo *et al.,* 2019). The demand for irrigation would become higher to counteract this issue, putting even more strain on water resources.

Another major challenge is the rise in sea level due to global warming, which influences the conditions surrounding coastal farming practices because of reduced coastal aquifer quality. This is brought about by high rates of groundwater abstraction, which causes saltwater intrusion into coastal aquifers and land loss (Downing *et al*., 1997; IPCC, 2014b). Furthermore, differences in seasonal precipitation patterns will bring about changes in the moisture of soil along with shifts in groundwater recharge and river runoff, negatively affecting crop yields. Finally, the disturbed periodicity of precipitation throughout the season resulting from climate change could also adversely affect crop planting and growth regimes (Altieri & Nicholls, 2017; Pereira, 2017).

Variations in the spatial patterns of precipitation and temperature due to climate change may cause previously suitable agricultural land with great potential to be unsuitable for farming activities in the future (IPCC, 2014b; Raman, 2020). These adverse climate change effects are particularly worrying for developing countries such as in Africa, where agriculture plays a major role in individual and communities' livelihoods and substance regimes. Some of the specific effects of climate change in Africa are expounded on below.

2.2.2 The Impact of Climate Change on Africa and Food Security

According to Faccer (2017) and Pereira (2017) there is still great uncertainty surrounding the precise direction and extent of the climatic changes Africa will face. However, since the first IPCC report there has been a substantial increase in the reliability of projected climate change impacts on agricultural systems. Short-term predictions for the continent entail extreme wet or dry years, high variability in precipitation and areas that were formerly semi-arid progressing into arid. Long-term predictions suggest that Africa's temperatures might increase higher than the global average and will likely persist throughout the year, regardless of the season (Awojobi & Tetteh, 2017; IPCC, 2018b). Generally, an increase of between 3°C – 4°C is expected across the continent by 2099, exceeding average global temperatures by approximately 1.5 times (Bryan *et al.,* 2013). These projections pose a significant threat, especially for central southern Africa and the central semi-arid areas of the Sahara where warming is likely to be the highest.

Africa is extremely vulnerable to the adverse effects of climate variability as it includes approximately two-thirds drylands. As a result of topography other socio-economic and physical characteristics, Africa is regarded as the most vulnerable to the effects of climate change (Awojobi

& Tetteh, 2017; Welborn, 2018; Mashizha, 2019). Over the last century an increase of nearly half a centigrade has been observed in Africa's mean temperatures, with some areas showing a faster increase than others (Mutekwa, 2009; Pereira, 2017; Nhamo *et al.,* 2019). The gradual increase in temperature results in the occurrence of more warm spells and subsequently fewer cold days across the continent. The reoccurrence of drought in Africa illustrates the potentially severe impact climate variability could have on livestock, especially by exacerbating rangeland degradation (Lotter, 2017; Pereira, 2017). Land degradation is a serious threat for agriculture, affecting about 65% of Africa's population, especially those living in drylands. Between 10% and 20% of the drylands have already been degraded (FAO, 2009; FAO, 2010a). The combined effects of anthropogenic activities and climate change threatens the quality and productivity of available land by reducing soil fertility and suitability for cultivating crops (Pereira, 2017).

An estimated 40% of Africa's land is dedicated to pastoralism. The semi-arid and arid regions have to provide livelihoods to over 50 million agro-pastoralists and pastoralists who are some of the most vulnerable and financially challenged population subgroups (FAO, 2009; Ayantunde *et al.,* 2011; Ajani *et al.,* 2013). The vulnerability of these farmers to the effects of climate change are partly attributable to the following: varying and irregular rainfall patterns; soils with low potential; the possibility of epidemic diseases; exclusion from export markets for livestock; risk of conflict for the utilization of natural resources; and increasing human and livestock populations with a severe decrease in rangelands (Mwangi & Dohrn, 2008; Pereira, 2017; Mashizha, 2019). Altered crop production accompanied by an insufficient availability of grazing systems and feed crops is expected to adversely and permanently affect agricultural activities related to free range grazing of livestock and animal husbandry. This is worsened by fewer permanent pastures and water resources during the dry season when livestock mobility is critical for their survival (FAO, 2010b; Ajani *et al.,* 2013).

The projected consequences of climate change in Africa will not only compromise agricultural production but will also have significant implications for food security (Ziervogel *et al.,* 2014; Mashizha, 2019). The food security of a country, according to the FAO (2008), can be determined by looking at four primary components: food availability, food accessibility, food system stability and food utilization. Climate change is likely to adversely affect all of these components, although the impact and extent of these effects are expected to differ between locations on the continent. Agriculture provides food security through the production of food resources and as a source of livelihood, given that an estimated 60% of Africa's population depends directly on agriculture. This number is even higher in places such as South Africa, where 65% of agricultural households (about 1 725 000 subsistence farmers) engage in farming activities purely to meet their household food demands (Tibesigwa & Visser, 2015; Stats SA, 2019). Generally, a warming of more than 3°C will adversely affect crop production regardless of the region (FAO, 2010b). An alarming statistic for Africa, according to Davis *et al*. (2017) and Chersich and Wright (2019), is that an increase of over 4°C for the central interior of southern Africa in the far future is plausible and an increase of up to 6°C within this century could be seen for the continent (Awojobi & Tetteh, 2017). In accordance with these projections, Keane *et al*. (2009) along with Altieri and Nicholls (2017), suggest that the biggest agricultural loss will be experienced by countries in Africa, with some facing an estimated 50% loss of their total agricultural output and 10% of their overall maize production. This could potentially be devastating to household food production in Africa.

Factors that increase the vulnerability of Africa's agricultural sector to climate change, and consequently threaten food security, are the following: insufficient agricultural infrastructure and incentives; inadequate trade and financial policies; low investments in the sector and dependency on natural resources (Quinn *et al.,* 2011; Awojobi & Tetteh, 2017; Pereira, 2017). Special attention should be given to address these factors in order to improve the agricultural sector's resilience in the face of climate change and increase food security.

2.2.3 The Impact of Climate Change on Southern Africa

Classified as a semi-arid tropical region, southern Africa is considered to be among the regions most vulnerable to drought in Africa and in the world (Elum *et al.,* 2017; Nhamo *et al.,* 2019). Historical instances of drought in southern Africa substantiates this statement, for example the extreme droughts observed in 1992 and 1995, 2003–2004 and 2015-2017. Statistics are indicative of an eight to ten-year drought cycle (Vincent *et al.,* 2011; Masante *et al.,* 2018). In these regions, namely semi-arid and tropical regions, inter-annual and intra-annual rainfall variability are critical climatic elements that could amplify the negative effects of climate variability for agricultural outcomes (Landman *et al.,* 2017; Lotter, 2017).

Studies on the consequences of future climate change in southern Africa proposes that altered environmental balances, especially in precipitation, are expected to be the dominant adverse effect. This will bring great changes in agricultural production, such as cropping patterns, and in hydrological regions (Ziervogel *et al.,* 2014; Oduniyi *et al.,* 2019). Other future effects of climate change in southern Africa include an increase in temperatures, causing an acceleration of plant growth and a decrease in their growth period. Due to the rapid growth length of crops during their grain filling period, there might be an increase in woody content, thereby decreasing the quality of yields (Calzadilla *et al.,* 2013; Lotter, 2017). The availability of water for agricultural production is critical, therefore variations in precipitation will influence the success of southern African countries' agricultural production greatly. Altered frequency and distributions of precipitation and temperature caused by climate change threaten South Africa's agriculture with the increased occurrences of severe floods and droughts (Mutekwa, 2009; Ziervogel *et al.,* 2014; Lotter, 2017).

2.2.4 Climate Change Impacts on South Africa

The agricultural sector of South Africa is generally regarded as one of the economic backbones of the country (Oduniyi, 2018; Nhamo *et al.,* 2019). South Africa has a dual agricultural economy consisting of a well-developed commercial sector, and a subsistence farming sector predominantly located in traditional rural areas. It is estimated that more than half of the country's population depends on agriculture and agricultural-related industries for their livelihood, with almost 40 000 commercial farmers and an estimated 2.8 million South African households involved in subsistence farming (Schulze, 2016; Lotter, 2017). Agricultural land takes up roughly 80% or 100 million hectares of the total 121.9 million hectares of the country (Lotter, 2017). There is a diverse range of agricultural activities throughout the various provinces and regions. In the high summer and winter rainfall areas of the country, intensive crop cultivation and combination farming of crops and livestock are the primary farming activities. While other activities range from sheep farming in regions that are characteristically semi-arid to cattle ranching in bushveld regions (Turpie & Visser, 2014), only 12% of South Africa's surface area has high arability potential, with the major crops produced in the suitable areas including maize, wheat, sugar cane, oats and sunflower.

As previously mentioned, climate change adversely affects countries primarily dependent on agriculture and therefore natural resources for their livelihood. South Africa is not exempt from this description (Elum *et al*., 2017). Predictions about the effects of climate change on agriculture in South Africa correlates with the proposed effects on Africa as a continent. The vulnerability of the agricultural sector and the extent of the adverse effects is linked to the country's semi-arid nature, temperature and precipitation variations, increased farming activities on marginal lands, scarcity of water and frequency of droughts (Quinn *et al.,* 2011; Lotter, 2017). It should be noted that while some countries might not experience the expected effects of climate change on the African continent, South Africa unfortunately is likely to be one of the most adversely affected (Elum *et al.,* 2017). This statement is corroborated by Schlenker and Lobell (2010), who estimates a yield loss of up to 30% for South Africa at mid-century, as well as Oduniyi *et al*. (2019), who proposes a decrease of 10–20% in maize production over the next 50 years. With a loss of maize production, climate change would threaten one the country's largest food supplies as the industry accounts for 25–33% of the total gross agricultural production (Oduniyi, 2018). The vulnerability of the agricultural sector in correlation with the expected effects of climate change on South Africa prompts researchers to evaluate, mitigate and promote the adaptive capacity of farmers in areas that are characteristically agriculturally intensive.

Statistical evidence suggests that South Africa's average annual temperature has increased by 0.13° every decade since 1960. There is a trend of an increase in the number of hot days (with maximum temperatures exceeding 35°C) and a decrease in the number of colder days and this is expected to continue as a result of climate change (Mutekwa, 2009; Davis *et al*., 2017). Though this may be significant, changes in temperature is not the biggest challenge facing agriculture in South Africa. According to Blignaut *et al*. (2009), Schulze (2016) and Welborn (2018), the availability of water is the biggest constraint limiting the agricultural sector, with an estimated 60% of available water resources already being used for agricultural purposes. Considering the current excessive use of water resources for agricultural activities, climate change threatens to put further pressure on water resources already labelled as scarce (DEA, 2015; Elum *et al*., 2017). Uneven and irregular precipitation along with an average annual rainfall of between 450mm–500mm per year, which is lower than the global average of approximately 860mm, will contribute to the water constraints (Elum *et al.,* 2017; Oduniyi, 2018). In global terms, South Africa's water resources is referred to as being extremely limited and scarce, with projections suggesting that it would be one of the most water scarce countries in the world by 2025. Statistics from research done by Turpie and Visser (2014) substantiates this claim, indicating that the country's overall precipitation might decrease by 6.3% by the year 2050 and 9.5% in 2080.

Research further indicates that some provinces in the country are more vulnerable and susceptible to variations in climate than others (Schulze, 2016). Unfortunately, the provinces that are presently facing harsh environmental conditions will also be the most adversely affected by climate change. Partially due to its arid nature, the NWP is expected to be greatly affected as climate change continues to manifest in the 21st century.

2.2.5 The Impact of Climate Change on the North West Province and the Ditsobotla Local Municipality

The North West, Free State and Limpopo provinces are the three provinces most likely to be adversely affected by climate change (Gbetibouo & Ringler, 2009; Maponya & Mpandeli, 2012; Schulze, 2016). All of these are arid areas that are especially vulnerable to future variations in climate (Turpie & Visser, 2014). However, for the purpose of the study, the focus is specifically be on the NWP.

The NWP is an agriculturally intensive province with both large-scale commercial farmers and small-scale subsistence farmers. Subsistence farmers constitute roughly 70% of the NWP's farming population. It is estimated that agricultural activities account for about 18% of the province's employment, making it the biggest source of employment in the NWP (DoA, 2007; DRDLR, 2016). Maize and sunflower are extensively cultivated in the area, making the NWP one of the biggest maize producers in South Africa (DEA, 2015; Oduniyi, 2018). However, this productive capacity greatly depends on the relationship between rainfall and crop production. As such the potential implications of climate change could be devastating. Blignaut *et al*. (2009) suggest that a 1% change in rainfall patterns could cause more than a 1% change in the overall maize production of North West. Altieri and Nicholls (2017) along with Mambo and Murambadoro (2017) validate this threat by predicting North West to be one of the provinces experiencing drastic changes in rainfall patterns, which puts pressure on agricultural systems by reducing areas suitable for agriculture, shortening growing periods and decreasing yield potential.

The NWP is considered a dry region with the average annual rainfall ranging between 300mm–600mm and a history of prevailing and regular droughts (DRDLR, 2016; Mayowa, 2019). From 1970 to 2006, an estimated 11.3% decrease in annual rainfall was observed in the province, accompanied by a temperature increase of about 2.3% (Blignaut *et al*., 2009). Furthermore, irregular rainy seasons with an increase in early-season precipitation during the months of September and October, or in other cases later onset of precipitation, alter the usual seasonal agricultural process (Vincent *et al.,* 2011; Nhamo *et al.,* 2019). Widely implemented dryland crops are generally more sensitive to variations in climate, while irrigated crops tend to be less vulnerable (Lotter, 2017; Lalego *et al.,* 2019). However, due to the effect of climate change on rainfall patterns and water resources, the use of irrigation in the province will become increasingly limited. Additionally, crop production has become less profitable over the past two to three decades, both commercial and subsistence farmers continue to engage in unsound farming practices (DEA, 2015; Schulze, 2016). This includes cropping on marginal soils and overgrazing and overstocking of land, all of which contribute to the crop's vulnerability to the effects of climate change.

The province, and especially the study area, is also well known for its cattle farming practices (DRDLR, 2016). Overall, the projected increase in temperature implies an increase in cattle diseases and higher vulnerability. Climate change adversely affects feedlot cattle through increased temperatures, low wind speeds, relative humidity and increased solar radiation (DEA, 2015). Research suggests that cattle heat tolerance thresholds are likely to be exceeded in the NWP as climate change continues to manifest in the province, especially towards the latter part of the century when an increase of 6°C from 2080 is expected (DEA, 2013a; DEA, 2017). The majority of cattle farmers in the province favours open area grazing where cattle herds graze in the open, rather than feedlot farms. The practice of open area grazing is more sensitive to the implications of climate change due to the effects on the grassland and savannah ecosystems, potential decrease in veld quality, differentiation in lignification patterns, rainfall variations and decreased vegetation growth (DEA, 2015). All of these implications lead to the vulnerability of the cattle industry in the province.

The Ditsobotla Local Municipality is considered to be one of the regions most vulnerable to variations in climate. This could partly be attributed to the predicted climate change effects on the NWP's geographical location, which is expected to be greatly affected by prolonged drought, and also due to the locale's history of being the former homeland of the Bophuthatswana (Stacey *et al.,* 1994; Le Roux *et al.,* 2017; Agri SA, 2019). As a result of historical disadvantage, and the rich legacy of traditional practices, the areas occupied by subsistence farmers in former homeland regions generally have a high population density with very small land holdings of about 1 ha (Gbetibouo *et al.,* 2010; Schulze, 2016). The land holdings of these farmers are often used as communal land to allow enough space for livestock practices. The livestock densities associated with communal land tenure systems frequently exceed the carrying capacity of the land they occupy, severely affecting the quality of arable land (Quinn *et al.,* 2011; Schulze, 2016). Climate change adds to the already stressed environment as it further exacerbates the effects of land erosion and continually limits areas suitable for grazing. Extreme inequalities such as small land holdings due to unequal land restrictions further aggravate the vulnerability of rural municipalities such as Ditsobotla as it limits the possibilities of implementing adaptation measures. Adding to the vulnerability of the region is the primary agricultural practices the farming population of the Ditsobotla Local Municipality depend on.

Due to the Ditsobotla Local Municipality's high capacity for crop production approximately 57% of the region is cultivated, with maize cultivation dominating at about 90% (DEA, 2015; Savannah Environmental, 2018). Consequently, the area's economy extensively revolves around their agricultural services and production. The town of Lichtenburg in the Ditsobotla Local Municipality is among the most vulnerable to the effects of climate change and is suggested to experience the highest loss of maize production in the future (DEA, 2015). Historically, the district of the study locale has experienced severe and persistent droughts, such as the devastating droughts of 1992, 2013, 2015 and an intense drought in 2016 (DRDLR, 2016). Future projections of persistent droughts and variations of precipitation patterns shows that there is a great threat for maize farmers in the area. As the effects of climate change take hold in this region, maize harvests would only break even with production costs every seven out of 10 years in the Lichtenburg area (DEA, 2015). This would mean that future maize production in the area will no longer be economically viable. This should serve as a definite warning for the area where maize is the most frequently cultivated crop. Both commercial and subsistence farmers in the region will experience the detrimental effects of climate change, but there will be differences in how these two farming groups will be affected (Gbetibouo & Ringler, 2009; Deressa *et al.,* 2009). The fundamental differences between commercial and subsistence farmers might offer insight into the underlying causes of this differentiation.

2.3 Fundamental Differences Between Commercial and Subsistence Farmers

The ability of a farmer to persevere despite the challenges brought on by climate change depends on the farmer's ability to adapt to variations in climate. Prominent differences currently exist between commercial and subsistence farmers' CCA rates and their ability to implement modern agriculture techniques and methods (Quinn *et al*., 2011; Schulze, 2016). In order to understand this discrepancy in adaptive capacity, it is important to first comprehend the background of these two farming groups and the fundamental factors that contribute to their differences.

2.3.1 Farming Activities and Scale

Commercial farming can be seen as an input-intensive farming method where the yield is higher than that of subsistence farming. Unlike subsistence farming, where no share of the output is taken to market, with commercial farming most, if not all of the output is taken to the market to be sold (Archer *et al*., 2009). It can thus be said that subsistence farmers farm for their individual household's sustenance, while commercial farmers farm for the larger population and for export purposes (Calzadilla *et al.,* 2014; Schulze, 2016). Commercial farmers operate at a much larger scale, whereas subsistence farmers often occupy only a few hectares (1ha) for their agricultural activities. According to Oduniyi (2018), there is a correlation between farm size, agricultural sustainability and adaptive capacity since factors such as land degradation are associated with limited access to land. Due to the large scale of their activities, the commercial sector is responsible for 90% of all agricultural value added in South Africa. Commercial agriculture provides approximately 10–30% of all national employment, supplying a source of livelihood (either directly or indirectly) for about 8.5 million people (Calzadilla *et al.,* 2014; Schulze, 2016; Lotter, 2017).

Subsistence farmers often use a combination of various small farming activities, for example planting a variety of crops along with animal husbandry practices, to fulfill in their household consumption needs. This results in a way of living where the output of agricultural activity is directly used for household consumption instead of the majority of the output being generated for market and profit purposes. (Morton, 2007). It is a popular option for people who live in rural areas, mostly in developing countries, and comprises of a significantly higher population density per area than the commercial sector (Quinn *et al.,* 2011; Nhamo *et al.,* 2019). Subsistence farmers tend to use small areas of land for agriculture. According to Mutekwa (2009), in South Africa's subsistence farming communities, areas that can be used for crop cultivation are customarily allocated to separate households, while grazing areas are typically under communal ownership.

These cropping and grazing activities usually take an informal or traditional shape, such as the dependence on rain for irrigation (Quinn *et al.,* 2011; Calzadilla *et al.,* 2014). Importantly, 65% of the agricultural households in South Africa comprises of subsistence agriculture, providing livelihoods to more than a million farmers their families and communities (Tibesigwa & Visser, 2015). Unfortunately, due to a lack of finances and access to land, subsistence farmers often use risk-prone areas to conduct their activities, further exacerbating their vulnerability (Morton, 2007; Altieri & Nicholls, 2017). Lotter (2017) points out that the vulnerability of farmers is determined by their socio-economic circumstances and the biophysical conditions of their operating regions. The interaction between vulnerability and various other stressors and risks are constantly challenging farmers in a period where the effects of climate change are becoming ever more prevalent. Thus, vulnerability, stressors and farmer resilience are the focus of the next section.

2.3.2 Vulnerability, Stressors and Resilience: Comparing Subsistence and Commercial Farmers

In the context of climate change, vulnerability relates to a system's susceptibility to the adverse effects of climate change and the degree to which the affected system is able to cope with the consequences (Laukkonen *et al.,* 2009; Schulze, 2016). From an agricultural perspective, vulnerability could be defined as the degree to which current environmental and climatic conditions exceed or are close to exceeding the tolerance limits of crops and livestock (Keane *et al.,* 2009; Buchmann *et al.,* 2010; Schulze, 2016). A complex interaction between factors exacerbating vulnerability, various stressors and risks are constantly challenging farmers, increasing their vulnerability in a sector that is already highly sensitive to climate change (Schulze, 2016; Lotter, 2017). Risks generally confronting farmers include yield or production risk; price or market risk; asset risk; institutional risk; and financial risks (Schlenker & Lobell, 2010; Lotter, 2017). Climate change exerts an influence on all of the risks mentioned, either indirectly or directly. For this reason, understanding and evaluating these risks are crucial in order to take appropriate actions to reduce them.

There is an argument that commercial farmers are less vulnerable to climate change than subsistence or smallholder farmers. However, the risks associated with large-scale farming operations are significantly higher (Yaro, 2013). There is higher financial investment in agricultural technology, equipment and it entails large-scale farming activities in uncertain environmental conditions. However, commercial farmers continually build their resilience by means of their social networks and access to the newest relevant information, allowing them to implement more sophisticated adaptation measures. Wiid and Ziervogel (2012) & Elum *et al*. (2018)emphasize the resilience of commercial farmers, linking it to their access to climate change information and agricultural information, social connections, a diverse knowledge base and financial capital allowing them access to agricultural insurance.

Subsistence farmers are confronted with a variety of climatic and non-climatic risks that could influence the entire community or on individual households. These include risks such as floods and drought, drastic market changes or animal and crop diseases (Twomlow *et al.,* 2008; Quinn *et al.,* 2011). Literature often identifies subsistence farmers as more susceptible to the effects of climate change and climate variation mostly because of the projected impacts on the geographical location of developing countries, in this case countries in Africa, and socio-economic circumstances limiting their adaptive capacity (Mertz *et al.,* 2009; Mutekwa, 2009; Altieri & Nicholls, 2017; Lotter, 2017).

The vulnerability of smallholder farmers to climate change is further exacerbated by various interlocking non-climatic stressors. Literature identifies these stressors as the following: environmental degradation as a result of rapid population growth, poverty and poorly defined property rights; market challenges and unpredictability; epidemic threats such as avian influenza/bird flu attacking communities and prohibiting trade; state fragility and the HIV/AIDS pandemic, which affects the household's labour capacity (Turpie & Visser, 2014; Schulze, 2016; Pereira, 2017; Nhamo *et al.,* 2019). Environmental degradation as a result of the rapid population growth greatly limits the area of land suitable for agricultural activities. Poorly defined property rights further add to this challenge as it limits the land available and security of land tenure for subsistence farmers. The identified social and health challenges often result in economic challenges as it prohibits market accessibility and trade. Despite the numerous stressors they face, a few resilience factors only associated with subsistence farming could aid in farmers' ability to cope with crises even if commercial farmers might be in a better position to avert the consequences of climate change in some ways (Morton, 2007; FAO, 2010b). As opposed to their commercial counterparts, subsistence households often have diverse livelihood sources of income, spreading potential risks and putting them in a better position to recover from a crisis. Allocating tasks between members of the family and utilizing their labour efficiently by for example assigning tasks appropriate to the member's abilities (children are assigned to small livestock and adults to larger species), along with their valuable indigenous knowledge, could build the resilience of subsistence farmers (Mertz *et al.,* 2009; Buchmann *et al.,* 2010; FAO, 2010b). Farmers' level of resilience is an important factor that could enable them to cope better with the effects of climate change and could prevent subsequent failure to adapt to climatic variations entails.

2.3.3 The Impact of Climate Change and the Consequences of Failure to Adapt

For commercial farmers, failure to adapt does not only entail extensive personal economic loss, it also affects their labour force, their labour force's families, and the agricultural economy of that area (Yaro, 2013). The demise of commercial farmers as a result of climate change could further aggravate food insecurity on a national level. Statistics for South Africa for 2050 projects a net revenue loss of approximately 18% for commercial agriculture, with probable maize production reduction of between 12 and 40%. Even more concerning, by 2080 the net revenue loss is predicted to increase to 110%, causing this sector to be completely unprofitable (Turpie & Visser, 2014; Nhamo *et al.,* 2019).

According to the research done by Turpie and Visser (2014), projections for 2080 also suggests that commercial farmers in the NWP will experience the greatest revenue loss in the country. Furthermore, the study estimates that crop farmers will experience the highest loss in the province, with a decline in their crop production of about 1.6% resulting in a devastating R126 662 600 loss. The NWP also follows shortly after the Limpopo province with livestock farmers most affected by province. This entails an estimated decline of 418% for livestock farmers in the NWP. Similar to the latter, farmers practicing mixed farming are also projected to be the worst affected in Limpopo and the NWP.

Climate change will exert an influence on three main categories of subsistence farmers' livelihoods: biological processes; environmental and physical processes; and human health and non-climate stressors (Morton, 2007). Biological processes in the agricultural context relates to the influence of climate change on crops and animals, a category especially concerning for subsistence farmers in Africa. This alludes to climate change increasing the potential of transboundary plant pests and diseases invading smallholder crops, such as the armyworm, cassava disease and wheat rust (Morton, 2007; IPCC, 2014b; Oduniyi *et al*., 2019). The threat is exacerbated by the currently limited knowledge about the effect of crop diseases and pests on smallholder systems. The second category, environmental and physical processes, influence subsistence farmers to a great extent. According to Awojobi and Tetteh (2017), the most common climatic events associated with the manifestation of climate change in Africa are drought, land degradation, desertification and flooding. There is a great correlation between this category and the livelihoods of subsistence farmers. Examples include for instance loss of livestock due to persistent droughts in Somalia, Ethiopia and Kenya. These events caused distress to almost 11 million individuals, prompting a mass migration of herdsmen (Besada & Sewankambo, 2009). The greatest concern pertaining to the third category is the expectation of health issues increasing in correlation with climate change. A rise in malaria and water-borne diseases is of specific concern (Nhamo *et al.,* 2019).

Subsistence farmers often lack the necessary resources to use anticipatory action against climate change when compared to commercial farmers (Hassan & Nhemachena, 2008; Vincent *et al.,* 2011). Due to the extent of the implications of climate change for subsistence farmers, failure to adapt successfully could lead to social disruption of the group, food insecurity and intense deprivation, population dispersion, or in extreme cases, failure to adapt could have fatal consequences (Bryan *et al*., 2009; Tibesigwa & Visser, 2015; Altieri & Nicholls, 2017).

From the literature it is evident that while some studies suggest subsistence farming might be at higher risk to climate change owing to their limited ability to implement adaptation methods (Mutekwa, 2009; Lotter, 2017), others indicate commercial farmers to be the riskier sector due to higher investments in unstable and uncertain environmental and economic conditions (Yaro, 2013). Regardless of which sector might be at higher risk, the ability of both to adapt to climate change is important for the survival of vast populations.

2.4 Conclusion

The aim of this chapter was to investigate the existing literature on climate change and its various dimensions. From an agricultural perspective, climate change poses a significant threat to developing countries, including South Africa and the study area. Unfortunately, it is these communities that are often the least able to adapt and cope with the risks and adverse effects associated with climate change (Twomlow *et al.,* 2008; Aniah *et al.,* 2019). The chapter also explored the interaction between vulnerability, climatic and non-climatic stressors and risks, revealing the complexity and multidimensional nature of climate change impacts. The discussion pointed out that the effects of climate change will be different for the two farming groups. Subsistence farmers constantly battle problems of the isolation of their agricultural businesses, almost no support structures, uncertain opportunities to participate in world markets and little to no access to technological advances (Schulze, 2016). Commercial farmers may be more resilient to unforeseen and unfavourable environmental circumstances, but the risks they take in their agricultural businesses are often greater than that of subsistence farmers. For them, failure to adapt entails great economical loss, which not only affects the farmer, but also transfers to loss of livelihoods for the farmer's employees and financial loss for agricultural businesses in the surrounding area.

The reality of climate change has become an undisputed fact. It is arguably the greatest persistent threat facing society, and it will continue to intensify in the future. However how we should adapt to these changes is still uncertain (Wiid & Ziervogel, 2012; Aniah *et al.,* 2019; Nhamo *et al.,* 2019). Adaptation in agriculture is critical as it would promote food-, income- and survival security despite the difficult environmental circumstances caused by climate change (Hassan & Nhemachena, 2008; Lotter, 2017; Alemaw, 2020). Therefore, the next chapter explores existing literature on the available adaptation methods with respect to climate change for agricultural practices, along with the factors that could aid or hinder a farmer's decision to adapt.

CHAPTER 3 CLIMATE CHANGE ADAPTATION: CONTEXTUALIZING ADAPTATION IN AGRICULTURE

3.1 Introduction

Climate change is undoubtedly one of the greatest systemic threats facing humanity in the 21st century (Welborn, 2018; Zwane, 2019). It continually alters the dynamics and causes uncertainties in agricultural production. Modern agriculture has tried to minimize and cope with climate variations and weather-related extremes through adaptation (Crane *et al*., 2011; Mashizha, 2019).

There have been arguments in favour of postponing adaptation strategies based on the assumption that climate change will happen at a gradual pace. Such arguments justify the idea that immediate actions to adapt to future changes in climate is not needed. Other reasons for delaying adaptation to climate change is the belief that cheaper and better technology will be available in the future. However, predictions suggest that future changes in climate will occur more rapidly and with a high probability of surpassing the affected community's ability to cope with disastrous ramifications (IPCC, 2007a; FAO, 2010a; Mayowa, 2019).

Due to the uncertainties surrounding climate change and the fact that it is accompanied by a rapid onset of imminent weather extremes, this phenomenon is likely to progressively challenge the agricultural sector. It can cause natural resources (like water) and the fields dependent on them to reach their tolerance thresholds, testing their resilience and exposing their vulnerabilities towards climate variations (Marshall *et al.,* 2013; Ziervogel *et al.,* 2014). The vulnerability of the agricultural community to climate conditions is often viewed as a factor of the extent to which farmers may be influenced by variations in climate (Gbetibouo & Ringler, 2009; Yaro, 2013; Schulze, 2016). Those who are less resilient, who are frequently exposed to perturbations and who have a limited adaptive capacity, are considered to be the most vulnerable farmers. As climate change is expected to further exacerbate their vulnerability, it is important to facilitate the implementation of appropriate adaptation methods, thereby ensuring that livelihoods are not damaged by climatic events (Claessens *et al.,* 2010; Nhamo *et al.,* 2019). This chapter explores responses and methods that could reduce the risk to climate change, as well as the factors hindering or supporting farmers' decisions to adopt these strategies.

3.2 Climate Change Mitigation vs. Adaptation

Montmasson-Clair and Zwane (2016) and Mambo (2017) note that climate change is connected to a significant risk for society and the natural environment. Currently two appropriate societal responses can reduce these risks, namely mitigation- or adaptation strategies. Mitigation strategies are generally concerned with reducing or preventing the process of climate change by reducing greenhouse gas emissions resulting from human activities (Nyong *et al.*, 2007; Rosenzweig & Tubiello, 2007; FAO, 2019). Alternatively, it could refer to the actions employed as a means to reduce or limit the extent or continued manifestation of anthropogenic climate change in the long term (Welborn, 2018). Thus, mitigation strategies aim to address the root causes of climate change with hope of reducing the probability of extreme climatic events and their adverse consequences. According to Swart *et al.,* (2003), mitigation strategies can be categorized into two distinct groups, technological solutions or strategies that include social solutions such as changes in individual behaviour. Literature acknowledges the importance of technological solutions in the form of green energy solutions such as solar, wind and tidal energy, all of which is aimed at reducing the dependence on carbon emitting fossil fuel sources, thereby reducing greenhouse gas emissions.

During the 1990s and early 2000s, the climate change community was for the most part preoccupied with mitigation attempts (Nyong *et al*., 2007; Adger *et al.,* 2009). One of the core reasons relates to mitigation's ability to reduce the negative outcomes of climate change on the various climate-sensitive earth systems. According to Mambo (2017) and Elum *et al.* (2017), these climate-sensitive systems include forestry, coastal conservation, disaster prevention, management of water resources, and agriculture. In contrast with mitigation, it has been argued that adaptation strategies often fail to reduce the negative impact in all of these systems that are sensitive to changes in climate (Füssel, 2007). Another reason for the initial emphasis on mitigation has been the perceived longevity and reliability of this strategy's outcome, namely reducing the impact of climate change, since it is concerned with addressing the main causes. As opposed to mitigation, there is a higher uncertainty regarding the efficiency and outcome of adaptation strategies, since they are based on future climate and impact projections, both of which are challenging to predict (IPCC, 2013; Schulze, 2016; Pereira, 2017).

Recently, there has been a greater emphasis on changing the social or behavioural causes of global warming in order for mitigation efforts to be effective in the long run (IPCC, 2007a; Fazey *et al.,* 2010). Instead of focusing on reducing society's contribution to global warming, the other societal response to climate change, namely adaptation, is primarily concerned with enabling communities to cope with the adverse effects of climate change (Twomlow *et al*., 2008; IPCC, 2012a; Akinnagbe & Irohibe, 2014). However, the advantages of adaptation methods and the combination of both mitigation and adaptation efforts are increasingly emphasized as present studies suggest it to be more efficient when addressing climate change challenges (Laukkonen *et al.,* 2009:287; Elum *et al.,* 2017). One of these arguments is based on statistics indicating the persistent increase of temperatures by at least 2°C in this century, regardless of greenhouse gas emissions being limited by mitigation (Keane *et al.,* 2009; IPCC, 2012a; IPCC, 2014b; Huq *et al.,* 2018; Welborn, 2018). The UNFCCC was the first to link adaptation and mitigation together (Barrett, 1998). Since then, experts have reached relative consensus that there could be better results for responding to changes in climate when mitigation and adaptation strategies are linked rather than set in opposition (Nyong *et al.,* 2007; Laukkonen *et al.,* 2009; IPCC, 2014b). The agricultural sector is one of the most vulnerable to climate change, but it is simultaneously also a major contributor to greenhouse gas emissions, meaning that linking adaptation and mitigation strategies in this sector is crucial (Rosenzweig & Tubiello, 2007; Mutekwa, 2009; Akinnagbe & Irohibe, 2014). Options should therefore not consider either mitigation or adaptation, but rather how they can be utilized in unison to optimize efforts to reduce the impact of climate change on society.

In order to successfully link mitigation and adaptation strategies, it has become increasingly important to be able to anticipate the effects of climate change on the environment and to improve vulnerable communities' capacity to adapt (Twomlow *et al.,* 2008; IPCC, 2012a; Schulze, 2016; Nhamo *et al.,* 2019). Different kinds of resources have to be available to create a positive environment to implement mitigation and adaptation. However, this is unrealistic for vulnerable developing countries that do not always have the needed resources to adapt (Füssel 2007; Lalego *et al.,* 2019; Nhamo *et al.,* 2019:2). This threatens the sustainability of agricultural systems in developing countries. Unfortunately, it is these societies that are often the most reliant on agriculture for their livelihood (Altieri & Nicholls, 2017; Oduniyi, 2018).

In agriculture, the importance of successful adaptation is increasingly linked to the food, income and livelihood security of farmers and their communities. Farmers can reduce the potential implications of climate change by implementing adaptation strategies, which range from technological advancements to timely adjustments of their operations (Ajani *et al.,* 2013). Thus, for the purpose of this research the primary focus was on the societal response of adaptation towards climate change. Identifying available adaptation methods applicable to South African farmers and understanding the factors hindering or promoting their implementation could enable them to cope with the variations in climate despite the vulnerability of the agricultural sector.

3.3 Climate Change Adaptation Strategies Available to the Agricultural Community

Consensus is growing about the urgency of implementing adaptation strategies to minimize the agricultural sector's vulnerability towards climate change. A major challenge is that not all strategies are universally applicable, causing farmers' responses to vary across regions (Niles *et al.,* 2015; Aniah *et al.,* 2019). Different backgrounds and motives for farming often result in great variations in the adaptation choices of subsistence and commercial farmers. Literature suggests that large-scale farmers (commercial farmers) will choose their adaptation methods based on the prospect of optimizing their agricultural output while implementing sustainable farming methods (DAFF, 2010; DAFF, 2013). Subsistence farmers on the other hand are more likely to make adaptation decisions motivated by increasing their resilience towards climate change and ensuring their survival and sustainability of their livelihoods (Bryan *et al*., 2009; Yaro, 2013).

Despite different motivations for adapting, there are general categories of adaptive responses that are applicable to all scales of farmers. It is important to note that the dynamic nature of adaptation strategies may cause them to differ between short-term or long-term applicability. Furthermore, most of these strategies are interrelated and used in combination (Hassan & Nhemachena 2008). The available adaptation methods can be classified into the following general categories:

3.3.1 Adjustments to Farming Operations

This adaptation response is concerned with the range of adjustments that farmers make to their usual farming activities to cope with climate change. A widely practiced operational adjustment is the modification of crop types and varieties to best fit observed and predicted environmental conditions (Rosenzweig & Tubiello, 2007; Vincent *et al.,* 2011). For example, in response to increasing temperatures, farmers adjust by opting for (i) crop varieties with more efficient water utilization, (ii) crop varieties with a higher tolerance for heat, (iii) early maturing crops, and (iv) mixed farming practices (Twomlow *et al.,* 2008; Newsham & Thomas, 2011; Wiid & Ziervogel, 2012; Otieno & Muchapondwa, 2016).

Another popular strategy, especially favoured by subsistence farmers, is the tactical distribution of agricultural activities throughout the season to avoid intra-seasonal differences in rainfall patterns (Morton, 2007; Akinnagbe & Irohibe, 2014). This means managing agricultural practices to ensure that sensitive stages in crop development or livestock are protected from periods where climate variations are most likely to occur. An example of such operational adjustment is altering the usual planting dates of some crops in response to changing and unpredictable weather patterns (Deressa *et al.,* 2009; Ajani *et al.,* 2013).

Some farmers use dry planting techniques such as dry ripping instead of allowing the rains to soften the grounds first. This allows crops to be planted with the first rainfall of the season (Vincent *et al.,* 2011). Farmers also make use of a cultivation technique known as intercropping, where one field is used to plant multiple crops to prevent soil erosion and to preserve soil fertility. The same motive urges farmers to increase their rotation between crop types (Rosenzweig & Tubiello, 2007; Schulze, 2016).

3.3.2 Conservation Practices

The use of soil conservation techniques to cope with the increased occurrence of droughts allows soil to maintain moisture more efficiently while also improving soil fertility and yields (Hobbs *et al.,* 2008; Schulze, 2016; Elum *et al.,* 2017). A primary conservation practice implemented to allow natural restoration of soil nutrients is the increase of fallow periods by allowing fields to rest by not planting any crops (Rosenzweig & Tubiello, 2007). To preserve soil nutrients and prevent excessive extraction, farmers also reduce the density of livestock or crops in their fields (Bryan *et al.,* 2013).

A popular multi-purpose conservation practice is mulching, where previous harvest residues are left in the field. This approach preserves soil quality and fertility as the previous crop residues create a barrier against wind and water erosion, while also stabilizing soil temperature and preventing excessive evaporation (Yaro, 2013; IPCC, 2014b; Akinnagbe & Irohibe, 2014).

Minimum tillage has continually gained much attention among South African farmers as this technique involves minimal soil disturbance during the land preparation phase, which aids in conserving organic carbon contents in soil and also has the advantage of being cost-effective (DEA, 2015; Schulze, 2016). For the most part, both subsistence and commercial farmers can adopt conservation farming as it is cost-effective and a substantial input is not necessary, making it easily adoptable for resource-constrained farmers. However, used by commercial farmers in an input-intensive environment, conservation farming can become expensive when taking into account the machinery required for minimum tillage during ploughing (Knowler & Bradshaw, 2007; Vincent, *et al.*, 2011).

3.3.3 Shade and Shelter

In an effort to protect livestock and crops against heat, wind, drought, frost and cold, farmers apply shade and shelter methods such as planting trees to provide natural shelter/shade against natural elements (Benhin, 2006; Ajani *et al.*, 2013). Other sheltering methods include covering their livestock or plants with grass, nets or plastic. In extremely cold environments, livestock farmers sometimes provide heat to their livestock through firewood or paraffin heaters.

3.3.4 Improved Irrigation

With water being the main factor limiting agricultural practices in South Africa, using irrigation more efficiently often seems to be one of the most needed and possible effective adaptive responses (Blignaut *et al.,* 2009; Akinnagbe & Irohibe, 2014; Lotter, 2017). Some irrigation strategies farmers tend to apply are (i) the use of wetlands for their agricultural activities, (ii) the use of sprinkler or micro-irrigation instead of flood irrigation and (iii) the use of underground water by building boreholes on their land (Elum *et al.,* 2017; Nhamo *et al.,* 2019).

3.3.5 Increased Chemical Application Methods

As an attempt to reduce the risk of decreased production yield as one of the predicted short-term effects of climate change, farmers are constantly adjusting their chemical application quantity and methods (Keane *et al.,* 2009; Vincent *et al.,* 2013). For example, to counteract increased evapotranspiration caused by higher temperatures, some farmers adjust by increasing their application of appropriate chemicals to slow down the evapotranspiration process (Benhin, 2006; Deressa *et al.,* 2009; DAFF, 2010). To preserve the moisture content and fertility of the soil, farmers increase farm manure application to their land. They also apply more lime to maintain the correct pH balance of the soil.

3.3.6 Diversification of Livelihood Activities

Some farmers are tactically spreading their household/community's sources of income to reduce the risks associated with farming and unforeseen climatic conditions (Crane *et al.,* 2011; Yaro, 2013). This means adopting livelihood activities beyond the agricultural sector, decreasing their dependency on the success of their crop yield or other farming practices. Therefore, the household may continue to persevere even if the farmer fails to adapt successfully to climate change, which is greatly important during a time where environmental conditions are becoming increasingly unpredictable (Twomlow *et al.,* 2008; Akinnagbe & Irohibe, 2014).

3.3.7 Financial Coping Strategies

Some strategies relate to financial adaptations such as getting farm insurance. Sufficient financial capital allows farmers to purchase agricultural related insurance (e.g. crop insurance) to prevent potential loss of income should unpredicted environmental conditions have a detrimental effect on production yield (IPCC, 2007a; Crane *et al*., 2011; Mashizha, 2019). In South Africa crop insurance is the most developed type of agricultural insurance, covering multiple non weather and weather-related risks. Weather related risks covered through crop insurance includes hail and drought, while non weather-related risks include unforeseen catastrophes caused by disease and pests outbreaks. New agricultural insurance products, for example weather-based index insurance, also motivates farmers to take proactive action towards reducing their risks. According to Elum *et al*. (2018), the indemnity of weather-based index insurance is based on the area's history of the occurrence of a specific weather parameter. However, this strategy is mostly limited to commercial farmers as opposed to small-scale farmers, who often do not have sufficient resources for this strategy (Welborn, 2018). This strategy is further confined to commercial farmers due to the slow payment of claims not alleviating the adverse impacts of losses on the livelihoods of affected farmers in a timely matter.

3.3.8 Strategies for Pastoralists and Livestock Farmers

The strategies that have been identified tend to be less effective for livestock farmers and pastoralists, forcing them to adapt differently (Morton, 2007). Generally, farmers resort to breeds with a higher heat tolerance in response to increasing temperatures. Most livestock farmers also cope with long dry seasons by producing and stocking their own feed, such as lucerne (Benhin, 2006; IPCC, 2007b). Another coping strategy commonly used is indigenous disease management and supplementary feed methods for their livestock (Morton, 2007; Akinnagbe & Irohibe, 2014).

Using mobility to their advantage is the main and most effective way in which pastoralists can adapt to changes in climate (Bryan *et al.,* 2013). Unfortunately, the encroachment of nearby cities (extension of city borders) accompanied by commercial farmers' growing need to extend their land, constantly decreases the mobility of these farmers (Ziervogel *et al*., 2006; Ayantunde *et al.,* 2011) Pastoralists attempt to diversify the species composition of herds and to increase their herd size as a precautionary coping strategy. Past evidence suggests there is a positive correlation between species diversification and herd sizes pre-crisis, leading to better herd survival rates after the crisis has passed (IPCC, 2007b; Little *et al.,* 2008). Additionally, pastoralists use diversification of herd species to their advantage by strategically allocating labour for women, men and children to species fitted for them, which enables farmers to manage livestock more efficiently.

As mentioned previously, modern climate change information has not always been available to all farmers. Regardless of the lack of information pertaining to available and applicable adaptation strategies, these farmers have managed to survive mostly by using indigenous information passed on to them by previous generations of farmers. The next section investigates the survival and adaptation strategies originating from indigenous knowledge.

3.4 Indigenous Knowledge and Adaptation

Indigenous knowledge could be defined as local knowledge that is constantly evolving and that has developed from the experiences and interactions of a community with their environment. It is passed on from one generation to the other, traditionally by word of mouth (Osunade, 1994; Ajani *et al*., 2013). Alternatively, traditional knowledge represents the cumulative information, practice, and perceptions of the relationship between living beings and their environment obtained from generational and cultural transmission (Buchmann *et al.,* 2010; Wolf & Moser, 2011). In the context of this study, indigenous knowledge relates to a continuous cycle of traditional and cultural adaptive practices that has evolved from the experiences of each farming generation and is passed on to the next generation small-scale or subsistence farmers.

Most large-scale farmers have the advantage of social networks, access to credit and new climate change information, along with a range of possible adaptation strategies. Subsistence farmers rarely have the same assistance available to them (Wiid & Ziervogel, 2012; Turpie & Visser, 2014). Despite the lack of available modern-day agriculture or adaptation information, subsistence farmers still manage to survive in spite of the environmental challenges threatening their livelihood (Nyong *et al*., 2007; Hassan & Nhemachena, 2008). This indicates that though subsistence farming communities have been isolated from emerging climate change and CCA information, they have persisted by developing indigenous strategies, allowing them to adjust to perceived variations in climate (Twomlow *et al*., 2008; Newsham & Thomas, 2011). Research suggests that the ability of indigenous knowledge to promote the implementation of adaptation strategies should not be underestimated as it serves as the basis for important agricultural decision making in many subsistence farming communities (Davies & Ebbe, 1995; IPCC, 2007a; Adger *et al*., 2009; FAO, 2010b).

Indigenous knowledge has been largely overlooked in the process of formulating adaptation strategies. Researchers are now becoming more aware of the positive influence it could have when integrated with other knowledge (Mertz *et al.,* 2009; Newsham & Thomas, 2011; Wiid & Ziervogel, 2012; FAO, 2019). Including indigenous knowledge in formal adaptation strategies could lead to the formulation of sustainable, low-cost strategies with a higher participation rate (Robinson & Hebert, 2001; Ajani *et al.,* 2013). Adding to the importance of including indigenous knowledge is its ability to facilitate biodiversity preservation, which is regarded to be an efficient mitigation strategy. According to Buchmann *et al*. (2010) and Green and Raygorodetsky (2010), the preservation of indigenous and local species is useless without accurate information on how to grow and manage them. Indigenous knowledge systems have this critical information.

Subsistence farmers are known to use local predictions of climate and cultural models of weather to determine how they should adapt their farming activities. For example, they may adjust their cropping patterns and planting dates (Nyong *et al*., 2007). Particularly prominent in literature regarding indigenous knowledge strategies is the use of early warning systems and the ability of traditional farming communities to recognize and respond to changes in climate parameters (Thomas *et al*., 2007; Mertz *et al.,* 2009; Bryan *et al*., 2013). Research on the early warning systems within traditional communities has shown it to be a highly interesting field. One such example is discussed in research by Newsham and Thomas (2011). They refer to farmers in North Central Namibia who are of the belief that early fruit production on Omhuzi trees indicates a good rainy season. The farmers use the Omhuzi tree indicator to aid them in their decision of crop variety. Some even opt for early maturing crops with the prospect of good rainfall to yield two harvests in one year. Due to the diverse and area-specific nature of local knowledge, the full scope of indigenous adaptation strategies is yet to be studied and understood fully. However, there are some general IK strategies that have been identified in literature. These are discussed below.

Indigenous knowledge strategies often correlate with modern adaptation strategies. One such strategy is soil conservation by mulching and no-till operations, which help to conserve carbon in soils (IPCC, 2007b; Ajani *et al.,* 2013). Traditional knowledge has found the application of natural mulches to aid in pest control and disease management, while also moderating soil temperatures and extremes. In water-limited areas farmers have over generations learned and adopted water and soil management strategies to enhance the soil's water storage ability and to simultaneously counter soil degradation. For example, traditional farmers in Nigeria were found to include ridges, known as tied ridges, at regular intervals across furrows that are created between crop rows, causing the crops to be planted on slightly raised beds (Altieri & Nicholls, 2017). Another fascinating indigenous conservation strategy is the "Zai" technique. Traditionally used in western Sahel, specifically in Burkina Faso, the Zai technique involves digging circular pits during the preseason and inserting handfuls of organic materials, such compost or manure into the pits (Brown & Crawford, 2007; FAO, 2010b). This allows for an increased concentration of organic matter, improved water infiltration and improved water retainment after the area has received rain, subsequently improving the soil quality (Danjuma & Mohammed, 2015). Thereafter seeds are sown into the pit, increasing the crop's access to water and additionally protecting the seedlings against wind damage. With regard to fertilizer, subsistence farmers tend to opt for organic materials instead of chemical alternatives, such as with the above-mentioned Zai technique, which could be beneficial in reducing damaging GHG emissions (Claessens *et al*., 2010).

Another prominent indigenous adaptation strategy in literature is agroforestry. Commonly used among traditional farming communities, this practice combines growing trees, planting crops and/or having livestock in the same land management unit (FAO, 2010a; Ajani *et al.,* 2013; Akinnagbe & Irohibe, 2014; Maponya *et al.,* 2020). Similarly, some subsistence farmers have coped with changing conditions by growing shade-resistant crops in areas where sun exposure are heavily restricted, such as forests. An example of this practice can be found in the south western parts of Nigeria where farmers adapted by growing shade tolerant crops such as Yam and Cocoyam in forest areas (Ajani *et al.,* 2013). This substantiates the belief that traditional knowledge of plants could aid in creating efficient and successful agroforestry projects today (Nyong *et al.,* 2007; Buchmann *et al.,* 2010).

Interestingly, farmers in traditional communities are also likely to gravitate towards livestock rearing as their main agricultural activity as a means of adaptation rather than adapting their crop practices. Research substantiates this statement by concluding that small-scale farmers switched to livestock practices in periods of extreme temperatures and scarce precipitation, for instance during the reoccurring droughts in the NWP, South Africa (Seo & Mendelsohn, 2008; Thomas *et al.,* 2007; DEA, 2015). Thus, the switch to livestock farming is in itself a coping strategy based on indigenous knowledge.

Though inclusion of indigenous knowledge could have great benefits and should be explored for future adaptation strategies, it should not eliminate the use of modern scientific knowledge entirely, but rather compliment modern adaptation strategies (Wolf & Moser, 2011; Newsham & Thomas, 2011; Elum *et al.,* 2017). Unfortunately, even with the resources of scientific knowledge and the wealth of traditional knowledge, both commercial and subsistence farmers are still confronted by other constraints influencing their decisions to adapt (Vincent *et al*., 2011; Yaro, 2013). The next section explores some of the constraints and determinants farmers have to consider when they want to initiate adaptive responses.

3.5 Determinants of Farmers' Adaptation Decisions

The implementation and planning of adaptation strategies are influenced by a diverse range of constraints in multiple contexts (IPCC, 2007c; Biesbroek *et al*., 2013; Elum *et al.,* 2017). Although literature tends to discuss each adaptation constraint individually, they rarely tend to act in isolation from each other. As a result, farmers are forced to navigate various interacting constraints to successfully reach a chosen adaptation objective (Shen *et al*., 2011; Yaro, 2013). Adger *et al.* (2009) identifies three distinctive dimensions that may limit a farmer's decision to adapt, namely environmental/physical limits, which include access to natural resources; economic limit relating to financial capital; and lastly technological limits. Understanding and considering the constraints to adaptation and the contributing factors when formulating adaptation strategies could facilitate their adoption as part of agricultural activities (Brooks, 2003; Yaro, 2013; IPCC, 2014a). This is further substantiated by Vincent *et al.* (2011), who argues that the identification of barriers to adaptation is crucial as it will only become harder to build sustainable adaptation methods, while the effect of climate change will continue to increase the vulnerability of developing countries such as South Africa. Some of the main factors limiting or supporting South African farmers' use of adaptation strategies are discussed below.

3.5.1 Environmental or Physical Limitations

The environmental or physical transformations of an area due to climate change affect the farmer's possibilities of adaptation. Climate attributes, namely precipitation and temperature, influence farmers' production and ultimately adaptation strategies, as they are forced to choose their livestock species and crop cultivars based on the climate of their surrounding environment (Hassan & Nhemachena, 2008; Keane *et al.,* 2009; Gbetibouo *et al.,* 2010). When the environment changes drastically, for example land degradation occurs as a result of reoccurring droughts, farmers are limited to the adaptation strategies that are available and appropriate to them. Lack of access to natural resources is another constraint that keep farmers to adapting, for instance, the abundance or lack of water in an area is highly susceptible to climate change (Quinn *et al.,* 2011; IPCC, 2014b; Ziervogel *et al*., 2014). A lack of substantial water resources could restrict the use of adaptation methods such as irrigation for farmers in the affected area. Similarly, a loss of soil and water quality due to increased temperatures and varying precipitation patterns can be a barrier to agricultural activities and can limit appropriate adaptation strategies (Olesen *et al.* 2011; Meijer, 2013). This further validates a statement by Bryan *et al.* (2009), who asserts that access to larger areas of land and quality soils are critical determinants of adaptation for South African farmers.

3.5.2 Economic Limitations

Financial factors are also a main determinant of adaptation, with the most prominent constraints emerging from literature being a lack of credit, a limited financial capacity and the presence of poverty, especially in subsistence farming communities (Morton, 2007; Yaro, 2013; IPCC, 2014b). Due to the extensive limitations and consequences this adaptation barrier brings to a farmer's operations and adaptive capacity, it has been identified as a determining factor of vulnerability to climate change (Padgham, 2009).

Without sufficient credit, farmers are restricted from getting insurance, which helps them lower their risk to climate change, and they have a limited ability to adopt new technology that that could increase yields (IPCC, 2014a; Oduniyi *et al.,* 2019). A primary contributor to insufficient credit and/or funds is the lack of access to national markets and international agricultural businesses. In this instance, commercial farmers might have the advantage as access to markets provides them with the input they need to conduct their agricultural activities (IPCC, 2007a; Deressa *et al.,* 2009). These inputs, which enable commercial farmers to continue farming successfully despite climate change, include access to new crop varieties, advanced irrigation technology and fertilizers (Nyanga *et al.,* 2011; Vincent *et al.,* 2011; Nhemachena *et al.,* 2014). The literature emphasizes this category as a major limitation, especially for subsistence farmers due to their predominantly restricted access to the previously mentioned resources and inputs.

3.5.3 Access to Technology and Farm Assets

The use of technology often offers opportunities for adaptation. Key aspects that may promote or hinder the incorporation of technology in adaptation methods include access, its availability, its effectiveness for climate risk management purposes and the acceptance of technology by the users and relevant stakeholders (IPCC, 2014a; Nhemachena *et al*., 2014). The application of model-based support systems in the decision-making process related to adaptation strategies benefit greatly from climate-related technological advances such as seasonal forecasts (IPCC, 2007b; Crane *et al*., 2011). Integration, dissemination, and access to such information could facilitate the adoption of appropriate adaptation strategies. Regardless of the benefits, little support for climate risk management in the agricultural sector often limits the demand for such products. The IPCC (2007b), Ajani *et al*. (2013) and Nhamo *et al*. (2019) suggest the use of climate technology and information, for instance, improved early warning systems may allow some lead time prior to the onset of an event. Lead times provide the affected area or community with an opportunity to put preliminary strategies into place.

Farm assets such as heavy machinery facilitate the adoption of more advanced and effective adaptation methods. Literature shows a correlation between farm assets and the farmer's ability to adapt (Hassan & Nhemachena, 2008). Due to the large scale of commercial farmers' activities, they have access to better finances and they consequently possess the ability to invest in modern agricultural technology. This includes access to heavy machinery that enables farmers to adapt more efficiently (Kurukulasuriya & Mendelsohn, 2006; Nhemachena *et al.,* 2014).

3.5.4 Education, Awareness, Perceptions and Farming Experience

Education, farming experiences and perceptions are complicated, yet critical aspects that affect a farmers' decision to implement adaptation strategies (Buchmann *et al*., 2010; Milfont, 2012; Elum *et al.,* 2017). Knowledge and education on climate change, different agronomic practices and the potential benefits of adaptation enable farmers to respond to changes in climate more efficiently and to apply action specific measures (Maddison, 2007; Wolf & Moser, 2011). A higher level of education and more agricultural experience the promote participation of farmers in initiatives to manage available natural resources more responsibly. A better education is also associated with a greater understanding of and access to information about adaptation strategies, climate predictions and improved technologies (Bryan *et al*., 2009).

Awareness of climate change may urge farmers to use adaptation strategies in their agricultural activities if they know about the potential positive effect adapting to climate change may have on their production (Marshall *et al.,* 2013; Nhemachena *et al.,* 2014). Awareness of climate change also plays an important role in a farmer's decision to use modern agricultural technology. Increased adoption of modern agricultural technology, such as heavy machinery, can enable a farmer to adapt more successfully (Kurukulasuriya & Mendelsohn, 2006; Pereira, 2017).

Of the previously mentioned adaptation barriers in this section, farming experience is thought to be the most influential factor prompting farmers to adapt (Wolf & Moser, 2011; Niles *et al.,* 2015). However, perceptions are formed based on climatic differentiations observed on a day-to-day or yearly basis. As a result, research indicates a greater relationship between a farmer's perceptions of climate change and short-term climatic events rather than long-term changes in climate (Bryant *et al.,* 2000; Vogel & O'Brien, 2006; Wiid & Ziervogel, 2012). This causes significant challenges regarding the agricultural community's capacity to implement adaptation measures, as most CCA methods focusses on the latter timeline of long-term changes in climate (Ziervogel *et al*., 2008; Bryan *et al.,* 2013). Risk has an influence on what adaptation strategies a community might adopt or reject. A community's perception and knowledge of risk is consequently an important decision-making factor for the participants. This factor turns into a limitation if the individuals involved do not perceive long-term climate change risks as significant enough to warrant action (Vogel & O'Brien, 2006; Wolf *et al.,* 2009).

A different perspective that is not often mentioned as a limiting factor, is the perceptions of farmers and the farming community of indigenous adaptation methods. Farmers that have been isolated from modern information and technology have shown great resilience through the implementation of indigenous methods, despite detrimental and continually changing environmental circumstances (Altieri & Nicholls, 2017). Yet an existing bias towards western information and methods being more efficient have greatly undermined the mainstreaming of traditional adaptation methods (Buchmann *et al.,* 2010; Green & Raygorodetsky, 2010). Consequently, the exclusion of indigenous adaptation methods could hinder the implementation of modern CCA methods by traditional farmers.

3.5.5 Social and Cultural Limitations

Social and cultural barriers have been underestimated in past research. But in recent literature these factors have been emphasized as constraints of adaptation because of their influence on societal values, cultural norms and beliefs, and individuals' or communities' perception of risk (O'Brien, 2009; O'Brien & Wolf, 2010; Wolf *et al.,* 2013). Various cultures and communities approach and perceive predictions and knowledge of climate change differently. This variations in knowledge between communities testifies to the different values that persist and could lead to adaptation constraints (Adger *et al*. 2009; Adger *et al*., 2013).

Other social factors, for example social networks, can facilitate adaptation by spreading information about successful adaptation methods and climate change trends/predictions (Reid & Vogel, 2006; Gbetibouo *et al.,* 2010). Relevant to this factor is access to markets, which provides the farmers involved with a platform to gather and share information among each other. As a result of these social connections and access to markets, commercial farmers tend to have a better support structure and access to new information regarding agriculture (Maddison, 2007; Wiid & Ziervogel, 2012).

Literature suggests that household size, also referred to as human capital, could allow farmers to adapt to methods that are more labour intensive as the cost of labour is lower for them (Hassan & Nhemachena, 2008; Bryan *et al*., 2009). It also has the potential to enhance the resilience of households by allowing them to diversify sources of livelihood, therefore spreading their risk with respect to climate change (Gbetibouo *et al.,* 2010; Oduniyi & Tekana, 2019). With subsistence communities often favouring collective household participation in farming activities, they might have an advantage to adopt some strategies more easily (Bryan *et al*., 2013).

3.5.6 Governance and Institutional Constraints

According to Berman *et al.* (2012) and the IPCC (2014a), public, municipal and private institutions all have an influence on local adaptation. These institutions are often interlinked and play a vital role in how local communities are affected by variations in climate and their ability to respond.

Biesbroek *et al.* (2013) proposes governments are the primary actors in removing or creating factors hindering adaptation. Research shows governments to be key to the governance of adaptation and to understanding the barriers that limits farmers' adaptive capacity. In other words, governments have the ability to constrain or enable adaptation at a national, regional or local level. Several studies, including Ziervogel *et al.* (2014) and Pereira (2017) argue that governing bodies can prohibit adaptation at all levels if the system is not operating efficiently as a result of insufficient policy guidance; poor coordination within the system and between levels; or insufficient governmental resources to assist adaptation. Another fact that strengthens this belief is the ability of governments to change the legislation, which often creates barriers to adaptation. They can also provide communities and municipalities with the resources they might need (Biesbroek *et al*., 2013; IPCC, 2014a). An example of this limitation is the preference of informal cross-border trade in Africa due to the time consuming and expensive bureaucratic procedures associated with formal trade. Formal trade offers storage of crops during times where there is an influx of supply, while informal trade does not have access to such facilities. Consequently, this leaves farmers without the advantage of storing previous yields vulnerable during periods when low crop yields are prevalent (Mauyo *et al.,* 2007; Berman *et al*., 2012).

The determining or limiting factors mentioned in this section, such as governmental and institutional constraints, have a profound influence on the adaptive capacity of a country, region or community. It affects their ability to prepare for, adjust to and respond insightfully to the effects of climate change (Biesbroek *et al.,* 2013; Wolf *et al.,* 2013; IPCC, 2014a). The absence of adaptive capacity could potentially entail inefficient adaptation methods implemented by farmers or even lead to maladaptation (Berman *et al.,* 2012).

3.6 Adaptive Capacity

Brooks and Adger (2005) and Mashizha (2019) contend that the presence of adaptive capacity is a prerequisite for the formulation and application of effective adaptation methods that can reduce the detrimental consequences of climate change. Taking this into consideration, the following section focusses on adaptive capacity and the agents affecting the adaptive capacity of a country, including South Africa and its farmers.

Adaptive capacity relates to a system's potential or ability to respond insightfully to changes and variations in climate, which includes adjustments to current technologies, resources and behaviour (IPCC, 2007a; Buchmann *et al*., 2010; Pereira, 2017). From an agricultural perspective, adaptive capacity could be defined as the range of agroecological and social preconditions that allow individual farmers or farming communities to respond to changing environmental conditions in a resilient manner (Schulze, 2016; Altieri & Nicholls, 2017). Various factors have an influence on the capacity of a country to respond to climate change and climate-related extremes, such as climate change knowledge, perceptions and policies, causing adaptive capacity to vary even between the regions in a country (Ziervogel *et al*., 2006; Crane *et al.,* 2011; Nyanga *et al.,* 2011).

It is important to take into consideration that climate is only one challenge that affect the ability of farming communities in developing countries to cope and adapt, especially for those living in Africa (Yaro, 2013; Elum *et al*., 2017; Pereira, 2017). The adaptive capacity of developing countries is challenged by the multidimensional nature of the effects of climate change on different aspects of society. These aspects include the impact on a community's ecosystem services, livelihoods and agricultural activities, accompanied by limited resilience and areas with a high vulnerability (Thomas *et al.,* 2007; Mertz *et al.,* 2009; Mambo & Faccer, 2017). As adaptive capacity represents the potential to adjust, building capacity is a crucial step in decreasing the vulnerability of African countries, which are considered to be highly susceptible to risks and hazards caused by climate change. South Africa is one of these countries (Buchmann *et al*., 2010; Wiid & Ziervogel, 2012; Welborn, 2018).

3.6.1 The adaptive capacity of South Africa and the study area

Research suggest a strong correlation between a country or system's adaptive capacity and its vulnerability to unfavourable environmental conditions. Adaptive capacity is often viewed as a crucial component of vulnerability (Berman *et al*., 2012; DEA, 2017a; Mashizha, 2019). Factors contributing to the vulnerability and adaptive capacity of a country include the country's extent of dependency on natural resources, its economic stability and wellbeing, institutional stability and its perceptions of environmental changes (Vincent, 2007; Berman *et al.,* 2012; Elum *et al.,* 2017). Due to the susceptibility of their natural resources to the adverse effects of climate change farmers in developing countries often have a low adaptive capacity, threatening their survival and resilience (Vincent, 2007; Thomas *et al.,* 2007; Awojobi & Tetteh, 2017). Adaptive capacity and vulnerability to climate change are, however, extremely difficult to measure due to their strong attachment to local contexts. Vulnerability also varies between regions within a country (Reid & Vogel, 2006; IPCC, 2014a).

When considering the mentioned aspects that influence the adaptive capacity of a country, South African farmers face great challenges as they move through this century. From an ecosystem's perspective, South Africa will be especially influenced due to reduced water, variations in precipitation patterns and limited food resources as proposed by the DEA (2015) and Schulze (2016). These researchers highlight that many parts of the country are faced with increased drought and non-sustainable soil water availability during the crucial growing periods of crops. Climate change will affect livelihoods and agricultural activities in the country and in the NWP specifically. The 2015 DEA report revealed the most vulnerable sectors in the province to be the mining sector, rural livelihoods, ecosystems and the agricultural sector, further constricting the ability of the farmers in the NWP to respond adequately to climate change. The final aspect adversely affecting adaptive capacity is that of limited resilience and high vulnerability. Literature has already established an alarming relationship between the vulnerability of South Africa and the continued manifestation of climate change (Benhin, 2006; Nhemachena *et al.,* 2014; Schulze, 2016). Unfortunately, this does not exclude the study area, as Turpie and Visser (2014) identify the NWP as one of the provinces most vulnerable to the ramifications of climate change.

Considering the proposed correlation between vulnerability and the aspects affecting adaptive capacity, statistics are indicative of a low adaptive capacity for the NWP where the Ditsobotla Local Municipality is situated. As previously mentioned, the Department of Environmental Affairs (2015) proposes that the agricultural sector of the NWP is highly vulnerable to the impacts of climate change, accompanied by a concerning low adaptive capacity. One of the main attributes of this vulnerability is the dominating preference of maize production in the province. Maize yield is known to be extremely sensitive to changes in precipitation patterns, which is predicted to become more erratic as the effects of climate change continues to manifest in the country (Blignaut *et al.,* 2009; IPCC, 2014b; Welborn, 2018).

Bearing in mind that a large area of the Ditsobotla Local Municipality of the NWP falls within South Africa's maize triangle, the future consequences of climate change are likely to further exacerbate the vulnerability of farmers operating in this region (Gbetibouo *et al.,* 2010; DRDLR, 2016). Thus, this study aims to further explore the various constraints that challenge farmers in the region as they attempt to implement adaptation measures; what preferred methods of adaptation they employ; and to what extent indigenous knowledge plays a role in the farmers decisions.

3.7 Conclusion

Natural hazards on their own do not cause disasters, it is the result of an exposed, unprepared and vulnerable society in combination with a hazard that leads to disasters (Birkmann & von Teichman, 2010; IPCC, 2012a). After exploring the two societal responses available for reducing society's risk towards climate change, namely mitigation and adaptation, the importance of successful adaptation was emphasized. However, the importance of mitigation methods should not be excluded as a combination of both mitigation and adaptation efforts is suggested to be more efficient when attempting to address climate change challenges.

Consensus is growing about the urgency of implementing adaptation strategies to minimize the agriculture sector's vulnerability towards climate change. Available CCA measures in agriculture range from adjustments of farming operations to technological solutions and livelihood diversification (Ajani *et al.,* 2013). A major challenge for successful adaptation is that not all strategies are universally applicable, causing farmers' responses to vary across regions (Niles *et al.,* 2015). Often overlooked, including indigenous knowledge systems when formulating CCA strategies has the potential to increase the applicability of adaptation methods to subsistence farmers. Furthermore, indigenous strategies can facilitate the formulation of sustainable and cost-effective methods (Robinson & Hebert, 2001). However, the inclusion of indigenous knowledge does not need to replace the use of modern scientific knowledge, but rather to complement existing and future modern adaptation strategies. The use of modern or indigenous adaptation strategies largely depends on a farming communities' adaptative capacity.

Mashizha (2019) contends that the presence of adaptive capacity is a prerequisite for the formulation and application of effective adaptation methods. From an agricultural perspective, the adaptive capacity of farmers often corresponds with their potential or ability to respond insightfully to changes and variants in climate. A trend of possible differentiation in the adaptive capacity of commercial and subsistence farmers have emerged after the qualitative phase of this study had been concluded. As factors such as climate change knowledge and perceptions influence farmers' capacity to respond to climate change and climate-related extremes, the aim of the next chapter is to obtain and analyse relevant quantitative information pertaining to this trend for further exploration.

CHAPTER 4 METHODOLOGY

4.1 Introduction

The aim of the qualitative inquiry in Chapter Two was to investigate the range of consequences climate change could have on agriculture. Climate change already exerts an influence on the agricultural sector and will continue to do so during the 21st century. South Africa is extremely vulnerable to climate change as a developing country. An exploration of the interaction between vulnerability, climatic and non-climatic risks indicated a difference between commercial and subsistence farming systems' ability to adapt. Added to this is the prediction that commercial and subsistence farmers are likely to be affected differently due to differences in aspects such as resource availability. Despite of these differences, climate change threatens the livelihood of both kinds of farmers, emphasizing the importance of their ability to adapt. Chapter Three explored the range of appropriate responses towards climate change. Of all the appropriate responses, CCA seems to be imperative, directing the research towards the various adaptation strategies available to farmers and the factors limiting adaptation.

This chapter provides an in-depth discussion of the research design and methods chosen to successfully answer all the research questions. This is followed by the rationale for choosing the selected approaches for each phase of the research and an evaluation of each of these methods.

4.2 Research Design

The research design refers to the set of methods chosen to integrate the different components of this study to effectively address the research problem. To gain a comprehensive understanding of all the aspects and influencing factors pertaining to the topic, the research questions were formulated to investigate the impact of climate change on agriculture and the agricultural sector of the region; the theoretical tenets of climate change adaptation; the range of CCA methods applicable to the farmers in the study area; and the factors that might prohibit them from adopting these methods.

For such an undertaking a method was needed that allowed an in-depth exploration into the existing body of literature and a numerical measurement of the theoretical findings. The exploratory sequential mixed-method approach granted the use of both qualitative and quantitative methods in a single study (Onwuegbuzie & Leech, 2006). As proposed by Cameron (2009), Onwuegbuzie and Combs (2011) and Schoonenboom and Johnson (2017), a mixed method could be defined as a study where the researcher collects and analyses data, integrates the findings and draws inferences using both qualitative and quantitative approaches or methods in a single study. The following section offers an explanation of the chosen research design and the overall experience of using this design.

4.2.1 Exploratory Sequential Experience and Evaluation

This study was conducted using an exploratory sequential approach, meaning the initial database of qualitative results and findings was used to build on the results of the second (quantitative) database (Creswell, 2014). This design was best suited for the research as the initial qualitative inquiry allowed for the development and refinement of a quantitative instrument (Fetters *et al.,* 2013). The initial qualitative phase was conducted by means of a deductive approach that entailed the exploration of relevant topics to gain insight from themes that emerge in order to answer the research questions (Vaismoradi *et al.,* 2013). This served as the basis for the collection of quantitative data during the second phase (Cameron, 2009). The quantitative approach used in the second phase of the research allowed the data collected in the qualitative phase to be evaluated and tested for a more comprehensive study (Creswell & Plano Clark, 2007).

Following a mixed-method design proved to be extremely complex, causing many difficulties when trying to establish definite descriptions for data collection and analysis approaches within the traditional qualitative or quantitative frameworks. A major lesson learned while investigating the various approaches available, was to look beyond the typical quantitative or qualitative boxes that research methods are easily forced into. The flexibility of these methods has been highly underestimated in past research methodologies but are increasingly being valued in mixed-method designs. Regardless of the difficulties faced as a result of choosing the exploratory sequential mixed-method design, it has paid off with rich, meaningful results.

4.3 Sampling

Literature and sources were carefully chosen based on their relevance to the study (such as relevance to the study area, to the South African context, to agricultural systems, and whether the information was still applicable to present circumstances) and their credibility.

This evaluation criteria used to ensure the credibility of the theoretical framework of the study included the following points of consideration:

Accuracy: Are the information verifiable against other reliable resources?
Is the information based on proven facts?

Authority: Who is the author?
Does the author have the relevant qualifications to ensure factual and quality information?

Objectivity: Is the information based on proven facts or the opinion of the authors?

Currency: The date of publication was a great evaluation of the applicability and credibility of the sources.

Coverage: Does the information give significant insight into the research problem?

Before data collection from the questionnaires could commence, the researcher had to select appropriate respondents for the study. Purposive sampling was used to select the respondents' representative of the commercial and subsistence farmers of the study region. Purposive sampling is a nonrandom sampling technique where respondents are deliberately chosen on the basis of their specific characteristics or on their similar traits (Teddlie & Yu, 2007; Etikan *et al.,* 2016). Purposive homogeneous sampling was best suited for the selection of respondents as it permitted the researcher to gain information rich data, whilst also representing the population as accurately as possible.

In the context of this study the group of interest were individuals situated within the study locality whose primary source of livelihood is farming, and it was consequently divided into the two subgroups (commercial and subsistence farmers within the study locale) chosen to be investigated by the researcher at the beginning of the study. Respondents for the sample size were selected based on whether they are commercial/subsistence farmers and the area in which they are situated within the Ditsobotla Local Municipality. This meant visiting small communities and towns within the Ditsobotla Local Municipality's boundaries, such as Biesiesvlei, Bospoort, Coligny and Gerdau (Figure 4.3), to identify respondents from the target populations (commercial and subsistence farmers) willing to complete the questionnaire. Through this the researcher aimed to represent commercial and subsistence farmers from multiple areas of the region to increase the reliability of the results. After the respondents were successfully identified data collection from the questionnaires commenced.

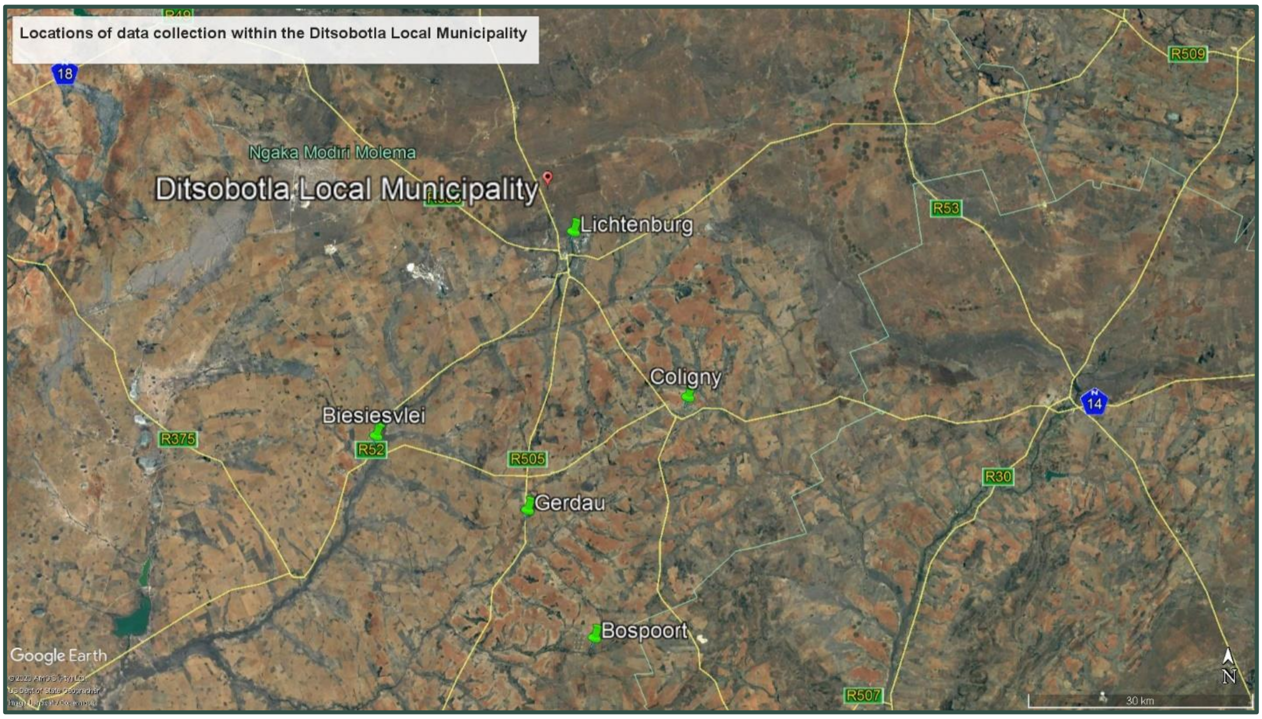

Figure 4.1 The locations and their surrounding areas in the Ditsobotla Local Municipality where data collection commenced (Source: Google Earth Pro, 2020).

Identifying farmers for the commercial group was relatively easy. However, identifying farmers for the subsistence group proved to be more time consuming. This obstacle was mostly due to the vast similarities between small-scale and subsistence farmers, with minor differences causing them to be classified as separate groups. According to Schulze (2016), both small-scale and subsistence farmers operate at a relatively small scale and often have diverse sources of livelihood. However, while subsistence farmers only use their crops and livestock for household consumption, small-scale farmers often sell their produce and also use it for their own needs. In order to overcome this research barrier, more effort was put into exploring unfamiliar communities and areas to find suitable respondents. A total of 25 commercial and 25 subsistence farmers were selected, which allowed the researcher to collect information-rich data by means of a suitable questionnaire.

4.4 Data Collection

4.4.1 Collection of Qualitative Data

The researcher first investigated the existing literature on the topics of climate change; CCA; the relationship between climate change and agriculture; the difference between commercial and subsistence farmers; and the adaptive capacity of agricultural systems through document analysis.

The material sources chosen by the researcher were for the most part derived from:

- Primary resources or empirical scholarly works such as dissertations and research articles. Primary sources were favoured in this study in an effort to avoid the potential misinterpretations present in secondary sources.

- Scholarly and peer-reviewed journals, which were used for their high-quality empirical information. Some of the journals that proved to be extremely helpful in this study included the peer-reviewed international journals *Global Environmental Change*, and *Climatic Change.*

- Conference publications, such as the FAO conferences. This type of source was especially useful during the investigation into prevailing DRR and CCA frameworks.

- Government reports, such as the South African Department of Environmental Affairs' 2015 vulnerability assessment report for the NWP. Government reports were primarily used to contextualize South African agricultural systems, as well as those in the Ditsobotla Local Municipality, within the framework of climate change and CCA.

The sources were explored by the researcher as a means to gain insight into all the relevant dimensions of the topic, while also identifying relevant themes to be used for the quantitative phase of the study. According to Alhojailan (2012), themes derived from literature could be generated by following an inductive or deductive approach. For the qualitative inquiry of this study a deductive thematic reasoning approach was used. Deductive reasoning was best suited for the qualitative undertaking, as ideas about and perceptions of the research topic have already been established in previous studies.

4.4.2 Collection of Quantitative Data

After identification of the themes (during phase one) a suitable questionnaire was formulated as a means of exploring the farmers' perceptions and knowledge of climate change, CCA and indigenous knowledge. These questions took the form of semi-structured questions. This was done in order to gain accurate insight into the perceptions of farmers and to allow space for respondent elaboration. A set of structured questions were formulated based on the themes in order to identify the methods of adaptation farmers in the study region implement, as well as the limiting factors they experience. Structured questions were asked in Likert scale form (on a scale of never, rarely, regularly, almost always and always) to establish relevance and not simply the applicability of the questions.

After respondent selection, the researcher collected the data by meeting each of the farmers individually. During each meeting, the farmers were made aware of the purpose of the study, of their anonymity and that the completion of the questionnaire was strictly voluntary. A self-administered questionnaire was distributed where respondent literacy allowed it. However, by remaining present the researcher was able to clarify any uncertainties regarding the questions or terms mentioned, as well as adapt into an interviewer-administered questionnaire setting when it was needed. This was done to avoid any possible distortion of the information collected, while increasing the reliability of the study by eliminating potential respondent misinterpretation of questions.

In cases where a language barrier was probable, the researcher was accompanied by a Setswana interpreter native to the area. The interpreter was thoroughly aware of the study purpose and of the importance to conduct the research in a non-leading neutral manner. Once the questionnaires had been completed, information had been obtained from a total of 50 farmers.

4.5 Data Analysis

4.5.1 Qualitative Data Analysis

A thematic analysis approach was chosen for this study because it is considered to be a hermeneutic form of content analysis, which is used to identify patterns in the information or data collected (Vaismoradi *et al.,* 2013; Nowell *et al.,* 2017). During a thematic analysis the researcher is urged to consider latent content, such as future projections of climate change that is yet to manifest, as well as manifest content, such as the effects of climate change that are evident today (Vaismoradi *et al.,* 2013). The thematic analysis consisted of a process where the researcher first familiarized herself with the information relevant to the study. After a good understanding of accessible and available literature was achieved the next step was to detect reoccurring patterns or themes of the viable adaptation strategies applied by farmers in the Ditsobotla Local Municipality and regions alike. The analysis of the information was done recursively to systematically organize the research material, which was ultimately clustered together to form the categories of adaptation strategies and the factors potentially constraining their adaptation. The themes emerging from the patterns ultimately became the categories for the final analysis during the quantitative stage.

However, as with any research approach, there were drawbacks to the deductive thematic analysis (Javadi & Zarea, 2016). Reliability was a general concern for a thematic analysis approach as variations could emerge in the interpretations of different researchers (Nowell *et al.,* 2017). To diminish the possibility of misinterpretations, the researcher aimed to gain insight by investigating multiple sources before accepting a theme as credible and relevant. This was especially challenging when investigating the importance of adaptation for both commercial and subsistence agricultural systems. While the implications of failure to adapt for subsistence farmers were relatively easy to obtain, literature regarding failure to adapt for commercial farmers were found to be more focused on agriculture in general and not specifically on the social and livelihood implications for the farmers themselves. Though more time consuming, the researcher was ultimately able to accumulate relevant sources.

Thematic analysis required the researcher to observe the overall themes of the information, and not just those pertaining exclusively to the different CCA methods the farmers of the Ditsobotla Local Municipality implement. As the analysis developed, it became difficult for the researcher to remain focused on the topic due to the multidimensional nature of climate change and agricultural systems. For example, the breadth of indigenous knowledge has not yet been investigated fully, it is a highly interesting topic with multiple layers unfolding as its being investigated. As such, identifying the themes only relevant to the study proved difficult. However, when circling back to the questions and objectives of the study, the relevant themes were easier to identify. Thus, the researcher gained a comprehensive understanding of the existing body of knowledge pertaining to all aspects of the research topic, while still focusing on the themes relevant to the study for the second quantitative phase.

After dealing with the limitations of the thematic analysis approach and completing the exploration into the theoretical tenets of the research topic, themes were successfully identified for the creation of an appropriate quantitative instrument. The method of analysis employed to complete the final phase of the study are thoroughly discussed, justified and evaluated in the next section.

4.5.2 Quantitative Data Analysis

The data collected from the questionnaires were analysed by means of a deductive content analysis approach. The approach was suitable for this particular data set due to its flexibility, permitting the researcher to evaluate and interpret the data gathered by means both the semi-structured and structured questions (Bengtsson, 2016). Content analysis is concerned with the classification of information with the use of systematic coding, from which the researcher can draw conclusions about the content (Rose *et al.,* 2015). This approach promoted the validity and reliability of the study due to its deductive coding nature, making the reliability more easily achievable as proposed by Bengtsson (2016).

Potential weaknesses of content analysis often relate to the process of coding and data interpretation. Development of a coding system involves interpreting latent and manifest content, creating a potential bias risk similar to other measurement techniques (Rose *et al*., 2015).

To ensure the validity, reliability and quality of the study findings, the researcher carefully followed four steps set out by Vaismoradi *et al.* (2013) and Bengtsson (2016). These steps were conducted recursively and were frequently revised by the researcher. They were the following:

- *Decontextualization*: This phase entailed familiarization with the data before breaking it down into smaller categories or meaning units (Erlingsson & Brysiewicz, 2017). A meaning unit contained the insights the researcher needed to answer the questions set out in the study aim. When a meaning unit has been identified, it was assigned a specific code to ultimately be interpreted as a theme, pattern, conclusion or to be presented as statistical data. For example, each possible limitation preventing farmers to adapt was assigned a unique code to ultimately be compared (limitations facing commercial vs. subsistence farmers) in the final research analysis. As opposed to inductive measures, reliability was easier to ensure with the use of a deductive approach while coding. This is due to fact that inductive coding constantly changes the codes as the analysis progresses, often obscuring the meaning units (Bengtsson, 2016).
- *Recontextualization:* After identification of the meaning units, the researcher had to make sure all the aspects in the content related to the aim of the study had been covered. The meaning units that had been identified in the first phase were compared with the study questions to make sure no units that are irrelevant to the study are included in the study outcome. One such meaning unit that was found to be included but that had no significant effect nor contribution to the study outcome was that of gender. Though it gives a rough estimate of the gender ratio of the Ditsobotla Local Municipality's farmers, no correlation was found between a farmer's gender and their perceptions of the terms, the adaptation methods they implement or the limitations they experience (based solely on the topics included in the questionnaire, not necessarily across all dimensions of climate change and agriculture) .
- *Categorization:* In order to create categories, especially for the information obtained by means of the semi-structured questions, the extended meaning units had to be condensed based on recurrent patterns. During this step, the categories used for the final analysis process were established (Erlingsson & Brysiewicz, 2017). This was done by dividing the data on the basis of the research questions that were used to formulate the quantitative instrument. Bengtsson (2016) proposes that the categories should be externally heterogeneous, but internally homogeneous after refinement. This means that, ideally, no data should be applicable to more than one category group, nor fall between two categories. This was especially challenging for the researcher given the complex and multidimensional nature of the study that was conducted. For example, each category of farming experience was initially given a specific code in order for the

researcher to identify possible connections to farming experience and measures of adaptations. However, this data did not affect the outcome of the study and would not have been confined to only one category. Circling back to the research questions allowed the researcher to successfully categorize the data that had been collected.

- *Compilation phase:* This was the final phase, where the researcher analysed the data after all the categories had been finalized. Content analysis in the final phase required the investigator to consider the data gathered by means the questionnaire from a neutral perspective (Bengtsson, 2016). After the data from the two groups had been processed and compared, the researcher considered how the findings from the quantitative phase corresponded to those in the qualitative phase.

4.6 Integration of Data

The data collected from the completed questionnaires were processed with the use of QuestionPro software. QuestionPro software allowed the researcher to analyse and use the Likert-scale data for the formulation of charts through assigning value to each rating on the Likert-scale, calculating the mean scores of each variable and creating charts based on the results. Spider charts were used as a graphical method of displaying the multivariate data in the form of a two-dimensional chart for a more comprehensible and visual representation of the findings.

4.7 Ethical Considerations

The researcher received ethics clearance from the North-West University (NWU) research ethics committee before administering the questionnaires and she adhered to their code of conduct. The research aims and objectives were clearly stated to the respondents, and researcher received consent from each respondent beforehand and assured them of their anonymity. Each farmer was aware that they could cease participation at any time during the process. This was generally a low-risk study and it did not include vulnerable individuals such as children.

4.8 Conclusion

The methods used to ultimately answer the research questions were discussed, justified and evaluated in this chapter. In both the qualitative and quantitative phases deductive reasoning was used to identify relevant themes and meanings. For the qualitative undertaking, a thematic analysis approach was applied to establish the main themes ultimately used to create the quantitative instrument. During this phase, an investigation was launched into the existing theoretical body of climate change, CCA and agriculture. Due to the multifaceted nature of the effects of climate change and adaptation strategies from an agricultural perspective, it was challenging for the researcher to not go beyond the relevant scope of literature. In order to evaluate whether the themes that had been investigated contributed to the study, the researcher often circled back to the research questions. In doing so, the researcher was able to successfully establish the themes to be used for the creation of the quantitative measurement.

During the quantitative phase various methods were employed to identify respondents, complete the collection process and analyse the data collected. Though minor challenges were experienced during the respondent selection process, it was easy to overcome by taking time and putting conscience effort into identifying appropriate farmers for the subsistence sample group. The use of content analysis proved to be the best suited method for analysing the data collected with the questionnaires, owing mainly to its flexibility. In order to ensure the credibility of results and to avoid the possible pitfalls of the chosen approach, appropriate steps were followed recursively and frequently revised by the researcher. The resulting comparisons between the qualitative and quantitative data ultimately gave answers to all of the research questions. The findings are presented in Chapter Five.

CHAPTER 5 FINDINGS AND DISCUSSION

5.1 Introduction

Since climate variability and climate-related extremes threatens agricultural production and the livelihoods of those dependent on this climate-sensitive sector, adaptation will be imperative for both commercial and subsistence farmers during the 21st century. The future of agriculture is laced with increased variations in climate, relatively uncertain environmental conditions and a high probability of more frequent climate-related extremes such as droughts and floods. In order to cope with the manifestation of climate change, there should be an emphasis on the understanding of the current adaptive capacity of South Africa's agricultural communities.

The objective of this study was to evaluate the potential differences in climate change adaptation strategies between the commercial and the subsistence farmers of the Ditsobotla Local Municipality in the North West province in an effort to improve understanding. Specifically, the research set out to identify the factors leading to a possible difference in the adaptation methods adopted by commercial and subsistence farmers in the region. The study also emphasizes the importance of building farmers' adaptive capacity, regardless of their farming group. The purpose of this chapter is to present the findings of the study. The results of the quantitative enquiry by means of questionnaires are presented as themes.

5.2 The Demographic and Background Information of the Respondent

It was important for the researcher to take into consideration the age and farming experience of the farmers as these factors play a vital role in their decision to implement adaptation strategies (Wolf & Moser, 2011; Niles *et al.,* 2015; Elum *et al.,* 2017). The household characteristics of the farmers were also investigated and presented in this section as a way of establishing the household's base level of resilience, and to establish the number of individuals whose livelihood might be affected by the effects of climate change.

The respondents' background information is presented in Figures 5.1 and 5.2 below.

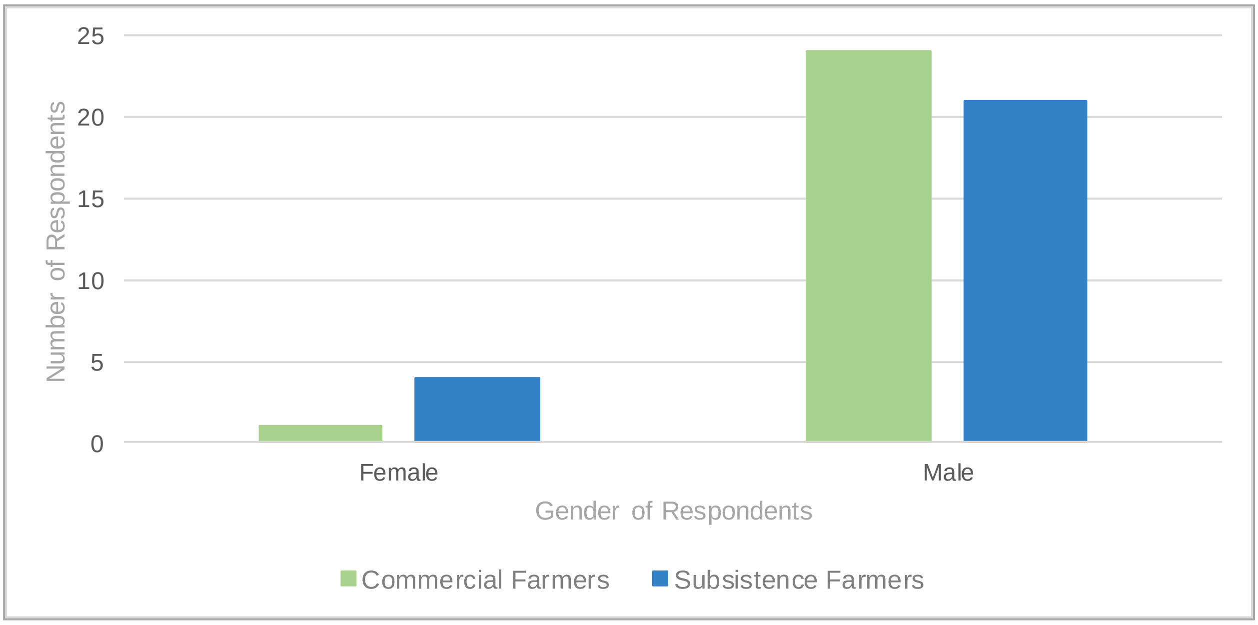

Figure 5.1: Gender distribution of the commercial and subsistence farmer respondents

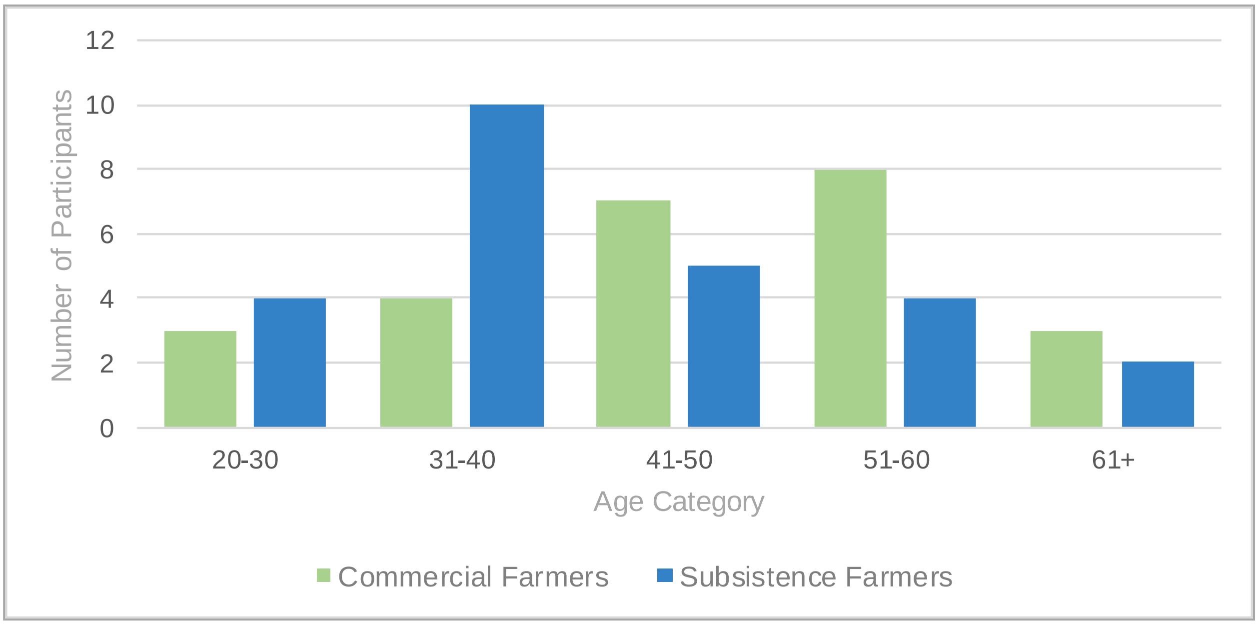

Figure 5.2: Age distribution of the commercial and subsistence farmer respondents

The respondents were predominantly male in both the commercial and subsistence farming groups with 4% female farmers and 96% male farmers for the commercial farming group and 16% females and 84% male respondents for the subsistence group. The age demographic was interesting as most of the commercial farmers (32%[N=8] of the respondents) fell into the 51–60 age group, whereas subsistence farmers were mostly in the age group of 31–40 years of age (40%[N=10]).

One commercial farmer noted,

> *"due to the unstable environmental and financial circumstances surrounding agriculture most young farmers from the region have either migrated to different countries or engage in seasonal migration to other countries depending on the host countries' agricultural seasons"*.

One of the subsistence farmers also mentioned that all of his children have moved to urban areas in search of work due to the political instability of their rural area. Though this might entail possible negative implications for the area's agricultural sector in the future (i.e. less people being interested in agriculture and decreases in the productivity of the area), the age demographics could also be an indication of the overall farming experience in the region. This could be a positive finding with regard to the implementation of climate adaptation methods, as farming experience was identified in Section 3.6 of the study to be a major influencing factor prompting farmers to adapt. Arguably, the Ditsobotla Local Municipality has a large pool of older, more experienced farmers that are open to adopting CCA or are already experimenting with such measures.

5.2.1 Respondent household size

The household size for commercial farmers were found to be four (4) family members per household in 36%[N=9] of respondent cases, while subsistence farmers generally had more individuals in their households with the highest averages being 6+ and 5 in 32%[N=8] and 28%[N=7] of respondent cases respectively. Due to their household size, more individuals in the immediate households of subsistence farmers are dependent on agriculture to meet their food consumption needs. In the case of maladaptation, it could have devastating effects on a greater number of individuals in the immediate households of the subsistence farmers. However, it is important to note that larger household sizes, as are characteristic of subsistence farming households, could also increase the resilience of the household during challenging circumstances, as more individuals can diversify their sources of income during the period of stress (Morton, 2007; FAO, 2010b).

5.2.2 Respondents' Farming Experience

The majority of commercial farmers (32%[N=8]) who participated generally had farming experience of 21–30 years, followed closely by the group of 31+ years of experience (25%[N-7]). The subsistence farmers mostly fell into the 11–20 years' experience category (48%[N=12]), followed by the 31+ years of experience (24%[N=6]).

This also substantiates the previous finding mentioned in Section 5.2 that the farmers in the region are generally of a more experienced generation of farmers.

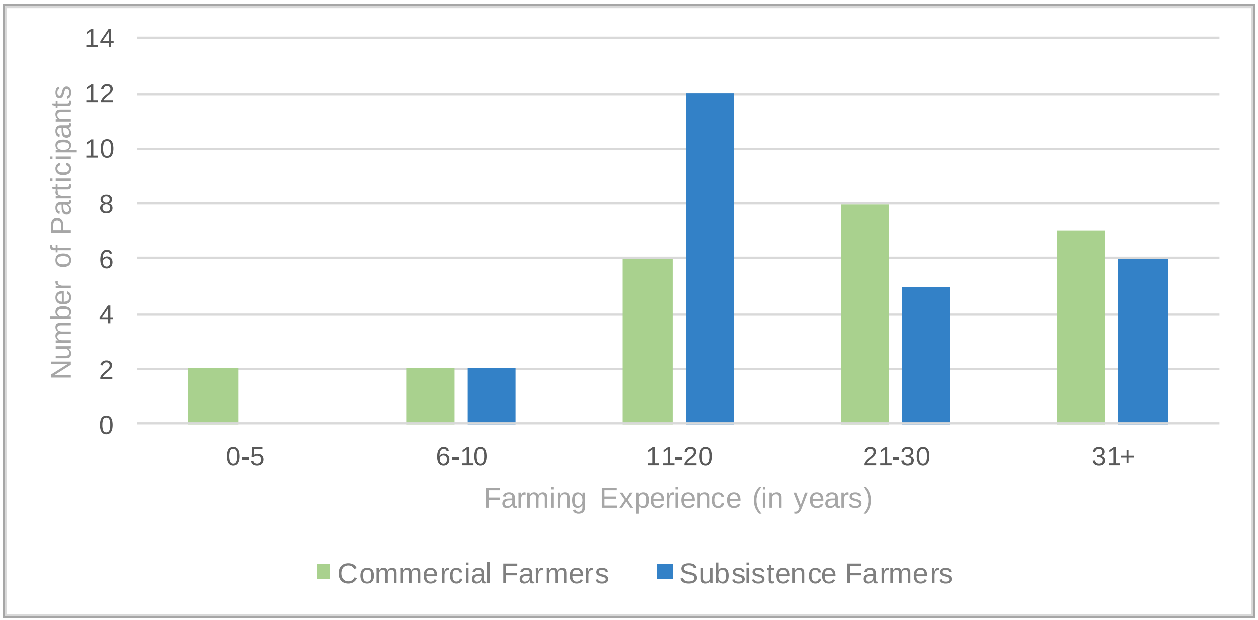

Figure 5.3: Farming experience (measured in their total years of farming) of the commercial and subsistence farmer respondents

As the literature in Chapter Three indicated, the longer the farming experience of the individual farmer, the greater the willingness to adapt new farming methodologies, such as those related to CCA (Wolf & Moser, 2011; Niles *et al.,* 2015). Thus, future interventions to introduce emerging CCA methods to farmers in the region will find a willing audience with the only challenges remaining relating to information dissemination and continued government support of such projects.

5.2.3 Primary Farming Activities

A large majority of both commercial (88%[N=22]) and subsistence (60%[N=15]) farmers in the region primarily practice mixed farming methods, i.e. a combination of crop cultivation and livestock husbandry. This was followed by livestock farming as their primary activity for 12%[N=3] of the commercial respondents (mostly cattle and sheep) and 32%[N=8] of the subsistence respondents (which included pigs, as well as poultry for household consumption). This corroborates the Department of Rural Development and Land Reform's information on the main farming practices for commercial farmers in the NWP. Interestingly, the primary agricultural activity practiced by subsistence farmers in the region differs slightly from the proposed primary agriculture activity of subsistence farming communities as identified by the Department of Rural Development and Land Reform. In this instance, subsistence farmers preferred mixed farming methods over a solitary focus on animal husbandry (DRDL, 2016). This could indicate that subsistence farmers in the region are already starting to adapt to a changing climate by shifting their production to more diversified sources

5.2.4 Number of Employees for Agricultural Activities

Of the two groups, only commercial farmers reported that they had employees for their agricultural activities, commensurate to their scale of farming. Subsistence farmers reported that they tend to use their household members as their labour force. In general, 44%[N=11] of commercial farmers employ between 5 and 9 individuals. This information allowed the researcher to establish how imperative adaptation is as it would not only be the farmer who would be negatively affected by climate change, but also the individuals they employ and their households. An estimate of how many individuals could be affected should the commercial respondents fail to adapt, was calculated by counting the median in each category (for example the median of the "5–9" category is 7, however with exclusion of the 20+ category) of how many individuals the farmers employ and multiplying that with the average household size of the Ditsobotla Local Municipality (3,7 individuals) according to data derived from StatsSA. The results showed the downfall of the 25 commercial respondents in the area, whether it be due to climate variations and climate related-extremes or other factors, could threaten the livelihood of an estimated 274 households, or 1 013 individuals.

The demographic data collected exemplify that there are several challenges and opportunities already present that could aid or hinder climate change adaptation in the Ditsobotla Local Municipality. The sections to follow further explore challenges and opportunities for climate change adaptation, organized according to the themes in the research questionnaire.

5.3 Questionnaire Theme 1: Understanding and Knowledge of CCA

In addition to farming experience, a farmer's knowledge was another factor identified in the literature that could promote adaptation (Maddison, 2007; Wolf & Moser, 2011). The discussion on this theme puts forth information on the farmers' knowledge of climate change, along with their view of whether climate change adaptation strategies are necessary. Section 3.6 highlights awareness as another factor that affects farmers' decision to adapt. Their observations of the physical climate change manifestations in their area are included in this theme. The questionnaire also sought insight into the reasoning behind farmers' adaptation choices and their information sources. The sub-themes presented below capture the essence of this theme.

5.3.1 The meaning of climate change

Commercial farmers seem to have a clear idea of what climate change entails, with most (96%[N=24]) having good knowledge of the term. Some of the farmers answered with words they associate with climate change. Prominent associations commercial respondents made with the term was "uncertainty" and that it's "worrisome" to them. Subsistence farmers on the other hand seemed to be slightly unfamiliar with the term as only 60%[N=15] of the farmers had an idea of what climate change means or what it could imply. One farmer from this group who had a good understanding of the term went as far as to associate the concept with the "end of the world". The overall lack of clarity around the term among subsistence farmers could be indicative of the lack of access to relevant and important climate change and adaptation information. Unfortunately, a lack of access to information was identified in the literature as a potential limiting factor for the implementation of CCA strategies (Maddison, 2007; Wiid & Ziervogel, 2012; Turpie & Visser, 2014).

5.3.2 Respondents' Understanding of the Term "Climate Change Adaptation"

What the farmers understood under "climate change adaptation" was fundamental for the research as the results represented respondent knowledge regarding the term. From the respondents representing the subsistence farmers, only a few (36%[N=9]) were familiar or had an idea of the term. One subsistence farmer said that climate change adaptation means adding water to the land if it's too dry, and to add water again if it doesn't rain. Another farmer's understanding of climate change adaptation was that the weather is changing, and the world is ending.

A large majority of commercial farmers were more informed and had a good understanding of what climate change adaptation means and entails. In total about 76%[N=19] respondents from the commercial farmer group indicated that they have an understanding of climate change and climate adaptation. One commercial respondent in particular gave the following explanation of climate change adaptation:

> *"It means that climate conditions are changing negatively to which every farm needs to adapt through the implementation of various methods".*

This disparity in the understanding of the concept between the two groups could possibly relate to the relative access the two groups of farmers have to relevant climate change information. According to Gbetibouo *et al. (*2010) and Wiid and Ziervogel (2012), commercial farmers get climate change information from their social connections and market access. It is plausible that the commercial farmers have significantly more access to information owing to their agricultural networks, comprising of consultants, farmers unions and Grain SA. Subsistence farmers on the other hand seem to rely heavily on government departments (i.e. Department of Agriculture, Forestry and Fisheries, Department of Rural Development and Land Reform) for such information. Often such departments have limited resources to distribute information to farming communities in rural areas. This may contribute to an ineffective system of information dissemination within the area.

5.3.3 The Need for Climate Change Adaptation

The majority of the respondents from the commercial farming group (96%[N=24]) believed that climate change adaptation is necessary, while only about 44%[N=11] of the subsistence farmers agreed. The results in the sub-theme presented in 5.3.2 above indicated that most subsistence farmers were not familiar with the term “climate change adaptation” which could explain why they did not affirm the necessity to implement climate change adaptation. Crucially, the subsistence farmers’ apparent low-level of understanding of climate change adaptation as a necessary activity was not borne out of a lack of belief or a distrust of the activity, rather it was a term that they had never been exposed to and they could therefore not form an opinion of it.

5.3.4 Environmental Changes Observed in the Area

There was significant overlap in the environmental changes subsistence and commercial farmers have observed in their surrounding areas. Increased temperature was the most observed change identified by 80%[N=20] commercial farmers and 44%[N=11] subsistence farmers. Variations in rainfall (i.e. irregular and sporadic rainfall patterns) followed with 36%[N=9] commercial respondents and 36%[N=9] subsistence respondents, and lastly higher frequencies and more intense droughts were mentioned by 20%[N=5] of the commercial farmers and 28%[N=7] of the subsistence farmers.

The environmental changes observed by the respondents correlate with the proposed effects climate change could have on the region according to the problem statement in Section 1.3 of the study. The findings are worrying for future agricultural production in the region, as the DEA (2015) suggests that any effects of climate change are likely to have a negative influence on farming practices in the province. The consequences of disasters such as drought often leave farmers with a great deal of damages, such as a severe loss of livestock and the deterioration of natural resources.

5.3.5 The Impact of Climate Change on Farming Activities

Most commercial farmers indicated that climate change has a severe impact on their agricultural activities (88%[N=22]), with only 12%[N=3] believing it to have a moderate impact. Subsistence farmers gave varying answers with the primary being severe (40%[N=10]). About 24%[N=6] believed it to have a moderate effect and 16%[N=4] believed that it has little impact. For the purpose of this research each category (ranging from none to severe) is a representation of the relationship these farmers have with climate change in their farming operations, whether they have observed the impact (such as livestock deaths and harvest failure) or have had to adjust their regular activities to be prosperous.

While this sub-theme could be a good indication of respondent awareness of the impact climate change has on their environment, it also stands as an argument for the risks these farmers have as a result of climate change. As mentioned in Sub-theme 5.5.2 later in this chapter, one commercial farmer acknowledged the huge risks connected to climate change when he suggested that only one unfavourable year could cause a farmer’s downfall due to all the financial constraints. Thus, the scale of their investments and operations cause the commercial farmers in the region to have a higher awareness of the devastating impact of climate change on their production and livelihood, both presently and due to probable future circumstances. On the contrary, the varying answers given by the subsistence respondents could reflect their risk associated with climate change owing to their relatively small-scale operations and different livelihood sources, which could help offset the extent to which climate change could have an impact on their agricultural operations (Yaro, 2013).

5.3.6 Frequency of Extreme Weather Events

From the commercial farmer perspective 100%[N=25], weather extremes such as floods and droughts are occurring more frequently in the region. Similarly, a majority of subsistence farmers (80%[N=20]) believed that climate-related extremes have become more frequent, while 20% did not agree with the statement. The slight disparity in the results between the two groups could be ascribed to the access the commercial farmers have to contemporary climate and weather information from sources identified in Sub-theme 5.3.7 below such as the internet, media, Grain SA and agricultural agents/consultants. This finding reinforces the previous findings of Sub-themes 5.3.1. and 5.3.5 about possible discrepancies in awareness and knowledge of climate change and adaption between commercial and subsistence farmers.

5.3.7 Sources of Agricultural and Adaptation Information

The greatest source of new climate change and best practice information for commercial farmers was online resources (12 respondents), the media (8 respondents) and agricultural networks such as NWK and consultants (8 respondents). Other sources mentioned included Grain SA and TLU SA. Subsistence farmers relied more on their surrounding community (8respondents), their own experiences (7 respondents) and indigenous knowledge such as from their grandfather or father (6 respondents) for information.

There was a significant difference with respect to the sources of the adaptation methods they implemented. While the sources identified by the commercial farmers were mostly social networks, established agricultural networks and online resources, the subsistence farmers learned about the methods they use mostly from indigenous knowledge and their own experiences of what strategies are more effective. The findings were as follows: Commercial farmers learned their methods from their social networks such as other farmers (36%[N=9]) and online resources (32%[N=8]). Subsistence farmers learned their strategies from indigenous knowledge (56%[N=14]) and their own experiences (36%[N=9]).

5.4 Theme two: Respondent strategies of climate change adaptation

This theme captures the different adaptation strategies adopted by the participating farmers. The first sub-theme is concerned with the farmers' diversification of livelihood strategies as a method to adapt to climate change. Spider charts are used to display the multivariate data in the form of a two-dimensional chart for a more comprehensible and visual representation of the findings.

5.4.1 Diversification of livelihood sources

The diversification of livelihood has been identified in the literature as a method of adaptation equally applicable to commercial and subsistence farmers. This would involve for instance selling their labour to other farmers or their spouses having income sources outside of agriculture. It is also an important way for farmers to reduce their risks and vulnerability in the face of unforeseen climatic conditions (Crane *et al.,* 2011; Yaro, 2013; Akinnagbe & Irohibe, 2014). From the respondents' profiles, 60%[N=15] (majority) of commercial farmers diversify their sources of livelihood. However, of those 80%[N=12] indicated that they have always done so. Most of these farmers share the sentiment that *"their choice of livelihood diversification was only made as a result of 'financial challenges' and as a 'strategic way of spreading possible risks' should their agricultural production be unprofitable" (Commercial Farmer).* Of the subsistence farmers, 92%[N=23] (large majority) indicated that they diversify their household sources of livelihood, while about 91%[N=21] of those have always done so. It could thus be said that the high livelihood diversification rate, especially among the subsistence farmers of the Ditsobotla Local Municipality, might serve as a resilience factor for these households in the future.

5.4.1.1 Operational adjustments by farmers

The most common operational adjustment by commercial farmers (CF) was crop rotation (81.82%), seasonal distribution of farming activities (72.73%) and implementing mixed farming practices (71.82%). For subsistence farmers (SF), the most common operational change is the seasonal distribution of farming activities (87.06%), closely followed by mixed farming practices (83.53%) and intercropping (72.94%). With regard to the least applied operational adjustment, both the commercial farmers and the subsistence farmers indicated that they do not apply dry ripping often if at all, as is portrayed in Figure 5.4 and Table 5.1 below.

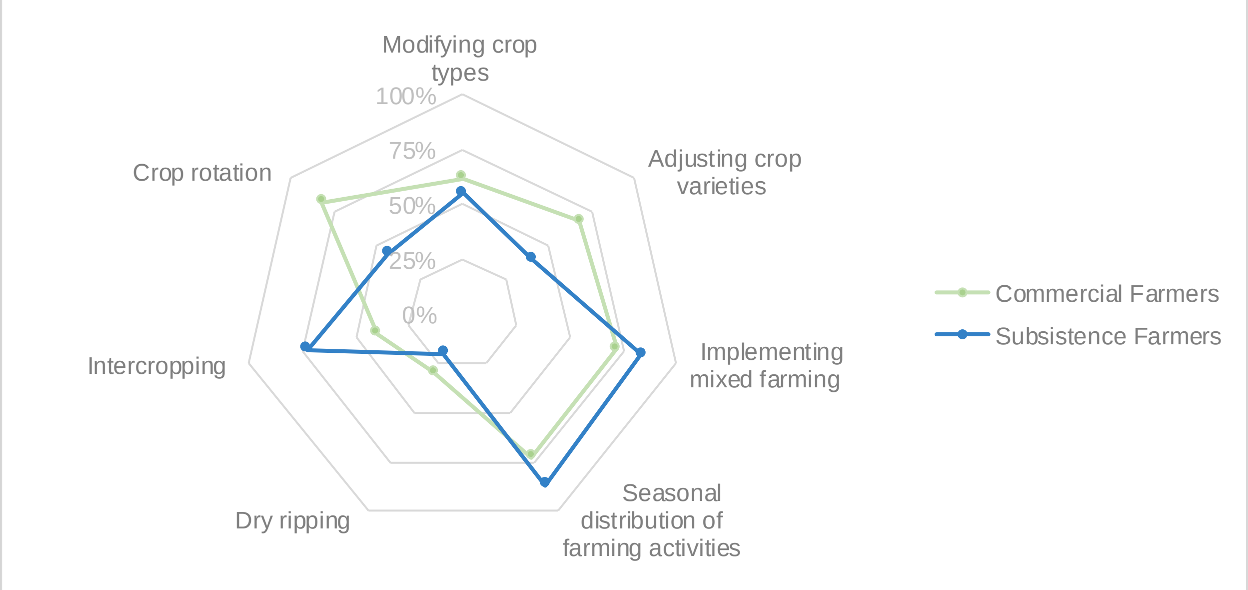

Figure 5.4: Operational adjustments by farmer respondents

Table 5.1: Respondents' operational adjustment scores

	Operational Adjustments	**CF Score**	**SF Score**
1.	Modifying crop types	3.091	2.765
2.	Adjusting crop varieties	3.409	2.000
3.	Mixed farming practices	3.591	4.176
4.	Seasonal distribution of activities	3.636	4.353
5.	Dry ripping	1.500	1.000
6.	Intercropping	2.000	3.647
7.	Crop rotation	4.091	2.176
	Average	**3.045**	**2.874**

5.4.1.2 Conservation practices

With regard to the conservation practices, the commercial farmers mostly incorporated minimum tillage (about 76%) and no-tillage (about 55%) into their practices, with periods of fallow being the least used method of conservation. As indicated by the scores in Table 5.2, subsistence farmers were less inclined to apply conservation practices when compared to operational adjustments. Among the subsistence farming respondents, mulching was used most at about 32%.

Notably, even when mulching is used, it falls between the "never" and "rarely" used ratings by subsistence farmers. No significant reports were received from subsistence farmers on the use of no-tillage and periods of fallow (resting fields) as adaptation options.

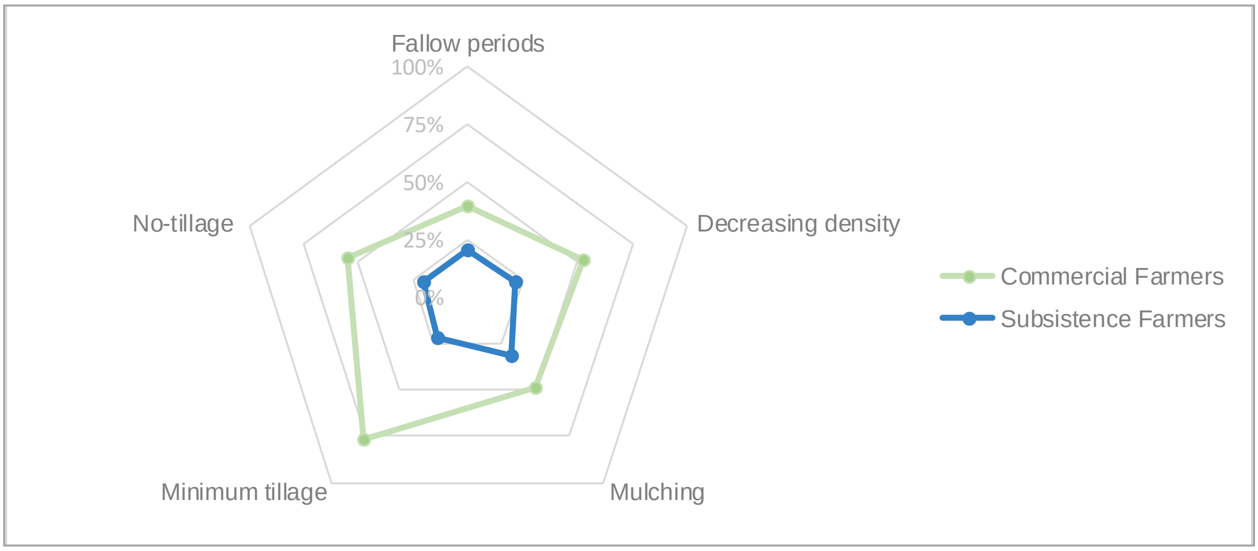

Figure 5.5: Conservation practices applied by the commercial and subsistence farmer respondents

Table 5.2: Respondents' conservation practices scores

	Conservation practices	**CF Score**	**SF Score**
1.	Periods of fallow	1.955	1.000
2.	Decreasing livestock/crop density	2.652	1.059
3.	Mulching	2.455	1.588
4.	Minimum tillage	3.818	1.118
5.	No-tillage	2.727	1.000
	Average	**2.721**	**1.153**

A possible explanation for subsistence farmers not resting their lands for the purpose of conservation could be their small land size as mentioned in Section 2.3.1. Whereas commercial farmers have the option to allow for periods of fallow, subsistence farmers have to use every area they have available for their food security. Unfortunately, the finding also validates concerns emerging from literature about the correlation between farm size and farm sustainability due to the high possibility of land degradation associated with small land holdings.

5.4.1.3 Shade and shelter techniques

The subsistence farming group seemed to implement shade and shelter techniques more often than their commercial counterparts. Subsistence farmers indicated that they cover their livestock or crops with materials such as plastic, grass or nets very often with an average score of 75.29%, giving it an average rating aligned with the descriptor "almost always". For commercial farmers, agroforestry had the highest score, though according to the score most farmers implemented it rarely as part their agricultural adaptation practices.

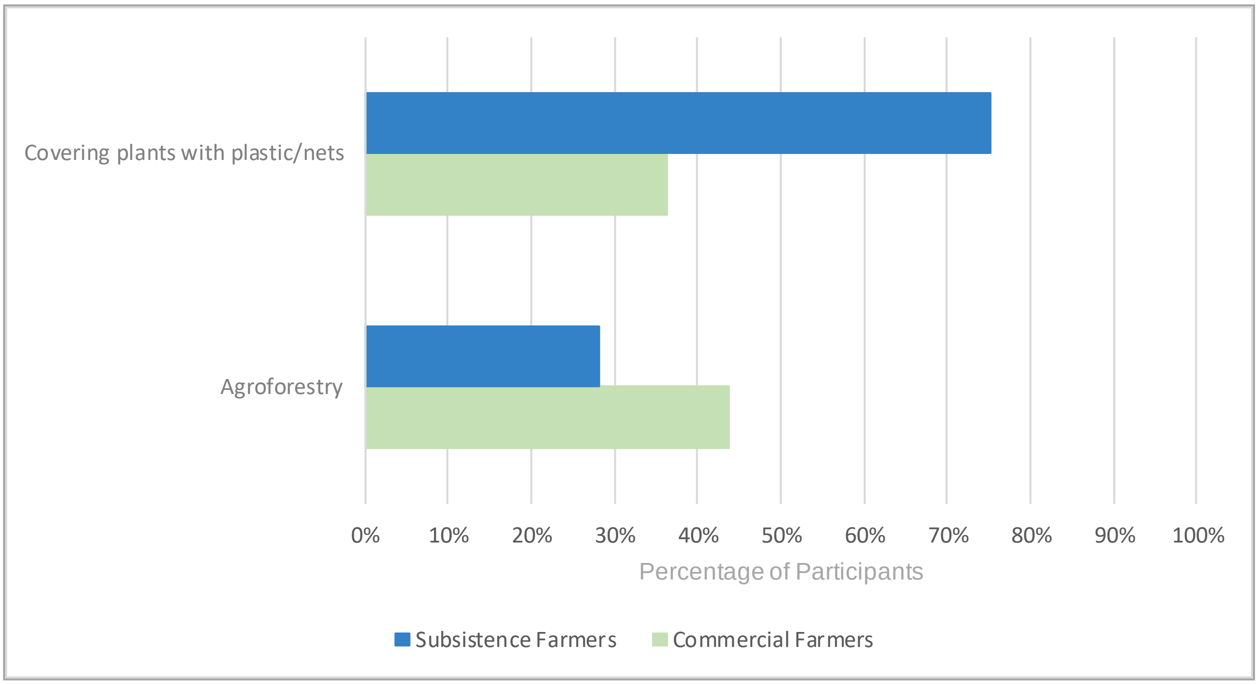

Figure 5.6: Shade and shelter techniques implemented by the respondents

Table 5.3: Respondents' shade and shelter strategies' scores

	Shade and shelter	CF Score	SF Score
1.	Agroforestry	2.182	1.412
2.	Covering crops/livestock	1.818	3.765
	Average	**2.000**	**2.588**

5.4.1.4 Irrigation methods

Few farmers in the region indicated that they use irrigation methods in their farming practices, with the highest irrigation-related score (outsides of boreholes) for commercial farmers being 2.3/5 and for subsistence farmers 1.5/5. As farmers in the region clearly rely heavily on rain-fed agriculture to drive production, the agricultural production of the region could be vulnerable to the threat of climate change. However, the results show that the method most often used by the commercial and subsistence farming respondents was boreholes. The use of boreholes for irrigation had an average score of 3.5 for the commercial farming group, thus putting the method within the overall rating of “regularly” and “almost always”. Among the subsistence farmers boreholes had an average score of 2.6, leading to the conclusion that boreholes are used on a regular basis by subsistence farmers in the region to support production activities.

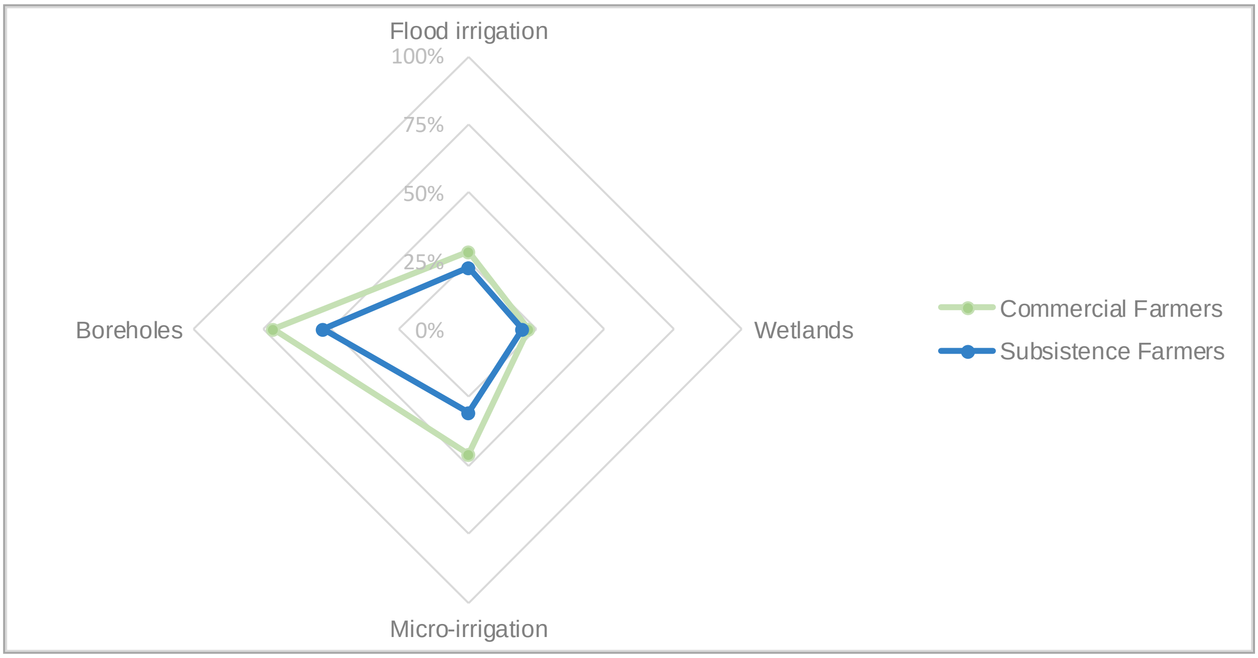

Figure 5.7: Irrigation methods used by commercial and subsistence farmers in the region

Table 5.4: Respondents’ irrigation methods scores

	Irrigation methods	CF Score	SF Score
1.	Flood irrigation	1.409	1.118
2.	Wetland irrigation	1.091	1.000
3.	Sprinkler/micro-irrigation	2.273	1.529
4.	Boreholes	3.545	2.647
	Average	**2.080**	**1.574**

5.4.1.5 Chemical/Fertilizer applications

A significant difference was found between the chemical/fertilizer applications of the commercial and subsistence farming groups. From the commercial perspective, this was the category with the highest implementation rate of all. The use of fertilizers is the most popular method applied by the commercial farmers as it scored an overall percentage of 93.64% based on the rating data. This means "always" is the average rating for fertilizer usage. Contrastingly, the subsistence farmer respondents indicated a low implementation of chemical and fertilizer applications, with the use of manure (47.06%) being ranked the most applied practice in this category.

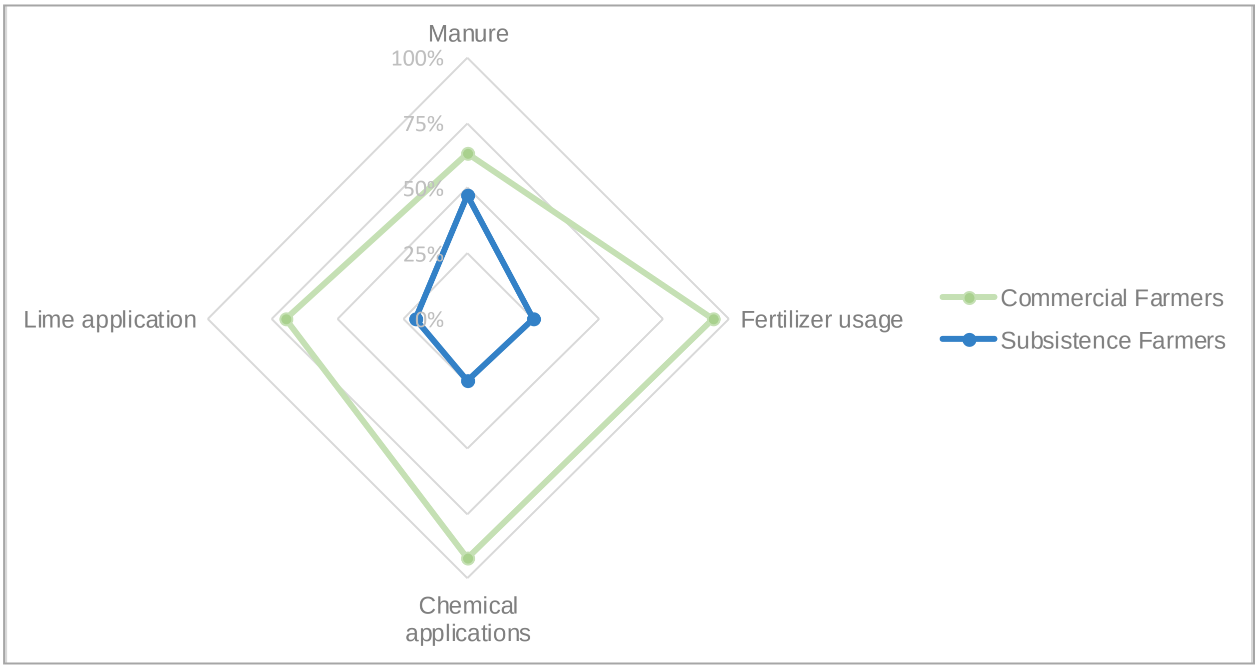

Figure 5.8: Chemical and fertilizer applications of the commercial and subsistence farmer respondents

Table 5.5: Respondent chemical and fertilizer application scores

	Chemical/Fertilizer applications	**CF Score**	**SF Score**
1.	Chemical applications	4.591	1.176
2.	Use of fertilizers	4.682	1.235
3.	Use of manure	3.182	2.353
4.	Lime application	3.500	1.000
	Average	**3.989**	**1.441**

The difference in the chemical and fertilizer application methods of the farmers is indicative of their access to the products. Commercial farmers tend to have better access to agricultural products such as commercial chemical and fertilizer applications, while subsistence farmers have to use the resources available to them, such as manure from their livestock.

5.4.1.6 Farm insurance

Farm insurance was found to be the second highest climate change adaptation method used by the commercial farmers in the area, with an average rating of 3.957, in other words the average rating for farm insurance was "almost always". None of the subsistence farmer respondents used farm insurance in their farming activities, which could be an indicator of their lack of access to capital and limitations in their adaptive capacity.

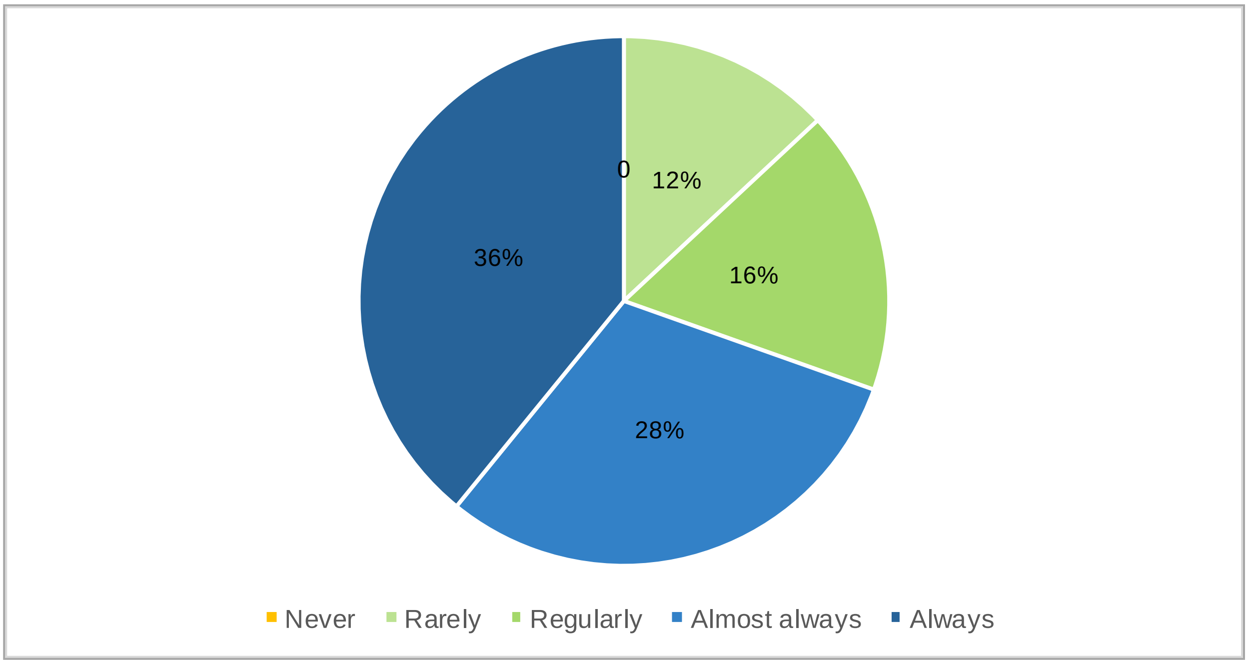

Figure 5.9: Farm insurance utilized by the commercial farmers of the study region

The findings in the above figure further substantiates the discussion in Section 3.3.7, which states that financial coping strategies are mostly confined to commercial farmers. In this regard the commercial farmers' ability to get farm insurance increases their adaptive capacity by decreasing the potential financial risks associated with farming operations.

5.4.1.7 Livestock farmers' adaptation methods

A comparison of the strategies used by the two farming groups showed a relatively similar average score of the climate change adaptation methods implemented by livestock farmers. Disease management was found to be the method most often applied by the commercial farming group (approximately 86%). This was followed by moving their herds (80%) and producing or stocking their own feed (about 75%).

The climate change adaptation method most used by the subsistence farming respondent group was building shelters for their livestock (about 82%), which was followed by the diversification of livestock species (about 63%) and allocating livestock species to appropriate family members (62.61%).

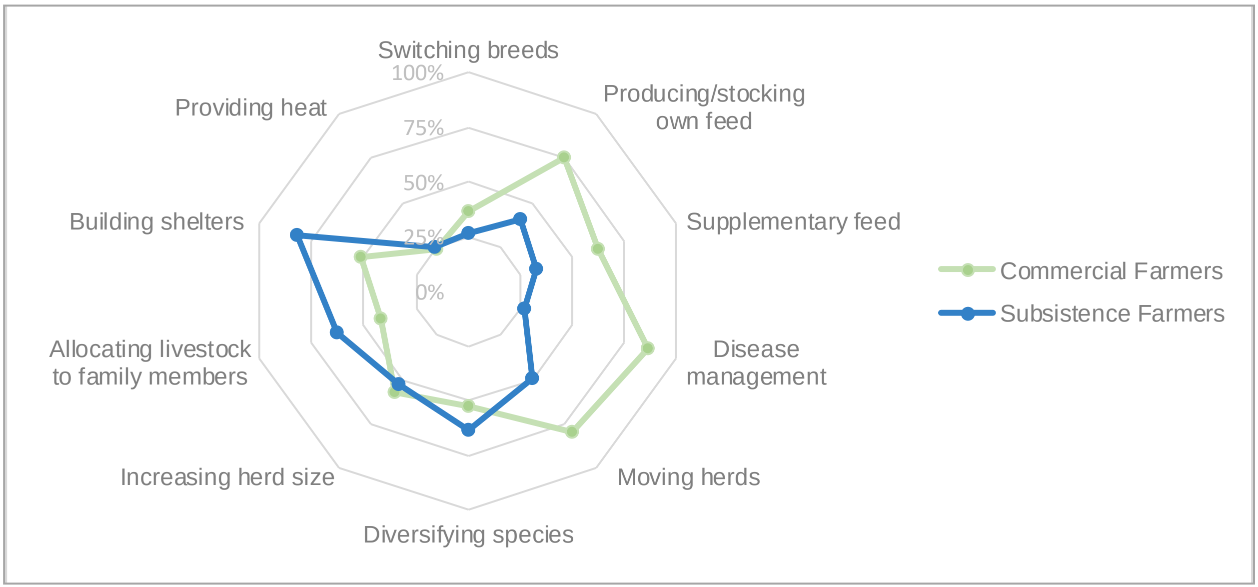

Figure 5.10: Livestock adaptation methods implemented by respondents

Table 5.6: Livestock farmers climate change adaptation scores

	Livestock farmers CCA	CF Score	SF Score
1.	Switching breeds	1.840	1.304
2.	Producing/stocking own feed	3.760	2.043
3.	Supplementary feed	3.120	1.652
4.	Disease management	4.320	1.348
5.	Moving herds	4.000	2.478
6.	Diversification of species	2.640	3.174
7.	Increasing herd size	2.840	2.652
8.	Allocating to family members	2.080	3.130
9.	Building shelters for livestock	2.565	4.091
10.	Providing heat to livestock	1.208	1.261
	Average	**2.837**	**2.313**

Once this base indication of the climate change adaptation methods implemented by the farmers of the Ditsobotla Local Municipality had been established, there was a need to gain a more holistic understanding of the reasoning behind the climate change adaptation choices made by commercial and subsistence farmers.

5.4.2 Reasoning behind the Strategies Implemented

Various reasons were given for the adaptation strategies implemented by the respondents. However, some were mentioned more than others. The most common reason driving commercial respondents to implement CCA strategies were for sustainability (24%[N=6]) and optimized yield (20%[N=5]). Other commercial respondents indicated that they implement CCA to ensure healthy livestock herds and to make their operations more manageable throughout the year. The results of the commercial respondents correspond with the literature indicating optimized yield and sustainability as the primary driving factors behind commercial operators' adaptation decisions (Schulze, 2010; DAFF, 2013).

On the other hand, subsistence farmers mainly applied the adaptation strategies according to their knowledge of what's best for their environment (48%[N=12]), and with the wellbeing of their livestock (24%[N=6]) and the resources available to them in mind (24%[N=6]). One subsistence respondent mentioned implementing adaptation methods because he "needs to feed his family". The findings also align with some of the primary motivations prompting subsistence farmers to adapt as identified in the literature. The literature pointed to livelihood sustainability and increasing their resilience towards climate change (Bryan *et al*., 2009; Yaro, 2013).

5.4.3 Unique adaptation methods

Over and above the adaptation strategies identified by the farmers as presented above, farmers were also able to identify unique adaptation strategies. Additional adaptations among the commercial farmers were mostly directed at decreasing the possibility of overgrazing. One such method was administering supplements to livestock urging them to eat types of grass and plants they would normally find more distasteful. Commercial farmers indicated that this strategy permitted efficient utilization of land resources and countered land degradation from overgrazing. Another method aimed at decreasing land degradation was the increase of water points for livestock, which also keeps them from overgrazing. To improve water use efficiency, one commercial farmer indicated that he schedules irrigation for night times, which decreases evaporation rates. One farmer also mentioned that he produces his own compost to use as fertilizer for his crops. The use of nature signals was also identified as an additional climate change adaptation method by another commercial farmer, who has learned about the identifiers and signals from his father.

A few adaptation strategies not identified during the qualitative enquiry of the study were mentioned by the subsistence farming respondents. The absence of these methods in the literature does not necessarily mean they aren't used by subsistence farmers in other regions, as traditional adaptation methods have not yet been fully studied and identified. However, it could indicate that these additional methods of adaptation are unique to the subsistence farmers of the region and constitute a form of traditional knowledge. Some farmers indicated that they carefully decide on which combination of crops and vegetables to use for their intercropping practices. The decision is based on the belief that some combinations could be beneficial to each other (for example tomatoes and onions), while other combinations (such as tomatoes and cucumbers) could be detrimental to one or both of the crops. Some farmers indicated that during the fruiting period they remove the smaller "fruits" to leave those with more potential with more space and access to water.

Another unique subsistence farming adaptation method that was mentioned in the literature is a shade and shelter strategy. What was not specifically described, is the covering of crops with grass shelters (field photos inserted below). This technique was identified by 16%[N=4] individual subsistence farmers, who all indicated that they create small shelters in the form of grass domes or grass "houses" to protect their vegetables in particular during sensitive growth stages, as well as to increase moisture conservation.

Figure 5.11: Photograph of grass dome

Figure 5.12: Grass shelter covering tomato plant

Figure 5.14: Grass dome view from within

Figure 5.13: Grass shelter view from above

(Sources: Own contribution)

The photos were taken by the researcher with the permission of the subsistence farmer. These represent the actual crop covers they use to protect their crops during sensitive growth stages. Each farmer uses their own initiative to build these covers, which also means that each farmer has a unique way of building their “crop houses”. As presented in the photos above, the particular farmer has adapted the structure by including sponges underneath the “roof”. He indicated that this helps significantly with moisture conservation and protects vegetables from high temperatures.

5.4.4 Additional Strategies the Farmers would want to Implement

The farmers of the region expressed a willingness and interest in implementing additional adaptation strategies, especially if they were without limitations. The most frequent additional strategy subsistence farmers were interested in implementing was diversification of species (20%[N=5]), increasing their herd size (16%[N=4]) and giving their livestock supplementary feed (12%[N=3]). One female subsistence farmer said if no physical or financial limitations were present, she would plant more crops to sell at markets as an extra source of income. Commercial farmers on the other hand were more focused on irrigation (12%[N=3]), precision farming (8%[N=2]), conservation practices (8%[N=2]) and buying new machinery (8%[N=2]). One commercial farmer expressed an interest in the implementation of temperature regulating shelters for livestock and poultry practices. This was an interesting finding considering it was not mentioned as an adaptation method during the qualitative exploration in the first phase of the research.

Though all the farmers have applied methods of adaptation as part of their agricultural practices, they are still faced with many factors that could keep them from adopting other adaptation strategies. To better understand the differences in the adaptation methods the commercial and subsistence respondents use, the next theme is an exploration of the possible factors hindering adaptation within agricultural systems.

5.5 Theme Three: Factors Constraining Farmers’ Adaptation to the Impacts of Climate Change

The range of possible factors limiting the adoption of climate change adaptation measures was thoroughly discussed in Chapter Three of this study. The discussion below investigates the applicability of these factors to the farmers of the Ditsobotla Local Municipality. Respondents were able to provide an in-depth understanding of what factors hinder them from adapting, as well as how often these aspects exert an influence.

5.5.1 Factors that Keep Farmers from Implementing Adaptation Strategies

Farmers participating in the study were able to identify the factors that hinder climate change adaptation in their area. The biggest issue for commercial farmers was variations in rainfall (almost 80%), which has an overall rating of “almost always”. Variations in temperature was the second greatest factor limiting adaptation for them (about 74%), followed closely by a lack of access to water (69%). For subsistence farmers, the greatest limiting factor was a lack of access to machinery (extremely high number of 99.2%), with a lack of access to chemicals being the second biggest limiting factor (an estimated 93%). Lack of access to markets (92%) and lack of access to fertilizers (92%) followed closely. Figure 5.15 and Table 5.7 below present the factors that keep farmers from implementing adaptation strategies.

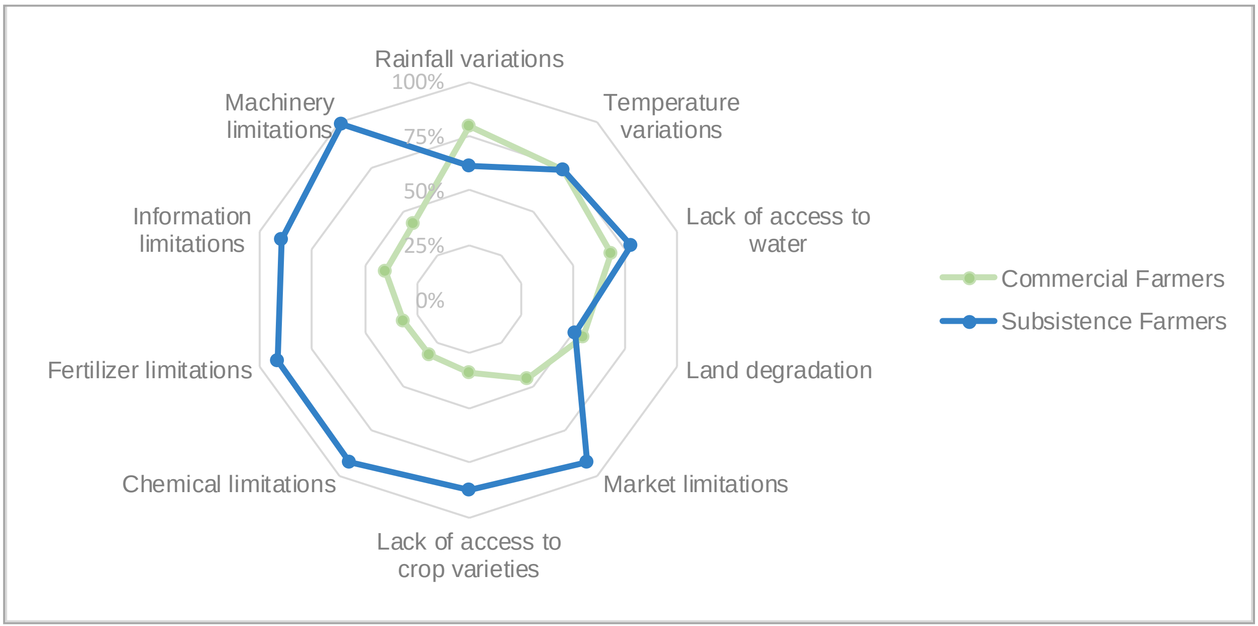

Figure 5.15: Factors constraining the adaptation of respondents

Table 5.7: Scores of the factors constraining respondents from adapting

	Factors limiting CCA	**CF Score**	**SF Score**
1.	Variations in rainfall	3.960	3.080
2.	Variations in temperature	3.680	3.680
3.	Lack of access to water	3.440	3.920
4.	Land degradation	2.760	2.560
5.	Lack of access to markets	2.280	4.600
6.	Lack of access to crop varieties	1.680	4.400
7.	Lack of access to chemicals	1.560	4.640
8.	Lack of access to fertilizers	1.560	4.600
9.	Lack of access to information	2.000	4.480
10.	Lack of access to machinery	2.120	4.960
	Average	**2.504**	**4.092**

As is evident from the results, commercial farmers are mostly inhibited by environmental factors, while subsistence farmers' implementation of adaption measures are more greatly affected by economic and productive challenges.

The different limitations experienced by the commercial and subsistence farmers should be considered in order to design climate change adaptation programmes suited to their specific circumstances. These will increase implementation rates and facilitate successful adaptation (Vincent *et al.*, 2011; Yaro, 2013; IPCC, 2014a; Niles *et al.,* 2015).

5.5.2 Other limitations

Both farming groups identified financial limitations as an additional constraint. This issue was highlighted by 40% of the commercial farmers. Their responses carried an undertone of desperation for financial support, as unstable environmental conditions make it nearly impossible to continue agricultural production where economic outcomes no longer justify the financial inputs of commercial farming. The farmers were generally concerned for their future in agriculture, emphasizing that only one "bad" year could lead to their downfall as they receive no financial aid from the government. For subsistence farmers, financial factors were also the most mentioned limitation. Other limitations mentioned by the farmers include poor product prices for the commercial operators and limited access to land for subsistence farmers.

The emotion and passion evident in the respondents' answers for this particular sub-theme were a true testament of the hardships and difficult circumstances surrounding agriculture in South Africa. Most CCA literature gives detailed descriptions of the possible limitations commercial and subsistence farmers might face, but very few address the issue of their emotional wellbeing in the face of challenging circumstances and climate change. Section 3.5.4 of Chapter Three alluded to the exclusion of indigenous knowledge in modern climate change adaptation as a great constraint for especially subsistence farmers. The following theme is an exploration of the perceptions and inclusion of indigenous knowledge in the present-day practices of the region's farmers.

5.6 Theme Four: The Role of Indigenous Knowledge

The findings of Sub-theme 5.3.7 affirm the research propositions that commercial farmers have more access to contemporary and formal knowledge networks with strategies to address climate change. On the other hand, subsistence farmers still rely mostly on their historic traditional knowledge and the farmers own lived experience to adapt to climate change. It is important to state that contemporary knowledge (as applied by commercial farmers) is not superior to traditional knowledge. Instead a major observation from the study is the need for future climate change adaptation strategies to include both traditional and contemporary knowledge.

5.6.1 Understanding of Indigenous Knowledge

Before exploring the respondents' view of whether indigenous knowledge is still applicable today, it was important to first establish their understanding of the term. Though the exact term “indigenous knowledge” was mostly unfamiliar to the farmers, most of them had a good understanding of what it meant once it was referred to as “traditional knowledge”. A total of 72%[N=18] of the commercial farmers and 56%[N=14] of the subsistence farmers knew what it means and entails. After referring to the term as *“traditional knowledge”,* one subsistence farmer responded by describing it as the lessons taught to her by her grandmother, who have gained the knowledge through her own farming experiences. Another exceptional description of the term was given by a commercial respondent who described it as *“invaluable experience of farmers that have been analysed and added to throughout the years”*. He also gave a second description, explaining it as ongoing tests and trials executed and documented by thousands of people over extended periods in specific geographical areas.

5.6.2 The Value and Applicability of Indigenous Knowledge in Modern Day Agriculture

Most of the commercial respondents (80%[N=20]) believed that traditional and indigenous knowledge is still applicable to farming activities and to the methods of adaptation today. The subsistence farmers agreed, with most of the respondents indicating yes (80%[N=20]) and only 20%[N=5] feeling that indigenous knowledge is less applicable today. There was also a consensus amongst the two farming groups regarding their personal application of indigenous knowledge in their operations. The commercial respondents (76%[N=19]) and the 76%[N=19] subsistence respondents indicated they do apply indigenous knowledge regularly in their practices today. One commercial farmer gave an example of such application by stating that he has learned about increasing waterpoints for livestock as a method to conserve his grazing from his father.

According to one subsistence farmer, the belief that indigenous knowledge is no longer applicable today stems from the circumstantial differences between her and her grandmother. She explained that the lessons her grandmother taught her are not applicable to her present environmental circumstances, as her grandmother *“did not have access to nearby water sources and had to carry buckets of water from a dam which was kilometres away”* whereas she has access to a borehole for irrigation.

5.7 Theme Five: Respondents’ Recommendations for Building the Adaptive Capacity of Farming Communities

The respondents identified areas that could be improved to make recommendations for increasing the adaptive capacity of farming communities. From the subsistence respondents’ perspective, the adaptive capacity of farming communities could be improved significantly by financial aid and with increased access to resources such as materials for shelters, information resources and access to water resources. Some respondents also mentioned access to land as another method of improving the adaptive capacity of these communities. One subsistence farmer alluded to the problems farmers face with regard to livestock theft as he mentioned his “chickens are being stolen by individuals living in the neighbouring communities”, suggesting increased security and stricter laws could improve the coping capacity of livestock farmers.

Most of the commercial farmers believed the dissemination of climate change related information and the sharing of knowledge between farmers could improve the adaptive capacity of rural communities. They also highlighted government aid and financial relief as ways to build the resilience of their communities. One commercial respondent in particular mentioned *“agricultural extension officers should be more accessible”* and that *“mentorship should be encouraged*”. A noteworthy recommendation another commercial farmer mentioned was that *“the government should promote cohesion between all farming groups”,* which in turn could also increase the adaptive capacity of farming communities, an admirable sentiment.

5.8 Conclusion

The focus of this chapter was to present findings of the empirical enquiry into the various climate change adaptations used by the commercial and subsistence farmers of the Ditsobotla Local Municipality. The extensive investigation into all the dimensions of climate change adaptation allowed the researcher to gain insight while contextualizing climate change adaptation within the agricultural systems of the area. The data collected by means of the questionnaire that was formulated as a measuring instrument from the findings of the first qualitative phase of the research, were analysed and processed to answer the remaining research questions and to identify prominent themes. Comparisons were drawn between the commercial and subsistence farmers’ climate change adaptation methods and limitations, as well as between the qualitative and quantitative findings of the study. Some major adaptation trends in the two farming groups was the frequent implementation of operational adjustments and diversification of livelihood resources. The common limitations hindering both the farming groups from adopting other strategies were variations in temperatures, financial factors and a lack of governmental support.

The greatest disparities found between the commercial and subsistence farmers was the difference in access to relevant climate change information and access to agricultural products (such as fertilizers and chemicals). Additionally, there was also a difference in some of the limitations these farmers face. The results of the structured questions revealed that commercial farmers were primarily hindered by adverse and uncertain environmental circumstances, while subsistence farmers face a diverse array of limitations, including environmental, technological and market-related aspects. As is evident from the findings of Chapter Five there are some areas of overlap and differences between the commercial and subsistence farmers’ climate change adaptation methods, limitations and perceptions. It is therefore important to consider these variations during the formulation of adaptation strategies and initiatives in order for them to be effective and applicable to farmers facing different challenges and circumstances. The concluding chapter of this study considers the findings from the qualitative phase and the quantitative phase in relation to each of the research questions formulated at the outset of Chapter One. This is followed by recommendations for improving the adaptive capacity of agricultural communities.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The research conducted in the Ditsobotla Local Municipality revealed climate change will only add to the litany of difficulties farmers face in a sector that is characterized by uncertainty and complexity. The opportunity to collect and compare information from opposite ends of the farming spectrum (i.e. commercial and subsistence) resulted in unique insights into the perspectives, motives and determining factors for the adoption of climate change adaptation measures within agriculture. It also allowed for an in-depth comparison of the existing body of literature and findings from the agricultural practices of the farmers in the study area.

While the results of the questionnaire were thoroughly discussed and compared extensively in the Chapter Five, Chapter Six gives an in-depth overview of the research findings. These findings are discussed as they relate to each of the research questions formulated to guide this study. The final research question receives special attention as recommendations are proposed for building the resilience of farming communities. The chapter closes with potential areas for future research on the topic.

6.2 Summary of Research Findings

6.2.1 The Impacts of Climate Change on Agriculture in a Developing Country Context

The investigation into the impact of climate change on developing countries showed their agricultural sector to be extremely vulnerable, owing to their high exposure to climate change and limited capacity to respond efficiently to its manifestation in their environment (Pereira, 2017; Awojobi & Tetteh, 2017; Oduniyi, 2018). The vulnerability of agricultural systems in developing countries are also embedded in the fact that these systems remain mostly dependent on rain-fed agriculture practices, further exacerbating their susceptibility to variations in rainfall patterns and periods of drought associated with climate change (Lotter, 2017). The predicted impact of climate change on developing countries' agriculture were identified as unpredictable rainfall patterns, increased temperatures, increased frequency of extreme weather events and the increased occurrence and severity of diseases and pests (Altieri & Nicholls, 2013; Lotter, 2017; Mashizha, 2019; Oduniyi *et al.*, 2019).

Another finding is that the implications of climate change is not and will not only be limited to economic losses due to a decline in agricultural yield in developing countries. The effects of climate change will affect a vast majority of the population who have built their livelihood on agriculture. It also threatens their food security, natural resources, water availability, biodiversity and culture (Ziervogel *et al.,* 2014; Mashizha, 2019). Taking into consideration the extent to which climate change is likely to affect farmers in Africa in general and South Africa in particular, facilitating their ability to cope and adapt to these changes is imperative. This contextual reality was the driving force behind the study's exploration into the theoretical tenets of climate change adaptation.

6.2.2 The Theoretical Tenets of Climate Change Adaptation

The literature study revealed that the postponement of vigorous climate change adaptation through policies and initiatives has been based on the assumption that climate change was and is likely to happen at a gradual pace, thus permitting affected societies enough time to adjust accordingly (FAO, 2010b). With this in mind, past efforts of the climate change community were primarily slanted towards a "mitigation over adaptation perspective". However, two major aspects have changed the course of the climate change community from focusing their energy primarily on mitigation as the main societal response towards global warming and changing environmental conditions to developing the field climate change adaptation. Firstly, statistics suggest that there will be a persistent increase in temperatures (of at least 2°C) during this century regardless of vigorous and strict mitigation strategies aimed at limiting global greenhouse gas emissions (IPCC, 2012a; IPCC, 2014b; Huq *et al.,* 2018). Secondly, future projections indicate a drastic increase in the frequencies and distribution of extreme variations in climate and intense climate-related events, such as droughts and floods (IPCC, 2018b Lotter, 2017; Oduniyi *et al.,* 2019). This increases the probability of climate change manifestations surpassing the ability of affected societies to cope with the detrimental impact in a resilient and timeous manner. Climate change adaptation is one of the few remaining avenues left to society to decrease the vulnerability of communities towards climate change, while also enabling them to cope with the detrimental effects.

The agricultural systems of developing countries are often extremely vulnerable to the effects of climate change. During this study, various strategies stemming from modern information and indigenous knowledge have been identified as measures for decreasing the vulnerability of these systems to climate change. Modern adaptation strategies fall into a few categories, such as operational adjustments and conservation practices, while the full scope of traditional strategies is yet to be investigated. It did therefore not necessarily allow for categorization. Nevertheless, a diverse set of traditional adaptation methods have been described in the literature, including agroforestry and the "Zai" technique. Although the adaptation methods currently applied by farmers have allowed them to continue operations during times of severe environmental stress in the past, the predicted implications of climate change could render some of the approaches insufficient in the future. There is growing consensus on the urgency of facilitating the implementation of effective adaptation strategies within agricultural operations. To establish the importance of such initiatives the next research question launched an investigation into the different influences of climate change on the Ditsobotla Local Municipality, both presently and in the future.

6.2.3 The Influence of Climate Change on Ditsobotla's Agricultural Sector

The inquiry into the influence of climate change on the agricultural sector of the NWP and the Ditsobotla Local Municipality revealed the high vulnerability of the farmers in the locale accompanied by increasingly challenging environmental circumstances in the future (DEA, 2015; Mambo & Murambadoro, 2017). The vulnerability of the local agricultural system can be attributed to a low mean annual rainfall, a history of prevailing droughts, small land holdings and high population density in certain area. The latter two challenges mostly affect subsistence farmers in the region (Le Roux *et al*., 2017; Agri SA, 2018).

The region is known as one of the largest white maize producers in the country as it is situated within South Africa's maize triangle (DRDLR, 2016; Oduniyi *et al.,* 2019). With this in mind, it is highly likely that climate change will continue to be a persistent threat to the region's primary crop production as research suggests that maize will be negatively affected by climate change (Pereira, 2017). Predictions that supports this estimate includes the high probability of a drastic increases in average temperatures (causing a shorter growth period) along with unpredictable and extreme changes in rainfall patterns in the NWP (Lotter, 2017; Mambo & Murambadoro, 2017). Information obtained from the questionnaire also substantiates the claims of climate change manifesting as higher average temperatures and increased variations in rainfall patterns. An astounding number of farmers (76% of all respondents) have observed these two changes in their farming practices and immediate environment, alluding to the importance of climate change adaptation for both commercial and subsistence farmers.

6.2.4 Farmers' Perceptions and Extent of Knowledge of Climate Change in the Ditsobotla Local Municipality's Farmers

Perception, knowledge, experience and awareness are some of the primary factors prompting farmers to adapt to climate change. The investigation into the perception and knowledge of the Ditsobotla's farmers of climate changed revealed a differentiation in the exposure the commercial and subsistence farmers have to the terminology with respect to climate change. Commercial farmers in the region possess a good understanding of the term, often associating climate change with "uncertainty". Most of them (96%) also saw adaptation within their agricultural practices as a necessity. Among subsistence farmers the concept was fairly unfamiliar to 40% of the respondents. Only 44% believed they needed to adapt their farming activities. The findings were indicative of the lack of access and exposure the subsistence farmers have to climate change information. This is worrisome considering the relationship between knowledge of climate change and the execution of climate change adaptation strategies.

The age and experience characteristics of the farmers in the region meant a higher potential for implementing adaptation strategies. The notion of increased farming experience correlating with a higher adaptation rate stems from the qualitative findings of this study. However, in this instance the commercial farmers with fewer years of agricultural experience applied the same adaptation strategies as those with more experience. In contradiction with literature findings, subsistence farmers who have fewer years of experience were more knowledgeable about climate change and applied creative methods of adaptation, such as picking the smaller fruits early to allow the fruits with a higher potential to develop under more favourable circumstances.

The subsistence farmer results could have contradicted the literature research findings with regard to farming experience due to another factor prompting farmers to adapt, namely awareness. Questions pertaining to the farmers understanding and applicability of the term "climate change adaptation" and their observations of environmental changes connected to climate change denote a strong correlation between younger subsistence farmers and a greater awareness and understanding of climate change and adaptation. From the commercial operator standpoint, 76% of the farmers knew the term "climate change adaptation" and 100% were aware of the effects of climate change in their area. This has led the researcher to oppose the belief of farming experience being the primary factor prompting farmers to adapt. In the case of the Ditsobotla Local Municipality awareness of climate change was found to be more influential as opposed to farming experience. Awareness of a topic such as climate change is also intrinsically linked with access of relevant information. It is therefore imperative to create better networks for the dissemination of the latest climate change information.

6.2.5 The Methods of Climate Change Adaptation Implemented by the Commercial and Subsistence Farmers

The adaptation category with the highest ratings for commercial farmers were chemical and fertilizer applications, which had an average rating of "almost always" or average score of 3.989. This was followed closely by farm insurance (average score of 3.957), operational adjustments (overall rating of 3.045) and livestock adaptation strategies (average score of 2.837). The adaptation categories least implemented by commercial farmers in the region were shade and shelter and irrigation strategies. The findings on the adaptation methods used by commercial farmers in the region align with the literature regarding their motivations for their choice of adaptation methods. It was found that most of the adaptation methods used by the commercial respondents were aimed at optimizing their yield, while decreasing their risks towards climate change.

On the other hand, subsistence farmers in the region mostly used operational adjustments as their strategies for coping with climate change. This category had an average rating of “regularly”, or a score of 2.874. None of the subsistence farmers have applied farm insurance as a method of adaptation, likely due to their scale of operations and financial limitations. The other categories with the lowest implementation rates were conservation practices (average rating of 1.153) and chemical or fertilizer applications (average rating of 1.441). The literature investigation suggested that subsistence farmers often opt for adapting their livestock practices rather than adjusting their crop activities (Thomas *et al.,* 2007; Seo & Mendelsohn, 2008). However, the results from this study contradicts the literature in this case as “operational adjustments” was the highest scoring category for the subsistence respondents, whereas livestock adaptation methods were only the third highest scoring category.

Operational adjustments were identified as one of the most implemented categories of both the commercial and subsistence farmers in the Ditsobotla Local Municipality. Diversification of livelihood was another adaptation similarity between the farmers as a significant number of respondents from both groups have diversified their sources of livelihood. With regard to the least implemented methods, both commercial and subsistence farmers in the region did not favour irrigation strategies, probably due to the low irrigation potential of the available water resources in the area. The methods with the biggest contrasting scores was the application rates of farm insurance, commercial farmers indicated high implementation rates while none of the subsistence respondents have applied farm insurance. Furthermore, chemical and fertilizer applications also had a high implementation rate among commercial farmers in the area, but it was one of the lowest scoring categories for the subsistence respondents. However, shade and shelter techniques had a higher adoption rate among the subsistence farmers as opposed to their commercial counterparts.

6.2.6 The Factors Hindering or Promoting the Farmers’ Application of Methods of Adaptation

An enquiry into the most influential factors hindering these farmers from implementing other climate change adaptation strategies have identified various factors limiting both the commercial and subsistence farmers of the Ditsobotla Local Municipality. The greatest limiting factors for the commercial respondents were variations in rainfall (about 79%) and variations in temperature (about 74%). For them, the biggest limiting factors were based on the difficult environmental challenges they face due to climate change. As the qualitative investigation of this study suggests, these challenges are likely to intensify as climate change continues to manifest during this century. Enabling these farmers to adjust efficiently to the effects is imperative so that they can contribute to South Africa’s agricultural sector and GDP. For subsistence farmers, the factors hindering them from adapting were mostly related to their limited access to agricultural machinery (99.20%) and chemicals (92.80%). Without access to basic agricultural products such as chemicals or fertilizers, their crops will likely be less resilient to the impact of climate change such as increased temperatures or crop diseases. In turn this could have a detrimental effect on the health of the household as they are directly dependent on their crops to meet their food consumption needs.

The results from the discussion on the additional limitations both farming groups face have shown financial support to be one of their biggest constraints. Considering that both groups of farmers agree on this limitation it is one that should not be taken lightly. These farmers constantly battle unstable environmental, and economic and political conditions. Those who have access to markets are often met with very low prices for their products, often causing their agricultural yield to be unprofitable, while those who don’t have access to markets are also left with immense challenges when attempting to meet their basic food needs. Arguably, these could also reduce adaptive ability and overall levels of resilience.

6.2.7 Recommendation for Eliminating the Factors Prohibiting the Application of CCA in Order to Promote the Effective Adaptation of both Commercial and Subsistence Farmers

Through the course of this study the greatest barriers to implementing CCA were found to be lack of information, difficult environmental circumstances, lack of political will and financial constraints. In order for agriculture to be sustainable in the future, it is important to establish well informed plans for eradicating these barriers of adaptation. A great starting point for such initiatives is asking the ones most affected by the detrimental impacts of climate change directly what they believe could eliminate the factors that keep them from adapting. Their views and recommendations along with solutions identified from the literature are discussed below.

The research conducted throughout this study continually emphasized knowledge and awareness of climate change as a requisite for implementing adaptation strategies. This refers not so much to possessing a theoretical understanding of the term, but rather to being aware of the precise impact of climate change in their area. It also includes insight into the probable future climatic conditions, enabling farmers to make informed decisions about adaptation. Farmers of the Ditsobotla Local Municipality had an awareness of the various impacts of climate change in their region, such as the observed droughts and changing rainfall patterns, but their information resources were limited to non-governmental networks, own experience and traditional knowledge. In order to eliminate the constraints placed on the farmers by the various challenging circumstances, it is imperative for governing bodies and authorities to acknowledge their role in building the adaptive capacity of all farming communities. Only with their support could better communication networks be established to improve the dissemination of relevant climate change information. Lastly, cohesion among all farming groups should be promoted as social networks stemming from unity offer invaluable information and experience exchanges among individuals who understand each other's challenges and hardships.

To help farmers navigate the detrimental effects of climate change within their environment, it is important to facilitate the creation of location-specific adaptation strategies. Consideration of the specific environmental characteristics of the areas these farmers farm in could result in more effective adaptation strategies with a higher implementation rate. However, this is not the only threat to agricultural systems in the area. Increasingly challenging circumstances surrounding the Ditsobotla Local Municipality's natural environment are often accompanied by discouraging political influences. The feeling that the financial input (especially associated with commercial farmers) required for production is no longer justified by the economic outcomes was emphasized throughout the study. To alleviate the limitations pertaining to financial factors, increased government aid is needed, especially for the commercial and subsistence farmers that are already established within their communities.

Finally, the value of the indigenous knowledge of these established farming communities should not be overlooked in the formulation of modern adaptation strategies. Taking into account the potential benefits of using indigenous knowledge in climate change adaptation strategies, such as increased adoption rates and creative cost-effective solutions, an all-inclusive approach should be mainstreamed globally with more adaption options specifically suited to the communities and their locations.

6.3 Observations Emerging from the Study

The extensive investigation into all the dimensions of climate change adaptation allowed the researcher to collect rich insights while contextualizing climate change adaptation within the agricultural systems of the Ditsobotla Local Municipality. Based on the findings, it is evident that climate change equals great difficulties for those dependent on a sector that is already laced with uncertainty and complex adversities. Frequent drought and irregular rainfall patterns observed in the region have increased the vulnerability of both farming systems. While it was evident that climate change threatens the livelihood sustainability of those dependent on agriculture in the region, it is certainly not the only threat they are facing. Thus, building and enhancing the adaptive capacity of farming communities, regardless of their farming group, should be encouraged and facilitated in any way possible.

The following observations were apparent throughout the study:

- While there was a noticeable difference in the scale of operations, the perceptions and knowledge of climate change adaptation and the constraints the two farming systems (commercial and subsistence) face, both groups have already initiated minor processes of adaptation. Commercial farmers in the region primarily focused on optimizing their yield (and ensuring yield in difficult environmental circumstances) by means of chemical and fertilizer applications. Subsistence farmers mostly aimed their adaptation strategies towards getting the maximum out of the land surface available to them by adopting intercropping practices and tactically spreading their agricultural activities throughout the season.

- The determination of farming communities to persevere in the face of adversities has contributed to a base level of resilience in spite of constricted governmental and financial support towards already established farmers. The unique and creative adaptation methods implemented by the subsistence and commercial farmers in the region are indicative of their resilience. However, the increasingly difficult and unpredictable circumstances that are highly likely to confront agricultural systems in the future should urge stakeholders in the sector to recognize the urgency of support, regardless of their self-initiated resilience.

- While there is an awareness of the manifestations of climate change in the area, there is a need for effective dissemination regarding the knowledge of best practices and adaptation strategies. The farmers in the region gained their current knowledge and understanding of climate change adaptation from their agricultural networks (such as Grain SA and Pannar Day), social networks (other farmers), indigenous knowledge and own experiences. Communication about appropriate and efficient adaptation strategies in relation to climate change, especially among subsistence farmers, could be enhanced by improving government extensions services in the area.

- The inclusion of indigenous knowledge in contemporary adaptation strategies has been greatly overlooked and underestimated in the past. Its integration would allow for cost-effective strategies with higher implementation rates, but progress is needed to identify areas for cohesion between modern and traditional knowledge.

- The adaptive capacity of farming communities was found to be multi-dimensional and dynamic in nature. Different aspects influence the adaptive capacity of the commercial and subsistence farmers in the region. This is also reflected in their choice of adaptation methods. Even with consideration of advantages connected to the subsistence and commercial farming communities respectively, the barriers they face could cause the advantages to not be sufficient for them to persist without government assistance.

6.4 Areas for Future Research

The understandings gained from this study emphasizes the need for further research. Opportunities for future research include the following:

- Further research is needed to better facilitate the integration of climate change adaptation strategies within the agricultural communities of developing countries, as the theoretical investigation suggested these countries will be the most affected by climate change. Strategies should specifically be designed for and be applicable to the locations and circumstances of the target communities.

- The study identified the various aspects that keep farmers from adapting some strategies that could enhance their resilience to the impact of climate change. However, an investigation of a greater scope of the barriers to adaptation could aid in promoting more focused action towards addressing these issues.

- In the Ditsobotla Local Municipality there is a need to improve communication between the government and farming communities, especially in the case of subsistence farmers. A lack of information was found to be a primary constraint of climate change adaptation for them.

- The presence of unique adaptation strategies among the farmers in the region revealed the need for a more comprehensive investigation into the extent and scope of indigenous adaptation strategies. Exploring such methods could provide valuable insights into alternative ways of adapting to future environmental circumstances in the absence of extensive financial and government support.

- This study highlighted the need for enhancing the adaptive capacity of vulnerable farming communities, such as those situated in the study area. There is scope for further inquiry into effective approaches for strengthening their capacity to adapt.

6.5 Conclusion

The impeding effects of climate change on the natural resources of developing countries make those dependent on agriculture vulnerable to variations in climate and occurrences of extreme weather events. The steadily declining state of agriculture owing to climate change manifesting in the form of increased temperatures, longer periods of drought and irregular rainfall patterns in the Ditsobotla Local Municipality and regions alike, threatens the sustainability of their commercial and subsistence farming communities. In an effort to navigate and cope with the effects, all of the respondents have already started to integrate climate adaptation strategies in their agricultural practices. The application of chemicals and fertilizers to ensure maximum yield was the most popular agricultural adaptation strategy among the commercial farmers in the area. Subsistence farmers favoured operational adjustments for optimized production and utilization of their land area. Unique indigenous adaptation strategies emerging from the study included the “grass shelters” built by the subsistence farmers, as well as increased water points for grazing conservation implemented by commercial operators. The findings on indigenous adaption strategies indicated a need for further investigation into indigenous knowledge for climate change adaptation in localized regions, as these techniques have the potential benefit of producing cost-effective strategies that are accessible to all types of farmers.

During the study, different factors were found to have the potential of improving or constraining the adaptive capacity of the respective farming groups. Some of the most prominent factors were related to market access, financial aspects and access to established social networks. However, these factors should not be identified as a means of deciding which farming system should receive priority for support. This study has emphasized the importance of increasing the adaptive capacity of all farmers. The differentiating factors should rather be used to formulate appropriate responses to ensure the sustainability of all agricultural systems. If governing bodies seize the opportunity to enhance the adaptive capacity of local farming communities, they are sure to find resilient and determined farmers with a willingness to participate in adaptation processes.

REFERENCES

Adesina, F.O., Siyambola, W.O., Oketola, F.O., Pelemo, D.A., Ojo, L.O. & Adegbugbe, A.O. 1999. Potentials of agroforestry for climate change mitigation in Nigeria: some preliminary estimates. *Global Ecology and Biogeography*, 8:163–173.

Adger, W.N. 1999. Social vulnerability to climate change and extremes in coastal Vietnam. *World Development,* 27(2):249-269.

Adger, W.N. 2003. Social capital, collective action, and adaptation to climate change. *Economic Geography,* 79:387-404.

Adger, W.N., Barnett, J., Brown, K., Marshall, N. & O'Brien, K.L. 2013. Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change,* 3:112-117.

Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D.R., Naess, L.O., Wolf, J. & Wreford, A. 2009. Are there social limits to adaptation to climate change? *Climatic Change,* 93(3):335-354.

Adger, W.N., Huq, S., Brown, K., Conway, D. & Hulme, M. 2003. Adaptation to climate change in the developing world. *Progress in Development Studies*, 3(3):179-195.

Agri SA. 2019. Agriculture drought report 2018/2019. https://www.agrisa.co.za/download/hr6Ar27BjkE6g5ikb7y2mneqi6RzJy8WGfPR9kfI.pdf Date of access: 18 Sep. 2019.

Ahmad, P., Ahanger, M.A., Alyemeni, M.N. & Alam, P. 2019. Photosynthesis, productivity, and environmental stress. 1st ed. Hoboken, NJ: John Wiley & Sons.

Ajani, E.N., Mgbenka, R.N. & Okeke, M.N. 2013. Use of indigenous knowledge as a strategy for climate change adaptation among farmers in sub-saharan Africa: Implications for policy. *Asian Journal of Agricultural Extension, Economics & Sociology,* 2(1):23-40.

Akinnagbe, O.M. & Irohibe, I.J. 2014. Agricultural adaptation strategies to climate change impacts in Africa: a review. *Bangladesh Journal of Agicultural Research*, 39(3):407-418.

Alemaw, B.F. 2020. Framework of best practice for climate change adaptation in Africa: the water-development nexus. (*In* Matondo, J.I., Alemaw, B.F. & Sandwidi, W.J.P., *ed*. Climate variability and change in Africa. Gewerbestrasse: Springer Nature Media. p. 71-90).

Alhojailan, M.I. 2012. Thematic analysis: a critical review of its process and evaluation. *West East Journal of Social Sciences*, 1(1):39-47.

Altieri, M.A. & Nicholls, C.I. 2017. The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change,* 140:33-45.

Aniah, P., Kaunza-Nu-Dem, M.K. & Ayembilla, J.A. 2019. Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savannah agro ecological zone of Ghana. *Heliyon*, 5(4):1-25.

Archer, E., Conrad, J., Munch, Z., Opperman, D., Tadross, M. & Venter, J. 2009. Climate change, groundwater and intensive commercial farming in the semi-arid northern Sandveld, South Africa. *Journal of Integrative Environmental Sciences*, 6(2):139-155.

Awojobi, O.N. & Tetteh, J. 2017. The impacts of climate change in Africa: a review of the scientific literature. *Journal of International Academic Research for Multidisciplinary*, 5(11):39-52.

Ayantunde, A.A., de Leeuw, J., Turner, M.D. & Said, M. 2011. Challenges of assessing the sustainability of (agro)-pastoral systems. *Livestock Science*, 139:30-43.

Ayers, J. & Dodman, D. 2010. Climate change adaptation and developement I: the state of the debate. *Progress in Development Studies,* 10(2):161-168.

Baethgen, W.E., Meinke, H. & Gimenez, A. 2003. Adaptation of agriculutral production systems to climate variability and climate change: lessons learned and proposed research approach. Paper presented at Climate Adaptation.net conference "Insights and Tools for Adaptation: learning from climate variability". Washington, DC, 18-20 November.

Balasubramanian, T.N. & Appadurai, A.N. 2020. Climate policy. (*In* Venkatramanan, V., Shah, S., Prasad, R., *ed.* Global climate change and environmental policy. Singapore: Springer. p. 37-54).

Barret, S. 1998. Political economy of the Kyoto Protocol. *Oxford Review of Economic Policy*, 14(4):20-39.

Basher, R. 2008. Disaster impacts: implications and policy responses. *Social Research*, 75(3):937-954.

Bengtsson, M. 2016. How to plan and perform a qualitative study using content analysis. *NurisngPlus Open*, 2:8-14.

Benhin, J.K.A. 2006. Climate change and South African agriculture: Impacts and adaptation options. University of Pretoria. (CEEPA Discussion Paper, 21).

Berman, E. 2017. An exploratory sequential mixed methods approach to understanding researchers' data management practices at UVM: integrated findings to develope research data services. *Journal of eScience Librarianship,* 6(1):1-19.

Berman, R., Quinn, C. & Paavola, J. 2012. The role of institutions in the transformation of coping capacity to sustainable adaptive capacity. *Environmental Management*, 2:86-100.

Berrang-Ford, L., Biesbroek, R., Ford, J.D., Lesnikowski, A., Tanabe, A., Wang, F.M., Chen, C., Hsu, A., Hellmann, J.J., Pringle, P., Grecequet, M., Amado, J.C., Huq, S., Lwasa, S. & Heymann, S.J. 2019. Tracking global climate change adaptation among governments. *Nature Climate Change*, 9:440-449.

Besada, H. & Sewankambo, N.K. 2009. Climate change in Africa: adaptation, mitigation and governance challenges. Special Report, The Centre for International Governance Innovation.

Biesbroek, G.R., Klostermann, J.E.M., Termeer, C.J.A.M. & Kabat, P. 2013. On the nature of barriers to climate change adaptation. *Regional Environmental Change*, 13:1119-1129.

Birkmann, J. & von Teichman, K. 2010. Integrating disaster risk reduction and climate change adaptation: key challenges-scales, knowledge, and norms. *Sustainability Science,* 5(2):171-184.

Blignaut, J., Ueckermann, L. & Aronson, J. 2009. Agriculture production's sensitivity to changes in climate in South Africa. *South African Journal of Science,* 105(1):61-68.

Briceno, S. 2015. Looking back and beyond Sendai: 25 years of international policy experience on disaster risk reduction. *International Journal of Disaster Risk Science,* 6:1-7.

Brooks, N. 2003. Vulnerability, risk and adaptation: a conceptual framework. Tyndall Centre for Climate Change Research, Working Paper 38. Norwich, UK.

Brooks, N. & Adger, W.N. 2005. Assessing and enhancing adaptive capacity. (*In* Elizabeth, L., *ed*. Adaptation policy frameworks for climate change: developing strategies, policies and measures. Cambridge: Cambridge University Press. p. 165-181).

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

Brown, O. & Crawford, A. 2007. Climate change: a new threat to stability in West Africa? Evidence from Ghana and Burkina Faso. *African Security Review*, 17(3):39–57.

Bruwer, A., van Staden, M., le Roux, A. & van Niekerk, W. 2017. Disaster management and risk reduction in South Africa. (*In* Mambo, J. & Faccer, K., *ed*. Understanding the social & environmental implications of global change. Stellenbosch: African Sun Media. p. 13-25).

Bryan, E., Deressa, T.T., Gbetibouo, A. & Ringler, C. 2009. Adaptation to climate change in Ethiopia and South-Africa: options and constraints. *Environmental Science & Policy*, 12(1):413-426.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S. & Herrero, M. 2013. Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Environmental Management*, 114:26-35.

Bryant, R.C., Smit, B., Brklacich, M., Johnston, R.T., Smithers, J., Chiotti, Q. & Singh, B. 2000. Adaptation in Canadian agriculture to climatic variability and change. *Climatic Change*, 45(1):181-201.

Buchmann, C., Darnhofer, I. & Grotzer, M. 2010. Farming systems dynamics: the quest for a methodology to measure social-ecological resilience in subsistence agriculture. (*In* Proceedings of the 9th European IFSA symposium, "Building sustainable rural futures: the added values of systems approaches in times of change and uncertainty". Wien: Austria. p.4-7).

Calzadilla, A., Rehdanz, K., Betts, R., Falloon, P., Wiltshire, A. & Tol, R.S.J. 2013. Climate change impacts on global agriculture. *Climate Change,* 120:357-374.

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R.S.J. & Ringler, C. 2014. Climate change and agriculture: impacts and adaptation options in South Africa. *Water Resources and Economics,* 5:24-48.

Cameron, R. 2009. A sequential mixed model research design: design, analytical and display issues. *International Journal of Multiple Research Approaches,* 3:140-152.

Cawthra, H. 2019. Emergence of the African savannah. *Nature Geoscience*, 12(8):588-589.

Chambers, R., Pacey, A. & Thrupp, L.A. 1989. Farmer first: farmer innovation and agricultural research. London, Intermediate Technology Publications.

Chersich, M.F. & Wright, C.Y. 2019. Climate change adaptation in South Africa: a case study on the role of the health sector. *Globalization and Health,* 15(22):1-16.

Claessens, L., Antle, J.M., Stoorvogel, J.J., Thornton, P.K. & Herrero, M. 2010. Assesing climate change adaptation strategies for small scale, semi subsistence farming. (Unpublished).

Cohen, D. & Crabtree, B. 2006. Qualitative research guidelines project. Robert Wood Johnson Foundation.

Crane, T.A., Roncoli, C. & Hoogenboom, G. 2011. Adaptation to climate change and climate variability: the importance of understanding agriculture as a performance. *Wageningen Journal of Life Sciences,* 57:179-185.

CRED (Centre for Research on the Epidemiology of Disasters). 2019. Disasters in Africa: 20 year review. https://cred.be/sites/default/files/CredCrunch56.pdf Date of access: 28 Jan. 2020.

Creswell, J. W. 2014. Research design: qualitative, quantitative and mixed methods approaches. 4th ed. Thousand Oaks, California: Sage Publications.

Creswell, J.W. & Plano Clark, V.L. 2007. Designing and conducting mixed methods research. Thousand Oaks, California: Sage Publications.

Creswell, J.W. & Plano Clark, V.L. 2011. Designing and conducting mixed methods research. 2nd ed. Thousand Oaks, California: Sage Publications.

Danjuma, M.N. & Mohammed, S. 2015. Zai pits system: a catalyst for restoration in the dry lands. *International Organization of Scientific Research Journal of Agriculture and Veterinary Science*, 8(2):1-4.

Davies, M., Guenther, B., Leavy, J., Mitchell, T. & Tanner, T. 2009. Climate change adaptation, disaster risk reduction and social protection: complementary roles in agriculture and rural growth. IDS Working Papers, 320:1-37.

Davies, S. & Ebbe, K. 1995. Traditional knowledge and sustainable development. Washington D.C.: World Bank. (Environmentally sustainable development proceedings series, 4).

Davis, C., Engelbrecht, F., Tadross, M., Wolski, P. & Archer van Garderen, E. 2017. Future climate change over Southern Africa. (*In* Mambo, J. & Faccer, K., *ed*. Understanding the social & environmental implications of global change. Stellenbosch: African Sun Media. p. 13-25).

Degener, J.F. 2015. Atmospheric CO_2 fertilization effects on biomass yields of 10 crops in northern Germany. *Frontiers in Environmental Science,* 3:48.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T. & Yesuf, M. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change,* 19(2):248–255.

Downing, T.E., Ringius, L., Hulme, M. & Waughnray, D. 1997. Adapting to climate change in Africa. *Mitigation and Adaptation Strategies for Global Change*, 2(1):19-44.

Eakin, H. 2000. Smallholder maize production and climatic risk: a case study from Mexico. *Climatic Change,* 45(3):19-36.

Elum, Z.A., Modise, D. & Marr, A. 2017. Farmer's perception of climate change and responsive strategies in three selected provinces of South-Africa. *Climate Risk Management,* 16:246-257.

Elum, Z.A., Nhamo, G. & Antwi, M.A. 2018. Effects of climate variability and insurance adoption on crop production in select provinces of South Africa. *Journal of Water and Climate Change,* 9(3):500-511.

Eriksen, S., O'Brien, K. and Losentrater, L. 2008. Climate change in eastern and Southern Africa: impacts, vulnerability and adaptation. Global Environmental Change and Human Security Report 2008:2. University of Oslo, Norway.

Erlingsson, C. & Brysiewicz, P. 2017. A hands-on guide to doing content analysis. *African Journal of Emergency Medicine*, 7:93-99.

Etikan, I., Musa, S.A. & Alkassim, R.S. 2016. Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(1):1-4.

Faccer, K. 2017. Global environmental change risks and the private sector. (*In* Mambo, J. & Faccer, K., *ed*. Understanding the social & environmental implications of global change. Stellenbosch: African Sun Media. p. 121-128).

Fankhauser, S., Smith, J.B. & Tol, R.S.J. 1999. Weathering climate change: some simple rules to guide adaptation decisions. *Ecological Economics*, 30:67-78.

FAO (Food and Agriculture Organization of the United Nations). 2008. Challenges for suitable land management for food security in Africa. Twenty-fifth regional conference for Africa, Kenya.

FAO (Food and Agriculture Organization of the United Nations). 2009. Review of evidence on dryland pastoral systems and climate change. Rome: United Nations.

FAO (Food and Agriculture Organization of the United Nations). 2010a. Global agro-ecological zones. Rome: United Nations.

FAO (Food and Agriculture Organization of the United Nations). 2010b. Climate change implications for food security and natural resources management in Africa. Twenty-sixth regional conference for Africa, Angola.

FAO (Food and Agriculture Organization of the United Nations). 2019. Governance challenges for disaster risk reduction and climate change adaptation convergence in agriculture. Rome: United Nations.

Fazey, I., Gamarra, J.G.P., Fischer, J., Reed, M.S., Stringer, L.C. & Christie, M. 2010. Adaptation strategies for reducing vulnerability to future environmental change. *Frontiers in Ecology and the Environment,* 8(8):414-422.

Feder, G., Just, R. & Zilberman, D. 1985. Adoption of agricultural innovations in developing countries. *Economic Development and Cultural Change,* 33(2):255–298.

Fetters, M.D., Curry, L.A. & Creswell, J.W. 2013. Achieving integration in mixed methods designs- principles and practices. *Health Services Research*, 48(6):2134-2156.

Fischer, G., Shah, M., Tubiello, F.N. & Velhuizen, H. 2005. Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990-2080. *Philosophical Transactions: Biological Sciences,* 360(1463):2067-2083.

Fussel, H.M. 2007. Adaptation planning for climate change: concepts, assessment approaches and key lessons. *Sustainability Science,* 2(2):265-275.

Gbetibouo, G.A. & Ringler, C. 2009. Mapping South African farming sector vulnerability to climate change and variability. Paper presented at the Amsterdam Conference on the Human Dimensions of Global Environmental Change ‘Earth System Governance: People, Places and the Planet’, Amsterdam, 2-4 December.

Gbetibouo, G.A., Ringler, C. & Hassan, R. 2010. Vulnerability of the South African farming sector to climate change and variability: an indicator approach. *Natural Resources Forum*, 34:175-187.

Govere, S., Nyamangara, J. & Nyakatawa, E.Z. 2018. Climate change and the water footprint of wheat production in Zimbabwe. *Water SA,* 45(3):513-526.

Green, D. & Raygorodetsky, G. 2010. Indigenous knowledge of a changing climate. *Climatic Change*, 100:239-242.

Hassan, R. & Nhemachena, C. 2008. Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis. *The African Journal of Agriculture and Resource Economics,* 2(1):83-104.

Helgeson, J.F. & Ellis, J. 2015. The role of the 2015 Agreement in enhancing adaptation to climate change. OECD/IEA Climate Change Expert Group Papers, No 2015(1). OECD Publishing, Paris.

Hobbs, P.R., Sayre, K. & Gupta, R. 2008. The role of conservation agriculture in sustainable agriculture. *Philosophical Transactions of the Royal Society*, 363:543-555.

Hulme, M. 1996. Climate change and Southern Africa: an exploration of some potential impacts and implications for the SADC region. Climatic Research Unit, University of East Anglia.

Hunn, E. 1993. What is traditional ecological knowledge? (*In* Williams, N. & Baines, G., *eds.* Traditional ecological knowledge: wisdom for sustainable development. Canberra: Centre for Resource and Environmental Studies, ANU. p. 13-15).

Huq, S., Mahid, Y. & Suliman, N. 2018. Evolution of climate change adaptation policy and negotiation. (*In* Zommers, Z. & Alverson, K., *eds*. Resilience: the science of adaptation to climate change. Elsevier. p. 63-75).

IPCC (Intergovernmental Panel on Climate Change). 2007a. Assessing key vulnerabilities and the risk from climate change. Contribution of working group II to the fourth assessment report of the IPCC. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. *eds*. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change). 2007b. Africa climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the IPCC. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. *eds*. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change). 2007c. Assessment of adaptation practices, options, constraints and capacity. Contribution of working group II to the fourth assessment report of the IPCC. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. *eds*. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change). 2012a. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A special report of working groups I and II of the IPCC. Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.K., Allen, S.K., Tignor, M. & Midgley, P.M. *eds*. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change). 2012b. Determinants of risk: exposure and vulnerability. A special report of working groups I and II of the IPCC. Field, C.B., Barros, V.R., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.K., Allen, S.K., Tignor, M. & Midgley, P.M. *eds*. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change). 2013. Long-term climate change: projections, commitments and irreversibility. Contribution of working group I to the fifth assessment report of the IPCC. Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. & Midgley, P.M. *eds*. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change). 2014a. Adaptation opportunities, constraints, and limits. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandea, P.R. & White, L.L. *eds*. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change). 2014b. Africa. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandea, P.R. & White, L.L. *eds*. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change). 2018a: Summary for Policymakers. Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. & Waterfield, T. *eds*. Geneva, United Nations.

IPCC (Intergovernmental Panel on Climate Change). 2018b. Impacts of 1.5ºC Global Warming on Natural and Human Systems. Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. & Waterfield, T. *eds*. Geneva, United Nations.

ISDR (International Strategy for Disaster Reduction). 2008. Climate change and disaster risk reduction. Geneva: Switzerland.

Javadi, M. & Zarea, K. 2016. Understanding thematic analysis and its pitfall. *Journal of Client Care*, 1(1):34-40.

Keane, J., Page, S., Kergna, A. & Kennan, J. 2009. Climate change and developing country agriculture: an overview of expected impacts, adaptation and mitigation challenges, and funding requirements. International Food and Agriculture Trade Policy Council, Geneva.

Kotze, I. & Rose, M. 2015. Farming facts and futures: reconnecting South Africa's food systems to its ecosystems. WWF Report. Cape Town, South Africa.

Kelman, I. 2015. Climate change and the Sendai Framework for disaster risk reduction. *International Journal of Disaster Risk Science*, 6:117-127.

Klein, R. & Smith, J. 2003. Enhancing the capacity of developing countries to adapt to climate change: a policy relevant research agenda. (*In* Smith, J.B., Klein, R.J.T., Huq, S., *ed*. Climate change, adaptive capacity and development. London: Imperial College Press. p. 317-334).

Knowler, D. & Bradshaw, B. 2007. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. *Food Policy,* 32:25-48.

Kruger, A.C. & Shongwe, S. 2004. Temperature trends in South Africa: 1960–2003. *International Journal of Climatology,* 24(15):1929–1945.

Kurukulasuriya, P. & Mendelsohn, R. 2006. A Ricardian analysis of the impact of climate change on African cropland. University of Pretoria. (CEEPA Discussion Paper, 8).

Kurukulasuriya, P. & Rosenthal, S. 2003. Climate change and agriculture: a review of impacts and adaptation. (World Bank Climate Change Series, 91:1-96).

Lalego, B., Ayalew, T. & Kaske, D. 2019. Impact of climate variability and change on crop production and farmers' adaptation strategies in Lokka Abaya district, Southern Ethiopia. *African Journal of Environmental Science and Technology* (In press).

Landman, W.A., Malherbe, J. & Engelbrecht, F. 2017. South Africa's present-day climate. (*In* Mambo, J. & Faccer, K., *ed*. Understanding the social & environmental implications of global change. Stellenbosch: African Sun Media. p. 7-12).

Laube, W., Schraven, B. & Awo, M. 2011. Smallholder adaptation to climate change: dynamics and limits in Northern Ghana. *Climatic Change*, 111(3-4):753-774.

Laukkonen, J., Blanco, P.K., Lenhart, J., Keiner, M., Cavric, B. & Kinuthia-Njenga, C. 2009. Combining climate change adaptation and mitigation measures at the local level. *Habitat International*, 33:287-292.

Le Roux, A., Mans, G., van Huyssteen, E. & van Niekerk, W. 2017. Profiling the vulnerabilities and risks of South African settlements. (*In* Mambo, J. & Faccer, K., *ed*. Understanding the social & environmental implications of global change. Stellenbosch: African Sun Media. p. 26-35).

Leichenko, R. & O'Brien, K. 2002. The dynamics of rural vulnerability to global change: the case of Southern Africa. *Mitigation and Adaptation Strategies for Global Change,* 7:1-18.

Little, P.D., McPeak, J., Barrett, C. & Kristjanson, P. 2008. Challenging orthodoxies: understanding pastoral poverty in East Africa. *Development and Change*, 39(4):585-609.

Lotter. 2017. Risk and vulnerability in the South African farming sector: implications for sustainable agriculture and food security. (*In* Mambo, J. & Faccer, K., *ed*. Understanding the social & environmental implications of global change. Stellenbosch: African Sun Media. p. 67-75).

Mace, M.J. & Verheyen, R. 2016. Loss, damage and responsibility after COP21: all options open for the Paris Agreement. *Review of European Community & International Environmental Law,* 25(2):197-214.

Maddison, D. 2007. The perception of and adaptation to climate change in Africa. University of Pretoria. (CEEPA Discussion Paper, 10).

Mambo, J. 2017. Risk and vulnerability to global change and climate change in South Africa. (*In* Mambo, J. & Faccer, K., *ed*. Understanding the social & environmental implications of global change. Stellenbosch: African Sun Media. p. 1-6).

Mambo, J. & Faccer, K. 2017. Understanding the social and environmental implications of global change. 2nd ed. Stellenbosch: African Sun Media.

Mambo, J. & Murambadoro, M. 2017. Municipal vulnerability to climate change. (*In* Mambo, J. & Faccer, K., *ed*. Understanding the social & environmental implications of global change. Stellenbosch: African Sun Media. p. 113-120).

Maponya, P. & Mpandeli, S. 2012. Climate change and agricultural production in South Africa: impacts and adaptation options. *Journal of Agricultural Science*, 4(10):48-60.

Maponya, P., Venter, S.L., Du Plooy, C.P., Backeberg, G.R., Mpandeli, S. & Nesamvuni, E. 2020. Timber-based mixed farming/agroforestry benefits: a case study of smallholder farmers in Limpopo province, South Africa. (*In* Venkatramanan, V., Shah, S. & Prasad, R., *ed*. Global climate change and environmental policy. Singapore: Springer Nature Singapore. p. 275-302).

Marshall, N.A., Park, S., Howden, S.M., Dowd, A.B. & Jakku, E.S. 2013. Climate change awareness is associated with enhanced adaptive capacity. *Agricultural Systems,* 117:30-34.

Masante, D., McCormick, N., Vogt, J., Carmona-Moreno, C., Cordano, E. & Ameztoy, I. 2018. Drought and water crisis in Southern Africa. Joint Research Centre technical report, European Commission.

Mashizha, T.M. 2019. Building adaptive capacity: reducing the climate vulnerability of smallholder farmers in Zimbabwe. *Business Strategy and Development,* 2(3):1-7.

Mauyo, L.W., Okalebo, J.R., Kirkby, R.A., Buruchara, R., Ugen, M. & Musebe, R.O. 2007. Legal and institutional constraints to Kenya–Uganda cross-border bean marketing. *African Journal of Agricultural Research,* 2(11):578–582.

Mayowa, A.O. 2019. The use of satellite-derived data and neural-network analysis to examine variation in maize yield under climate change. Pretoria: University of Pretoria. (Thesis – PhD).

McGrath, J.M. & Lobell, D.B. 2013. Regional disparities in the CO_2 fertilization effect and implications for crop yields. *Environmental Research Letters,* 8(1):14-54.

Meijer, A.D. 2013. Long-term tillage effects on soil erosion, physical properties and soil moisture. Raleigh: North California State University. (Thesis-PhD).

Mercer, J., Dominey-Howes D., Kelman, I. & Lloyd, K. 2007. The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. *Environmental Hazards*, 7:245-256.

Mertz, O., Mbow, C., Reenberg, A. & Diouf, A. 2009. Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management,* 43(5):804-816.

Michaelowa, A. 2001. Mitigation versus adaptation: the political economy of competition between climate policy strategies and the consensus for developing countries. Hamburg: Hamburg institute of international economics. (HWWA Discussion Paper, 153).

Milfont, T.L. 2012. The interplay between knowledge, perceived efficacy, and concern about global warming and climate change: a one-year longitudinal study. *Risk Analysis,* 32(6):1003-1020.

Mitchell, T., van Aalst, M. & Villanueva, P.S. 2010. Assessing progress on integrating disaster risk reduction and climate change adaptation in development processes. UK: Strengthening Climate Resilience. (Discussion Paper, 2).

Montmasson-Claire, G. & Zwane, M. 2016. Climate change adaptation and agriculture in South Africa: a policy assessment. WWF Report: South Africa. p.2-20.

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

Mutekwa, V.T. 2009. Climate change impacts and adaptation in the agricultural sector: the case of smallholder farmers in Zimbabwe. *Journal of Sustainable Development in Africa*, 11(2):237-256.

Mwangi, E. & Dohrn, S. 2008. Securing access to dryland resources for multiple users in Africa: a review of recent research. *Land Use Policy,* 25:240-248.

Newsham, A.J. & Thomas, D.S.G. 2011. Knowing, farming and climate change adaptation in North-Central Namibia. *Global Environmental Change*, 21(2):761-770.

Nhamo, L., Matchaya, G., Mabhaudhi, T., Nhlengethwa, S., Nhemachena, C. & Mpandeli, S. 2019. Cereal production trends under climate change: impacts and adaptation strategies in Southern Africa. *Agriculture,* 9(30):1-16.

Nhemachena, C., Hassan, R. & Chakwizira, J. 2014. Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa. *Journal of Development and Agricultural Economics,* 6(5):232-241.

Niasse, M., Afoud, A., and Amani, A., *eds*. 2004. Reducing West Africa's vulnerability to climate impacts on water resources, wetlands and desertification: elements of regional preparedness and adaptation. Gland: IUCN.

Nicholson, S.E. 2001. Climatic and environmental change in Africa during the last two centuries. *Climate Research*, *17*(2):123-144.

Niles, M.T., Lubell, M. & Brown, M. 2015. How limiting factors drive agricultural adaptation to climate change. *Agriculture, Ecosystems and Environment,* 200:178-185.

Noble, I. 2019. The evolving interactions between adaptation research, international policy and development practice. (*In* Keskitalo, E.C.H. & Preston, B.L., *ed*. Research handbook on climate change adaptation policy. Cheltenham: Edward Elgar Publishing. p. 21-48).

Nowell, L., Norris, J., White, D. & Moules, N. 2017. Thematic analysis: striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods,* 16:1-13.

Nyanga, P.H., Johnsen, F.H., Aune, J.B and Kalinda, T.H. 2011. Smallholder farmers' perceptions of climate change and conservation agriculture: evidence from Zambia. *Journal of Sustainable Development*, 4(4):73-85.

Nyong, A., Adesina, F. & Elasha O.B. 2007. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global Change,* 12(5):787-797.

O'Brien, K.L. 2009. Do values subjectively define the limits to climate change adaptation? (*In* Adger, N.W., Lorenzoni, I. and O'Brien, K.L., *ed*. Adapting to climate change: thresholds, values, governance. Cambridge: Cambridge University Press. p. 164-180).

O'Brien, K.L. and Wolf, J. 2010. A values-based approach to vulnerability and adaptation to climate change. *Wiley Interdisciplinary Reviews,* 1(2):232-242.

O'Brien, K.L., Sygna, L., Leichenko, R., Adger, W.N., Barnett, J., Mitchell, T., Schipper, L., Tanner, T., Vogel, C. & Morteux, C. 2008. Disaster risk reduction, climate change adaptation and human security. Global Environmental Change and Human Security Project Report 2008:3. Norwegian Ministry of Foreign Affairs.

Obergassel, W., Arens, C., Hermwille, L., Kreibich, N., Wang-Helmreich, H. & Ott, H.E. 2019. Paris Agreement: ship moves out of the dry dock. *Carbon & Climate Law Review*, 13(1):3-18.

Oduniyi, O.S. 2018. Implication of climate change on livelihood and adaptation of small and emerging maize farmers in the North West Province of South Africa. Pretoria: University of South Africa. (Thesis- PhD).

Oduniyi, O.S. & Tekana, S.S. 2019. Analysis of rural livelihood diversification strategies among maize farmers in North West province of South Africa. *International Journal of Entrepreneurship,* 23(2):1-11.

Oduniyi, O.S., Antwi, M.A. & Tekana, S.S. 2019. Prioritization on cultivation and climate change adaptation techniques: a potential option in strengthening climate resilience in South Africa. *Agronomia Colombiana*, 37(1):62-72.

Onwuegbuzie, A. & Collins, K. 2007. A typology of mixed methods sampling designs in social science research*.* *The Qualitative Report,* 12(2):281-316.

Onwuegbuzie, A. & Combs, J. 2011. Data analysis in mixed research. *International Journal of Education,* 3(1):1-25.

Onwuegbuzie, A. & Leech, N. 2006. Linking research questions to mixed methods data analysis procedures. *The Qualitative Report,* 11:474-498.

Osunade, M.A. 1994. Indigenous climate knowledge and agricultural practices in Southwestern Nigeria. *Malaysian Journal of Tropical Geography*, 1:21–28.

Otieno, J. & Muchapondwa, E. 2016. Agriculture and adaptation to climate change: the role of wildlife ranching in South Africa. Economic Research Southern Africa, Working Paper 579.

Padgham, J. 2009. Agricultural development under a changing climate: opportunities and challenges for adaptation. The World Bank Environment Department, Washington, DC.

Palinkas, L.A., Horwitz, S.M., Green, C.A., Wisdom, J.P., Duan, N. & Hoagwood, K. 2015. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health,* 42(5):533-544.

Parry, M., Rosenzweig, C., Iglesias, A., Fischer, G. and Livermore, M. 1999. Climate change and world food security: a new assessment. *Global Environmental Change*, 9:51-67.

Pereira, L. 2017. Climate change impacts on agriculture across Africa. (*In* Oxford Research Encyclopedia of Environmental Science).

Polit, D.F. & Beck, C.T. 2010. Generalization in quantitative and qualitative research: myths and strategies. *International Journal of Nursing Studies*, 47:1451-1458.

Potter, W. & Levine-Donnerstein, D. 1999. Rethinking validity and reliability in content analysis. *Journal of Applied Communication Research,* 27:258-284.

Quinn, C.H., Ziervogel, G., Taylor, A., Takama, T. & Thomalla, F. 2011. Coping with multiple stresses in rural South Africa. *Ecology and Society*, 16(3):1-10.

Raman, A. 2020. Ecological thinking and agricultural sustainability. (*In* Venkatramanan, V., Shah, S. & Prasad, R., *ed*. Global climate change and environmental policy. Singapore: Springer Nature Singapore. p. 1-36).

Reid, P. & Vogel, C. 2006. Living and responding to multiple stressors in South Africa – Glimpses from KwaZulu-Natal. *Global Environmental Change,* 16(2):195–206.

Robinson, J. & Herbert, D. 2001. Integrating climate change and sustainable development. *International Journal of Global Environmental Issues,* 1(2):130-148.

Rose, S., Spinks, N. & Canhoto, A.I. 2015. Management research: applying the principles. London: Routledge.

Rosenzweig, C. & Tubiello, F.N. 2007. Adaptation and mitigation strategies in agriculture: an analysis of potential synergies. *Mitigation and Adaptation Strategies for Global Change*, 12:855-873.

Savannah Environmental. 2018. Social impact assessment scoping report for the Lichtenburg 2 PV facility near Lichtenburg in the North West province. sahris.sahra.org.za › files › additionaldocs › 0.LichtenburgPV2 - FEIA.pdf Date of access: 3 Jan. 2019.

Schipper, E.L.F. & Pelling, M. 2006. Disaster risk, climate change and international development: scope for, and challenges to, integration. *Disasters,* 30(1):19-38.

Schipper, E.L.F., Thomalla, F., Vulturius, G., Davis, M. & Johnson, K. 2016. Linking disaster risk reduction, climate change and development. *International Journal of Disaster Resilience in the Built Environment*, 7(2):1-16.

Schlenker, W. and Lobell, D.B. 2010. Robust negative impacts of climate change on African agriculture. *Environmental Research Letters,* 5(1):014010.

Schoonenboom, J. & Johnson, R.B. 2017. How to construct a mixed methods research design. *Kolner Zeitschrift fur Soziologie und Sozialpsychologie*, 69(2):107-131.

Schulze, R.E. 2016. Agriculture and climate change in South Africa: on vulnerability, adaptation and climate smart agriculture. (*In* Schulze, R.E., *ed.* Handbook on adaptation to climate change for farmers, officials and others in the agricultural sector of South Africa. DAFF: Thematic Booklet 1. p.1-103).

Seo, S.N. & Mendelsohn, R. 2008. An analysis of crop choice: adapting to climate change in South American farms. *Ecological Economics*, 67:109-116.

Sharma, G. 2017. Pros and cons of different sampling techniques. *International Journal of Applied Research,* 3(7):749-752.

Shaw, R., Pulhin, J.M. & Pereira, J.J. 2010. Chapter 1 climate change adaptation and disaster risk issues and challenges. *Community, Environment and Disaster Risk Management*, 4:1-19.

Shen, L.Y., Ochoa, J.J., Shah, M.N. & Zhang, X. 2011. The application of urban sustainability indicators: a comparison between various practices. *Habitat International*, 35:17-29.

Smit, B. & Skinner, M.W. 2002. Adaptation options in agriculture to climate change: a typology. *Mitigation and Adaptation Strategies for Global Change*, 7:85-114.

Smit, B., Burton, I., Klein, R.J. and Street, R. 1999. The science of adaptation: a framework for assessment. *Mitigation and Adaptation Strategies for Global Change*, 4(3):199-213.

Solecki, W., Leichenko, R. & O,Brien, K. 2011. Climate change adaptation strategies and disaster risk reduction in cities: connections, contentions and synergies. *Current Opinion in Environmental Sustainability,* 3:135-141.

Songsore, E. & Buzzelli, M. 2016. The value of mixed method content analysis for understanding renewable energy deployment and policy outcomes. *Journal of Environmental Policy and Planning,* 1-19.

South Africa. 2019. National climate change adaptation strategy. (Notice 644). *Government Gazette*, 42446:4, 6 May.

South Africa. Department of Agriculture, Forestry and Fisheries. 2010. Atlas of climate change and the South African agricultural sector: a 2010 perspective. Pretoria.

South Africa. Department of Agriculture, Forestry and Fisheries. 2013. Climate change adaptation and mitigation plan for the South African agricultural and forestry sectors. Pretoria.

South Africa. Department of Agriculture, Forestry and Fisheries. 2018. Abstract of agricultural statistics. Pretoria.

South Africa. Department of Agriculture. 2005. Strategic plan: North West Department of Agriculture, Conservation, Environment & Tourism. Mmabatho.

South Africa. Department of Agriculture. 2007. Annual report: North-West Department of Agriculture, Conservation, Environment & Tourism. Mmabatho.

South Africa. Department of Environmental Affairs. 2013a. Climate Change Implications for the Agriculture and Forestry Sectors in South Africa. Pretoria.

South Africa. Department of Environmental Affairs. 2013b. Long-term adaptation scenarios flagship research program (LTAS) for South Africa. Pretoria.

South Africa. Department of Environmental Affairs. 2015. Climate Support Program: Vulnerability Assessment. Report for North-West Province.

South Africa. Department of Environmental Affairs. 2017a. Cape Winelands District Municipality: climate change adaptation summary report. Western Cape Province.

South Africa. Department of Environmental Affairs. 2017b. South Africa's 2nd annual climate change report. Pretoria.

South Africa. Department of Environmental Affairs. 2017c. South Africa's 3rd climate change report. Pretoria.

South Africa. Department of Rural Development and Land Reform. 2016. District Rural Development Plan: Ngaka Modiri Molema District Municipality. North-West Province.

South Africa. Department of Statistics South Africa. 2019. Quarterly labour force survey, Quarter 3. Pretoria.

Stacey, G.D., Van Zyl, J. & Kirsten, J. 1994. The causes and consequences of agricultural change: a case study of agricultural commercialization in the communal areas of South Africa. *Agrekon,* 33(4):275-281.

Streck, N.A. 2005. Climate change and agroecosystems: the effect of elevated atmospheric CO_2 and temperature on crop growth, development, and yield. *Ciencia Rural*, 35(3):730-740.

Swart, R., Robinson, J. & Cohen, S. 2003. Climate change and sustainable development: expanding the options. *Climate Policy*, 3(1):19-40.

Tashakkori, A. & Creswell, J. 2007. The new era of mixed methods. *Journal of Mixed Methods Research,* 1(1):3-7.

Taylor, S. & Bogdan, R. 1998. Introduction to qualitative research methods: a guidebook and resource. 3rd ed. New York: Wiley.

Teddlie, C. & Yu, F. 2007. Mixed methods sampling: a typology with examples. *Journal of Mixed Methods Research*, 1:77-100.

Thomalla, F., Downing, T., Spanger-Siegfried, E., Han, G. & Rockstrom, J. 2006. Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. *Disasters,* 30(1):39-48.

Thomas, D.S.G., Twyman, C., Osbahr, H. & Hewitson, B. 2007. Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South-Africa. *Climatic Change,* 83(3):301-322.

Tibesigwa, B. & Visser, M. 2015. Small-scale subsistence farming, food security, climate change and adaptation in South Africa: male-female headed households and urban-rural nexus. Economic Research Southern Africa, Working Paper 527.

Turpie, J. & Visser, M. 2014. The impact of climate change on South Africa's rural areas. *Financial and Fiscal Commission*, 14:100-160.

Twigg. J. 2004. Disaster risk reduction: mitigation and preparedness in development and emergency programming. London: Humanitarian Practice Network.

Twomlow, S., Mugabe, F.T., Mwale, M., Delve, R., Nanja, D., Carberry, P. & Howden, M. 2008. Building adaptive capacity to cope with increasing vulnerability due to climate change in Africa: a new approach. *Physics and Chemistry of the Earth*, 33:780-787.

UNISDR (United Nations International Strategy for Disaster Reduction). 2011. Global assessment report on disaster risk reduction: revealing risk, redefining development. UNISDR, Geneva.

Vaismoradi, M., Turunen, H. & Bondas, T. 2013. Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. *Nursing and Health Sciences,* 15(3):398-405.

Van der Merwe, S.W. 1965. The agricultural economy of the highveld region. *Agrekon,* 4(1):19-26.

Vincent, K. 2007. Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change,* 17(1):12-24.

Vincent, K., Cull, T., Chanika, D., Hamazakaza, P., Macome, E. & Mutonhondza-Davies, C. 2013. Farmers' responses to climate variability and southern Africa- is it coping or adaptation? *Climate and Development*, 5(3):194-205.

Vincent, K., Joubert, A., Cull, T., Magrath, J. & Johnston, P. 2011. Overcoming the barriers: how to ensure future food production under climate change in Southern Africa. Oxfam Research Report, Oxford. p.59.

Vogel, C. & O'Brien, K. 2006. Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. *Climate Research,* 33(1):111-122.

Welborn, L. 2018. Africa and climate change: projecting vulnerability and adaptive capacity. *Institute for Security Studies Africa Report*, 14:1-24.

Wiid, N. & Ziervogel, G. 2012. Adapting to climate change in South Africa: commercial farmers' perception of and response to changing climate. *South African Geographical Journal*, 94(2):152-173.

Wolf, J. & Moser, S.C. 2011. Individual understandings, perceptions, and engagement with climate change: insights from in-depth studies across the world. *Wiley Interdisciplinary Reviews: Climate Change,* 2(4):547-569.

Wolf, J., Allice, I. & Bell, T. 2013. Values, climate change, and implications for adaptation: evidence from two communities in Labrador, Canada. *Global Environmental Change*, 23(4):548-562.

Wolf, J., Lorenzoni, I., Few, R., Abrahmson, V. & Raine, R. 2009. Conceptual and practical barriers to adaptation: an interdisciplinary analysis of vulnerability and response to heat waves in the UK. (*In* Adger, W.N., Lorenzoni, I. & O'Brien, K., *ed.* Adapting to climate change: thresholds, values, governance. Cambridge: Cambridge University Press. p.181-196).

Yaro, J.A. 2013. The perception of and adaptation to climate variability/change in Ghana by small-scale and commercial farmers. *Regional Environmental Change*, 13(6):1259-1272.

Yohe, G. & Tol, R.S.J. 2002. Indicators for social and economic coping capacity- moving toward a working definition of adaptive capacity. *Global Environmental Change*, 12:25-40.

Zhou, L., Perera, S., Jayawickrama, J. & Onaopepo, A. 2014. The implication of Hyogo framework for action for disaster resilience education. *Procedia Economics and Finance,* 18:576-583.

Ziervogel, G., Cartwright, A., Tas, A., Adejuwon, J., Zermoglio, F., Shale, M. & Smith, B. 2008. Climate change adaptation in African agriculture. Rockefeller foundation report, Stockholm environmental institute. p.1-54.

Ziervogel, G., New, M., Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., Stuart-Hill, S., Myers, J. & Warburton, M. 2014. Climate change impacts and adaptation in South Africa. *Wiley Interdisciplinary Reviews: Climate Change,* 5(5):605-620.

Ziervogel, G., Nyong, A., Osman, B., Conde, C., Cortes, S. & Downing, T. 2006. Climate variability and change: implications for household food security. AIACC Working Paper, 20:1-32.

Zwane, E.M. 2019. Impact of climate change on primary agriculture, water resources and food security in Western Cape, South Africa. *Jamba Journal of Disaster Risk Studies,* 11(1):1-7.

APPENDIX A: RESPONDENT QUESTIONNAIRE

SECTION A: GENERAL INFORMATION

The study area:

The Ditsobotla Local Municipality and its towns, Coligny, Bakerville and Lichtenburg, are known for being agricultural intensive areas with a rich agricultural history. Many small farming surrounding the towns also rely heavily on agriculture for their livelihoods.

Objectives of the study:

This study is an investigation into 1) the impacts of climate change on agriculture, 2) the different adaptation methods commercial and subsistence farmers of the region implement and 3) the factors contributing to a difference in choice of adaptation strategies. The researcher aims to establish whether or not there is a differentiation between the adaptation methods of commercial and subsistence farmers and to gain insight into the factors potentially leading to this differentiation. The objective is to gain a more comprehensive understanding of the possible impacts' climate change could have on agriculture; how commercial and subsistence farmers perceive climate change; what methods they apply to cope with changing environmental circumstances; and what prohibits them from using other relevant methods.

Study justification:

It is the contention of this thesis that there is a differential in the ability and resources of subsistence and commercial farmers in the case study region to adapt to climatic variations. Understanding these differences, could provide the basis for recommendations on fostering equality in climate change adaption ' between the two farming groups.

Respondent privacy:

Please note that participation is strictly on a voluntary basis and that you are allowed to terminate your participation at any given moment. All your responses will be valued, treated with confidentiality and presented in a manner which protects your anonymity.

SECTION B: BACKGROUND INFORMATION

Please provide the following background information about yourself and your farming activities:

2.1.1 Gender

MALE	FEMALE

2.1.2 Age

20-30	31-40	41-50	51-60	61+

2.1.3 Household size

0-2	3	4	5	6+

2.1.4 Farming experience (in years)

0-5	6-10	11-20	21-30	30+

2.1.5 Do you consider yourself a commercial or subsistence farmer?

COMMERCIAL	SUBSISTENCE

2.1.6 What is your primary farming activities?

CROP	MIXED FARMING	LIVESTOCK

2.1.7 Does your household have sources of livelihood other than farming?

YES	NO

2.1.8 If yes, have you always diversified livelihood sources or not?

YES	NO

2.1.9 How many individuals do you employ to conduct your agricultural activities?

0-4	5-9	10-14	15-19	20+

SECTION C: CLIMATE CHANGE ADAPTATION METHODS

Please provide the following information regarding your perception of climate change adaptation and the methods you apply:

3.2.1 What do you understand by the term “Climate Change Adaptation”?

3.2.2 Do you think applying climate change adaptation methods is necessary?

3.2.3 Which of the following climate change adaptation methods do you implement?

Adaptation strategies applicable to Crop/Mixed farming						
	CCA strategies	Never	Rarely	On a regular basis	Almost always	Always
a) Operational adjustments:						
1.	Modifying crop types					
2.	Adjusting crop varieties					
3.	Implementing mixed farming practices					
4.	Seasonal distribution of farming activities (altering planting dates)					
5.	Dry ripping					
6.	Intercropping practices					
7.	Crop rotation					
b) Conservation practices:						
8.	Periods of fallow					
9.	Decreasing livestock/crop density					
10.	Mulching					
11.	Minimum tillage					
12.	No-tillage					
c) Shade and shelter:						

13.	Planting trees for shade					
14.	Covering livestock/crop with grass, nets or plastic					
15.	Providing heat to livestock through fires/ paraffin heaters					
	d) Irrigation methods					
16.	Flood irrigation					
17.	Use of wetlands for irrigation					
18.	Sprinkler/micro-irrigation					
19.	Boreholes					
	e) Chemical/fertilizer applications					
20.	Chemical applications					
21.	Use of fertilizers					
22.	Use of manure					
23.	Lime application					
	f) Financial					
24.	Farm insurance					

Adaptation strategies applicable to pastoralists and livestock farmers						
	CCA strategies	Never	Rarely	On a regular basis	Almost always	Always
25.	Switching breeds					
26.	Producing/stocking own feed					
27.	Use of supplementary feed					
28.	Disease management methods					
29.	Moving herds to other areas					
30.	Diversification of species					
31.	Increasing herd size					
32.	Allocating livestock species to appropriate family members					
33.	Building shelters for livestock					

3.2.4 Why do you use the techniques indicated?

3.2.5 Are there other adaptation methods you use that wasn’t included in the questionnaire, and if so what are they and where have you learned about them?

SECTION D: FACTORS PROHIBITING ADAPTATION

4.1 What are the factors prohibiting you from implementing other adaptation methods?

	Prohibiting/limiting factors	Never	Rarely	On a regular basis	Almost always	Always
a) Environmental/physical limitations						
1.	Variations in rainfall					
2.	Variations in temperature					
3.	Lack of access to water					
4.	Land degradation					
b) Economical limitations						
5.	Lack of access to markets					
6.	Lack of access to crop varieties					
7.	Lack of access to chemicals					
8.	Lack of access to fertilizers					
c) Technology and asset limitations						
9.	Limited access to relevant information					
10.	Lack of access to machinery					

4.2.1 Do you experience other limitations that have not been included in the questionnaire, if yes what are they?

4.2.2 If no limitations were present, what additional adaptation strategies would you like to implement in your farming activities?

4.2.3 Do you have any additional comments?

SECTION E: PERCEPTIONS OF CLIMATE CHANGE & THE ROLE OF INDIGENOUS KNOWLEDGE

5.1.1 What does "climate change" mean to you?

5.1.2 What environmental changes (such as in weather patterns or temperature) have you observed?

5.1.3 To what extend do you think climate change has or can have an effect on your agricultural activities?

NONE	VERY LITTLE	LITTLE	MODERATE	SEVERE

5.1.4 Do you think weather extremes (such as drought or floods) are occurring more frequently in your area?

YES	NO

5.1.5 What/who are your main sources of agricultural information?

5.1.6 Where have you learned about the adaptation strategies you implement?

5.1.7 What do you understand by the term "Indigenous Knowledge"?

5.1.8 Do you think indigenous knowledge is valuable and applicable today?

5.1.9 Do you use indigenous knowledge in your farming activities?

5.1.10 How do you think the adaptive capacity of farming communities can be improved?