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ASSESSING THE IMPACTS OF CLIMATE CHANGE AND ADAPTATION STRATEGIES ON SMALLHOLDER FARMING IN THE VHEMBE DISTRICT, SOUTH AFRICA

ZONGHO KOM

UNIVERSITY OF VENDA

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By

ZONGHO KOM

Student Number: 11607100

A Thesis submitted to the School of Environmental Sciences, Department of Geography & Geo-Information Sciences in fulfilment of the requirements for the degree Doctor of Philosophy in Geography at the University of Venda

PROMOTER:	**Dr. N.S. NETHENGWE**
CO-PROMOTERS:	**Prof. N. S. MPANDELI**
	Prof. H. CHIKOORE

September, 2020

DECLARATION

I, Zongho Kom, hereby declare that this thesis for a Doctor of Philosophy degree in Geography at the University of Venda, hereby submitted by me, has not previously been submitted for any degree at this or other university, and that it is my own work design and execution and that all reference material contained therein has been duly acknowledged.

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Signature Date 01/09/2020

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ABSTRACT

One of the major challenges facing all categories of farmers globally is climate change. African smallholder farmers are the most vulnerable to changes in climate. In most parts of South Africa, empirical evidence indicates the level to which climate change has impacted negatively on agricultural production. Rising temperatures, prolonged drought and decreasing rainfall have affected local farmers' livelihood and crop production. In the Vhembe District of South Africa's Limpopo Province, smallholder farming predominates and its vulnerability to climate change has increased for the past decades. This study, therefore, assesses the impact of climate change and adaptation strategies on smallholder farming systems in the Vhembe District To achieve this aim, qualitative and quantitative research methodologies were employed. A questionnaire was administered to a sample of 224 smallholder farmers to elicit data on perceptions; climate change impacts, adaptation and IKS based strategies to deal with climatic shocks. Focus group discussions (FGDs), semi-structured interviews with the extension officers elicited thematic data that complemented the interview survey. Climate data were obtained from the South Africa Weather Service (SAWS) for the period 1980 to 2015. Smallholder farmers' perceptions about climate change were validated by an analysis of climatic trends from 1980-2015. A thematic analysis of qualitative data and the Multi Nominal Logit (MNL) regression model was used based on socio-economic and biophysical attributes such as access to climate knowledge, gender, farm size, education level, and farmers' experience, decreasing rainfall and increasing temperature as farmers' determinants of their adaptation options to climate change. Furthermore, farmers' perceptions tallied well with climatic trends that showed flood and drought cycles. Most of the smallholder farmers were aware of climate change and its impacts over the past decades. The study further indicated that, due to the marked climate change over this period, farmers have adopted different coping strategies at on-farm and off-farm levels. In terms of adaptation, the major adaptive strategies used by smallholder farmers included the use of drought-tolerant seeds; planting of short-seasoned crops; crop diversification; changing planting dates; irrigation and migrating to urban areas. The study recommends a framework that would include water conservation (rainfall harvesting); investment in irrigation schemes and other smart technologies that integrate indigenous knowledge systems and modern scientific knowledge to enhance crop production.

Keywords: Vhembe District, Farmer perceptions, Indigenous Knowledge System (IKS), Multi Nominal Logit (MNL) and sustainable livelihood framework.

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LIST OF ACRONYMS

AR4	Assessment report (4^{th})
ARC	Agricultural Research Council
COPs	Conference of the Parties
DAFF	Department of Agriculture, Forestry and Fisheries
DAOs	Desired Adaptation Outcomes
DEA	Department of Environmental Affairs
DWAF	Department of Water Affairs and Forestry
ENSO	El Nino Southern Oscillation
FAO	Food and Agricultural Organization
FGDs	Focus Group Discussions
GCMs	Global Climate Models
GDP	Gross Domestic Product
GHGs	Green House Gases
HIV/AIDS	Acquired Immune Deficiency Syndrome
IDP	Integrated Development Plan
IKS	Indigenous Knowledge Systems
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
M&E	Monitoring and Evaluation
NCCC	National Committee on Climate
NCCRP	National Climate Change Response Policy
NCCRWP	National Climate Change Response White Paper
NEDLAC	National Economic Development and Labor Council
NGOs	Nongovernmental Organizations
SA	South Africa
SPSS	Statistical Package for Social Sciences
StatsSA	Statistics South Africa
SWAS	South Africa Weather Services
TAR	Third Assessment Report
UNFCCC	United Nations Framework Convention on Climate Change

VHEMBE DISTRICT	Vhembe District
WRC	Water Research Commission
WWF	World Wide Fund for Nature

CHAPTER ONE: INTRODUCTION

1.1. Background to the Study

Climate change is a global phenomenon that affects all sectors of the economy; however, efforts to reverse or overcome it may take centuries. According to the Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report, there has been an increase in the average global terrestrial and oceanic temperatures by 0.85 °C from 1880 to 2012 (UNFCCC, 2015). The IPCC review indicates that the period between 1983 and 2012 was the warmest in the past 800 years recorded (IPCC, 2016).

In order to combat climate change challenges globally, in 2015, about 200 national government representatives and tens of thousands of civil society observers were in Paris for the 21st Conference of the Parties (COP 21) under the umbrella of the United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC, 2015). The goal of the conference was to negotiate new international agreements that spell out how nations should collaborate to combat changes in climate with attention on the post-2020 period (Aghion *et al.,* 2015; UNFCCC, 2015). Furthermore, this conference represented a crucial advance towards developing a pathway to provide a reasonable chance that global average temperature will not increase by 2°C above pre-industrial levels.

Climate change is a very relevant theme among international communities, due to the dynamic interaction between the troposphere and weather conditions at the earth's surface (Solomon *et al*., 2013; Mngumi, 2016; Elisa & Builitijes, 2017; Makuvaro *et al*., 2018). The constantly increasing concentration of greenhouse gases (GHGs), land use changes and agricultural activities are the key causes of increasing surface temperatures on Earth (IPCC, 2007, IPCC, 2014). There is empirical evidence along with indisputable signs of global warming; however, scholars still debate the tempo of global temperature change (Ndaki, 2014). In 2007, the IPCC released the AR4 and similar scientific information about temperature change confirming this and stressing that climate and water-availability changes are worldwide, national and rural challenges that must be addressed as a matter of urgency (World Bank, 2012). This is a clear indication that, natural environmental and anthropogenic causes are responsible for this problem. The United Nations Economic Commission for Africa (UNECA) (UNECA, 2011) stated that climate change is responsible for altering the hydrological cycle, increased temperature and precipitation patterns over the globe with their negative impacts generally felt in Africa. The United Nations (UN), reported that unplanned management of capitals, insufficient planning and lack of political will contribute to the climate crises (UN, 2014).

Several studies on climate change have been conducted by various academic scholars. Research into climate status must be continuous as climate change studies are often done every 30 to 35 years, which is considered to be optimal (Brunet *et al*., 2015). Climate change is largely caused by natural and anthropogenic drivers, and can be explained as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (IPCC, 2014).

The global nature of the phenomenon requires that climate change policies are needed both at international and national level to develop and implement strategies to combat climate-related issues. In South Africa, in its National Climate Change Response Strategy, the Department of Environmental Affairs (DEA, 2012) reported that the major environmental crisis facing the country, at all sectors of the economy, is climate change. According to Hassan (2006), South Africa's statistical data suggest that the country's temperature has been increasing over the past four decades. South Africa has ethical as well as legal duties under the UNFCCC and its Kyoto Protocol, to contribute its fair share to the global greenhouse gas mitigation efforts (DEA, 2011; 2015). The government of South Africa has engaged in practices in line with the goals of the Kyoto Protocol, which were approved at a meeting of the UNFCCC in Kyoto, Japan (UNFCCC, 2006). The Kyoto Protocol set binding targets for industrialized countries to reduce their combined greenhouse gases emissions by at least 5% in the period 2008 to 2012, as compared to 1990 levels (DEA, 2011).

The Human Sciences Research Council (HSRC) in South Africa has noted that climate variability and change present an on-going challenge to the population's well-being and agricultural production program (HSRC, 2014). The effects of climate change are some of the main challenges for both commercial and smallholder farming systems (Deressa *et al.*, 2009; Bryceson, 2019). Turpie & Visser, (2013) stated that low agricultural input, extreme weather conditions associated with climate variability coupled with South Africa's already water scarcity, are some of the obvious negative impacts of climate variability and change on the smallholder agricultural sector.

The term 'smallholder farmer' is often used to denote 'lack of resource' and 'peasant farmer'. These terms imply farmers with limited resource endowment relative to large-scale or commercial farmers. As elucidated by Morton (2007), there is no universal definition of smallholder farmers, however, the term denotes growers who farm on a small portion of land (usually less than 10 ha, often less than 2 ha), and depend on their farms as their main source of both food security and income generation (Nagayets, 2005). Drechsel *et al*., (2006) add that smallholder farmers mostly have an average farm-size of 0.5-2 ha and their farming activities are under several limitations related to finances, labour, availability of farm inputs and limited knowledge. In South Africa, rural household farmers are found in the poorly-developed and less-resourced agricultural sector with a small portion of land, on which they cultivate subsistence crops and one or two cash crops (DAFF, 2012; Thamanga-Chitja & Morojele, 2014, Mpandeli *et al.,* 2015). According to Wiggins & Keats (2013), smallholder growers have a vital role in maintaining household food security, however, this crop-production sector faces grave challenges, such as water shortages, which will increase with climate variation (Balew *et al.,* 2014).

In South Africa, the term 'smallholder farmers' usually refers to black African farmers, as most of them cultivate on farm size which are small, relatively to those of white farmers who own large-scale farms (Shackleton *et al*., 2013). Agriculture production is the source of livelihood for 1.3 billion peasant farmers globally (IPCC, 2014). In tropical Africa, farmers are highly vulnerable to climate change. The Department of Agriculture, Forestry and Fisheries (DAFF) highlights that Limpopo Province has been characterized by low precipitation and recurrent drought problems especially in 1981–1982, 1988–1989, 1991–1992 and in 2004, this has hindered agricultural production over the decades in the Province (DAFF, 2014, Mpandeli *et al*., 2015). In 1992, many of the smallholder farmers and commercial farmers lost high volumes of livestock and crops due to a shortage of water. The Limpopo Province, however, in general, has always experienced extreme climatic variability and change (Oni *et al*., 2012; Mpandeli & Maponya, 2013; Maponya, 2013).

At present, smallholder farming in Vhembe District is experiencing multiple stressors including - highly variable rainfall, high temperatures, and environmental degradation. Small-scale farming is usually surrounded by uncertainties, limited access to capital, market, infrastructure and limited agricultural technologies. Agriculture is often seen as an appropriate employment-creating sector of the economy, especially in countryside areas, due to the low investment needed (Aliber *et al*., 2009); agriculture, hence, can contribute to employment and livelihoods through smallholder farming. Nhemachena & Hassan (2011) concur that rural households in Sub-Sahara Africa depend mostly on farming activities which remains the backbone, providing about 60% of service to the growing population and contributing about 30% of the GDP. Developing countries and low-income rural communities depend on climate as a factor greatly influencing rain-fed agriculture and their livelihood, like the case of communities in Vhembe District

The Vhembe District is well known for its fresh producers, with huge exports of good quality production and the efficiency of many smallholder farmers (Maponya & Mpandeli, 2012). The area produces approximately 4.4 percent of SA's total agricultural production, including 8.4 percent of the country's subtropical fruits and 6.3 percent of citrus fruits (DAFF, 2014). Vhembe District's climatic conditions consist of subtropical, mild moist winters and wet warm summers, which are suitable for smallholder farming. Precipitation per annum is approximately 500mm and mean annual evapotranspiration in the District is higher than the total rainfall in the whole Limpopo Province; this has resulted in low crop production over the past years. Musina Local Municipality is one of the areas with the highest rate of evapotranspiration, which exceeds 2.7m, resulting in poor agricultural production in the whole district (DAFF, 2014). In addition, studies confirm that rural households extensively depend on rainfall water for agricultural cultivation and good harvest (Mpandeli *et al*, 2015).

Studies on adaptive strategies to combat climate change and its related effects on smallholder farming systems in Vhembe District have been conducted both at provincial and local levels. Socio-economic activities suggest that the smallholder farming sector in Vhembe District is very sensitive to present and future climate shifts, as well as increased climate variability (Gbetibouo *et al*., 2009). Due to the complexity of Limpopo Province and particularly Vhembe District's climatic conditions, its geographic location and socio-economic status of the rural households, a detailed local scale spatial analysis is needed to assess the impacts of climate variations on farmers' perceptions of the changing climate and adaptive capacity as well as on local smallholder farmers' livelihoods.

In Vhembe District, farming is done on a small scale and farmers rely on rainfall, however, the annual crop production shows variability due to high fluctuation in rainfall and temperature. Agricultural activities in Vhembe District are additionally hampered by small farm sizes, increased soil impoverishment, inadequate farming markets, a lack of modern infrastructure and lack of adequate financial services (DAFF, 2012).

A basic knowledge of how smallholder farmers have reacted to climate change is needed for a better choice of adaptation strategies. Several studies indicated that it is an important starting point in analysing adaptive capacity, to understand how recent changes in the climatic conditions are perceived, analysed, interpreted and responded to by local smallholder farmers (Vincent

2007; Makuvaro *et al*., 2014; Makuvaro *et al*., 2018). Furthermore, Banerjee (2015) claims that it is also important to enhance stakeholders' policies towards combatting the effects that climate change brings to rural smallholder farmers, as well as have knowledge on their perceptions of climate change and adaptation strategies, and to determine the degree to which these coincide with actual meteorological data. An assessment of climate change and its effects on agricultural activities is of paramount importance as the current knowledge is limited. This study, hence, seeks to identify similiarities between smallholder farmers' perceptions on the state of the local climate and meteorological data, adaptive strategies, policy and indigenous knowledge on climate variation and their effect on livelihood framework in Vhembe District.

1.2. Statement of the problem

In developing countries, billions of people face challenges of scarcity of water, food insecurity and risks to health due to climate change (UNFCCC, 2006). This scenario will have a negative impact towards the achievement of the Sustainable Development Goals (SDGs) and United Nations Millennium Development Goals (UN, 2007). As part of the 2030 agenda, which the United Nations put forward in 2000, eight goals were named to eradicate extreme poverty, inequality, hunger, illiteracy and promote better health (UN, 2007). Developing countries, however, have been struggling to reduce poverty and inequality to improve the livelihoods of their population through primary industries, especially, agricultural and tourism sectors. Unfortunately, such commitments were made at the time climate change had only started becoming recognised as a global challenge for this century. Climate change is arguably one of the pressing challenges facing African nations due to their geographical location, low average income and their reliance on climate-sensitive sectors, such as agriculture and tourism. In Sub-Saharan Africa, the agricultural yield is particularly vulnerable to the impacts of climate change, and approximately 96% of crop yield depends on rainfall (World Bank, 2012). Climate change effects have been felt in almost all economic sectors, with agriculture being one of the worst affected. It has also been indicated in many research findings that recurrent droughts and heat waves due to climate change, and lack of appropriate political policies contribute to the climate change crisis (Mwenge-Kahinda *et al*., 2010; Amin *et al*., 2013; Bocanegra-Martinez *et al*., 2014).

Climate change threatens to deepen the problems already faced by rural farmers, such as inadequate technical information to orientate farming; lack of transportation services; lack of financial support systems to enable farmers to grow; disease; constraints on production and lack of on-farm infrastructures in Africa - especially in South Africa, which is a semi-desert country. The agricultural economy of South Africa comprises of a well-developed commercial sector as well as a challenging subsistence sector due to stressors like climate change, which usually translates into food insecurity and poor livelihood. Empirical evidence points out that, some of the impacts of climate change include decreased rainfall, increased temperature, heatwaves and evaporation in dry land areas, higher frequency of droughts, severe water shortage and arable land, decline in crop yield and biomass production, increased risk of food shortage and famine (Orinda & Murray, 2005; IPCC, 2007; Julius & Francis, 2013). Impacts of climate change are already being felt through high temperatures, rainfall decline, low humidity, reduced vegetation and increases in the frequency of coastal erosion (Neelin, 2011; Pelling, 2011). Smallholder farming in developing countries, especially in South Africa, plays a pivotal role to farmers' livelihoods and their economy. It is a primordial source of livelihoods, raw material and provides employment for the millions in rural communities; hence, this farming system contributes immensely to people's financial well-being in Africa.

In South Africa, approximately 40% of the country's underprivileged population live in the rural countryside and depends either directly or indirectly on rain-fed agriculture or livestock as a source of livelihood (Stat. SA, 2013). Agriculture also plays a major role in the country's economy, contributing to about 2.9% of GDP, 10% of formal employment and 10% of the total value of exports in 2000 (Benhin, 2008). Mpandeli (2014), conducted studies and reported that a large portion of smallholder farmers in Vhembe District, are extremely vulnerable to all sorts of climatic shocks, due to lack of climate knowledge and adaptive strategies.

In South Africa, large-scale commercial farming is mostly dominated by white farmers, who have advanced and well-established farming technologies and well-organised farms located on the most productive land which covers about 70% of the total land area. Presently, there are about 5000 commercial farming units in Limpopo Province. Smallholder farmers are situated in semi-arid inaccessible homestead areas with low levels of production technology and capacity to adapt to climate change, with a small farm size of about 1.5 hectares per farmer and a land surface covering about 30% of the provincial land.

In view of the role played by smallholding farms, it is necessary to analyse this farming system, which is extremely vulnerable and sensitive to changes in climate. Local farmers need to apply new adaptive strategies to support farming systems and livelihoods at household level. Researchers have conducted various studies on climate change impacts on agriculture, however, research into climate adaptive strategies, socio-economic drivers affecting smallholder farmers and non-climate change on smallholder farms, have generated limited knowledge. This thesis provides a basis or platform for understading how climate change may have impacted smallholder farming system and adaptation strategies, hence, its focus is on micro-scale level farming in Vhembe District A better understanding of the impacts of climate change, therefore, may stimulate adaptive strategies by stakeholders who make decisions in the agricultural sector.

1.3. Justification of the research

According to reports, local communities in developing countries are most affected by changes in climate, although, these same communities are neglected in terms of government service (Churi *et al*., 2013). Many rural farmers in South Africa are dependent on smallholder farming. Any negative effect of climate change on local agriculture could cause a fall of approximately 1.5% on the GDP of the nation by 2050, which is equal to the annual foreign direct investment in SA (Banerejee *et al*., 2008; Stat, SA, 2015). Weather data from 26 meteorological stations in South Africa was analysed by Kruger & Shongwe (2004), who discovered that in the past four decades, there has been an average of 0.13^{o} C increase in temperature per decade. According to their forecast, it could increase to 1.2^{o} C in 2020, 2.4^{0}C in 2050 and 4.2^{0} C by the year 2080. For rainfall, it is expected to decrease by 5.4% in 2020, by 6.3% in 2050 and 9.5% in 2080. Agricultural production is the most exposed sector of the country's economy due to its direct dependence on temperature and rainfall.

Knowledge of how household farmers perceive changes in local climatic conditions will bring about a better understanding of how smallholder farmers should choose strategies in response to climatic shocks on crops. There is, therefore, a growing need to quantitatively assess the major parameter that controls sustainable livelihoods, particularly, of farmers in Vhembe District

Based on the gap in knowledge, outlined below are pertinent research objectives, which controlled this study. There are few analytical research reports investigating and accessing existing meteorological data and smallholder farmers' awareness of climate change impacts and sustainable livelihood coping approaches in Vhembe District, hence, the urgency of this study. Although climate changes may affect South Africa, the distribution of this change may vary from one agro-ecological region to another due to biophysical conditions, land ownerships, economics, political situation, and the socio-economic fabric of the indigenous people and cultural history of the community. This study provides a baseline analysis of climatic change data over the last 35-year period, from 1980 to 2015. For this purpose, the study will focus on smallholder farmers' perceptions to climate variations, adaptive strategies, institutional policies, indigenous knowledge systems and sustainable livelihood framework in Vhembe District, South Africa.

1.4. Research aim, specific objectives and questions

1.4.1. Research Aim

The aim of the study was to assess the impacts of climate change on smallholder farming in Vhembe District The study also evaluates the effectiveness of adaptation strategies and alternative livelihood options.

1.4.2. Specific objectives

The specific objectives are:

(a) To examine smallholder farmers' perceptions about climate change in relation to climate trends,

(b) To assess the impacts of climate change on smallholder farmers' crop production;

(c) To identify smallholder farmers' adaptation strategies and determinants of adoption choice to climate change;

(d) To examine stakeholder strategies and local indigenous knowledge systems (IKS) employed to prevent climatic shocks and;

(e) To analyse smallholder farmers' alternative sustainable framework to cope with climate change.

1.4.3. Research questions

(a) How do smallholder farmers perceive climate change trends?

(b) What are the impacts of climate change on smallholder farmers' crop production?

(c) What are the response strategies and determinants of adoption choice to climate change?

(d) How effective are stakeholders' arrangement and indigenous knowledge systems put in place to combat climatic shock in the study area?

(e) What alternative sustainable framework can be used by smallholder farmers to avert problems arising from climate change?

1.5. Description of the study area

The study area is made-up of Levubu, Tshiombo and Nwanedi in the Vhembe District, Limpopo Province. The Vhembe District is situated in the extreme northern part of Limpopo Province, with agricultural activities as the main occupation of the local communities. The Vhembe District is subdivided into four municipal areas, namely, Makhado, Musina, Thulamela and Mutale (Figure 1) (Demarcation Board, 2006). It borders in the North East with Botswana, Zimbabwe in the North, and Kruger National Park in the East. Vhembe District cover a total surface area of 25 597 square km (9 883 sq. miles) of land.

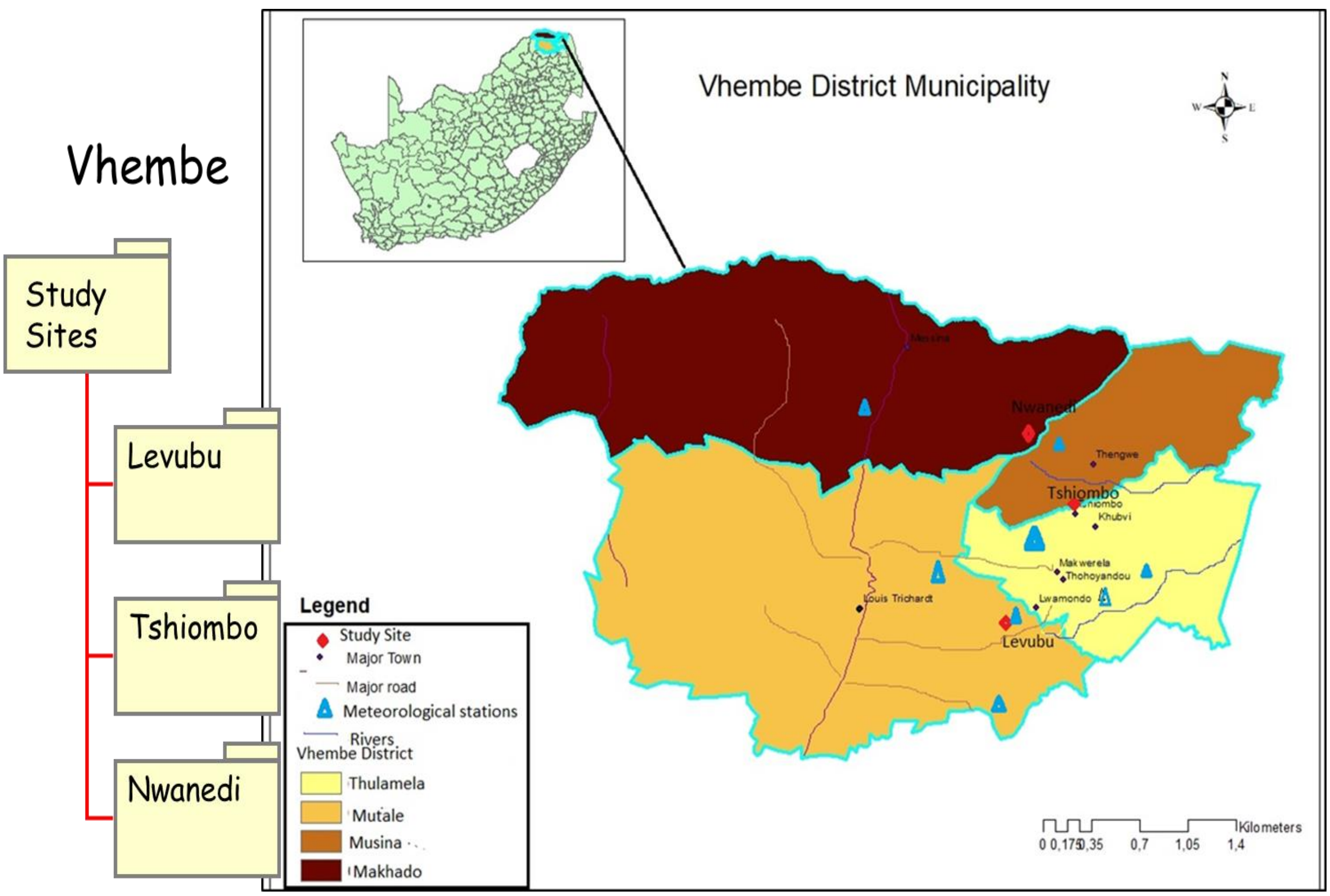

Figure.1.1. Location of the study sites and meteorological stations

1.5.1. Physical Characteristics

1.5.1.1. Climate

The Limpopo Province's climate ranges from tropical dry desert conditions of south of Zimbabwe to the tropical rainy area extending to the coastal plain of Mozambique. In the province, rainfall is unevenly distributed, with an estimate of about 90% occurring during months of October to April, usually intense in a number of isolated rainy days and in few isolated areas. Rainfall also varies significantly from year to year (DEAT, 2004; DEA, 2015). This spatial and uneven distribution of rainfall, limits crop production. The major agricultural production sectors in Limpopo Province face climate change challenge, through prolonged drought and flooding.

Vhembe District's climatic conditions are generally hot and humid, receiving the bulk of its annual rainfall in November through to March as in line with the Inter Tropical Convergence Zone (I.T.C.Z) as it moves south (Kabanda, 2004; Kabanda & Munyati, 2010). The area is generally subjected to high rainfall and an increase in vegetation growth, however, the Soutpansberg mountain range has an annual rainfall of about 2 000 mm and is the highest area that receives high amounts of rainfall in the municipality (DWAF, 2003; Nenwiini & Kabanda, 2013; Kephe *et al*., 2015)).

In Vhembe District, these climatic conditions have influenced agriculture activities and crop yield, as production highly dependent on climate variables. The annual minimum temperatures vary for the area from 10ºC during winter, whereas in summer the maximum varies between 34ºC to 38ºC; and even more, in some cases. Most parts of Musina and Mutale local municipalities, which are predominantly semi-arid, frequently experience prolonged droughts (Vhembe IDP, 2013/14).

1.5.1.2. Agro-ecological zones

The smallholder farmers are located in the agro-ecological zones that have diverse physical geographical patterns. The agro-ecological setting of this area is dominated by the inter-tropical convergence zone climatic conditions (Munyati & Kabanda, 2009). The adaptive strategies towards climate variations have been behind variations in smallholder activities for the past 35 years.

The three agro-ecological zones of the Province have different rainfall patterns. Empirical evidence shows that during good summer rainfall seasons, the Makhado areas and some parts of the Thulamela local Municipality areas experience an annual rainfall of approximately 2000 mm, whereas, minimum rainfall of 300mm is received in the semi-arid area of Musina Municipality. Table 1.1 indicates agro-ecological zones in the study area.

Table 1.1: Study sites and Agro-ecological zones in the Vhembe District

Study sites	Local Municipality	Types of farming activities	Agro-ecological zones
Levubu	Makhado	Smallholder and Commercial	Sub-tropical high rainfall, wet summer and hot dry summer, cold dry winter, dark loam soil
Tshiombo	Thulamela	Smallholder and subsistence farming activities	Sub-tropical minimum rainfall, wet summer and hot dry summer, cold dry winter, sandy loam soil
Nwanedi	Musina	Smallholder / game farming	Trust Savannah with grassy plan and few tress, low sub-tropical rainfall, high evaporation and hot summer, rocky sandy soil

Source: Munyati & Kabanda (2009).

1.5.1.3. Hydrology

Vhembe District has a limited supply of ground and surface water. The area is made up of a few catchment areas and there is a high demand of water for activities, such as agriculture, construction, human consumption and mining (LDA, 2012). The most important catchments in Makhado are the Nzhelele water catchment and the Luvuvhu water catchment. The Levubu catchment is dissected by the Levubu River, which takes its source from the south-eastern flanks of the Soutpansberg Mountain (DWAF, 2003).

1.5.2. Socio-economic characteristics

1.5.2.1. Population

The total population of the Vhembe District is 1 294 722, with a density of 50.6 habitants /km^2 (131/sg m) (SA Census 2011). The population was 1198 056 from the 2001 Census and 1 240 035 from 2007 Community Survey.The statistics reveal that from 2001 to 2007 the population of Vhembe has increased by 41 979 people, and 54687 from 2007 (community Survey, 2011 Census). The general pattern of the population in Vhembe Distric mainly comprises of 54.4% females, 45.5% males, with 51.3% of the population being under the age of 20 years (Vhembe District integrated development 2012/13-2016/17).

1.5.2.2. Agriculture

Vhembe District has a total area of 2,140,708 hectares, of which 247,757 are arable land. The agricultural system in the District is divided into two types - large scale commercial farming and smallholder farming known or subsistence (Vhembe District, 2011/12 IDP Review). White farmers own approximately 70% of the arable land, while only 30% belong to a small group of local farmers who are mostly black. The district has two existing agro-ecology locations, which are Levubu and Nwanedi valleys (Vhembe District, 2011/12 IDP Review). Part of the Vhembe Distric lies on the gentle slopes and in the valleys of the Soutpansberg mountain ranges (Niang *et al*., 2014). The valleys receive heavy rainfall from November to March; its alluvial soil is very fertile, and is suitable for farming many sub-tropical products, such as sweet potatoes, beans, vegetables, maize, tomatoes and pumpkins (Magombo *et al*., 2011).

Crop and livestock farming are the source of food production among the majority of households in the municipality, but the viability of these sectors has diminished over the years. Historically, households used to be self-sufficient in their production of food-related crops, such as maize, sorghum, groundnuts, and tropical fruits, as well as livestock, including cattle, sheep, goats, pigs and chicken. Presently, most households can barely produce adequate quantities of food from crops and livestock; and, increasingly they have sought to depend on purchased food commodities. For this reason, the study aimed to determine the link between climate change and food production in this municipality.

1.6 Operational definitions

Smallholder farmers: Smallholder farming is self-sufficient household farming wherein the farmers produce mainly for household consumption; hence, production is based on the family requirements rather than markets. Production is further reduced by limited technology and access to resources (Morton, 2007).

Vulnerability: A condition where people are easily harmed or affected by natural hazards and they find difficulties in coping with the situation (IFRC, 2013)**.**

Climate change: A change in climate for a classical period often ranging from 30 to 35 years, which is considered to be optimal period for observation (Brunet *et al*., (2015).

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects; this moderates harm or exploits beneficial opportunities (IPCC, 2001).

Adaptive capacity: The 'ability of a system to adjust to climate change (including climate variability and extremes) to moderate damages, to take advantage of opportunities or to cope with the consequences (IPCC, 2001)

Indigenous Knowledge system: Is traditional, ecological knowledge as "a cumulative body of knowledge, practice and belief, evolving by adaptation processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with their environment" (Berkes, 2012).

Sustainable livelihood: Forsyth (2007) defines sustainable livelihood as a livelihood that comprises people, their capabilities and their means of living, including food, income and assets. While livelihood assets are stock of capital resources available (human, social, financial, physical and natural assets) for the poor at household Community and societal levels in the forms of material or non-material. It includes their health, labour, knowledge and skills, friends and family, and the natural resources around them (Rakodi & Jones, 2012).

1.7. Thesis Outline

This study is structured into seven chapters, as follows;

Chapter One in which a general conceptualisation of the research problem, aim, objectives, research questions, and significance of the study are explained. Furthermore, the study area was described briefly with emphasis on the socio-economic activities and biophysical aspects of the area; this chapter ends by providing the study outline.

Chapter Two: provides a review of climate change across the global and continental variations using empirical information from Latin America, Asia, and Sub-Sahara Africa. This section also includes aspects ranging from, climate change, flood and drought as climatic indicators, adaptation of climate change, vulnerability to climate change impacts, climate change in South Africa, smallholder farmers' perceptions, indigenous knowledge and climate change, sustainable livelihoods approach and theoretical framework and climate change adaption policies and strategies both, international and local.

Chapter Three: deals with the epistemological and entomological aspects of the study. It also addresses the research design that guided the overall research method and techniques used to collect and analyse the data.

C**hapters Four to Six** present and discuss findings of the study. These chapters are structured around the following themes - an examination of smallholder farmers' perceptions on climate change in the study area from 1980 to 2015 and as well as assessing the impacts of climate change on smallholder farmers' crop production.

Chapter Five focuses on smallholder farmers' adaptation strategies and determinants of adoption choice towards climate change.

Chapter Six provides an examination of appropriate stakeholder strategies and local indigenous knowledge systems (IKS) employed to prevent climatic shocks and, analyse smallholder farmers' alternative sustainable livelihood framework amidst climate change.

Chapter Seven begins with the study conclusions as drawn from the findings, as well as the suggested recommendations for sustainable climate change coping mechanisms for smallholders' farmers, limitation of the study and issues requiring further research.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

The purpose of this chapter was to review published literature on climate change issues. The objectives of the study were used to guide this chapter. Therefore, the chapter is structured according to the objectives of the study. The objectives of the study were to assess the impacts of climate change and adaptation strategies, smallholder farmers' perception of climate change trends, institutional and indigenous approach in response to climate change. Hence, this review explored literature related to the thesis theme that establishes empirical evidence on the concepts of adaptation of climate change. The review further analysed smallholders' farmers' perceptions and knowledge of climate change. In addition, a review of indigenous knowledge adaptation strategies in response to climate change and farmers sustainable livelihoods was examined, an overview of climate change policies in South Africa is presented, and conceptual frameworks that guide the overall research were also presented.

2.2. Climate change in a global context

Climate change is defined as "'any change in climate over time, whether due to natural variability or as a result of human activity'' (IPCC, 2007). The Intergovernmental Panel on Climate Change (IPCC) definition to climate change stating thus "…a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". Therefore, climate change is a global phenomenon and has particularly been evident in the past three decades. The IPCC Fifth Assessment Report (2014) revealed an increase of average global land and ocean temperature by 0.85 °C from 1880 to 2012. This indicates how climate, especially temperature, has been changing with a negative impact on environmental and human activities (UNFCCC, 2007; IPCC, 2014). The period between 1983 and 2012 was the warmest in the past 800 years recorded (PCC-AR5-WG1, 2013). Hence, climate change effects are "the impacts of climate change on environmental and anthropogenic systems, relying on the thought of coping and adaptation strategies".

The presence of greenhouse gases (GHGs), such as nitrous oxide (N_2O), methane (CH_4), carbon dioxide (CO_2) heat up the planet and impact the earth's climate. The constantly increasing concentration of atmospheric greenhouse gases emitted by burning of fossil fuels results in Global Warming that causing climate change. The GHGs are not limited to fossil fuels. Human-made gases such as hydro fluorocarbons (HFCs) and per-fluorocarbons (PFCs) also affect the global climate (IPCC, 2007). Furthermore, human activities in the agricultural, industrial and infrastructure sectors contribute to the high concentration of greenhouse gases and related changes in climate (IPCC, 2007; IPCC, 2014). According to the IPCC's Fourth Assessment Report (AR4) (IPCC, 2007), the net effect on global warming is associated with human activity since 1750. The rise in GHGs has caused an increase in the amount of warming in the atmosphere and the heat that would be emitted into the atmosphere is trapped.

Climate variability and change are a hot theme among international communities due to the dynamic interaction between the troposphere and weather conditions at the Earth's surface (Solomon *et al*., 2013; Ngami, 2016; Elisa & Builitijes, 2017; Makuvaro *et al*., 2018). Notwithstanding concrete academic and scientific empirical evidence along with indisputable signs of global increasing temperature on the Earth's surface, there exist different opinions among scholars toward climate variability and change (Foster & Rahnstorf, 2011; Ndaki, 2014; IPCC, 2014).

Statistical data indicate that climate and water are a world-wide, national and rural challenge that must be addressed as a matter of urgency. Natural environmental and anthropogenic causes account for these problems. The United Nations Economic Commission for Africa (UNECA, 2011) stated that climate change is to responsible for altering the hydrological cycle, increased temperature and precipitation patterns over the globe with negative impacts generally felt in Africa. In addition, the UN (2014) reported that unplanned management of capitals, insufficient planning and lack of political policies contribute to the climate crises on agricultural household livelihood.

However, the UNFCCC (2015) considered climate change as "a change of climatic conditions which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable period". Perego (2019) supported this through a study of conceptual advance on global scale assessments of vulnerability informing investments for coastal population at risk of climate change. Climate change is one of the major challenges of the 21st century, as it affects all countries globally. It is a major disaster to the societies due to its extremely negative effects worldwide. The main impact is on the agricultural sector on which societies depend as their major source of livelihood (Tian & Lemos, 2018; Perego, 2019).

2.3. Indicators of climate change

Generally, any change in the average climate affects the frequency of extreme events. However, it is impossible to forecast the exact frequency and distribution of the extreme events. Climate change manifests through several indicators such as floods, heatwaves and drought (Khandlhela & May 2006; World Bank, 2008; Pavelic *et al.,* 2012). Hahn *et al*. (2009) stated that in the future, due to anticipated increase in CO_2 and methane concentrations in the ozone layer. Hence, changes in climate variables are forecasted to increase the earth's average temperature and likely to be accompanied by increased rainfall which can lead to flooding or decrease in temperature resulting in drought and heatwave.

2.3.1. Heatwaves

Studies have shown that there is no precise definition of a heatwave. Each heatwave arises from the need to characterise the impact of the increase in temperature for long periods in a special specific sector of interest such as human agricultural production and natural ecology. Hence, heatwaves are important for characteristics that are basically connected to drivers of "suffering from heat" to which living beings in general are subjected (Özkan *et al*., 2016. Heat waves could be classified according to their duration and/or their intensity which is measured by the amount that the recorded air temperature deviates from the reference climatological values.

2.3.2. Floods

Flooding events can be catastrophic within a short period of time unlike other natural hazards which evolve over time, such as drought. Changes in climate increase the surface temperature and rainfall patterns which bring heavy thunderstorms. Climate change related sea level rise is due to warming of the water, glaciers and melting of ice into the seas (Pavelic *et al.,* 2012; Mccathney *et al*., 2013b).

However, some studies indicate changes to the hydrological cycle resulting from higher temperature, high evapotranspiration and thawing of snow. Hence, high precipitation that causes floods is the manifestation of climate change (World Bank, 2008: Riederer & Foster, 2009). However, climate scientists' debate about floods, which is referring to hydrologic events, and policy decision makers refer to floods as destructive hazard (Hahn *et al., 2009*; Alexander, 2011). In South Africa, studies have reported that heavy precipitation during summer cause extreme floods that frustrate local farmers' household food security but also destruction of road infrastructures and indigenous goods and losses of lives (DWAF, 2004; DEA, 2011; SAWS, 2014).

Many flood victims follow a long period of post-flood recovery curves to redress losses or resume crop production and construction activities. In some worse circumstances, some victims never recover at all. Therefore, the entire local farmers' community may continue to suffer from the impacts of flooding for a long post-floods period. This is common where extreme and prolonged heavy precipitation and little or lack of mitigation measures such as drainage facilities and flood warning system expose farmers to extreme flood hazard (DWAF, 2004; World Bank, 2008; Mccathney *et al.,* 2013b). When a system lacks social safety nets such as flood insurance, it is very liable to natural hazards excesses. Flood victims have no compensation outside emergency relief provided by donor organization (Tarhule, 2005; Pavelic *et al.,* 2012). In the rural areas, the risks are higher. Moreover, in recent decades, increased urbanisation and its related environmental effects are found to have severe implications on flood risk exposure and vulnerability.

Population boom has overwhelmed town planning and controlling agencies. Hahn *et al*. (2009) highlighted that construction of unplanned shanty towns, some in flood prone regions where land price is cheaper or free, increases communities' exposure to flood hazards. Nethengwe (2007) conducted studies in Vhembe District and examined the flood risk and how the local community is vulnerability to this hazard. Physical factors such as rainfall, geology and topology are triggering causes of flood hazards.

2.3.3. Drought

Since the dawn of the 21st century, droughts constitute one of the natural hazards with the most devastating effects across the globe. It has significant impacts over vast areas across Europe, Asia, Africa, South America, Central America and North America (Batterbury & Warren 2001; Heim, 2002). Climate change and global warming do not only result in changes of averages but have far reaching consequences such as the total intensification of extreme weather events. Though most extreme weather events tend to be more abrupt, droughts take much longer to develop, last longer and are difficult to predict (Mishra & Singh, 2010).

Droughts are caused by changes in the hydrological cycle which consequently alter the precipitation processes (Devereux, 2007; Forster & Dougill, 2009). When this happens, seasonal precipitation fails to occur with the little or no rainfall creating a soil moisture deficit and a depletion of surface runoff and ground water recharge. However, Fraser (2006) argued that drought signifies more than the absence of rainfall. In a hydrological sense, it happens when surface water supplies steadily diminish during a dry spell. In agricultural sense, it occurs when the moisture shortage lasts long enough to negatively affect farm crops and livestock.

The duration of a drought may vary from short to long periods. However, continuous moisture deficiency during normal average conditions coupled with an imbalance between rainfall and evapotranspiration significantly prolong drought in an area (Fraser, 2006; Mishra & Singh, 2010). Devereux (2007) revealed that not all droughts have the same origin. Declining moisture content could lead to different impacts depending on the time of the year as well as the initial moisture available and various climatic influences. As such, most rural households are highly vulnerable to droughts as most of them are heavily dependent on rain-fed agriculture.

The average annual rainfall in the Vhembe District is 820 mm (ARC-ISCW, 2014). The rainy season starts in October in most areas of the Limpopo Province especially in the Vhembe District. The rainfall pattern peaks in January-February, and thus when floods are also expected. Rainfall exceeds the potential evapotranspiration in December to March.

2.4. Adaptation to climate change

Adaptation is defined as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007; UNFCCC, 2010). According to this definition, the term "adaptation", involves financial adaptation, socio-economic and institutional adjustment. Adaptation to climate change has been identified as a set of activities with which a population responds accordingly to various pressures resulting from a changing climate (Nyong *et. al*., 2007; Menike & Arachchi, 2016). Such responses or adjustments refer to environmental, social or economic, at a system level (IPCC, 2014; Komba & Muchapondwa, 2015). Therefore, climate change adaptation is when individuals and communities alter their regular ways of life and usual activities as a way to deal with climate change stimuli, irrespective of intent, spatial, temporal and performance (Komba & Muchapondwa, 2015; Makuvaro *et al*., 2018).

Adaptation to climate change is vital in developing countries where it is not a new phenomenon in the climate context. It is a concept that has been a common practice in recent years (Burton *et al*, 2006; Nelson *et al*; 2007; Turpie & Visser, 2013). During the commencement of the UNFCCC, mitigation was adopted as a strategy to deal with this dilemma, paying little attention to adaptation. The international society recognized that mitigation only cannot address climate change, therefore, adaptation was needed to be equally footed with mitigation (Hill, 2008; Mubiru *et al*., 2015).

Recently, the concept of adaptation has developed into an influential research area for many fields of study (Van Aalst *et al*., 2008; Obayela *et al*., 2014; Komba & Muchapondwa, 2015). It has been imperatively adapted as a policy response to the negative effects of climate change together with mitigation (Burton *et al*; 2006; Hill, 2008; Devi *et al*., 2017). In Sub Saharan Africa, most smallholder farmers depend on agriculture for their livelihood and as a major source of food security and resilience (Challinor *et al*., 2007, Hou *et al*., 2015; Garcia de Jalon *et al*., 2018). However, smallholder agriculture depends on climate variables, particularly precipitation and temperature (IPCC, 2007; FAO, 2008). The agricultural production environment is characterized by prolonged droughts, heatwaves, high temperatures, variable precipitation. This keeps Africa's smallholder farmers crop production low and high food insecurity (Maponya & Mpandeli, 2013). Uddin *et al*. (2018) addressed issues of climate change opining that the focus in recent decades placed more emphasis on minimizing the release of greenhouse gases. However, minimal progress has been made in this regard, whilst climate change has persisted thus having negative impacts on agricultural production. Recently, much attention has shifted from halting greenhouse emissions to adaptation methods that minimize vulnerability to various impacts of a changing climate (IPCC, 2010; UNFCCC, 2013). Due to the low level of technology, developing countries are generally considered to have the lowest adaptive capacity, the least degree of development of social institutions, also with highest historical ties and existing stressors linked to climate change (Nhemachena & Hassan, 2007; Chagutah, 2010; Panda *et al*., 2013).

Adaptive capacity, which is the ability within a system to adjust, ensuring minimal vulnerability is a dynamic concept. The association of the environmental aspect, social, cultural, political and economic forces that regulate vulnerability through exposures and sensitivities, and the way the system's components are internally reacting to shocks (Karakaya *et al*., 2014; Clay & King, 2019). Adaptive capacity to shocks has two dimensions which are coping and adaptive capacity to change. Coping ability refers to shock absorption. Adaptive capacity is related to time management capacity with respect to climate change which must take place by preventing and removing maladaptive practices. Maladaptation refers to various adaptation activities that fail to minimize vulnerability, and thus result in its increase instead. For instance, the adoption of improved irrigation systems or introductions of legislations that regulate the construction of buildings along coastal areas are some of the measures that can be implemented to prevent or avoid maladaptation.

However, in Rwanda, smallholder farmers employed crop intensification programs as a mechanism of climate shock management (Clay & King, 2019). Hence to mitigate climate hazard, local farmers should use resources to adapt land use techniques. However, it is important that adaptation should be given a significant role as the effects of climate change mainly in developing countries are intensifying.

Adaptive capacity is inversely associated with vulnerability. Theoretically, a population with high adaptive capacity tends to have more success in coping with climate change as well as reduced vulnerability. According to IPCC (2013) formal indicators of both vulnerability and adaptive capacity that may assist in determining vulnerable situations include drivers like income, infrastructure, and state of civil society. Other potential indicators of adaptive capacity are encompassed insurance mechanisms (Bewket *et al*., 2013; Klein *et al*., 2014).

In South Africa, a National Climate Response White Paper was developed as a first comprehensible outline of national strategy for climate mitigation and adaptation strategy. The strategy adopts a sectoral framework approach, as well as identifies the basic need for coordination of responses between various sectors. Many adaptation choices are advocated across sectors. In the agricultural sector, farmers' organisations are particularly interested in climate change. Ziervogel et al. (2014), reported that apple farms in the Western Cape Province have been replaced by vineyards which are more tolerant and drought resistant. In the southern Cape plantation farmers have adapted crops to livestock farming and have improved their water-storage capacities. In Vhembe District, farmers in the district use drought-resistant crops and crop diversification techniques as adaptation methods. These farmers change crop varieties most of the planting seasons, but very few farmers were adopting drought-resistant crops (Maponya & Mpandeli, 2014).

2.5. Adaptation theories to climate change

Although global environmental agreement on changes in climate conditions becomes less concern in the short-term, adaptation is unavoidable due to increase in temperature, decease in rainfall, heat waves and prolonged drought is now receiving more importance attention. Even though adaptation analysis is increasing on the scientific program, this interdisciplinary field is still characterised by an evolving epistemological base. There is wide recognition that there are crucial barriers to adaptation, but a comprehensive set of theories that explain this observation is still not in sight. There is need for the clarification of the concept of adaptation in a way that makes theories applicable for adaptation design. There is a broad set of theoretical literature that reflects on the relation between adaptation, vulnerability and resilience. The study will only examine two examples (Brooks, 2003).

2.5.1. The central theory of resilience to climate change adaptation

Several studies have reported that, building resilience to the impacts of climate changes and to bring sustainable benefits. Therefore, agricultural managers, as a major priority, need to implement and adhere to best techniques such as that code of Conduct for Responsible designated in the FAO (IPCC, 2014).

There are multiple definitions of resilience concept, Millier et al., (2010); Cote & Nightingale (2012), defined as the capacity to recovery after an external shockwave or pressure. Therefore, the resilience of a system is validated by enduring disorder, preserving system functions and regulating, and recovery to an equilibrium state (Gunderson et al., 2002). These definitions of resilience have backgrounds base in ecology and ecosystem changes (Holling, 2002). Farmers' progress in this direction should be vital contribution to maintaining biodiversity, preserving the soico-cultural and crop production system to change and however, enhancing our ability to anticipate and adapt to inevitable changes in climate in the natural environment and associated agricultural production.

Folke et al., (2002), stated that resilience is often discussed as an antonym of vulnerability, IPCC, cited that, vulnerability to climate change is the degree to which a system is susceptible to or incapable to cope or recovery with, adverse impacts of climate change, such as climate extremes and variability (IPCC, 2014). Several research and studies have demonstrated that the rapport between resilience and vulnerability is nevertheless complex. Miller et al., (2010), reported that, organism can be equally resilient and vulnerable at the same time depending on the specific risks and external stresses (Vicent et al., 2013). For examples smallholder farmers along the river Levubuu bank may be vulnerable to flooding as a result of its physical location be highly resilient to prolonged drought, heatwaves and dry spells.

2.5.2. An action theory of adaptation to climate change

Many literatures currently agree that, substantial barriers inhibit measures to cope with the impacts of climate change. However, the incoherent use of terms like planned adaptation or adaptive capacity seems to be of little help in analysing the nature of these barriers or suggesting ways to overcome (Nelson et al., 2007).

However, adaptations are processes within entities and systems, or adjustments made by human systems. In our approach, we specifically refer only to human individuals and collective actors (IPPC, 2014, Nelson et al., 2007). Action requires farmers and an intention, and this intention is directed towards an impact of climate change. It is crucial to note that the theory presented in this section serves as a basic unit of analysis. It describes a core configuration that is meant to be as simple as possible. When complex real-world adaptations are to be analyzed with the theory, the following concepts need to be recombined in different ways to consider multiple interrelated stakeholders (IPCC, 2014).

In the theory, a stimulus is demarcated as a change in biophysical, such as specific rainfall, temperature, drought, and heatwaves, and flooding variables associated with climate change. In a very precise meaning, this has to be distinguished from weather events. Stimuli can refer to changed values of statistical parameters such as average intensity, frequency, or higher statistical momenta (IPCC, 2007). Actions must be `actual´ but stimuli may be potential or actual. They can also refer to abrupt large-scale events in the earth system. In many practical cases it is not relevant to insist on this distinction (Nelson et al., 2007). There is also a difference between strictly meteorological effects, such as temperature and precipitation patterns on the one hand, and more or less indirect effects such as rising sea level or greater frequency of river floods.

2.6. An overview of climate change impacts in global context

Extreme temperatures, floods, drought and water scarcity are expected because of global climate change, mainly due to anthropogenic activities which lead to increased GHGs emission. Due to high temperatures and low precipitation the availability of food needed for community livelihoods will be reduced. This climate variability across the globe will severely affect agriculture. Global warming scenarios mostly bring about a decline in crop yields due to increasing temperature and declining rainfall, and consequently reducing crop quality and increasing food insecurity.

2.6.1. Climate change impacts in South America

South America comprises of 14 nations (Seo & Mendelsohn, 2008). Climate variability and change caused the destruction of the natural environmental ecosystem (UNFCCC, 2007). According to Aerts *et al*. (2004), changes in climatic conditions are threatening to destroy a huge part of biodiversity and endanger species in these areas. Literature indicates that the Amazon ecosystem is home to an estimated 40% of the global remaining tropical forest. It probably has the World's richest biodiversity, thousands of plant and animal species, thus vulnerable to impacts of climate change (Seo & Mendelsohn, 2008).

There are large commercial plantations and agro-industry businesses that are highly developed in most parts of South America. Seo & Mendelsohn (2008) reported that many parts of the continent still depend on smallholder farming systems. The farms are highly sensitive to climate change than the commercial agriculture. Smallholder farms are more sensitive and vulnerable to extreme temperature, prolonged dry spells, heatwave and fluctuation of rainfall (UNFCCC, 2007; UNFCCC, 2011). The Amazon region is particularly vulnerable to extreme climatic events. The area is prone to climate related changes that include high occurrence and intensity of extreme conditions, especially the ones related to the ENSO phenomenon. Tens of thousands of deaths and extreme economic losses as well as social disruption have been the result of floods in the past years. For instance, the 1998 Mitch hurricane resulted in more than ten thousand fatalities with adverse destruction to infrastructure, with Honduras and Nicaragua being the worst affected. However, the north-eastern part of Brazil is more prone to drought, including the related impacts (Charvériat, 2000).

2.6.2. Climate change impacts in Asia

South Asia makes up about one fifth of the world's population. Its geographical location makes it the most disaster-prone region on Earth. The increase in population and environmental resource degradation, with persistent high rates of poverty and food insecurity make South Asia a highly vulnerable area to the potential effects of climate change (IPCC, 2014; Waibel *et al*., 2018).

The agricultural sector in Southeast Asia is the main economy driver and livelihoods of the rural communities (FAO, 2018). The IPCC (2014) reported that adverse effects of climate variability and change are expected to negatively affect agricultural activities in Southeast Asia. Asia is geographically located where there is increasing occurrence of prolonged droughts, increased temperature and intense monsoon rainfall. Several studies concluded that climate variability and change cause adverse consequences for crop productivity and food security (Iglesias *et al*., 2011; Waibel *et al*., 2018). According to studies conducted by Boonpragpb (2005) between 1991 and 2002 the Vietnamese agriculture witnessed crop harvest losses worth some 50 million Thai Baht (estimate 1.3 billion EURO). Research studies conducted in Vietnam reported that Vietnam is one of the top five countries mostly affected by increasing sea levels. Hence, the effect of prolonged flooding has caused damage to rice plots along the Red River Delta banks and Mekong Delta (Dasgupta *et al*., 2007; Waibel *et al*., 2018).

Asia is the biggest continent on the planet, covering approximately four different climatic zones namely boreal, arid and semi-arid, tropical and temperate. It is, however, faced with daunting environmental as well as social and economic challenges in the various attempts to preserve its valuable natural resources. Major concerns are noted over land and ecosystems degradation posing threats that undermine food security. To compound this situation, there is a deterioration in water and air quality coupled with the ever-increasing consumption levels. The subsequent wastes generated have led to unsustainable increase on the already existing environmental problems.

In addition, Asia is particularly vulnerable to natural hazards such as tsunamis, typhoons and landslides. The occurrence and intensity in extreme weather incidences that include tropical cyclones, heat waves, drought, dust storms etc. have risen significantly and has been attributed to changes in climate (Cruz *et al*. 2007). Furthermore, hunger, increased exposure to diseases, reduced income and livelihoods that affect human survival are some of the resulting impacts. Gbetibouo (2009) supported that to reduce negative impacts of climate change, smallholder farmers must practice adaptation strategies. These strategies should be both technically suitable and economically practicable. Local farmers would require advance technologies and investments means to adaptation to climate, such as crop variety and change their planting dates.

2.6.3. Climate change impacts in Sub-Saharan Africa

Africa, for the past decades, has been identified as one of the world's most exposed regions to the effects of changes climate (IPCC, 2014; Niang *et al*., 2014). According to World Bank (2013) about 65% of Africa's labour force is employed in the agricultural sector and since 2000, there has been an increase in agricultural activities. Agricultural yields in Sub-Saharan Africa are particularly vulnerable to the actual impacts of climate variability and change. Approximately 96% of crop yield depend on rainfall (World Bank, 2015a). With the increasing temperatures observed in Africa towards the end of the 20th century, if mitigation approaches of climate change are not taken, the warming trend will continue. In the years 2017-2100 comparative to 1971-2000, increase in temperature of 4 – 6° C are likely to take place in subtropical Africa with low mitigation strategies (IPCC, 2014). Hence, this warming temperature are expected to cause more intensive extreme weather conditions, heatwaves, hurricanes, monsoon winds, tropical winds and El Nino situation (IPCC, 2001; Niang *et al*., 2014).

Smallholder farmers in the tropics are already facing various threats to agricultural production. Extreme changes in climate are projected to have an adverse effect on local farmers, thus putting the farmers' livelihoods at further risks. Farmers in Africa tend to be more susceptible to many climatic impacts particularly because of the over reliance on rain-fed farming for their livelihoods. Due to the deepening of climate change stress, more attention has been paid to agricultural vulnerability in Africa because most countries are facing tremendous climate stresses and are more prone to climate change impacts. Most regions in Africa are characterized by the most fluctuating climates globally both seasonally and decennially. According to Shiferaw *et al*. (2014), the situation is deepening since crop production in Sub-Saharan Africa depends on rain-fed smallholder or subsistence agriculture. About 89% of cereals production in Africa are rain-fed, meaning that once there is an extreme climatic event like prolonged heat waves and drought in a season, there will be total crop failure due to lack of water from irrigation. These extreme climate change events can result in poverty and unsustainable livelihoods within communities. The UNFCCC study concluded that more than 30% of the Sub-Saharan African population lives in extreme drought-prone zones with about 230 million people being affected by drought annually (UNFCCC, 2007). Many studies conducted in Africa have shown the risks to the sector from climate change (Asseng *et al*., 2011; Lobell *et al*., 2011; Maponya & Mpandeli, 2013). It is reported that the overall impact of climate change on production of major cereal crops in the African continent would likely be damaging (Niang *et al*., 2014; IPCC, 2014).

Further, Africa is currently facing increased water shortages, which have led to a rise in the possibilities of water conflicts since most Africa's river basins are transboundary (De Wit & Jacek, 2006; AGRA, 2013). Farming systems that depend on either rainfall or irrigation have been impacted greatly in most African countries, especially the subsistence and smallholder farmers in sub-Saharan Africa. Due to climate change, many crops are lost, particularly as a result of shortened farming seasons. A report by AGRA (2013) indicates that climate change will result in an overall decrease of many smallholder crops such as happened to sorghum in Sudan, Ethiopia, Eritrea and Zambia; maize in Ghana and South Africa; millet in Sudan; and groundnuts in the Gambia. More than half of the African population (60%) is threatened by starvation as a result of climate change, and this figure is expected to increase around the year 2080 (ASFG, 2013).

2.7. Smallholder farmers' perceptions and knowledge of climate change

There are various climate disasters which create, vulnerability, resilience; these necessitate coping and adaptive capacity from farmers to climate change in arid and semi-arid places, however, the adaptation methods can be easy if the smallholder farmers are aware and able to identify the climate change already affecting their livelihoods. Studies have concurred that smallholder farmers' capability to observe changes in climate is a pre-condition for their preferred adaptation and coping strategies to negative climate impacts (Kihupi *et al*., 2015; Mubiru *et al.,* 2015). Coping and adaptation methods of smallholder farmers rely on preconceived knowledge level towards climate change (Apata, 2011; Obayela *et al*., 2014; Kihupi *et al*., 2015).

Odekunle *et al*. (2007) reported that rain-based methods of farming are commonly practised method in Nigeria. Rainfall is an essential element of climate, which can significantly have negative effects both on yield and livestock rearing in Nigeria. Research also highlighted how crop yields and livestock farming systems can be affected by climate change due to inadequate adaptive capacity (Hou *et al*., 2015). Some studies believed that the information possessed by most smallholder farmers is inadequate to carry out extensive valuation of strategic adaptation and coping strategies. Findings by IPCC (2014) show that local knowledge by smallholders as well as their vulnerabilities are gradually being included in inter-disciplinary and multi-stakeholder evaluations. Scientific research across Africa focusing on the assessment of the main climate change effects is important, especially for the incorporation of smallholder farmers' knowledge as well as other climatic stresses (Heltberg *et al*., 2009; Nyasimi *et al*., 2013; Mubiru *et al*., 2015; Adegnandjou *et al*., 2018).

Despite the great advancement of climate science in addressing issues of climate change, particularly its negative impacts on the farming sector across the world. Therefore, to comprehend and deal with the problem at lower levels such as the rural smallholder farmers in Africa is an area of fundamental importance which is still lacking (Tschakert *et al*., 2014; Van Griensven *et al*., 2016). This is on the premise that in many areas across the globe, farmers deal with issues of climate change depending on how they perceive the changes as well as their indigenous knowledge base (Li *et al*., 2013; Abid *et al*., 2015). Furthermore, Morton (2017) argued that indigenous knowledge needs to be utilized together with scientific knowledge systems for developing efficient adaptation methods to climate change.

Extensive research on climate variation effects has been conducted, with many highlighting agricultural production as the most impacted (Glantz *et al*., 2009; FAO, 2016). Hence, climate change impacts on farming activities are predicted to differ across the global (Maponya, 2012; Glantz *et al*., 2009). In general, smallholder farmers' adaption decisions are based on the perception of climate variation and variability in their natural environment.

Climate variation shows significant uncertainty regarding the extent, temporal and the spatial trajectory on how smallholder household decision-making is affected (Wise *et al*., 2014; Ylhäisi *et al*., 2015; Yousefpour & Hanewinkel, 2016). Patrick (2014) reported how communities respond to precarious situations, as people suffer repercussions from undermining the possibility of a hazard affecting them. As such, households that are dependent on farming are likely to be more vulnerable to climate variability without adequate adaptation strategies (Li *et al*., 2013; Maponya & Mpandeli, 2013). This brings the need for understanding the perception of the smallholder farmers to the impacts of climate change and variability at the local areas (Kassie *et al*., 2013; Shemdoe *et al.,* 2014; Pirttioja *et al*., 2015).

2.8. Adaptation strategies of smallholder farmers to climate change

Resilience is defined as the ability of individuals/households/communities and/or systems to avoid alleviate or otherwise deal with threats and recuperate from climatic impacts. Though resilience appears to be the opposite to vulnerability but it is noteworthy adding a temporal aspect to the notion, such that a system is regarded as resilient if not very vulnerable to climatic hazards. It is worth noting that adaptive capacity includes two aspects, which are responses and recovery from shocks and changes. They both have a vital contribution as far as resilience is concerned, since they determine the ability of a system to either recover from and/or to adapt to shocks or changes.

Thus, in the context of vulnerability, resilience has been defined by way of "resilience of what to what" (Pasteur, 2011). Nevertheless, such a focused approach to resilience can diminish the system's ability to be resilient in other ways (Cifdaloz *et al*., 2010). Therefore, it should be defined in a way that encompasses all aspects "about coping with uncertainty in all ways" (Folke *et al*., 2009). Resilience gives more importance to the ability of any system to recover as well as make some alteration with time in order to adjust to a dynamic environment. As such, not only are the relative changes in shocks to be taken into consideration but how much change has occurred. In other words, the issue remains on the extent to which a system can be considered to have adapted before being regarded as a new system altogether.

For instance, in the agricultural sector, there are certain activities that can be adopted to enhance resilience to threats posed by an ever-changing climate. In the face of climate variability, farmers could decide to depend on new crop varieties that have proven to be more adaptable to climate change or improved farming systems already adopted successfully in other places (Epule *et al*., 2017; Pirttioja *et al*., 2015). Hence, the need to depend on the biggest base of agricultural resources becomes imperative for such an achievement. These agricultural resources are also subject to the impacts of climate change, yet they are very vital for adaptation.

Changes in climate have also threatened livestock production and smallholder farmers have enhanced techniques to manage this sector under extreme climatic conditions (Maponya & Mpandeli 2013; Menike & Avachchi, 2016). Farmers in Botswana practice shifting livestock activities and borehole rotation, water transportation to arid regions during dry periods and pollarding to preserve the tree cover and regularly (Stringer *et al*., 2009; Agrawal & Lemon, 2015; Clay & King, 2019). Livestock farmers in Tanzania and Uganda adopted management techniques such as selling cattle to reduce herds to manageable size with the focus on water resources, introducing new livestock breeds and growing new fodder crops (Zizinga *et al*., 2017; Kristjanson *et al*., 2012).

According to studies conducted in East Africa on climate change adaptation, the choice of diversification at the farm level is critical for income resources and food available for the household (Thornton *et al*., 2011; Kristjanson *et al*., 2012: Kihupi *et al*., 2015; Zizinga *et al*; 2017). Highly creative households engaged in diverse cropping and off-farm activities tend to be better off and food secure than those with less innovative and less cropping activities. Farmers in Southeast Asia have diversified their farming systems and introduced new varieties of sweet potatoes and vegetables, and supported rice yield (Krishna, 2011; Solomon & Rao, 2013).

It is thus necessary to maintain a varied genomic material that should include both indigenous and enhanced crop varieties. Mostly, such varieties have been specifically suited to certain conditions, and adopted for diverse uses. The preservation of genetic resources may increase the resilience potential of the whole system (Hou *et al*., 2015). The success of this potential effect is dependent on increased accessibility of the genetic resources to farmers who need them. Therefore, these elements establish "seed bank" that allow farmers to acquire the seeds they need. Regional coordination of seed rules and regulations can be crucial, especially where seed varieties must be moved to adapt to climate change (Mubiru *et al*., 2015; Nngumi, 2016; Adegnandjou *et al*., 2018; Makuvaro, 2018).

Institutional organisations are also engaged about the effects of climate variability and change and assist smallholder farmers in coping and adaptation strategies to effects of climate change. The government of South Africa supports farmers in provinces such as North West, Eastern Cape, Limpopo and Kwazulu-Natal by providing poultry farming, smallholder horticulture, for tomatoes growers to supplement maize and reduce poverty (Thomas *et al*., 2007; Oni *et al*., 2012; Maponya, 2013; Mpandeli *et al*., 2015). Farmers in Limpopo Province have created a maize cooperative association that addresses marketing risks and decreases transport costs. The Botswana government assists households in managing water shortages by installing inter-basin water transfer, improved water recycles and purchasing water from neighbouring nations (Stringer *et al*., 2009).

Vhembe District has witnessed extreme weather conditions in recent years. When the temperature is high, evapotranspiration increases. Temperatures can reach more than 38^0 C during summer. The average monthly maximum temperature can reach more than 35^0 C, especially during summer (Mpandeli, 2006). Vhembe District farmers have always applied different coping and climate change adaptation strategies in order to increase production during drought periods. The coping strategies include adjust fertilizer inputs, crop diversification, food preservation and destocking during uncertainty periods

2.9. Indigenous knowledge in the context of climate change

As global communities face climate change along with the emerging potential effects on the environment. However, it is crucial that decision-making regarding policies and actions be informed by the available information to combat these unknowns. There has been a growing consensus among climate experts in the 21st century that exclusive formal scientific knowledge is not enough in dealing with the climate catastrophe (Kalanda-Joshua *et al*., 2011). The knowledge of indigenous communities normally denoted as local, indigenous or traditional knowledge, is being gradually recognized as a significant basis for climate knowledge and adaptation methods. This information, previously seen as fundamental across various fields that include sustainable development, agroforestry, traditional medicine, biodiversity conservation, soil science, and natural resource management, is expected to contribute significantly in enhancing adaptation to climate change and variability.

Intergovernmental Panel on Biodiversity and Ecosystem Services define indigenous and local knowledge as the “multi-faceted arrays of knowledge, know-how, practices and representations that guide societies in their innumerable interactions with their natural surroundings (IPCC, 2007; 2013). This interplay between people and place has given rise to a diversity of knowledge systems that are at once empirical and symbolic, pragmatic and intellectual, traditional and adaptive”. The United Nations, Educational, Scientific, and Cultural Organisation says IKS refers to the “understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. For rural and indigenous peoples, local knowledge informs decision-making about fundamental aspects of day-to-day life (Maponya, 2012; Akullo *et al*., 2013; Jiri *et al*., 2016). This knowledge is integral to a cultural complex that also encompasses language, systems of classification, resource use practices, social interactions, rituals, and spirituality. These unique ways of knowing are important facets of the world’s cultural diversity and provide a foundation for locally-appropriate sustainable development”.

According to Berkes (2012), indigenous knowledge, traditional, local knowledge, and ecological knowledge are defined as “a cumulative body of knowledge, practice, and belief, evolving by adaptation processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with their environment.” The various names were adopted to co-exist in the literature in the thesis. They include local knowledge, indigenous knowledge, traditional knowledge, farmers' knowledge, ethno-science, folk knowledge and indigenous science. Although this knowledge has different connotations from one local community to another, they have enough consistent meanings that are used interchangeably throughout this thesis.

However, indigenous knowledge, which is of importance to climate change and adaptation, can be found within local communities in South Africa (Maponya & Mpandeli, 2013; Jiri, 2016; Masinde & Bagula, 2016). Ethno-science knowledge is transferred and renewed from generation to generation, ensuring the livelihoods of the local population by ensuring food security, environmental preservation, and early warning systems for disaster risk management (Nganzi *et al*., 2005; Ogallo, 2010; Jiri *et al*., 2016). Local knowledge is considered as social capital for the poor people for food production and to enhance survival. Furthermore, indigenous knowledge system (IKS) is particularly important as it provides attainable solutions in dealing with and adapting to climate change (Nyong *et al*. 2007; Adeoye *et al*., 2013; Ncube & Lagardien, 2015). Such information is easily incorporated since it originates from the local communities and points out that indigenous knowledge enhances environmental resilience from the local level (Kalanda-Joshua *et al*., 2011; Berkes, 2009). Jiri *et al*. (2015) noted that oral history by the elders of the local communities is important in understanding the progression of climate change and how this is perceived by the local farmers.

2.9.1. Indigenous knowledge and climate adaptation

Indigenous knowledge systems for adaptation to climate change have recently been recognised at the international level. The IPCC fourth assessment focuses on climate change adaptation and further attention was on effects and responses at the national, province and local levels and the indigenous knowledge support (IPCC, 2007). However, climate change is a cross-cutting issue which negatively affects all sectors of the population, especially local communities due to their dependence on climate sensitive agricultural activities. Therefore, there is absolutely nothing new about climate change to indigenous communities. The communities have developed both coping and adaptation strategies that have been transferred from generation to generation. The IPCC confirmed at the 32nd conference of the IPCC in 2010 that "Indigenous or traditional knowledge may prove useful for understanding the potential for certain adaptation strategies that are cost-effective, participatory and sustainable" (IPCC, 2010). Hence, studies in Sub-Saharan Africa revealed that indigenous farmers highly depend on rain-fed agricultural activities and environmental based resources which are more climatic sensitive but with inadequate adaptive capacity (Thornton *et al*., 2008; Hassan & Nhemachena, 2008). However, a lot of literatures have indicated that there is much to learn from traditional-based methodologies to climate change and adaptive capacity (Berkes, 2012).

There are various indigenous coping and adaptation strategies to climate change that have been formulated by rural communities. They are designed in a way that meets the local farming system. An assessment of indigenous coping and adaptation strategies in Kenya found that farmers have identified a variety of methods employed for better livelihoods (Kimani *et al*., 2014; Ogallo, 2010). These include livestock transfers to wet areas during the dry period, diversification of cattle and crops; herd changes through sales or herd separation, use of traditional seeds; specific food storage techniques and controlled food rations during food shortage season (Akullo *et al*., 2007; Ncube & Lagardien, 2015; Masinde & Bagula, 2016).

Smallholder farmers across the world adopt numerous methods to aid them in ensuring that there is as minimal susceptibility as possible to the changing climate variables. The advances in early warning systems utilised in predication of climatic hazards together with the vast indigenous knowledge has been vital in reducing the vulnerability to climate shocks (Gbetibouo, 2009; Chanza, 2014; Jiri *et al*., 2016). This has allowed farmers to come up with complex schemes of obtaining, managing, forecasting, analysing and decision making as far as the weather is concerned. For instance, Egeru (2012) studied the Teso sub-region of Uganda to evaluate how IKS have been used by farmers to predict weather. Findings indicate that by determining the intensity of the easterly winds or cloud colour, farmers were able to predict rainfall situations. Consequently, the use of these indigenous methods in weather prediction can be argued to be very helpful for local farmers particularly in minimizing their level of vulnerability.

Many studies in Sub-Saharan Africa have indicated that climate change disturbs the capacity of local people in utilizing natural resources (Krisha, 2011; Egeru, 2012; Adeoye *et al*., 2013). Smallholder farmers have been adapting to past natural changes from generation to generation using traditional knowledge (Beckford & Barker, 2007; Gyampoh *et al*., 2009). This indigenous knowledge is free and easily accessible to smallholder farmers and can be a crucial strategy towards sustainable growth (Odero, 2011). Nevertheless, ecological issues are naturally localised and spatially differentiated from one area to another, temporarily and agronomical (Krishna, 2011; Chanza, 2014; Debela *et al*., 2015). Whereas, smallholder farmers, through continued experimentation, trial and error with their local environment, have developed traditional knowledge which they used in coping against climate change (Krishna, 2011; Beckford & Barker, 2007; Maponya & Mpandeli, 2013; Jiri *et al*., 2016).

Smallholder farmers in developing countries deal with the impacts of anthropogenic and natural climate change by engaging indigenous traditional farming systems as a strategy to adapt to climate change and variability (Odero, 2011; Masinde & Bagula, 2015). Through the constant interaction between the local farmers and their environment, it has been possible for the farmers to acquire experience on crop production, including resistance to reduced soil moisture content, increased heat and pest and diseases varieties; new water harvesting technologies to cope with decreasing water; soil water preservation; soil conservation done by minimum tillage and other practices methods (Adeoye *et al*., 2013; Ncube & Lagardien, 2015). In addition, the following have also been practised; the control of fragile soils; food storage and preservation techniques such as fermentation, herbal plants, sun drying and smoking to ensure food security and preservation for a longer duration; indigenous seeds selection less vulnerable to pests and diseases and tolerant of higher temperatures and resistant to drought effects, intercropping and diversification of crops; weather prediction systems through early warning systems to determine short medium and long term climate variability and changes and expected impacts such as floods, drought and storms; change of diet preference; control and management of crop pests and diseases; and management of food shortages through the identification of emergency crops/food like local and wild edible fruits and vegetables to ensure survival during food shortages (Gyampoh *et al*., 2009; Odero, 2011; Debela *et al*., 2015;). It is noteworthy that lively and active interactions of the households and their environment have been observed to be instrumental in making informed decisions relating to their environment and the possibilities that it can provide for their living.

As one way of managing the impacts of increasing higher temperature conditions and heat waves, smallholders' farmers employed intercropping of heat-tolerant plant and early-maturing crops, with a short cycle of harvest, (Below *et al*., 2010; Dankelman, 2010; Kalanda-Joshua *et al*., 2011; Biggs & Moya, 2012). By practising intercropping, farmers grow a mixture of crop varieties together on the same field in a single growing season but harvest at different times (Mpandeli, 2006; Altieri & Koohafkan, 2008; Debela *et al*., 2015). Altieri & Koohafkan (2008) showed that beans and maize may be planted in the same farm, but beans are planted in the middle of the growing season and harvested before the maize. In North China, traditional early-maturing maize is intercropped with late wheat; something commonly practised (Debela *et al*., 2015). Traditionally, the practice of mixing crop varieties is important to smallholder farmers, and especially so for subsistence food production, as it can delay the beginning of diseases, reduce the spread of disease-carrying spores and create less favourable conditions for the spread of certain pathogens (Kijazi *et al*., 2013; Gukurume, 2014). The traditional method does not employ or require the application of organic fertilizers, insecticides or advance technologies farming methods (Altieri & Koohafkan, 2008; Biggs & Moya, 2012).

According to Denison & Wotshela (2009), Ncube & Lagardien (2015) report that really indigenous knowledge are rare in South Africa and further documented that most of the traditional knowledge practices were imported from “Outside”, as it is noted that “outsiders” settling in South Africa also employed indigenous activities. A lot of literature has illustrated how the European settlers adopted indigenous tree’s skins and leaves as strategies to cope with drought in the arid provinces in South Africa including Vhembe District (Farrell et al., 2009). Alcock (2010) used a method that covered indigenous knowledge and weather folklore to gather indigenous weather indicators for South Africa. The knowledge system covers different traditional groups in South Africa. Further, Mpandeli & Maponya (2013) in their studies in Vhembe District documented that local farmers are beginning to adopt and use indigenous knowledge indicators as an instrument for weather forecast during farming.

2.10. Overview of the Sustainable Livelihoods Framework (SLF)

The SLF forms the core of the Sustainable Livelihoods Approach and serves as an instrument for the investigation of people’s livelihoods. It provides a useful guide for the analysis on livelihoods based on capabilities, assets and activities required to make a living. Livelihood assets and capital are used interchangeably as they are an important component of the SLF because they form the strength upon which people construct their livelihoods and achieve their goals.

Therefore, the Sustainable Livelihood framework is an attempt to go beyond the narrow conventional approaches which have focused only on certain aspects of poverty, such as low income excluding other aspects such as vulnerability and social exclusion. The framework pays more attention to the various factors and processes which either constrain or enhance poor people’s ability to make a living in an economically, ecologically, and socially sustainable manner (Krantz, 2001)

A livelihood is a composition of five basic capital assets serving different functions necessary for a means of living. Someone within a livelihood is entitled to these various assets by social relations, institutions, and organizations. Some authors combine physical capital and financial capital into one single category, known as economic capital (Scoones *et al.,* 2012). However, due to differences in their nature, in this study they are treated as separate entities independent of each other. In addition, the access mechanisms are equally different. Both physical and financial capital access can be supported by cooperative actions through organisations. The SRL Framework also allows considering correlated levels of investments with the potential to directly influence or improve the capacity of smallholders to invest them, increasing their capabilities through social relations, institutions, and organizations that provide increased opportunities to individuals. This means considering several types of collective investments: (i) collective level investments in landscapes and resource management, (ii) collective investments to improve access to markets – cooperatives, associations, (iii) socially oriented collective investments (self-help groups, etc.), (iv) corporate and private stakeholders' investments upstream and downstream; and (v) public goods.

2.10.1. Livelihood assets

Ellis (2002), drawing from the work of Chambers & Conway (1992), define the concept of livelihood as "the capabilities, assets including financial, human, nature, social and physical which required activities for a means of living". Solomon (2014

Assets are of special importance for empirical research to ascertain if a community has the capability of escaping from poverty. The evaluation of the five livelihood assets or capital which are human, social, natural, financial and physical capital is key to ascertain the sustainability of livelihoods (Turner, 2009; Prowse, 2010; Van Dijk, 2011).

2.10.2. Natural assets

There is a strong relationship between access to land and other natural assets, particularly water. Water is one of the most binding constraints on smallholder farming investment, especially in semi-arid and arid areas. The vulnerability of the poor farmers' livelihood in less developed countries is largely influenced by the inaccessibility of natural capital resources (Magombo *et al*., 2011). However, the vulnerability framework includes shocks and trends as a manifestation of natural processes that destroy natural assets.

2.10.3. Human assets

In addition, human capital comprises of knowledge and labour. It is required to make use of any of the four other types of capital assets. The human assets in the context of rural development consist of agricultural knowledge and ability to work, which enable the underprivileged households to pursue several livelihood strategies to achieve their livelihood outcomes. Several studies reported that measuring human capital asset at household level requires information vis-à-vis household size, skill levels, health, education level and leadership potential (Gaillard *et al*., 2009; Magombo *et al*., 2011).

Further, human asset appears in the generic background as a livelihood capital, that is, as a building block of achieving livelihood results. Its accumulation can also be an end. Many societies regard ill-health or lack of education as core dimensions of poverty and thus overcoming these conditions may be one of their prime livelihood purposes (Monica, 2013). The livelihoods method seeks to promote choice, opportunity, and diversity to achieve livelihood objectives. This is nowhere more apparent than in its treatment of livelihood strategies – the overarching term used to denote the range and combination of activities and choices that societies undertake to achieve their livelihood aims consist of productive activities and investment strategies (Magombo *et al*., 2011).

Furthermore, recent discussions have drawn attention to the enormous diversity of livelihood strategies at every level within geographic areas, across sectors, within households and over time. Piya *et al*. (2011) identified the main drivers of human capital strategies diversification, the agricultural intensification (poor expand their livelihoods from agricultural activities), intensification (which refers to more outputs per unit area gain through capital investment in farming or multiple in labour inputs) and intensification (which is explained as the ability of the poor to bring more area under cultivation) and livelihood diversification (Scoones, 2009). Nguthi & Niehof (2008) claims that agricultural intensification is an increase in average input on labour or capital on a smallholding, either cultivated land alone or on cultivated grazing land for increasing the value of output per hectare.

2.10.4. Financial assets

According to Colvin & Schroeder (2012), the society uses financial resources to achieve their goals and comprises the availability of cash in stocks or regular inflows of money, which enables people to adopt different livelihood strategies. In the case of smallholder farmers, there is an urgent need to improve financial services and the banking organization so that they work more effectively for agriculture production. Most smallholders in the developing countries have limited or no access to financial capital other than in informal ways, which tend to be enormously expensive and very limited. Furthermore, microfinance in the Developing World has not proven to be an effective tool to support investment in smallholder agriculture.

Therefore, this situation particularly affects financial asset for medium- and long-term investments. Financial loans are also needed, insurance being a prominent one to create incentives for smallholders' farmers to invest more regularly. Regular inflows of cash include labour income, grants, or other transfers from the state or remittances (Morse *et al*., 2009; Petersen & Pedersen, 2010). To understand financial asset of the poor smallholder with a view to eradicating constraints of access, an analysis of various elements such as the source of income and means of access needs to be accompanied.

2.10.5. Physical capital

Physical asset comprises the basic infrastructure and producer goods needed to support livelihoods, whereas, infrastructure consists of the physical milieu that help societies to meet their basic desires and to be more productive. Infrastructure is also considered as those tools and equipment that people use to function more effectively (Murambadoro, 2009; DFID, 2000).

Infrastructure as a physical asset includes roads, rails, and telecommunications which are key to the integration of the inaccessible areas where many of the poor live. Not only are the population able to travel between rural and urban areas more easily if the transport infrastructure is good, but they are also more likely to be better informed about opportunities available to improve their living standard (Murambadoro, 2009; DFID, 2000). For example, without transportation infrastructure, essential farm products cannot be distributed effectively, agricultural yields remain low and it is then difficult and expensive to transport limited products to the market. The increased rate (in terms of all types of capital) of production and transport means that producers operate at a comparative disadvantage in the market.

2.10.6. Social capital

There is a strong relationship between 'the poor's livelihoods growth and institutional arrangements. Duncombe (2006) described social capital assets as the characteristics of social organisations and their connectedness that increase people 's trust and ability to unite members in a more formal way by their system of rules, cultural norms and sanctions. In relation to social capital assets in the context of a livelihood culture, it is defined "*as a structure,* function, product and identity, through its influence on everyday lives of people and accordingly people's engagement with and uses of culture*"* (Daskon, 2010). These are the social networks through which members can source assistance in order to achieve their desired livelihoods.

Ultimately, livelihoods assets are diverse resources that are manipulated communally towards the desired needs of the poor using constructive and regulatory mechanisms as a strategy to sustain communal resources (Morse *et al.,* 2009). The determinant of access to the social capital can be through birth, age, gender or class and the membership can be different within the household (Daskon, 2010). To understand social relations as a key to sustainable and equitable access to social capital asset, Agrawal (2007) concludes that rules should be locally created for easy enforcement and the monitoring of compliance. According to Agrawal (2007), local can be expressed in terms of birth, residency, and contiguity of location as well as contributions to the creation of a local institution.

2.11. Climate change adaptation policies in South Africa

There were comprehensive set of policies that allow climate change adaptation within an environment in South Africa. These policies include the National Climate Change Response Strategy (NCCRS), the Integrated Rural Development Programme (IRDP), the Agricultural Policy, and Land Redistribution for Agricultural Development Policy on Agriculture and Sustainable Development and the National Agriculture Research and Development Strategy, amongst others. More importantly is the NCCRS, which provides an overall policy framework for climate change adaptation and mitigation at the national level (DEAT, 2010; DEA, 2015). The strategy offers comprehensive support to the policies and principles laid out in the Government White Paper on Integrated Pollution and Wastewater Management (2000), as well as other national policies such as those relating to energy, agriculture, and water (DEAT, 2010; DAFF, 2015).

However, in as much as the NCCRS highlights the potential impacts of climate change in various sectors, it fails to provide a persuasive analysis of the socio-economic implications of climate change (DEA, 2011; DEAT, 2010). Consequently, its proposed actions cannot cater for strategic interventions that would adequately build the resilience of the sectors and the economy against the impacts of climate change. Climate change will have an impact on economic growth, thus making it imperative to consider socio-economic vulnerabilities and adaptation responses at a policy level (DEAT, 2010).

Several restrictions surface in South Africa’s rural development strategies and poverty reduction policies. For instance, the South African land reform process is believed to have slowed down. Some argue that it has failed completely, and tensions observed between an appropriate development path at the macroeconomic level and the needs at a microeconomic level have been identified as being responsible for this failure. It is further hypothesised that the land and agrarian reform programme has failed to free itself of the effects on neo-liberalism (Bond, 2008; Mudhara, 2010).

Madzwamuse (2010) argued that although liberal policies with the potential to enhance adaptive capacities at various levels are in place, the issue of landlessness continues to compound poverty. Madzwamuse (2010) advanced that landlessness deters communities, especially in the rural areas, from access to a source of livelihood through farming and other land-based activities. Furthermore, landlessness diminishes poor people's capacity to use land as a reproductive asset. In addition, while a small number of women gained access to land through the Land Redistribution for Agricultural Development (LRAD) programme and other land reform programmes between 1994 and 2000 in South Africa, land reform did not take place at a sufficiently large scale to benefit the great majority of poor rural women.

The policy environment in South Africa is constantly shifting and these changes need to be considered in adaptation strategies simultaneously with time investment in a political drive aimed at renewing commitments towards sustainable development, equity and addressing some of the policy gaps highlighted above. Related to the agricultural policies is the initiative to develop the economy and to reduce poverty (Madzwamuse, 2010). Macroeconomic policies such as the Growth, Employment and Redistribution (GEAR) plan are said to have effectively denied the poor development opportunities and marginalized them from the economy. As a result, the poor were de facto excluded from one of the fundamental pro-poor responses to climate change (Madzwamuse, 2010).

2.11.1. Policy frameworks and climate change in South Africa

Various policy and regulatory frameworks guiding climate change governance exist in South Africa. These include key sectoral, national, and global policy instruments and other regulatory frameworks underpinning environmental protection and climate change governance processes in South Africa.

According to Mokwena (2009), South Africa has become decisively integrated into climate change and related environmental regimes at regional, continental and international levels by signing and/or ratifying a bewildering array of protocols, treaties, agreements and frameworks that guide its policies, programmes and strategies in this regard (see figure 2.1).

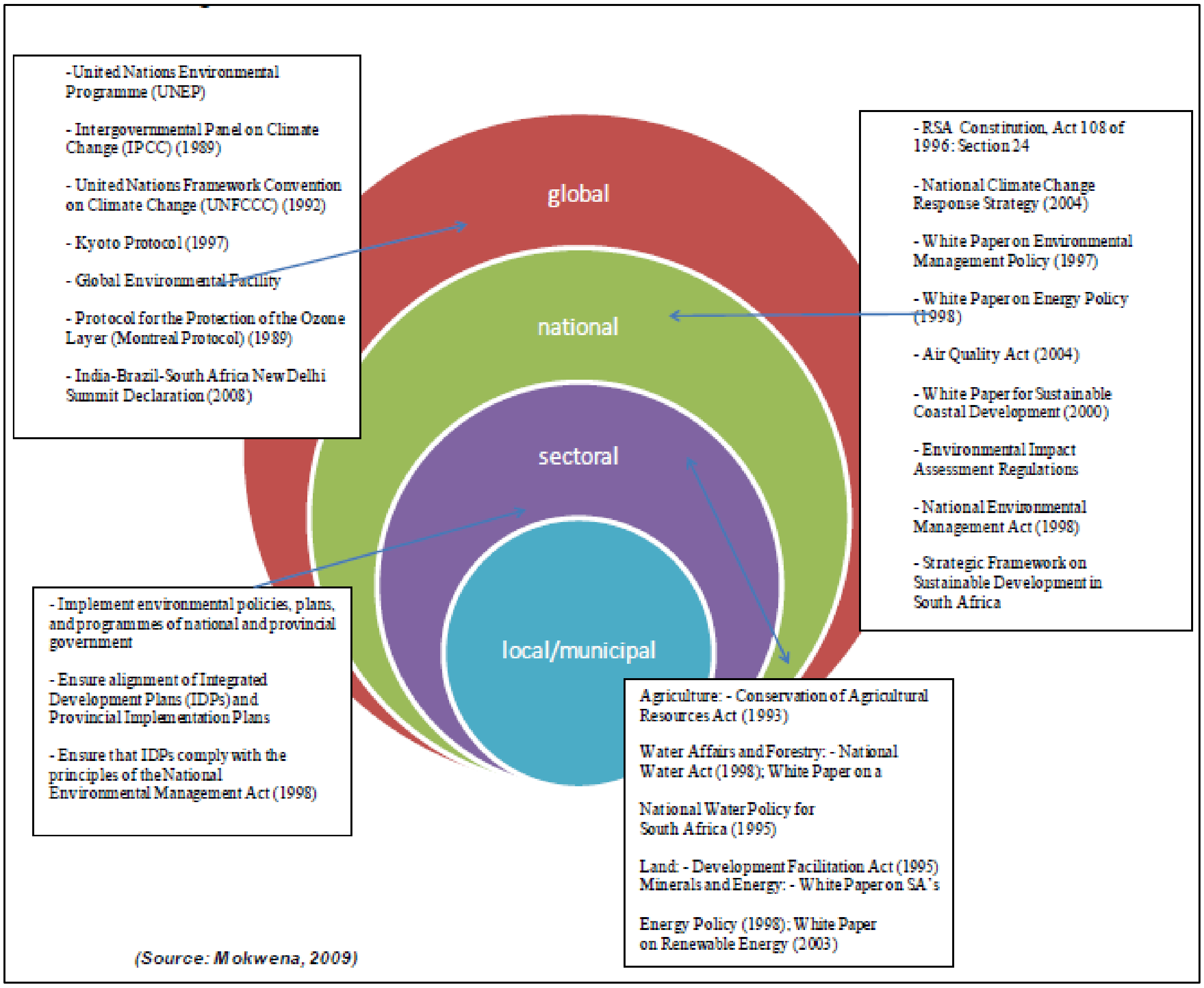

Figure. 2.1. A review of existing policies and legal acts related to climate change (Mokwena, 2009).

For example, in addition to being one of the signatories to the Kyoto Protocol, South Africa also has a trilateral agreement with India and Brazil, whose focus is strengthening the three countries' commitment to combating climate change and advancing the goal of sustainable development in these three countries (Mokwena, 2009; IPCC, 2013). Mokwena (2009) and DEA (2015) stated that with regards to national policies and strategies, the South African Constitution (Act 108 of 1996) provides an overall legal framework for government responses to the challenges of climate change and related environmental problems. In reference to the Bill of Rights within the country's Constitution, it is noted that the country's natural environment, together with the rights of South African citizens to access and enjoy a healthy natural environment are both promoted and protected (South African Constitution, 1996).

Evidently, for Mokwena (2009), the elaborate legislative and regulatory framework that is currently in place in South Africa is likely to be ineffective if the institutional mechanisms and financial resources meant to ensure implementation are ineffective (Mokwena, 2009; DAFF, 2015). Just as the international environmental and climate change governance regime are meaningless without nation-state mitigation and adaptation strategies, so are national legislative provisions that rely on one of the chief instruments for government policy implementation that is incapable of fulfilling this function (Mokwena, 2009).

2.11.2. Multi-dimensions climate change in South Africa

The seven dimensions of climate change is an initiative being led by South Africa, which provides a new framework for dialogue and action around climate change. The works on climate action cuts across the fields of science, policy, technology and finance. Therefore, empower nations to pursue low-emission development and boost their capacity to adapt and be resilient to climate heating. It is also necessary to implement the Paris Agreement, the world's roadmap for tackling climate change (Thomas, 2016). The contributions of the people of South Africa include, bringing science to policymakers, playing a leading role in transformative global partnerships, and helping dozens of countries develop national plans to cut greenhouse gas emissions. The multi-dimension of climate change includes;

- Science matters because climate change is occurring as results of anthropogenic activities which poses significant risks, in many cases, it is already affecting a broad range of human and natural systems. The compelling case for these conclusions is provided in advancing the science of climate change because it is the closest thing, we have to an objective reference point for debates that might otherwise lack grounding (UNEP, 2017, Chris & Keuk, 2018).
- Law acts as an authoritative bylaw at scale. Our best hope for rapid climate mitigation still lies in international law, ideally with agreement on a global carbon budget and national commitments commensurate with the need to keep most of our remaining fossil fuels in the ground (IPCC, 2016; UNFCCC, 2015). However, law assist to administer effective carbon taxes, to reinterpret the fiduciary duty of trustees to balance short-term shareholder value with longer-term risks, and perhaps even to create the crime of "ecocide" that could, for instance, help to limit deforestation (IPCC, 2016; DoE, 2017; Reddy et al., 2017).
- If we considered economy, capitalism is the planet's operating system, and given the time constraints, there is need for us to respond to the climate change problem from within the

system that created it. That means following capital flows, recognising the harm they can do and rapidly redirecting them so that they help us move towards a viable future. In practice that means divesting from fossil fuels and reinvesting in renewables, while transparently linking growth strategies to ecological constraints (UNFCCC, 2015; IPCC, 2014; DoE, 2017).

- As considering technology, we need innovative forms of creating, storing and transporting energy urgently. However, while we think of gadgets as speeding things up, the process of technological development from basic research through to intellectual property battles to commercialisation can be painfully slow. The time-sensitivity of the climate challenge calls for an acceleration of the most needful forms of technological advancement (UNFCCC, 2015; Reddy & Peta, 2017).
- Democray is important as it is a mechanism for making collective decisions, and climate change is the biggest collective action problem of all time. On the one hand, short electoral cycles militate against the kinds of long-term thinking that climate change requires. On the other hand, if we can mobilise the requisite political will in civil society, politicians will follow with the appropriate regulation and market signalling (UNEP, 2017; Anna & Morris, 2018).
- Our culture plays a vital role because its response to climate change is informed by everything from its place in formal education to implicit consumerist values in advertising to how the media frames judgments on systemic risk as scientific “uncertainty”. Culture is the ideological dimension where the battle for the relative importance of climate change compared to other priorities has to be fought and won (Fuhr et al., 2018; Wolpes & Reddy, 2015).
- Behaviour matters in climate due to climate-related human behaviors and Institutions. Some examples include; improved understanding of human behavior and decision making in the climate context, institutional impediments to limiting or adaptation responses, determinants of consumption, and drivers of climate change (UNEP, 2015; UNFCCC, 2015; Anna & Morris, 2018).

2.12. Conceptual framework

Figure 2.2 illustrates the conceptual framework which guides this study: it focuses on the impacts of climate change on smallholder farming and adaptation strategies employed by the farmers. Smallholder farmers need to have information and knowledge about climate change before making any decision for adaptation based on their perception of the negative effects as well as policies on climate change. Adaptation is due to result of depending on rain-fed agriculture practice by smallholder in response to the stressor. If reducing current vulnerability is the starting point to adaptation, then poverty reduction is essential to the process, by understanding the dynamics of livelihoods. Therefore, for better adaptation towards the impacts of climate change, there is a need for the government to put in place policies in a bottom-up approach that will support smallholder farmers adapting to climate change and sustainable livelihood at the farmers level.

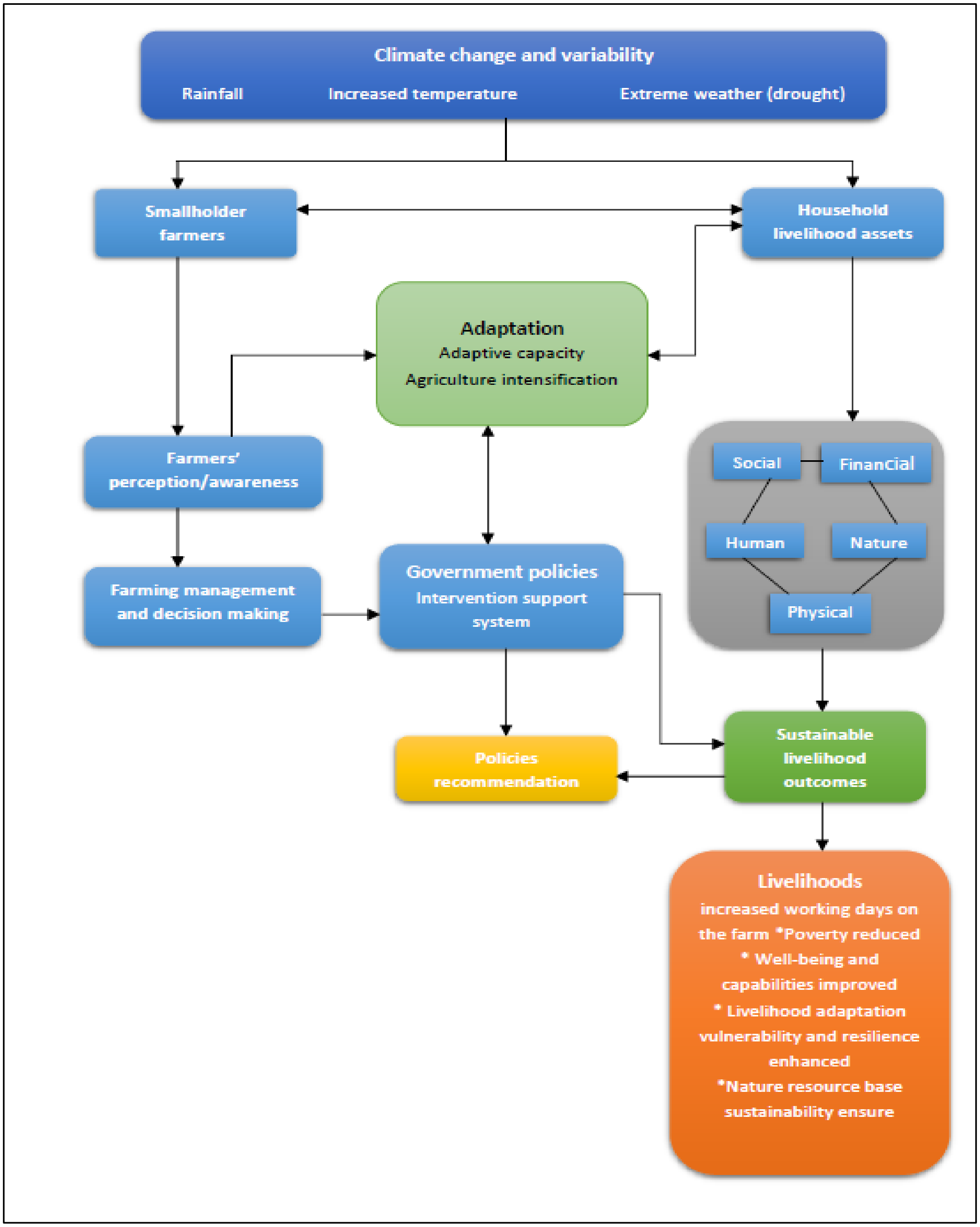

Figure. 2.2. Conceptual framework (Adapted and modified climatic and livelihood framework by Scoones & Chambers (2009).

2.13. Summary

This chapter focused on the concept of climate change, effects on local farming, as rain-fed agriculture activities is the mainstay of economy back-bone and households' primary source of livelihoods. The chapter further assessed the literatures on smallholder farmers' perception and knowledge to climate in the agricultural sector, smallholder farmers' vulnerability to climate change; also employing indigenous knowledge systems (IKS). Furthermore, it also brought to light information in terms of the theoretical framework it examined. Despite these climate change challenges, South Africa, through national and local levels, is determined to combat climate effects on local crop production; hence, implementing adaptation policies strategies. This literature chapter lead to the next chapter that draws detailed philosophy of the study design and research methodology employed in this thesis.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Introduction

This chapter describes the methods developed and employed in addressing the various questions developed from the research main aim; which is "*to assess the impacts of climate change and adaptation strategies on smallholder farming in Vhembe District, South Africa*". Therefore, to unpack the research aim, it was suitable to find techniques that enable the study to capture data on vulnerability in the face of smallholder farmers' social livelihoods and climate stressors. This study therefore selected a descriptive research design that utilises the elements of both quantitative and qualitative methodology with more focus on Participatory Rural Appraisal (PRA). PRA is a set of participatory visual techniques for assessing group and community resources.

This chapter also aims to justify the entire research process including the methodology and methods, so, that when the study presents the results and findings of the research, they will be based on the design and methodology.

3.2. Research Design

This study adopted a mixed technique of Participatory Rural Appraisal and descriptive research design, which was employed to gather data on the impacts of climate changes on smallholder farming system for the past three decades, and adaptation strategies to climate change. Johnson *et al*., (2007), review that, during research procedures; gathering both PRA and other qualitative and quantitative data enables the complete realisation of the research problem. The main reason for using qualitative approaches is that, the approaches emphasise observations about the natural environment and capture social life as it is experienced and perceived by the smallholder farmers rather than the numerical representations of the categories predetermined by the study. Hence, a single PRA or quantitative methods are individually limiting in achieving the study objectives due to the complexity of climate change issues in crop productions and farmers' livelihoods. However, when both strategies are employed in combination, they complement one another which allow for added complete analysis (Johnson *et al*., 2007)).

The purpose of using descriptive research techniques was to determine the smallholder farmers' adaptive strategies, as well as farmers' choice for adaptation to climate change impacts. Therefore, data were gathered from farmers' socio-demographic attribue and perceptions of climate variability and change. The study further separates variables and relates them in determining the nature and direction of relation. In each case, the study delimits which factors to survey and the instruments for collection and analysis of data, to encourage validity and affect tallies (Creswell, 2009; Leedy & Ormrod, 2010).

The study represents a paradigm shift in social research toward Participatory Rural Appraisal with descriptive design which attempt to achieve a holistic understanding of behaviour, knowledge, perceptions and understanding the concept under study. Thus, data were collected using focus group discussions (see Appendix E) and semi-structured interviews (See Appendix B) from smallholder farmers to probe farmers' perceptions and knowledge about climate change.

The analysis of data is based on the subjective nature reality due to each farmer's point of view. Therefore, "it produces an understanding of the problem based on multiple contextual factors" (Miller & Brewer, 2003). Moreover, during systematic walks and observation, the researcher shared indigenous knowledge systems about climate change among smallholder farmers in Levubu, Tshiombo and Nwanedi area (See Appendix D), further, to enable extension officers and agricultural scientists to put together appropriate intervention methods for a better livelihood among local farmers. Figure 3.1 illustrate the research design flow chart methodology.

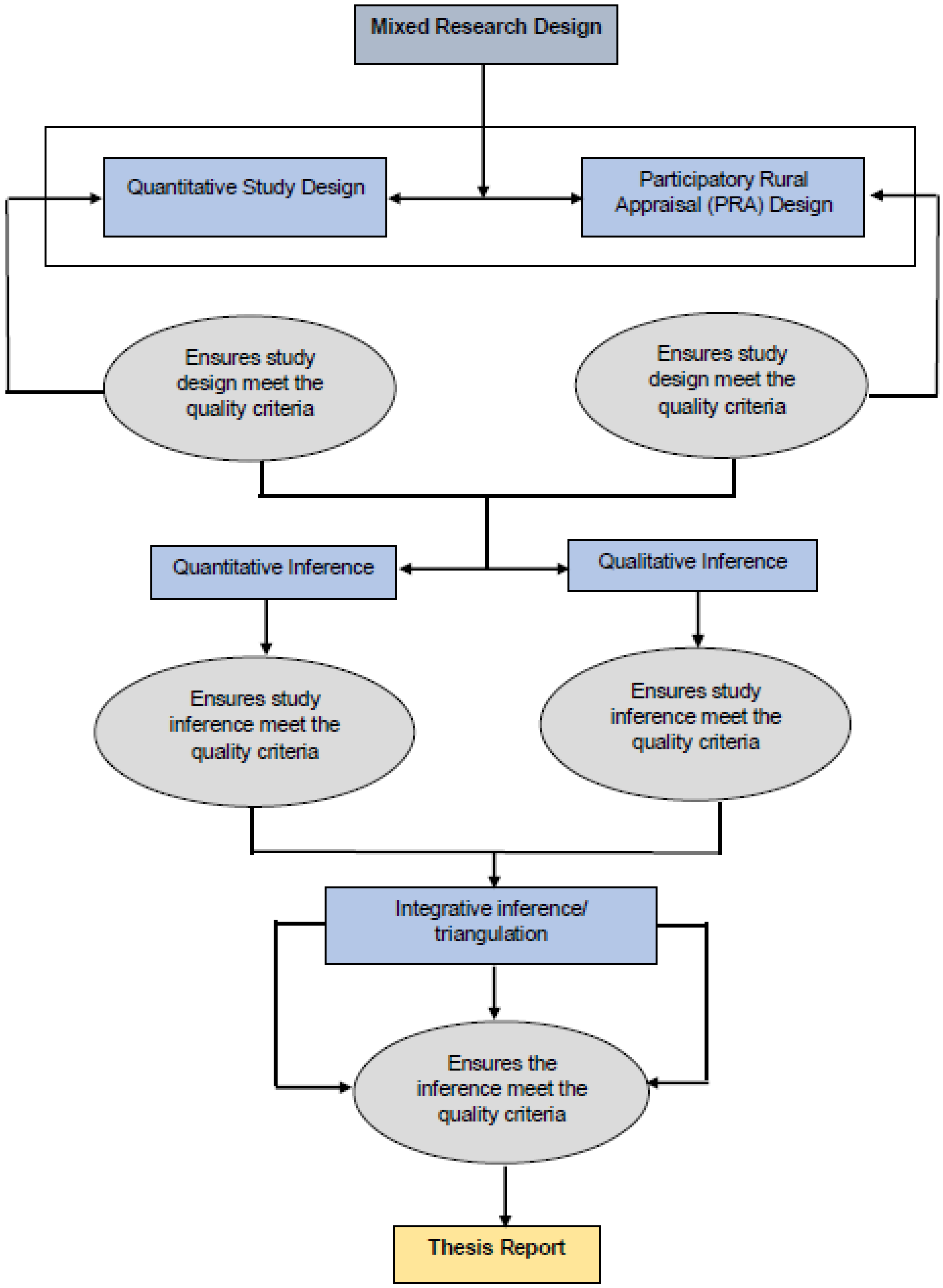

Figure. 3.1. Flow chart of research design and methodology

3.3 Motivation for choosing the study area

The project was conducted in Vhembe District, as the majority of community members' in the district are operating on small hectares of land although there are commercial farmers especially in Levubu and Nwanedi areas. Several studies have shown that, farmers in rural South Africa are concerned with negative climate change impacts especially on crop production. Bocanegra-Martinez *et al*., (2014), reported that, persistent prolonged dry spells as a result of changes in climate, poor planning and lack of political will and commitment are the major causes of poverty and equality among smallholder farmers. The rural Vhembe District is one of those districts where smallholder farmers lack knowledge about climate change issues, experience low crop production from rainfed agriculture and have high poverty level in South Africa. The smallholder farming system in the district is characterised by both intensive and extensive farming rain-fed. The final selection of the three case study sites which are; Levubu, Nwanedi and Tshiombo were based upon feedback and comments during a pilot visit, where, large proportion of land parcel was used for smallholder farming system and farmers amidst harsh climatic conditions and poor harvest. As much as the land was receiving annual rain of about 400mm to 500 per annum (Kabanda, 2011; DAFF, 2013; IDP, 2014). This low annual rainfall in the Vhembe District causes limited and shortages of water with frequence drought weather conditions.

Most smallholder farming activities in the district depends mostly on seasonal rainfall with some smallholder farmers using furrow-irrigation system to irrigate crops especially in Tshiombo and Nwanedi areas. However, any adverse variations in precipitation and temperature have a large effect on crop productivity and farmers' livelihoods in the community with an active agricultural economy. The geographical context and the Soutpansberg mountain range in the district municipality, makes it frequently prone to dry spells, which often grow into severe extreme climate conditions such as drought and semi-aridity (Maponya & Mpandeli, 2013; DAFF, 2013; Mpandeli *et al*., 2015).

3.4. Sample technique and unit of analysis

This sub section focuses on the details of the target smallholder farmers practicing smallholder farming system, data were collected using a sampling frame as well as sample size selected from the smallholder needed in the study area. Inferences were drawn from farmers' perceptions, knowledge and adaptation strategies characteristic of the study area. It was not possible to survey the entire farmers in Vhembe District practicing smallholder farming hence a representation unit of 224 sample of the farmers were selected from three study sites. Some of the results can be deduced to the entire District, while others are context dependent.

The unit of analysis for the study was smallholder farmers located in Vhembe District This District was selected as a result that households' farmers for the past 15 to 30 years have observed extreme meteorological weather occurrences. Mpandeli (2014), reported that a large portion of smallholder farmers in Vhembe District, are extremely vulnerable to all sort of climatic shocks, due to lack or low education background (see chapter 5). Therefore, it is challenging for them to access technology knowledge, they have poor financial resources and assistance, smallholder farmers have a low level of resilience resulting in low adaptive capacity.

A total of 224 farmers as the sample size were used to reduce cost and time expenses due to the geographical constraints of the participating farmers' dispersed households. The ideal level of accuracy principles was employed to determine the suitable sample size; however, levels of confidence of 95% and 5% of truthfulness were used to choose the sample size for the study's objectives. To minimize bias and errors as well as to increase soundness so that inferences can be gotten forms the entire target farmers. Therefore, this study has employed a statistical equation (1) to calculate the sample size from the target farmers. The Cochran equation was adopted to ascertain the sample size for this research, according to Godden (2004), as indicated in equation 1 below.

$$n = \frac{Z^2\, p\,(1-p)}{e^2}$$

Where: n = sample size

Z = z Value (1.96 at 95% confidence level)

p = Estimated proportion of sample (assumed to be 30%)

e = Margin of error (assumed at 0.07)

Henceforth: $n = \frac{1.96 \times 1.96 \times 0.3(1-0.3)}{0.0049}$

= 224

The study employed purposive sampling of the 224 smallholder farmers in the study area and the sample size was proportionally divided among the three study sites. A total of 68 participants were from Levubu, 79 from Nwanedi, whereas, 77 participants were from Tshiombo. Criteria to select the participating sample were set as follows: the respondents were individual smallholder farmers, practicing crop production, producing for subsistence and the excess for sale, with high level of dependency on rainfall for planting and farm size ranging between 1 to 8 hectares and also farming experience.

The sample size was obtained from local farmers by selecting every Z, where X stands for the total number farmers at the study sites and n was the sample size preferred (Saunders, 2011). For this study, sample size is needed to reduce costs and time, and environmental limitations of the dispersed farmers. To determine precision and accuracy, criteria were used to determine the appropriate sample size. This study used 95% and 5% confidence level of correctness for the survey. However, this was used to reduce bias and increase validity, so that inferences can be made for the whole target unit of analysis. Therefore, a total of 236 questionnaires were administered. However only 228 were collected from the respondents and 224 questionnaires were effectively completed and used for analyses. The contingent of farmers in the study sites, helped in the number of questionnaires to be administered. The farmers' household heads were expected to respond to questions on climate change and variability as perceived by them, for the past three decades (See Appendix A). Some of the items were; rainfall amount has increased during summer season; rainfall amount is the same for the past 30 years. There is a late start of rain fall, increased temperature, decreased temperature, the growing season seems to be shorter and there is high frequent drought.

A semi-structured interview was employed for data collecting. It was also necessary for the study to examine climate change impacts and smallholder perceptions at the study sites in Vhembe District Selected household heads were used by the study during the semi-structured interviews to answer the questionnaire. During the focus group discussions and interviews questions about household demographic attributes were asked for example regarding farming experience in 15 years and above, age of household head, educational level, gender and household income. The data collected during the group discussions and face to face interviews, farmers' perception and knowledge from questionnaire were triangulated. The local language used by the farmers was TshiVenda. To maintain the credibility and a high standard of the project, members of the research team were Tshivenda native speakers with a good knowledge of local ethnicities in the areas under study.

There was a need for the research instrument to be pre-tested before the actual field survey with household farmers. Pre-testing was done some weeks before the field survey with the farmers. The main aim of this important exercise was to assess if the data collection tools were appropriate for collecting the required statistics.

3.5. Research assistants

Due to a large sample size of data collected, limited time and vast study area for the study, the study recruited research assistants, for the three sites (Levubu, Tshiombo and Nwanedi). The research assistants were also employed because the researcher could not speak the local language, Tshivenda. The assistants were recruited based on the meeting of the stipulated criteria. The individual must be a Master's student at the University of Venda, from the Department of Geography & GISc, and accustomed to the study environment and in-depth socio-cultural knowledge of the communities. These assistants were trained before conducting the data collection process.

The research assistants choosen for the study, have engaged and have some experience as field assistants. Their education background was taken into account, intellect and specialised carried out that expected to manage the challenges related with worth farmers' surveys data. Hence, keeping the credibility and standard of research all members of the research assistant team were Tshivenda native speakers and customs of the communities under research investigation and with good knowledge of the indigenous people.

Training: The training for the modified research tool was held in the first week of June 2017 at the University where all the RAs were present. The purpose of conducting the workshop was to ensure common understanding of the survey instrument by the team members, to promote data quality and the integrity of the findings. The benefits of the workshop were that the team members shared the same understanding of survey objectives and expected fieldwork outputs.

3.6. Data collections techniques

Data used for this study were collected from both primary and secondary sources. Secondary data were collected from journal papers, unpublished manuscripts, symposium papers and books. Further, meteorological data order from the SAWS was used to show long-term variations and climate change patterns from 1980 - 2015. This variation was to limit the callous work of scientifically showing the incidence of climate change as well as verifying information from farmers' perception, however utilizing available scientific data. While, agricultural information was requested from DAFF and was utilised for this analysis. Furthermore, primary data was gathered through questionnaires, semi-structure interviews, transect observations, oral history etc. Beside initial desk study, a wide range of primary data collections instruments were used as follows;

3.6.1. Field survey

In this study, field survey walks helped in observing environmental impacts of changes in climate, such as declining water volume in the stream and rivers, low crop production due to prolong drought conditions, household vulnerability to climate variation, adaptation methods. The overall field survey technique in this research has facilitated the study to establish a good picture of the study areas. Therefore, it was possible to formulate appropriate questions for each data collection instrument, for example questionnaire and interview guide for group discussion and key respondent interviews. The advantage of this field survey approach was preferred to accomplish the objectives of the study that focus on an analysis of climate vulnerabilities and farmers' adaptive strategies in the study area, as illustrated in chapter five.

3.6.2. Focus group discussions

This study further uses semi-structured interview questions to gather data through FGDs (see Appendix E). FGDs are employed to collect in-depth qualitative data about groups' perception, altitudes and experiences on a particular subject under study (Onwuegbuzie *et al*., 2009). Therefore, in this study, FGDS were employed to gather in-depth qualitative information on farmers household and stakeholders state of the local climate. As well as considering key changes in the farming system, adaptation methods and their sustainability, socio-economic consequences of the change in climate, policy implications, perceptions towards climate change, interventions and experiences towards climate change. One focus group discussion from each study area was conducted. In the group discussions smallholder farmers and extension officers who are familiar and assumed having experience on adaptation measure against negative impacts of climatic change in the research site were involved.

During focus group discussions, more attention was taken to intentionally interview individual farmers who were involved in practicing crop cultivation for more than 15 years. However, smallholder farmers were selected into groups on their experience, that they have been engaged in growing crops. Also, indigenous knowledge and idea of climate change which enable them to express their views freely. These group discussions were composed of both genders, so the group was not selected based on sex or educational level. Respondents were entirely made-up of smallholder farmers and extension officers.The participants in the focus group discussions were made-up of both genders, and they freely debate among themselves and challenged each other's opinions, without feeling victimised based.

3.6.3. Semi-structured interviews

Another key data collection instrument employed in this study was semi-structured interviews. It was done through verbal expression between interviewer and farmers. The study took the task of asking pertinent questions to seek necessary information related to the objectives of the study. Fontana & Fredy (1994), reported that, semi-structured interview as a procedure of data collection from the major respondents after considering a range of benefits accompanying with this instrument. This technique helps the study to have control and level of flexibility in respect to the administration of the interview.

This technique of data capturing was necessary, as it was used to examine the impacts of changes in climate on crop production and adaptive strategies in the study sites. The interview was done by selected representatives of each household. Smallholder farmers had to answer depending on their know-how, perceptions, awareness, experience and traditional knowledge in climate change conditions. Moreover, how climate change has influenced their livelihoods? Hence, farmers were requested to give a suitable time for the interview in a quiet environment, where the farmers can freely express their opinion without been influenced in their responses.

However, the main shortcoming of the technique was that, most respondents were unable to speak or understand English language. To solve this language dilemma, the study had to employ two field research assistants fluent in Tshivenda and English for translation – see section 3.6.5 (field assistant).

3.6.4. Questionnaire survey

In addition to in-depth and key informants' interviews, the questionnaire was another vital instrument that was used gathering data from the study area. Due to various advantages attributed to questionnaires, it was adopted to this study. In this study the population used was 224 out of 230 households' farmers were surveyed (See Appendix A). Lincoln & Guba (2000), refers to questionnaire survey, where the study poses specific questions of interest about the theme of the study and this frequently comprises planned analyses to assure that individual question of each respondents is questioned in the same manner.

Further, the survey questionnaires are sub-divided into sections according to theme as follows; demographic and socio-economic attributes of the participants from households addressing farmers' characteristics such as gender, age, marital status, household size, education level and annual household income. While another section is evaluating the major effects of changing climate. Furthermore, assessing farmers' perception of climate variability and change, also, investigating the adaptations strategies practices employed by smallholders' farmers of general climate variations (temperature and rain from 1980 – 2015 (see chapter 4 & 5).

Therefore, information was collected by asking smallholder farmers if they were conscious of the changing climate and how knowledgeable they are about the term 'climate change' for the past 15 to 30 years. They were asked about the perceived changes in climate patterns and climate change-related extreme events with categorical answers ('increasing', 'decreasing', 'no change etc.). Further, the Likert scale was also employed to evaluate perceptions. The study considered a recall period of 15 years for perceived changes. Similar studies have shown that smallholder farmers relate weather conditions to their individual knowledge of increasing occurrences of harsh weather conditions, such as flooding and drought, and associated risks with climate variations (Bell, 2012). Indigenous knowledge and local agriculture techniques are included (See Appendix D). Before general questionnaire survey for the three sites, a trial survey was carried out on 15 smallholder farmers having a common socio-economic context to verify the easiness with which farmers responded to all the questions, and to confirm that the questions are significant to this study and to approximate the period required to answer each survey questionnaire.

The questionnaire sought to draw demographic profile, socio–economic attributes of farmers, and perception of the state of local climate trends, consequent crops production changes and livelihoods of households, coping and adaptation strategies to climate change and sustainable smallholder's farmers' management system. Apart from the perceptions, local climate changes in the study area were of interest to investigate and analyse the drivers influencing smallholder farmers' views regarding their choice of adaptation. For the best adaptation strategies' choice by farmers, an Empirical Framework was used as choice of adaptation method, specifically, to establish a rapport between the probabilities of choosing an adaptation choice and the farmers.

3.6.5. Story telling

Bryman (2008) reported that storytelling can be used by the study during interviews with indigenous people and FGDs. This is a process in which indigenous people are asked to recount their past events and to reflect on them. The study employed an open-ended questionnaire, thus, providing farmers an opportunity to share their stories, and prohibited any probability of farmers expressing what they assumed the interviewee wishes them to say.

However, to ensure that indigenous farmers were able to offer a good historical perspective within the context of changes in climate variations from their local knowledge, only those farmers who were above 40 years were invited for the interviews. This age control was intended of getting a group of farmers who have been farming for more 15 years to date in the area and clearly understand the impacts of changes in climate parameters on crop yield for the past years.

Through this technique, data on past and present extreme weather conditions such as prolonged dry spells, drought and flooding incidences, IKS on state of local weather forecasts, types of traditional adaptation strategies and agricultural system were obtained and debated during the storyteller interview.

However, a time-limit of about 15 to 30 years of climatic change was used for data collection although some smallholder farmers were able to remember some event that happened between 1980 and 2000. Elliott & Campbell (2002) stated that the use of 30 years is required as it is the time period normally measured within the range of human remembrance.

Therefore, both qualitative and quantitative designs helped to provide the study conclusions (i.e. rational assumptions) on impacts of climate change and adaptation strategies employed by smallholder farmers in response to climate. As such, the study used a combination of quantitative and qualitative data collection inquiries to address the issue of data reliability and validity.

3.6.6 Documents survey

Document analysis included a literature review of published documents on the effects of changes in climate on smallholder farming system at the various levels. Also review linked between smallholder farmers' crop productions and their livelihood. In chapter 2, a detail literature survey was conducted to develop various important aspects and variable links with change in climate variations and interaction on smallholders farming system and corresponding to farmers' livelihood.

This research focused mostly on important aspects which were obtained from South Africa Weather Service (SAWS), South African Human Research Council (SHSRC), Agricultural Research Council (ARC) and governmental official data in Vhembe District and White Paper documents, which provided up to date information about the past and recent changes and variations of climate change and crop production in Vhembe District from 1980 to 2015.

3.7. Ethical protocols

This section was intended, so, that all ethical procedures are followed. All protocols for the safety of local farmers in the process of data collection were observed during the survey. Permission was given by the Vhembe District Department of Agriculture, local municipalities and the extension officers. Whereas, smallholder farmers provided oral and written consent before the beginning of each session (see Appendix below). This study is non-invasive and involves no risk to the communities involved in the study. All participants willingly consented to participate in the data collection process of the research. The smallholder farmers' security issues of data interviewees, questionnaires such as confidentiality, anonymity and consent for interview would be adhered to. Lincoln & Guba (2000) cited that, ethics customs for conduct that differentiate and stipulate acceptable and unacceptable actions.

It was necessary to obtain written permission from each local authority and the key respondents in the study (smallholder farmers, and traditional leaders and gatekeepers). Also, a letter of ethical cleareance was issued by the University of Venda, Research Ethics Committee (see Appendix) Project NO: SES/17/GGIS/08/1412, giving the right of the research team to conduct research activities throughout this period in the study area.

Another important ethical consideration was anonymity: the names of the farmers were kept secret. During several field surveys, the participants identified themselves by name. This is part of local culture of the Vha-Venda people. The respondents participated in this study willingly, that is, they were not forced in any way if she/he chose to stay anonymous. The household names were only used to clarify or verify data during the research field survey period.

Photographs of the subjects were therefore guaranteed to be protected and arrangements about how information was going to be handled, together with farmers' interest in controlling the access of other data about themselves.

3.8. Data processing and analysis

After the research team was done with data collection from the field survey, data processing and analysing data was the next step to be.

The mixed nature of the data meant that both parametric and non-parametric analysis software were employed, depending on the category of data collected. Qualitative data collected from smallholder farmers' interviews, focus group discussions, and field survey were coded, using Microsoft Excel 2010 statistical package Further, Cross-tabulation was made, particularly to assess multiple response questions. This permitted evaluation of different study limitations between Levubu, Nwanedi, and Tshiombo. As for the meteorological records, that is long-term rainfall and temperature variations, SPSS software was employed to analyse the data and graphical presentation is used in the results and discussion below.

Data analyses were also done using the statistical software package (SPPS 23). The results of the analysis were summarized and presented statistically as frequency tables, figures, charts, percentage distributions and tables. Policy analysis was obtained from related literature and Participatory Rural Appraisal (PRA) of Vhembe Districts and government officials. Both analysis results of in-depth interview information were used together, and results were presented in the following chapters (Chapter 4, 5 and 6).

The meteorological data were observed by grouping based on the respective study areas, and the representative data were taken for climate variation analysis of the study areas. Temperature and rainfall showed a long-term change. This data analysis uses SPSS software to perform a variation analysis and to simultaneously factor in seasonal components of rainfall and temperature.

Meteorological data collected from the metrological stations nearest to Tshiombo, Levubu and Nwanedi were used to compensate for the lack of weather stations in two selected areas. Levubu climate data was collected within Levubu, Tshakhuma, Entabeni and Vondo meteorological stations used for Levubu study site, whereas, climatic data collected from Tshipise and Messina meteorological stations was employed for Nwanedi study area and Tshiombo study site used data from Thohoyandou and Folovhodwe meteorological stations.

3.8.1 Multinomial Logit Regression Framework (MNL)

Multinomial Logit Framework (MNL) was employed to analyse the drivers influencing smallholder famers' choice of adaptation strategies to climate variations in Vhembe District MNL framework is used as methods of adaptation choice. Magombo *et al*., (2011), stated that the relationship between the probability of choosing and adaptation preference and the explanatory variable indicated Chapter five. This MNL regression framework was frame to the adoption choice of climate change adaptation, the study further indicated that, Multinomial Logistic regression framework have the advantage that it brings the analysis of adoption among several strategies of adaptation.

Let Z signify a random variable with values {*1, 2…J*} for a positive integer *J* and *X* set of variables. In this research, *Z* is a dependent variable and represents the adaptation ,choices methods from the set of adaptation measures, whereas, the *X* represents the dynamics that effect choice of the adaptation strategies which contains household attributes as described in table***, and *P1, P2…PJ* as associated probabilities such that *P1* + *P2* … + *PJ* = *1*. This tells how a certain change in *X* factors affects the response probabilities *P(y = j/x), j = 1, 2…J.* Since the probabilities must sum to unity, *P (Z = j/x)* is determined once the probabilities for *j = 2…J* are known;

$$P\ \left(Z = \frac{1}{x}\right) = 1 - (P2 + P3 + \cdots Pj) \quad \text{.................................... (Equation 1)}$$

MNL framework, it is usual to designate one as the reference category. The probability of membership in other categories is then compared to the probability of membership in the reference category. Consequently, for a dependent variable with j categories, this requires the calculation of j – 1 equation, one for each category relative to the reference category, to describe the relationship between the dependent variable and the independent variable. The choice of the reference category is arbitrary but should be theoretically motivated. The estimation of MNL framework for this study was conducted by normalizing one category which is named as base category or reference estate. The adaptation measures were grouped into eight because farmers used more than one strategy, and the base category was "No adaptation strategy". The theoretical explanation of the framework is that in all cases, the estimated coefficient should be compared with the base group or reference category. Therefore, the choice of the reference category is based on empirical literature and theoretically motivated. The generalized form of probabilities for an outcome variable with j categories is:

$$Pr(y_i = j|x) = pr_{ij} = \frac{\exp\,(x'\beta j)}{1+\sum_{j=2}^{j}\exp\,(x'\beta j)}\ , \quad j = 1, 2 \ldots J \quad \text{..................... (Equation 2)}$$

For $j > 1$

The parameter estimation of the MNL framework only provides the direction of the effect of the independent variables on the dependent (response) variable; estimates represent neither the actual magnitude of change nor probabilities. Differentiating Eq. 2 with respect to the explanatory variable provides the marginal effect of the independent variables which gives as:

$$\frac{\partial pi}{\partial xk} = pj\left(\beta jk - \sum_{j=1}^{j=1} pj\beta jk\right) \quad \text{... (Equation 3)}$$

Marginal effect of marginal probabilities is the function of probabilities and measures the expected change in probabilities where adaptation choice is being made by a unit change of the independent variable from the mean.

3.9. Summary

This chapter described the methodology and data collection instruments used for collected information among smallholder farmers. This chapter mainly focused on how to explore methods to achieve the specific objectives of the study, developed from the main objective, accessing the impact of climate change and adaptation strategies on smallholder farming in Vhembe District All the three study sites practice a smallholder farming system of crop production, but different types of crops are grown in certain sites due to changes in climate.

The research design adopted for this study is a mixed approach namely Participatory Rural Appraisal (PRA) and the collection of quantitative data; For this study, the period of 36 years from 1980 to 2015 was used. Accordingly, data collection mainly involved smallholder farmers' responses and some farm extension officers and was carried out form 224 sample smallholder households using questionnaires. Whereas, in-depth interviews, focus group discussions and transect walks, with the aim to compare with farmers responses. Further, weather data was collected from 6 meteorological stations located near the study sites and across the study areas.

However, in this study, data were collected using both methods, hence, a combination of data analysis methods were used. The questionnaire variables used for analysis where group, ordinal and the measurement variables were not normally distributed non-parametric tests chi-square (X2) tests were employed to show the association between independent and dependent variables. In the overall data analysis of the farmers' determinant choice of adaptation strategies to climate change was analysed using the Multi Nominal Logit (MNL) framework. The analytical tests in many places were supported by descriptive statistics, and this involved computation of percentages of single variables, the median and average outcomes. SPSS version 20 statistical software was used for analysis. The preceding chapter focuses on climate change analysis variations based on smallholder farmers' perceptions and meteorological data in the context of climate change and variability. However, the results served as an important input to the following chapters of the study as follows; perception, crop yield, and adaptation strategies, institutional organisation and Indigenous Knowledge System in response to changes in climate variations.

CHAPTER FOUR: SMALLHOLDER FARMERS' PERCEPTIONS ON CLIMATE CHANGE AND ITS IMPACTS ON CROP PRODUCTION

4.1. Introduction

Although there is a significant advancement in understanding and dealing with challenges of climate change and its impacts on crop productions at the national and local levels, awareness of and concern for the problem at micro-scale, especially among smallholder farmers in Vhembe District, remain crucial and little attention has been paid to it. Hence, this chapter seeks to understand smallholder farmers' perceptions about climate change in relation to climate trends, and further examine climate impacts on smallholder farmers' crop production. This assessment of climate change in the study area is grounded on the farmers' perceptions and knowledge of climate change. But the study revealed that smallholder farmers use the term "*climate change*" to mean both "*climate variability*" and "c*limate change*". Although climatological terms and farmers' expressions are not always identical, hence, it was important to validate both terms. This validation is necessary as it brings a multi-perspective description of the climate conditions in the district. It was also necessary to understand the local climate change by assessing recorded meteorological data from 1980 – 2015 in the study area. This evidence was vital in planning for adaptation strategies, as discussed in the next chapter.

4.2. Smallholder farmers' perception and knowledge of climate change

The findings of the results revealed that 80.5% of the farmers were aware of the different aspects of climate change, for the past decades. Farmers' perceptions regarding climate indicators correlated both temperature and rainfall (Table 4.1). Whilst most 80.66% of the smallholder farmers' responses showed that the rainfall is unevenly distributed from one area to another and 19.44% of them felt that the rainfall volume was unchanged. The most visible change in climate for about 80% of the farmers was a shift in the start of rainfall. 82% of respondents said they had noticed that rainfall on-set currently was late as compared to the past three decades. Furthermore, 90% of smallholder farmers perceived the rainfall season getting shorter over the past 35 years. Table 4.1 presents the indicators used to summarise smallholder farmers' perceptions of climate change based on precipitation and temperature. A concern among smallholder farmers is the local climate variability and changes that are affecting crop production, which they depend on for their livelihoods. A substantial number (80.4%) of farmers perceive high-volume floods and few dry spells as evidence of climate stressors and this is affecting growing season as they were obtaining less produce. During the focus group discussions (FGDs) and interviews, changes identified were negative according to smallholder farmers and extension officers. During these sessions, respondents were very categorical that there are changes in rainfall which seems to be decreasing during the summer seasons. One of the extension officers from Tshiombo was adamant that there were some significant variations in terms of rainfall amounts, early cessation and distribution patterns. However, there are other studies in the past, with similar analysis of outcomes of smallholder farmers' perceptions tallying with climate change (Hou et al., 2015). There are some differences in the investigations' methodologies, however, the results of this study complement findings of studies conducted by Schlenken and Lobell (2010) who reported that in tropical Africa, crop production has been decreasing steadily for the past few decades. Most of the smallholder farmers reported a decrease in rainfall and increasing temperatures. Altsehuler and Brownlee (2016) also highlight in their studies that historical meteorological data correlate with farmers' perceptions, which is an evidence of climate change.

Also, temperature increases were the major visible aspect of climate change identified by respondents who indicated that it has been increasing regularly in recent decades. These findings are aligned with the study of Menike and Arachchi (2016) who argue that local farmers have witnessed rising of climate variations in some years. A study conducted by Gbetibouo and Ringler (2009) comparing vulnerability parameters across South African provinces, revealed some similarities as well as differences with the results of the current study. In the present study, rainfall trends indicated a general declining pattern, whilst on the other hand; temperature has showed a steady increase in the past three decades. This complements findings of Wetende et al. (2018) on farmers' perceptions of climate variations in Siaya, sub-county of western Kenya. During the focus group discussion, smallholder farmers reported, that there was a late start of rainfall and early cessation, as compared to the past. The current study, however, did not go into detail to statistically analyse the inter-annual variability using the climate data available, although, the results from all other sources - questionnaire, interviews and focus group discussion - support this fact. This concurs with findings of a study conducted by Ayandlade et al. (2018) comparing meteorological data with local household farmers' perception of climate change, a case study from Southwestern Nigeria.

One of the farmers had this to say;

"As for temperature, I strongly believed it has increased because when I grew up, it used to be very cold during the months of April and September and we never had mosquito here." (Local Farmer, Nwanedi).

Table 4.1: Major Indicators of climate change during the past 35 years in Levubu, Nwanedi, and Tshiombo.

Perception on Climate change indicators	**Levubu N = 68**	**Nwanedi N = 79**	**Tshiombo N = 77**	**Total Percentage**
	%	**%**	**%**	**%**
Rainfall amount has increased during summer season	8.8	16.5	13	12.9
Rainfall amount seem to be decreasing during summer	89.7	94.9	92.2	92.4
Rainfall amount is the same for the past 30 years	10.3	8.9	10.4	9.8
Early cessation of rain fall	92.6	91.1	87	90.2
Late start of rain fall	88.2	91.1	90.9	90.2
Increased temperature	88.2	92.4	92.2	91.1
Decreased temperature	8.8	7.6	7.8	8.9
Frequently drought	75	82.3	83.1	80.4
Growing season seems to be shorter	88.2	89.9	85.7	87.9
Weather seems to be unpredictable	85.3	84.8	80.5	83.5

The study further sought information from farmers, on the best options and ways to access climate knowledge. During interview, smallholder farmers were posed questions, such as *"Who provided you with this information about climate change?"* The purpose was to identify the medium through which respondents, in these sites, gathered information about climate change and their information preference. The findings revealed in Figure 8, indicate that the majority of the farmers have knowledge and are aware of change in local climate as well as its effects, through their knowledge and experience.

High level education activists and NGOs are advocating for remedies for climate change; hence, they are involved with the youth through education processes on adaptation strategies. The majority of the farmers have access to radios and there is increased levels of literacy among the youth in the study area, hence, the low level of knowledge of the real causes of environmental change, is among the older farmers, age 61 and above, due to their higher levels of illiteracy and too much adherence to indigenous knowledge and cultural values of the society.

The findings of this study revealed that 40.5% of respondents were aware of climate change through radio sources, while experience or personal understanding of climate change was ranked the second in terms of access to information on climate by 23.1%. Television communication was indicated as a source of information by 17.1% of the farmers. Other sources of information such as newspapers, meteorological bulletins, agricultural extension officers, neighbours, NGOs, religious bodies, village meetings, educational seminars, were not selected and there was no access to information through the Internet for the respondents. A similar study conducted by Mpandeli (2014) stated that the major sources of information for farmers were predominantly neighbours, extension officers, radio and experience of climate change.

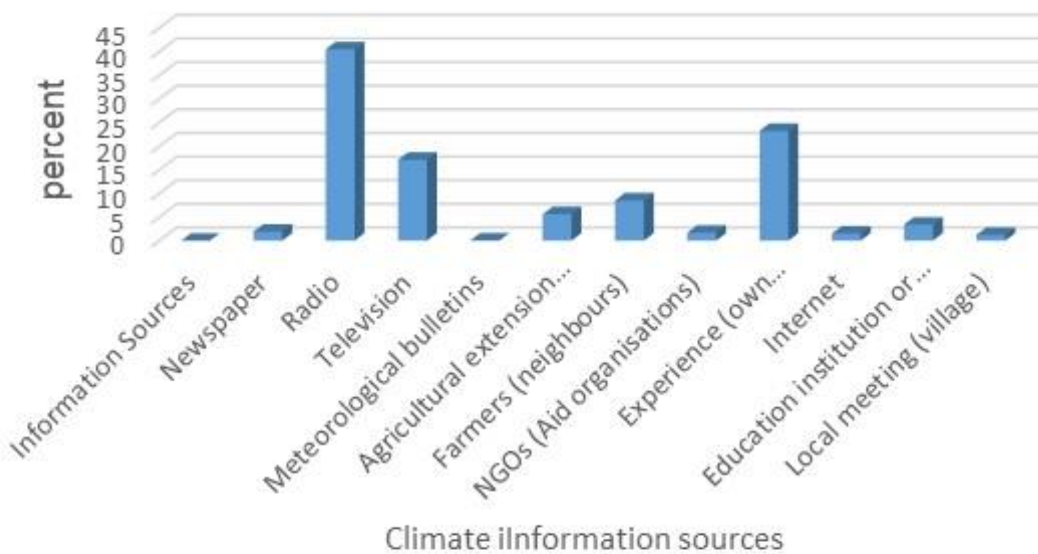

Figure. 4.1: Source of farmers' access to climate knowledge

4.3. Temperature and rainfall trends

Rainfall and temperature are essential variables of climate, and so the analysis of changes in these climatic variables characterises the key task in detecting climatic changes. In this study, the analysis of rainfall and temperature variability was based on secondary data collected from South African Weather Service stations in proximity to the study sites in Vhembe District The results and discussions provided in the following sections, therefore, reflect the climatic conditions of the district focusing on stations at Levubu, Tshiombo and Nwanedi.

4.3.1. Temperature trends

An observation of the Vhembe District annual mean temperature trends from 1980 to 2015, suggests two epochs of different change rate, a first epoch of gradual increasing temperature from 1980 until the late 1990s, and a second epoch of abrupt regime shift of warming temperature rate from 2000 to 2015. This regime change indicates a more rapid warming and accelearated climate change from about 2000 (Figures 4.2, 4.3 and 4.4). This warming trend is consistent with trends found across Limpopo River Basin, South Africa (e.g. Jury 2016, Kruger & Shongwe 2004). This warming has resulted in increased evaporation from surface soils and open water bodies with implications on rain fed agriculture and water supply. A study by Mpandeli *et al*., (2015) found that prolonged dry spells in the 1988/1989, 1991/92 and 2004/2005 summer rainfall seasons resulted in lack of water in the area. There were also substantial negative effects on crops and livestock production and consequently on food security and rural livelihoods

Temperature trend for Levubu

Most farmers' respondents during focus group discussions in Levubu perceived that temperatures have increased for the past three decades. Farmers' perceptions on temperature seem to be supported by the meteorological data for Levubu site (Figures 4.2) which show that annual mean temperatures have been increasing steadily during the study period. Hence, there was a regime shift to a warmer epoch from 2000 to 2015, however with fluctuations. Piecewise regression shows a shift of > 0, 5^0 C, around the year 2000. This regime shift coincided with a major flood that affected the Vhembe District following the landfall of tropical cyclone Eline in February 2000.This result is in line with the studies by Rodionov (2006) which revealed abrupt climate change on a theoretical basis in North Pacific in North America.

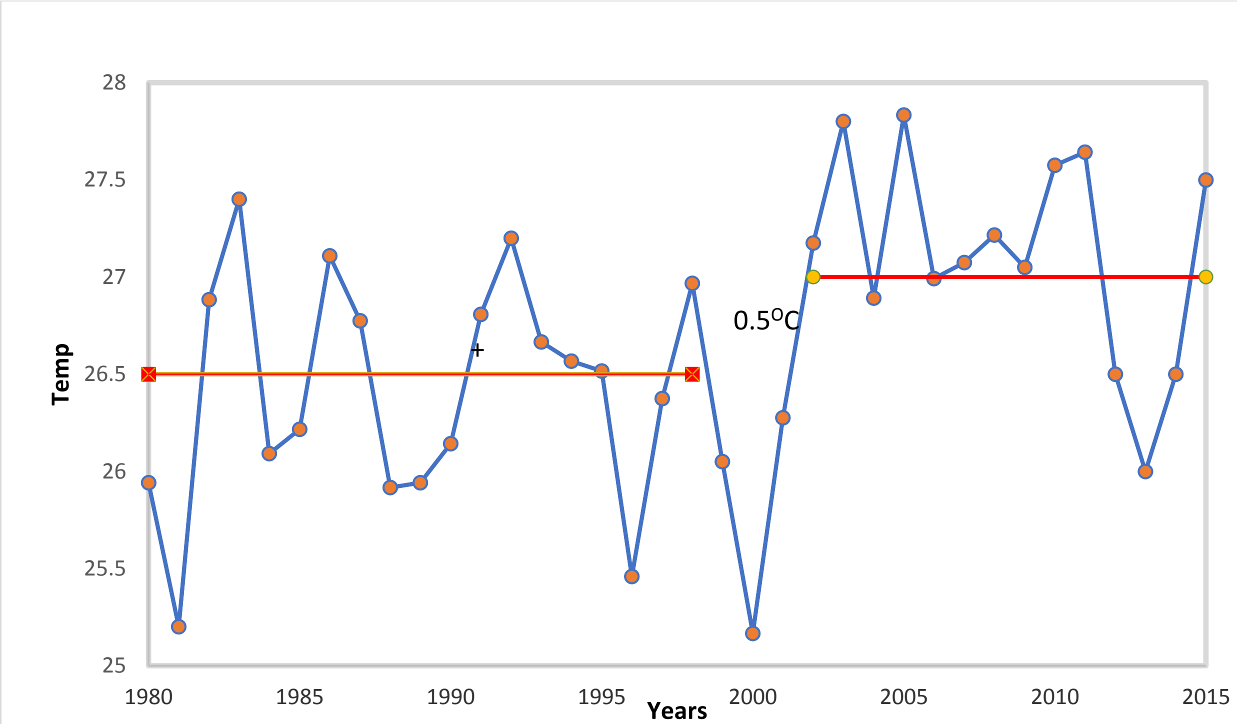

Figure. 4.2. Annual mean temperature trend for Levubu from 1980 – 2015

Temperature trend for Tshiombo

As indicated in Figure 4.3 there was a general increasing annual maximum temperature change from 1980 to 2015. The trend line shows that the annual mean temperature increased approximately but with an abrupt change quite visible from the year 2000. A regression trend reveals a regime shift around 2000 to a warmer epoch with about 0.7^{O} C. The result indicates that the temperature undergoes a rapid shift from one stable epoch to an alternative stable state with obviously different means between 1980 to 2000 and 2002 to 2015.

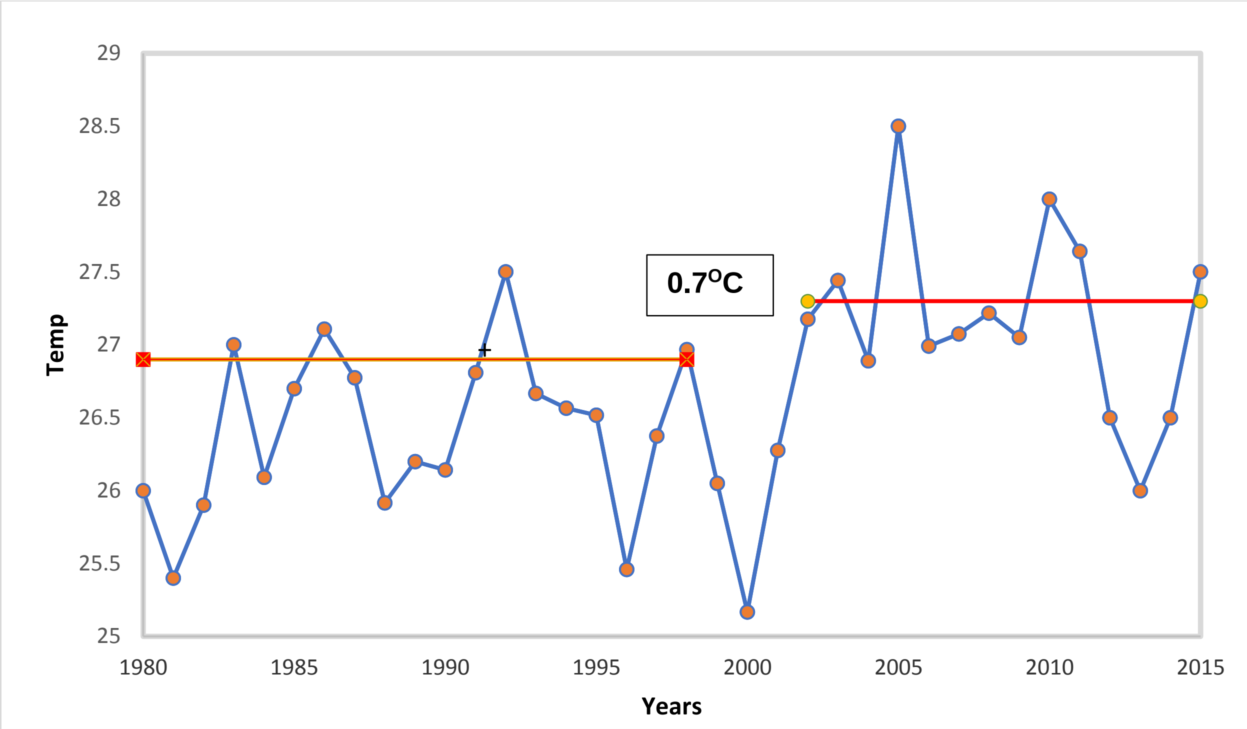

Figure. 4.3. Annual mean temperature trend for Tshiombo from 1980 – 2015

Temperature trend for Nwanedi

Similarly, at Nwanedi weather stations the mean record indicated a general increasing annual temperature change from 1980 to 2015. The trend line indicated a general increasing trend (Figure 4.4) with a regression line revealing a shift of about 0.9^{0}C warmer. The study revealed that warming trends were higher from the 2000s onwards. This higher shift suggests that in Nwanedi area was characterized by relatively high evapotranspiration as the mean annual temperature is relatively higher. This implies that surface water availability is adversely influenced which further negatively affect the moisture content of the soil thereby affecting crop production of the rural farming societies. This regression technique allowed us to detect breakpoints in the time series. Similar findings were obtained from the studies conducted by Karl et al (2000) who used piecewise regression model to analyse time series of different climatic variability and change breakpoints in linear trends.

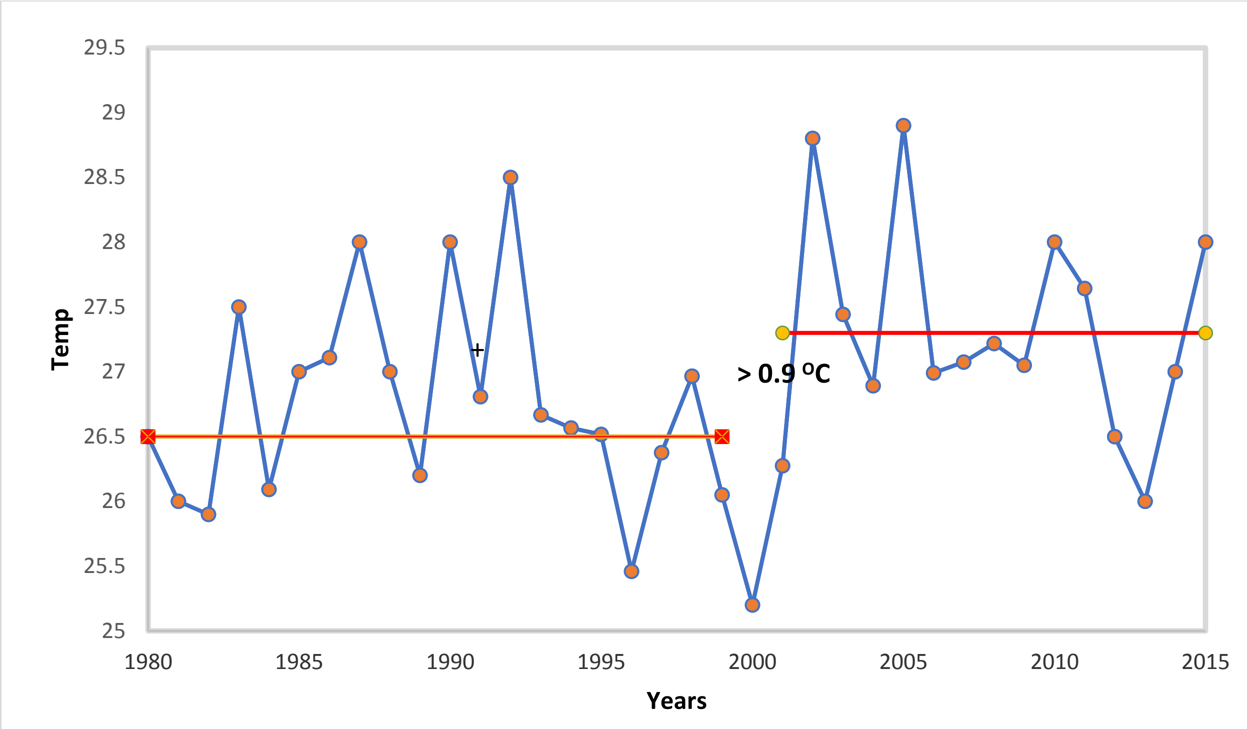

Figure. 4.4. Annual mean temperature trend for Nwanedi from 1980 - 2015

4.3.2. Rainfall Trends

As shown in Figures 4.5, 4.6, and 4.7; decadal variations were analysed to determine whether rainfall has changed significantly over time in the study sites. A sample t-test at a 0.05 level of significance was used to estimate the slope line. As indicated in Figures 4.5, 4.6 and 4.7, the slope line equations are generally negative suggesting a general decline in rainfall in all study sites. The majority of the farmers who took part in focus group discussion in the study area also perceived that rainfall was decreasing and accompanied by few extreme events. The observed gap with respect to the trend of rainfall perhaps associated to the recent drought events of 2014/2015 and 2015/16, which are fresh in the mind of farmers at the time data collection.

Rainfall trend for Levubu

The highest rainfall recorded in the Levubu area was for the periods 1999/2000 and 2011/2012 and 1992/1993. These periods were characterized by extreme events which resulted in floods. The results from data recorded from 1980 to 2015 within Levubu meteorological stations illustrated that for the past 35 years, rainfall has been decreasing steadily within this study site. It was also found that mean annual rainfall in Levubu is higher relative to Nwanedi and Tshiombo.

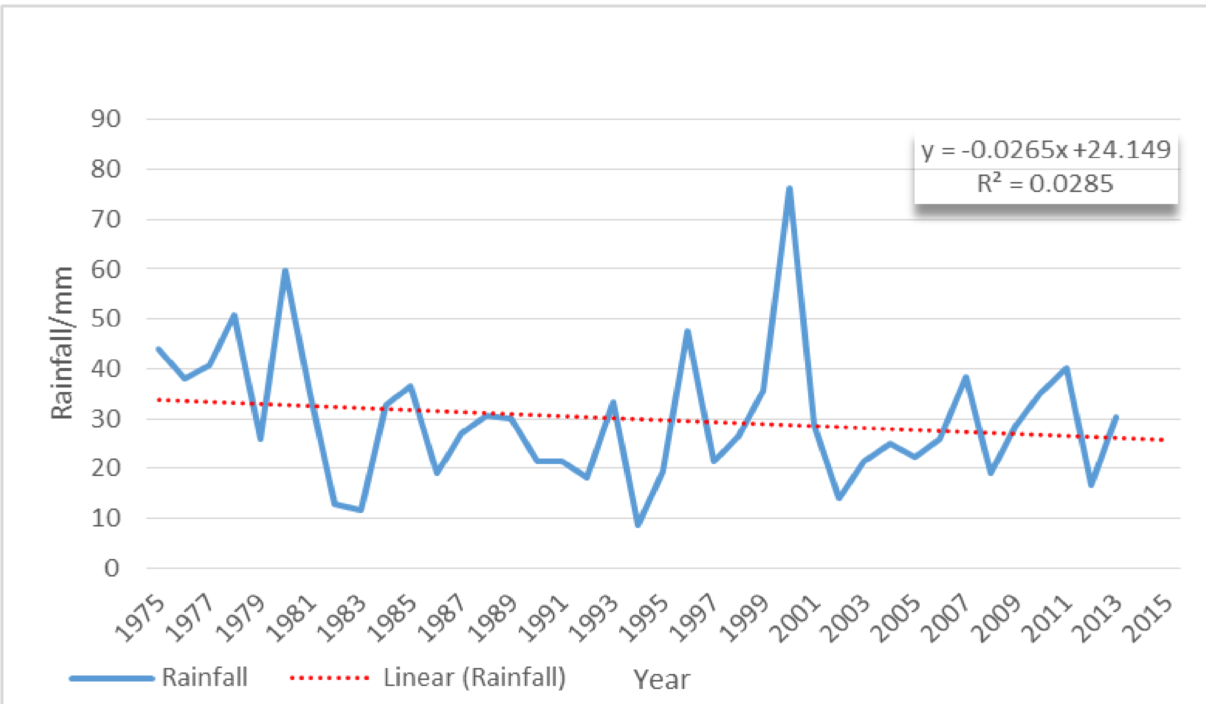

Figure. 4.5. Annual mean rainfall trend for Levubu from 1980 – 2015.

Rainfall trend for Tshiomb

As indicated in Figure 4.6, the higher mean annual rainfall was recorded in 1995, 1996, 1999, 2000 and 2001, which showed years of floods event. Statistical trend analysis of annual mean rainfall also depicted a decreasing trend and compared favourably with the views of the farmers' responses.

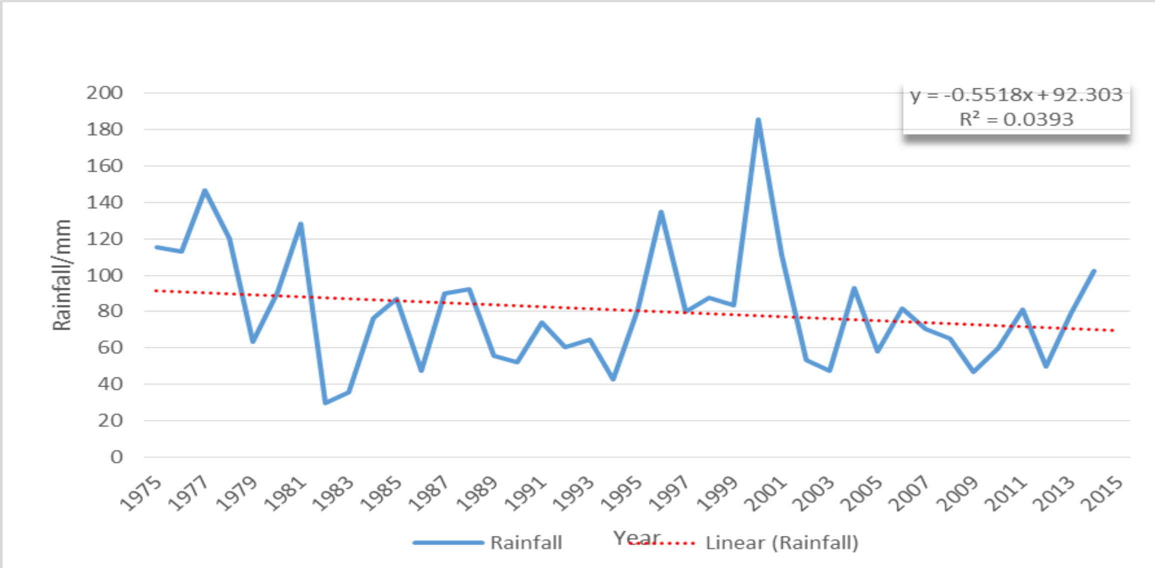

Figure. 4.6. Annual mean rainfall trend for Tshiombo from 1980 – 2015.

Rainfall trend for Nwanedi

This study area also indicated rainfall anomalies in the periods of 1999/2000 and 2000/2001 as indicated in Figure 4.7, associated with floods induced by tropical storms. The year 2000 experienced the highest number of heavy rainfall events particularly during the months of January and February. February month in the year 2000 saw devastating floods in Limpopo Province of South Africa due to the landfall of tropical cyclone Eline. It is important to note that the finding of this study is in line with results of previous studies by Kabanda (2004), Nenwiini (2009) in area closer to the Soutpanesburg Mountain in Vhembe District There is a general decreasing annual mean rainfall trend as indicated by the trend line. However; this trend line is as a result of the change in climate by a factor of 0.0285. This value is also computed by using the slope equation, "y= - 0.5518x + 92.303".

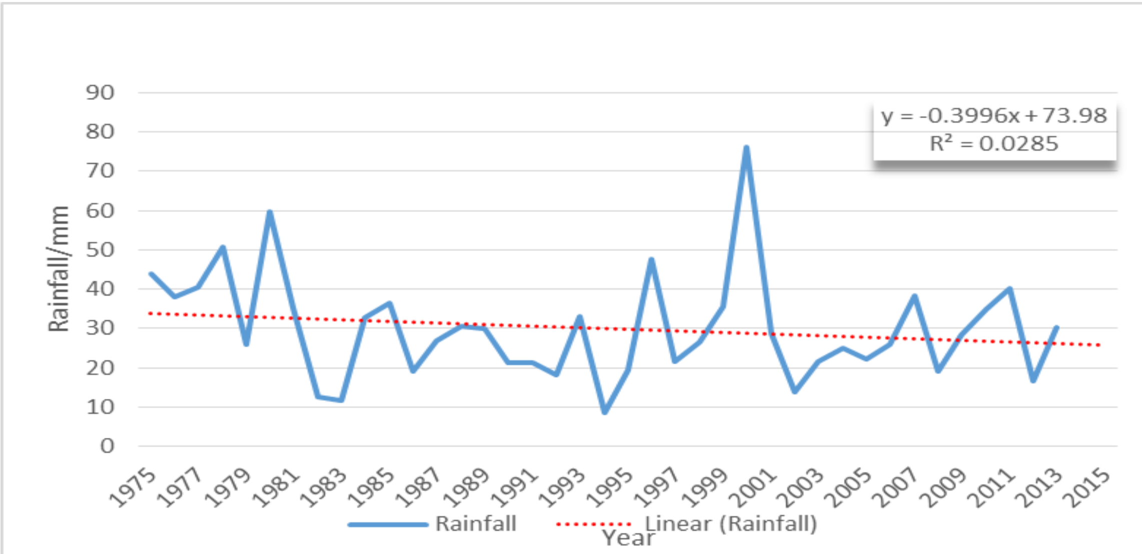

Figure. 4.7. Annual mean rainfall trend for Nwanedi from1980 – 2015.

The results from data recorded within Levubu meteorological stations illustrated that for the past three decades, rainfall has been declining steadily within the study area. It was also found that mean annual rainfall in Levubu is significantly more rainfall relative to Nwanedi and Tshiombo due to its location. The study area was also described by rainfall variability that can affect crop production practices of smallholder farmers since they total depend on the rain. The result of the focus group discussions held with smallholder farmers also revealed that the rainfall pattern was generally variable and unpredictable. This results in diverse rainfall zones, with high variability of rainfall that may be linked to the complex topography of the area. Similar findings were obtained from previous studies conducted in the area by Singo (2008) and Nenwiini & Kabanda (2013). This higher rainfall is due to the geographical location of Levubu as the climate is influenced by the Soutpansberg Mountain range. The moist airflow from the Indian Ocean flows over the Drakensberg escarpment and forms orographic rain clouds. Therefore, these climatic conditions make Levubu a suitable region for both smallholder farming and large-scale commercial agriculture.

The findings also revealed that local farmers have witnessed the increase of climate variations in recent years. The three study areas experienced the wettest season in 1999/2000 and the driest season was in 1991/1992. It is no surprise that the wettest season was 1999/2000 as tropical cyclone Eline invaded southern Africa in February 2000 (Dyson & Van Heerden, 2001; Chikoore et al., 2015) and was responsible for a wide range of heavy rainfall events over South Africa including the Vhembe District The dry seasons in 1991/1992/1993 and 2004/2005 were linked to El Nino events and were the most intense. Previous studies such as by Welderufael et al., (2013) have indicated that El Niño is usually associated with drought conditions in South Africa.

4.3.3. Smallholder farmers' perceptions of climate change and Meteorilogical data

The results of the study reveal that local farmers' climate change perception is not sufficient to generalise the actual variations of climate variability and change, however, their perception of climate change is basically personal, area specific, and also influenced by other factors. Therefore, it is important in comparing farmers' climate change perceptions/ knowledge with actual meteorological data in the study sites to know the adaptation strategies. The study indicated that the majority of the farmers believed that the amounts of rainfall have decreased in the past years in their areas. Analysis of rainfall data was in line with farmers' perceptions of rainfall decline in the study sites. This tally between farmers' perceptions of an increase temperature variation and meteorological findings are in line with previous studies (e.g. Ayal et al., 2013; Legesse et al., 2018). The study findings further showed that there was a slight variation in climate from one study site to another. Obviously, different crops were planted at different sites and times due to the different onsets of rainfall. There was no available historical crop production information available for comparison.

The findings confirm the perceptions of the farmers and agricultural extension officers that for the past three decades rainfall has been decreasing. These findings are in line with previous studies conducted in Vhembe and Sekhukhune Districts of Limpopo Province (e.g. Mpandeli *et al*., 2015; Gbetiboua & Ringler, 2009). Therefore, the results of the meteorological stations in Vhembe District are a good benchmark. However, for the winter crops during the months of June, July and August, farmers also indicated that poor yields were a result of numerous dry soil days as a result of prolonged drought.

4.4. Assessment of smallholder farmers' perceptions on crop production

4.4.1. Impacts of climate change indicators on crop production

The projected temperature increases by between 1.4 to 5.8°C over the period 1990 to 2100 (IPCC, 2014), reported that, this increase in temperature will result in large changes in the frequency of extreme events which can have severe effects of crop production (Griggs & Noguer 2002). Smallholder crop production is sensitive to increased temperature and declines rainfall and this can result in a decline in average yields of groundnuts. In southern highlands of Tanzania, a similar study was conducted which indicated that a higher dependence on weather for crop production has occasionally exposed some regions to food insecurity especially more in years with decline rainfall (Menike & Arachi, 2016).

Intensity of precipitation also plays an important role in climate change, including the timing of intraseasonal dry spells and drought duration. These events are critical to crop yield. Several studies have indicated that climatic variability and change can have adverse impacts crop production (Nhemachena & Hassan). However practical climate effects are more multifaceted. For example, summer season maize and rice under rainfed conditions indicate a strong positive correlation with intensity of rainfall. Therefore, higher yields are associated with increased availability of soil moisture content during the planting seasons (Koide *et al.,* 2013).

Furthermore, changes in climatic conditions have resulted in shifting seasons which are directly linked to temperature and rainfall variation. An increase in temperature is enough to extend the summer season and delay the winter (IPCC, 2007). The various seasons are shifting with a prolonged dry season and therefore delays in the start of the rainy season. These changes in seasons affect the timing of planting seasons and flowering and pollination.

Therefore, impacts of weather extremes were also considered in this study. The impacts of other weather extremes such as drought, flooding and heatwaves have also influence on crop yield in the district. The frequent occurrence of heatwaves and drought will stress crops by increasing the rate of evapo-transpiration and resulting in an increased in plant temperature, affecting the flowering and pollination rate. These will affect crops which are very sensitive to water availability and heatwave conditions. In the study area, such crops include; maize, vegetables and peanuts. An intense and prolonged drought in some part of the district may become unsuitable for crop production and farmers' livelihoods. This harsh climatic condition may go as far as discontinuing the production of certain crops and resulting to food insecurity. This is in line with the study conducted by Sivakumar et al., (2005), stated that a decrease in rainfall in Sub-Saharan Africa will turn semi-arid regions into arid.

4.4.2. Crop production trends

The results of the findings revealed that about 87% of local farmers mentioned that crop yield produced were enough in the 1980s and in 1990s. During focus group discussions, farmers reported that they harvested tonnes of maize, beans, sweet potatoes, tomatoes and vegetable in each season. These harvests were sufficient for the households throughout the following season although household sizes have also grown due to population growth. While 7% of the informants mentioned that they were not sure of the harvests production were enough and only a negligible of 3 percent not enough pre- 1990. While in Vhembe District, smallholder farmers are known for supplying agricultural products to street vendors if they produced or harvested sufficient products (Mpandeli, 2006).

However, as for post-1990 crop harvest, 75% of the respondents stated that the harvests have declined. The main cause of decline in crop production was lower rainfall due to prolonged dry spell resulting in streams and rivers drying out which bring insufficient water for furrow irrigation. While a negligible of 8.5% who uses boreholes or irrigation for crops, could still harvest enough crop yields. This finding is in line with the study by Madzivhandila (2015), who stated that irrigation systems and boreholes are owned only by the rich smallholder farmers which enable them to irrigate their crop, while poor farmers cultivate crop yield for survival and with little or no access to water.

Further, in order to understand smallholder farmers' perceptions of climate variations, Lemma (2016), have emphasised in a study carried out in East and West Gojam in the highlands of Ethiopia, were majority of local farmers confirmed that early cessation of rainfall, late start of rainfall, frequent droughts and flooding have become obvious features of the climate variation and it is destroying crops yields. Further, similar studies highlighted that historical meteorological data correlated with farmers' perception, which indicated the evidence in climate change (Adejuwon & Odekunle, 2006; Altsehuler & Brownlee, 2016). However, temperature was the main visible climate change as is showed to have been constantly increasing for the past seasons. These findings are partly accordant with the study of Menike & Arachchi (2016) who argue that smallholder farmers have witnessed rising of climate variable variations. Therefore, as temperature indicates an increasing variation over time, rainfall had no clear variation. Whereas, the studies conducted by Gbetibouo & Ringler (2009), comparing vulnerability parameters across South Africa provinces, suggested little similarity as well as some differences with the results of the current study. In the present study, rainfall and temperatures revealed a clear pattern. As rainfall indicated a declining variation pattern, temperature has shown a steady and increasing trend in the past three decades. In a study of Wetende *et al*., (2018), farmers' perceptions of climate variations and adaptation strategies in Siaya sub-county of western Kenya indicated that there was a late start of rainfall and early cessation, as compared to the past years. Although the current study did not go into detail to statistically analyse the inter-annual variability using the climate data available, the results from all other sources from questionnaire, interviews and focus group discussion support this fact. This concurs with findings of a studies conducted which comparing meteorological data with local household farmers' perception of climate change, a case study from Southwestern Nigeria (Ayandlade *et al*., 2018).

Other interesting key findings of this study suggest that climate variability and change in the study sites have been significant from 1980 – 2015. The meteorological data collected from the stations shows evidence of high climate variability and change.

4.4.3. Climate change challenges on crop production

As the findings have revealed, the majority of the smallholder farmers in Vhembe District cultivated a variety of crops in the 80s and 2000 period. The farmers grow crop such as sweet potatoes, maize, groundnuts, bambara ground nuts, pumpkins, beans, and as well as variety of vegetables produced in large amounts at the study sites. During this period farmers produced enough crops and the extra amount were stored up to keep their harvest in order to sustain them throughout the season. However, in the post-2000 period, it appears it has been difficult to produce enough crops and harvests have declined. Only few farmers in the study areas are still struggling to produce a variety of crops, which are mostly maize, potatoes and vegetables as a result of changes in climatic conditions that are not favourable to crop production. Local farmers have reported that rainfall season has been so short in recent period and they can no longer carry out the cultivation activities as normal. This concurs with findings of the study conducted by Komba & Muchapondwa (2015), citing that the effect of shorter and lower rainfall season has damaging impacts on crop production; such as low crops harvest and shortage of seeds for the new planting season and decrease in agricultural production. Several studies conducted in southern Africa have shown those impacts of changes in climate on maize production, a staple crop in Zimbabwe and northern part of South Africa, using dynamic crop growth framework CERES maize (Nhemachena & Hassan). The findings indicated that maize harvest was expected to significantly decrease by approximately 11-17% under conditions of irrigation and non-irrigation. This narrative is also consistent with findings by Ziervogel *et al*., (2004) and Lemma, (2016). Further, Eregha *et al*., (2014), using an error correction frameworkling technique, found in a study conducted in Nigeria that the impact of climate change on crop production varies depending on the type of crop cultivated and the length of the rainy season. Presently in the study area, those farmers who still harvest enough crop yields are those who have established boreholes and irrigation system in their farms.

4.4.4. Likert scale analysis of the impacts of smallholder Farmers' Perception on Climate indicators

During FGDs smallholder farmers were questioned to show their knowledge of climate change with indicative indicators of rainfall and temperature. A five-point Likert scale was used to shows the magnitude and direction of change (See Appendix A). Results reveal that the majority (82%) of the local farmers perceived as temperature increases and on the other hand, 86.3% perceived a decrease in quantity of rainfall over the past 15 to 30 years. Further, a sample of about 89% and 91% of smallholder farmers perceived rainfall amounts to be decreasing during the summer season coupled with an early cessation respectively for the past 15 to 30 years. Hence, Likert mean value show that early cessation is the most important to have had changed with highest variability in starting late and early cessation over the past 15-30 years followed by temperature. Table 4.2 shown the liker scale of farmers' perception of climate during the past 30 years.

Further, the results reveal that 11% of smallholder farmers perceived that temperature has been decreasing and only 8% perceived rainfall has been increasing. While on the other hand, 8% and 9% perceive rainfall and temperature there was no change. This intra local farmer's change of climate variability perceptions including agro-ecological zone of the farmer's household, educational level, farming experience and age, access to climate knowledge and to institutions.

Table 4.2. Indicators of farmers' perception of climate indicators during the past 30 years

Statement of weather indicators variables	1	2	3	4	5	Grand score	Total Percent (%)
Rainfall amount has increased during summer season	0	0	15	78	113	206	92.0
Rainfall amount seem to be decreasing during summer	204	10	0	0	0	214	95.5
Rainfall amount is the same for the past 30 years	0	0	24	71	107	202	90.1
Early cessation of rain fall	0	9	69	33	54	165	73.7
Late start of rain fall	190	11	12	0	0	213	95.1
Increased temperature	199	18	2	0	0	219	97.8
Decreased temperature	0	0	0	50	174	224	100
Growing season seems to be shorter	158	44	17	0	0	219	97.8
Weather seems to be unpredictable	170	21	8	0	0	199	88.8
Frequent drought	190	15	2	0	0	207	92.4

Highly agree =1 **Agree** = 2. **Not certain** = 3. **Disagree** = 4. **Highly disagree** = 5

4.5. Summary

This chapter has provided essential evidence of smallholder farmers' perceptions by matching them with meteorological historical data in selected study areas in Vhembe District In order to achieve its objective, the study incorporated qualitative and quantitative techniques, to explore how ethnographic data from smallholder farmers' perceptions of climate change, tallies with meteorological variation data, from 1980 – 2015. An in-depth data presentation and discussion of state of the local climate change in the study sites in Vhembe District were highlighted in this chapter. Smallholder farmers, extension officers and local leaders have witness extreme weather conditions, such as a decrease rainfall, increased temperature and this pose challenges, as well as imposes challenging on the majority of smallholder farmers and their household livelihoods and also food security. The findings revealed that there has been a significant change in climate parameters, there has been decrease in mean rainfall and increasing mean temperature variations across the study areas, there was corroboration between farmers' experiences and analysed meteorological data. The chapter further revealed that crops have been negative affected in the past three decades. While previous studies have focused on the Limpopo Province as a whole, what happens on a micro scale is still unanalysed, leaving the smallholder farmers in Vhembe District vulnerable to climate change impacts on crops.

Recognised climate changes include that rainfall amounts have decreased, late start of rainfall, increased temperature, frequent drought and shorter growing seasons, and hence poor crop yields. Their reported perceptions indicated that rainfall distribution has become unpredictable and erratic, affecting their crop yield.

Empirical evidence showed that a solid understanding of climate change will bring about favourable adaptation techniques of tackling the challenges posed by climate variability and change on farmers' crop harvest. Therefore, the next chapter deals with factors employed by smallholder to pursue adaptation strategies in response to climate change.

CHAPTER FIVE: ADAPTATION STRATEGIES IN RESPONSE TO CLIMATE CHANGE IN VHEMBE DISTRICT

5.1. Introduction

In the previous Chapter, there was evidence that Vhembe District smallholder farmers perceive climate change to be occurring in their areas. This chapter therefore seeks to answer objective three of the study - *"evaluate and analyse how smallholder farmers in Vhembe District have been adapting to climate change trends, and which determinants affect farmers' choice of adaptation strategies in the study area*". To achieve this, local farmers were selected from three ecological zones in the District and data were collected through questionnaires, focus group discussions, then analysed. Smallholder farmers should be able to use adaptive strategies in order to minimize the negative impact of climate change. However, for the local farmers to do this, there is a two-step procedure - farmers must, first, perceive climate change (as discussed in Chapter 4) and the second step requires farmers' response to changes through adaptation strategies as will be discussed in this chapter. Understanding adoption and opportunities for effective coping and adaptation strategies is necessary to minimize climate shocks at farm level. The choice of adaption within individual farmer's households is normally determined by the local agricultural cycle that includes seasonal climate variation as well as other socio-economic drivers.

This chapter identifies socio-economic attributes, analyses climate change adaptation and coping strategies used by smallholder farmers to combat climate dilemma, followed by identifying the determinants of farmers' adaptation choices to climate change using socio-demographic and physical aspects.

5.2. Farmers' socio-economic attributes in response to climate change

5.2.1. Gender

The results of the study revealed that out of the total sample of 224 respondents, 55.2. % was female, while 44.8% were male as shown in Table 5.1. Agricultural activities were predominantly carried out by female farmers in the research area whom were mostly household heads. In the study sites, households headed by female farmers were most likely to employ new crops and diversification in response to climate change. Nhemachena & Hassan (2007), confirmed that households headed by women have the capacity to take up climate change adaptation strategies, due to their exposure to climate knowledge system and being active in farming. On the other hand, households headed by male farmers, were more likely to migrate to nearby urban areas like Thohoyandou, Makhado, and Polokwane, and even as far as Gauteng Province for jobs opportunities in times of farming challenges. Buyinza & Wambede (2008), however argue that households headed by male farmers do employ improved adaptation techniques against climate variation. Studies in West Africa, confirmed that there is a higher probability of adopting agricultural technologies among households headed by men, due to the higher levels of education by men-headed households (Hou *et al*., 2015; Adegnandjou *et al*., 2018). The high levels of education enable men to be relatively flexible in adopting new crops and hybrid improved seeds, and using climate knowledge. This was not the same case with smallholder farmers in Levubu, Nwanedi and Tshiombo.

5.2.2. Household heads

As observed, out of the 224 farming households, 37.5% represents the age group of 41-50 years, followed by an older age group of 51-60 with only 28.6%; elderly household heads aged above 61 years only made up 18.3 percent, while, the 31-40-year group made up a total of 15.6% of the informants. The fact that more than 85% of the household heads were above 41 years of age enhanced the reliability and depth of data elicited as the information required span a period of over 35 years. A similar study carried out in Nigeria by Obayelu *et al*., (2014), showed that, socio-economic aspects on choices of climate change affect farmers and adaptation to climate variation can be influenced by household age and that, older farmers were more active in farming activities than youths. The youth have less interest in agricultural activities, as they see it as older people's occupation. Moreover, older farmers are interested in following traditional techniques with which they are comfortable with than adopting western system of agriculture. These findings confirm results of studies conducted by Acquaah (2013) and Uddin *et al*, (2014). It can therefore be concluded that current farm techniques could disappear with time as the older generation are the custodians of indigenous knowledge, hence, the youth should be considered for training in these agricultural activities for the future.

5.2.3. Marital status

The household marital status of the farmers showed that about 48.2% were single (that is both divorced and widowed), 16.5% were married, and this indicated that there is a higher level of unmarried households in the study area. It was noted that married households were more productive and active than the single or divorced households. The married families have a large household sizes which provide the needed labour.

5.2.4. Farmers' household Size

In the Vhembe District, smallholder farmers' household sizes, comprised of 1-4 members, according to a field survey; this represents 72.3% of the total farming population in the study area, while household sizes of 5 – 8 individuals represent 27.7% of the total respondents, as shown in

Table 5.1. According to the Living Conditions Survey of Households 2014/2015 Statistics South Africa (2017), the average household size in South Africa was 3.3, which correlates with the results of this study. This study further showed that there is no significant difference in Levubu, Nwanedi, and Tshiombo, when comparing household sizes. Large family' size, with a large labour force, may decide to divert some of this force to off-farm production, to earn extra income, to reduce consumption pressure caused by a large household. Zizinga *et al*., (2017), conducted a study on farmers' choice of adaptation method in response to climate trend in South Western Uganda and the findings revealed that household labour sizes plays a vital role in the adaption of particular adaptation techniques. Household sizes, in terms of the number of people staying in the household, who provide the labour force as an input for agricultural activities, usually manual labour, has an impact on production. This narrative is also consistent with results by Balew *et al*., (2014). This has lead to smallholder farmers in Vhembe community increasing their family size as means of increasing agricultural production.

5.2.5. Household income

As indicated in Table 5.1, the average household income per month was also relevant, as it influences some variables, such as availability of farm inputs, like fertilizers and hybrid seed. There were four groups of income levels. The study findings reveal that 31.7% of household received below R 1500 per month, while 35.7% were receiving income between R 1600 – 2500, and 18.8% respondents received between 2600 – 3500, with only 13.8 % who were getting above R 36000 per month. The study showed that income from agriculture was a major household economic resource. The result analysis from the study indicated that farm income for the household has an important impact in improving crop varieties and buying of improved seed varieties. When income increases, farmers tend to invest in products such as buying of chemicals and improved seed varieties and getting involved in crop diversification. This study is in line with previous work by Maponya & Mpandeli, (2013) and Ayanlade *et al*., (2017). This is true with smallholder farmers in the study sites, as some crops require some fertilizer and pesticide application to improve farmers' harvest.

5.2.6. Education level

Data from the fieldwork have shown that some household respondents did not receive any formal education, as represented by 50.7%. Another 30.3% attended the basic level of education - grade one to eight, while 8.9% and 7.9% have Grades 9-12 and certificate levels respectively. 1.9% reported possessing university level qualifications. The results of this study reveal the importance of education for accurately perceiving climate change. Better levels of educational lead to stronger positive impacts on farmers' perceptions of climate change. This shows that educated farmers have a better understanding of climate change and are more likely to use advanced means of adaptation strategies to improve their agricultural products; this was hypothesised as a determinant of adaptation to climate variation. This finding concurs with several studies in Africa (Hassan & Nhemachena, 2008; Makuvaro *et al*., 2018). The results further confirm that attaining higher education levels predisposes individuals to better farming experience and awareness of the benefits it also fosters a willingness to undergo training and acquire new knowledge about climate variability and change (Solomon & Rao, 2013).

5.2.7. Farming experience

The number of years a farmer has spent cultivating crops on a farm is considered as his/her agricultural experience. Possessing many years of farming experience implies that one is better informed about climate variability and change in relation to crop produced. In the study areas, experienced farmers are likely to use adaptation strategies which had reduced the effects of change and improved crop production. Adegnandjou *et al*., (2018), thus concluded that farming experience help with the easy implementation of any adaptation techniques. This study also revealed that households with experience in agricultural production of not less than 10 years, had a minimum age of 31 years. These findings disagree with studies by Hassan & Nhemachena (2008), who argue that, the age of farmers does not matter when it involves adaptation methods for climate variation, but rather the number of years involved in farming activities that count the most.

Table 5.1. Socio-economic attributes of the farmers' households

Variables	**Levubu**		**Tshiombo**		**Nwanedi**		**Total**	
	No	**(%)**	**No**	**(%)**	**No**	**(%)**	**No**	**Percent (%)**
Number of household interview	62	30.8	68	33.8	71	35.3	201	**100**
Gender								
Female	34	58.8%	37	54.4%	40	56.3%	111	**55.2%**
Male	28	41.2%	31	45.6%	31	43.7%	90	**44.8%**
Size of household								
1-4h	48	77.4%	55	80.8%	53	74.6%	156	**77.6%**
5h – 8h	14	22.6%	13	19.2%	28	25.4%	52	**25.8%**
Farming experience(years)								
10-20	43	69.4%	39	57.4%	47	66.2%	129	**64.2%**
21-30	19	30.6%	29	42.6%	24	33.8%	72	**35.8%**
Age of household head								
31-40	10	16.2%	9	13.2%	11	15.5%	30	**14.9%**
41-50	23	37.1%	25	36.8%	30	42.3%	78	**38.8%**
51 – 60	19	30.6%	21	30.9%	18	25.4%	58	**28.9%**
61+	10	16.2	13	19.1%	12	16.9%	35	**17.7%**
Marital status								
Single	30	48.3%	35	51.5%	38	53.5%	103	**51.2%**
Married	11	17.7%	10	14.7%	11	15.5%	32	**15.9%**
Widowed	12	19.3%	9	13.2%	12	16.9%	33	**16.4%**
Divorced	9	14.5%	14	20.6%	10	14.1%	33	**16.4%**
Educational level								
Non-formal education	23	37.1%	28	41.2%	34	47.9%	85	**42.3%**
Grade 1-8	25	40.35	26	38.2%	27	38%	78	**38.8%**
Grade 9-12	7	11.3%	6	8.8%	5	7.1%	18	**8.9%**
Certificate/Diploma	5	8.1%	7	10.3%	4	5.6%	16	**7.9%**
University	2	3.2%	1	1.5%	1	1.4%	4	**1.9%**
Household income (R/month)								
Below 1500	17	27.4%	22	32.4%	26	36.6%	65	**32.3%**
1600 – 2500	23	37.1%	26	38.2%	25	35.2%	74	**36.8%**
2600 – 3500	15	24.2%	11	16.2%	9	12.75	35	**17.4%**
3600 +	7	11.3%	9	13.2%	11	15.5%	27	**13.4%**

5.3. General adaptation overview

The findings of the study revealed that smallholder farmers, together with their external support system, currently in place, lack the adaptive capacity. However, smallholder farmers are using the best coping strategies they have to adapt to the effects of climate change for both short and long terms. Most of the identified impacts are mostly negative and related to the effects of temperature and rainfall variations in the past three decades as discussed in chapter four. The analysis of result from the quantitative data collected from the survey revealed that smallholder farmers have been coming up with various farming strategies to combat climate change effects on crops in their areas. These major strategies are termed – farm holders' agricultural response (see Table 5.2).

The study further revealed that the responding farmers have been employing various adaptation strategies in response to climate variation, both at the farm level and off-farm level. Some of the changes are adapting to the increased temperature variations by introducing drought-tolerant crops; introducing improved maize cultivars which give both higher yields and are pest-disease-resistant instead of the traditional cultivars; shifting from seasonal-long cycle crops to varieties that have short cycles of about two to three months from cultivation to harvesting; changing planting dates, such as delaying the planting period until the rainy season starts, and focusing on furrow irrigation from streams rather than relying on rain-fed agricultural production only (Schehen *et al*., 2016; Devi *et al*., 2017).

5.3.1. Farmers' adaptation strategies in response to climate change at farm level

In South Africa, farmers have had to adopt different strategies to overcome climate variability and change as farming is the main occupation of the majority of the local black communities. Based on the present survey data collected from 224 smallholder farmers, using focus-group discussion and semi-structure interview, to analyse the participants' perceptions of climate change issue in order to better understand the coping and adaptation strategies used by smallholder farmers. This is because these farmers' precarious future due to climate change calls for innovative livelihood strategies. The condition is even more acute for the marginalized smallholder farmers in Vhembe District For the foreseeable future, they have no option but to at least cope with or ideally adapt to the changing climate.

Across the Vhembe District, most smallholder farmers attributed reductions in crop yields to rising temperatures and changing precipitation patterns. Although the perceived impacts varied across the three study sites, the magnitude of potential climate change impacts on all participants were significant in the last decade. Most commonly observed changes include an increase in temperatures, as stated by 96% of the respondents; low rainfall by 94%; rainfall variability by 95% and increased recurrence of drought and floods by 58%. Most of these respondents have also admitted having altered their farming practices to minimize their vulnerability and/or to adjust to the changing weather conditions. These include adopting strategies, such as, diversifying crops and planting new crop varieties. The findings have shown that farmers' perceptions on climate change have had an impact on their livelihoods, as most have consequently changed their farming practices in response to their perceptions (Gandure *et al*., 2013). Findings from similar studies have also concluded that farmers' perceived changes in their local climatic conditions are a significant driver in the implementation of various adaptive measures and livelihood strategies.

Table 5.2. Reveals that, out of the 224 farmers surveyed in the study sites, 79.1% have used hybrid improved seeds or have diversified to new crops, as a climate change adaptation strategy over the past three decades. Similar findings were highlighted by Gunathilaka *et al*., (2018), in a study done in Sri Lanka.

Table 5.2. Farm adaptation strategies for rainfall and temperature

On-farm adaptation strategies	Frequency (No: 224)	Percent (%)	Area(s) of adaptation
Improved new crops/diversification	159	79.1%	Levubu/Tshiombo/Nwanedi
Higher crop varieties	120	59.7%	Levubu/Tshiombo/Nwanedi
Drought resistance crop	178	88.6%	Tshiombo/Nwanedi
Changing planting dates	198	98.5%	Tshiombo
Shorter cycle crops	190	94.5%	Nwanedi
Intensifying furrow irrigation	169	84.1%	Tshiombo/Nwanedi
Mixed Crops	187	93%	Levubu/Tshiombo
New hybrid crops	181	79.1%	Levubu

In addition, 59.7% of participants agreed that cultivation of higher crop production varieties make up for decreased household food; 94.5% claimed to have adopted planting for shorter cycles, while 98.5% of the them had shifted planting dates by delaying the planting season for some crops. Due to the prolonged dry spells, 88.6 % of households have adopted crop varieties which are more drought-tolerant. Similar studies by Epule *et al*. (2017), showed that changing crop planting dates was employed as a climate change adaptation strategy in the Sahel regions.

5.3.2. Higher yielding crop varieties

The study further revealed that local farmers have adopted to the extreme climatic shocks conditions; such as, a prolonged dry spell, drought, heatwave, the decline in rainfall, and increase in temperature. These have been overcome by shortening the growing season through growing improved hybrid seeds and short-cycle crop varieties, thereby slowly abandoning some of their indigenous seed species. One of the major problems that farmers are facing in the study area is the increase of crop–livestock pests and diseases, thus, 59.7% farmers used improved crop varieties as an adaptation strategy. Farmers also used drought-tolerant and short-maturing varieties of crops, in addition to using chemical fertilizers to increase crop productivity and pesticides to control pests and diseases. The findings of this study reveal that farmers have for the past years slowly abandoned the growing of traditional beans, maize species, and other crop varieties due to yield decline and pests and diseases attacking these crops. A similar study by Setimela & Kosina (2006), confirmed that respondents in Vhembe District selected Zm 521 (maize) and Open Pollinated Variety species (OVPs) because of its comparatively high and stable production, resistance to drought and early maturity. Local farmers, hence, choose to change from traditional crops to other crop varieties; a technique used for disease management and yield improvement.

The focus-group discussions and interviews held with farmers and extension officers revealed that adaptation strategies are similar across all the study sites, although, it was imperative to also to get in-depth data of adaptation and coping strategies from the different study sites. Each study area further identified crops and crop varieties cultivated. Some of the crops identified as better crop varieties include maize, peanut butter, sweet potatoes, sugar beans, tomatoes and green pepper. In relation to Table 5.2, it was indicated that, 59.7% of the farmers chose hybrid improved maize varieties as crops that have higher yields to replace open-pollinated variety maize. For example, local farmers in Tshiombo replaced some plots of crops with sweet potatoes and green beans; farmers at Levubu have identified Irish potatoes and improved maize as higher yielding crops; in Nwanedi, smallholder farmers reported watermelon and tomatoes as the best choice with higher yield, while for Tshiombo farmers, sweet potatoes were the crop with a very high yield, along with hybrid maize cultivars. These results are in line with Grab *et al*., (2015) findings on a study carried out in Northern China, which stated that the high temperature of C3 plant for uncultured photosynthesis study was inferior to that of C4 plant. These results also resonate with findings from Pirttioja *et al*., (2015), conducted on wheat yield varieties which was in line with previous studies in Finland by Peltonen-Sainio *et al*., (2011) which showed that crop varieties are used to adapt to climate change. These results also confirm a study in Africa conducted by Mahouna *et al*., (2018), which showed using higher-yielding crop varieties as adaptation strategies, in South Benin. Studies conducted in Limpopo Province, South Africa also confirm these findings (Maponya & Mpandeli, 2012; Gandure *et al*., 2013). One smallholder farmer in this study mentioned that:

> "*I have received seeds in the planting season and after the beginning of first rainfall, and I started planting, as the season experienced prolonged dry spell of rain, it resulted that only hybrid seeds survived the extreme climate conditions and ended up with some good yields and whereas local indigenous seeds do not survive this climate conditions"* (Household farmer, Nwanedi*).*

Further, agricultural extension official reported that for a smallholder farmer to accept and cultivate certain types of maize or beans species, it must be of higher yield than the local types, as well as have a good taste. The results of a study by Dedewrwaerdere & Hannachi, (2019) assert that smallholder famers are shifting to crops with good market prices with the intension of getting better income. Therefore, low production varieties have low income returns and affect the livelihoods of the majority of smallholder in the Vhembe District This concurs with results of studies done by Perego (2019), using analysed crop prices and land titles in Uganda, which concluded that crop prices have a strong effect when smallholder farmers have access to markets. The unpredictable, prolonged dry spells and abnormally increased temperatures have also contributed to negative climate change and low crop production. However, moisture-stress-tolerant crop varieties were used as an adaptation strategy by smallholder farmers to combat these negative impacts during the drought season in the study areas. In relation to the low precipitation, smallholder farmers had to make a choice of crop varieties which are resistant to drought.

The data presented through interview and FGDs, in this study revealed that, maize, sweet potatoes, beans, and onions, as well as cabbage varieties, were the main crops which varied from one study site to another. During focus group discussions, the study showed that farmers have changed their planting calendar; hence, the planting of crops is done only when it rains. The study highlighted that due to numerous drivers and farming from season to season, farmers had to introduce new crop varieties in the areas depending on their climatic conditions. During the focus-group discussions in Tshiombo, one of the elderly farmers responding on the issue of introducing of new crops, stated that the growing season for crop is determined by the climate, hence, if there are no rainfalls, then farmers do not plant. These findings are similar with some surveys which revealed that farmers used drought-resistant crops as a strategy of adaptation to climate change (Maponya & Mpandeli, 2012, Komba & Muchapondwa 2015). Recent studies conducted by Pradel *et al*., (2019), indicated that potato varieties are used for climate change adaptation in India, which is in line with the findings of Fisher *et al*., (2016) who highlighted how drought-resistant crops promote more climate-secure farming in Ananthapur, Andhra Pradesh.

In Tshiombo area, sweet potato, onions and beans were adopted as drought-resistant crops in response to harsh climate change and although these crops are drought-resistant most of the smallholder farmers still grow them with irrigation water where possible, due to the extreme climate.

One elderly farmer said:

> "*Here in Tshiombo, we used to produce watermelon in the 1990s, which is most common in the moist area, particularly in Levubu area. Watermelon is common now, but we never had this crop here in the past. Many farmers depend on it, because rainfall has decreased, with little rainfall you can grow it. While from 1980 to 2000, we used to depend on maize as our staple crop, nowadays, maize farming is rare in Tshiombo because there is no enough rainfall for a farmer to be able to cultivate*" (Elderly farmer).

5.3.3. Changing planting dates and shortening cycle crop varieties

The majority of smallholder farmers preferred employing shorter-cycle crop varieties, to adapt to climate variation, especially, when they were not certain about the local climatic conditions and if they are not accessing climate advisory information well in advance. This strategy was employed by farmers in Levubu, Tshiombo, and Nwanedi, where seasonal rainfall variability has encouraged farmers to adopt crop varieties with shorter cycles and this forms part of climate change adaptation strategies. The continuous climate variations, therefore, have forced smallholder farmers to change planting date patterns, as another adaptation strategy. A similar study conducted by Turpie & Visser (2013), reported that changing planting and harvesting dates are the main strategies smallholder farmers used to adapt to climate change. Acquaah (2011), in line with the present study, mentions that changing planting dates and crop varieties are the frequently preferred adaptation strategies by smallholder farmers in Morogoro, Tanzania. This is in accordance with similar studies by Singh *et al*., (2014), on peanuts and cotton in West Africa, while, Hammer *et al*., (2002), argue that it is only partially true, since shifting in these indicators should reflect genetic variability.

In each study site, crops appeared to be distributed differently, maize remained the main cultivated crop in Tshiombo and around Tshakhuma area; Levubu area is well known for producing horticulture crops, whereas, watermelons and tomatoes varieties are planted in Nwanedi and in Tshiombo sweet potatoes were predominant. Results from the questionnaires affirmed that, in Tshiombo 64.8% farmers cultivated improved maize and 45.6% cultivated improved beans. In Levubu 70.2% of the farmers cultivated beans, as a shorter-cycle crop and 44.8% of the farmers in Nwanedi indicated that they had adopted better short-cycle tomatoes varieties and 40% were using similar type of new vegetables. These results are similar to findings which highlighted that, variations in planting dates and crop variety in accordance with regions' characteristics as well as the economic factors in relation to the scheduling of operations, were common practices for farmers (Eyshi Rezaei *et al*. 2017). These findings concur with results of studies done by Hu *et al*, (2017), which reported that, shifts in cultivar and planting dates have regulated rice growth duration under increasing temperature in China since the early 1980s. Similar findings were obtained from studies concluded in Southeast Asia, which saw rice farmers shifting to planting rice with shortened growth duration over the past thirty years (Zhang *et al*., 2013; Zhao *et al*., 2016).

During the interviews for this study, farmers maintained that it was now unadvisable to practice early planting because of the low and variable rainfall. They argued that early-planted crops, such as maize and vegetables dry and wither due to prolonged dry spell and extreme heat. This problem is also aggravated by the lack of infrastructure for storage facility. Household farmers reported that in previous years, one would sow seeds during the onset of the rainy season, but the current shorter rainfall season, which now runs from November to February, was forcing farmers to concentrate on shorter-cycle crop varieties. In West Africa, results of studies conducted with regards to the high intra-seasonal rainfall variability, demonstrated that early planting dates can lead to low yields due to extreme weather events which occur shortly after planting (Waongo, 2015; Adegnandjou *et al*., 2018). Late planting dates, although it has been proven can limit poor crops harvest, but the practice also correspond to short growing seasons which in turn can reduce harvest.

However, changing planting dates decreases the effects of crop damage or loss from prolonged weather conditions, such as, extreme drought and dry spells, causing an epidemic of crop diseases and insect pests which in turn result in poor harvests and food insecurity. Similar studies conducted in the Lilongwe District, concluded that farmers in Sub-Sahara Africa, especially, in hot and dry regions, if they plant crop varieties that have short duration for maturity (within 2 – 3 months), it will allows farmers to minimize and evade the damaging effects of moisture-stress on crop yields (Zinyengere *et al*. 2014), These narrative are also consistent with studies conducted on groundnuts and cotton, in West Africa (Loison *et al*., 2017; Singh *et al*., 2017).

5.3.4. Mixed-cropping farming

During the field survey and focus group discussions, farmers indicated that they employed mixed-crop method, to adapt to the changing climate, this was one of the traditional farming practices used to improve crop yield. The results in Table 5.2 reveal that 93% of farmers in the study areas practiced this farming system which involved selected crop types being cultivated simultaneously on the same piece of land by farmers to reduce the depletion of soil nutrients and soil moisture. These findings are in line with previous studies which highlighted that growing leguminous crops such as beans and groundnuts, together with maize plants help to reduce soil degradation, thereby, adding nitrogen to the soil (Singh *et al*., 2016; Wolz & Delucia, 2018). The practice of mixed cropping is better than mono-cropping. Similar findings were obtained from studies by Patterson & Gardener (2015), who reported that mono-cropping is a poor technique in farming, as cultivating the same or similar crops on the same plot year after year leads to pests' and diseases' outbreaks and concentrates nutrient uptake from the same soil depth, leading to nutrient depletion. In the Vhembe District, local farmers said, mixed cropping of cowpea, Bambara groundnuts and maize was essential for the soil as the combination has a significant ability to fix nitrogen in the soil, these crops are considered "green manure" as they increase soil fertility.

Smallholder farmers also practice this technique to guarantee some harvests in the event other crops fail due to climate shocks. A study conducted by Nngumi (2016) in Tanzania reported that most cultivated fields within the study area were characterised by two or more crop types dependent on the farmers' preferences and farm location. A similar study in Western Australia by Ghahramani & Bowran (2018) argued that mixed-farming methods have attributes that can be adopted for mitigation of the impact of climate variability and change, on agricultural production. Crop production on drylands in Vhembe District was characterized by intercropping of predominantly, maize with pulses of Bambara groundnut, beans and groundnuts with local pumpkins. (Figure 5.1, 5.2, 5.2). One of the farmers supported mixed farming as is shown by the following comment:

> "*Mixed intercropping technique of farming, support in the controlling of insect pests because pests damage certain crops flower and leaves. The pulses of many other crops among the main crop, therefore increasing the chance of insects to encountering bad stimuli, confuses them with taste and bad smell which is difficult for the insects to identify the chosen crop to prey on still the crop grow to maturity with limited damage from the insect pests*". (Farmer in Tshiombo)

As the result of the findings reveals, farmers in the district practise mixed-cropping methods to ensure a good harvest, in case some crops do not produce or fail. A farm size is also a factor for this type of farming system. During the field survey, it was observed that most of the farm land in the study sites were cultivated with various crops, depending on the farmers' choice and farms' location. It was also noticed that many of the crop grown in Nwanedi were drought resistant, such as beans, tomatoes and okra. This observation is in line with empirical evidence from various literatures that growing both trees and crops on the same farms land has the benefit of decreasing risk of evapotranspiration during extreme heat wave (Beedy *et al*., 2010; Magrini *et al*., 2016). This is possible for Nwanedi smallholder farmers, as the area is located in semi-arid ecological zone with high temperature.

Figure. 5.1. Mixed cropping of maize and local pumpkin under trees in Levubu (field survey 2018).

Figure. 5.2. Intercropping of sugar bean and local pumpkin in Nwanedi (field survey 2018).

Figure. 5.3. Mixed maize and Bambara groundnut Levubu (Field survey 2018).

5.3.5. Smallholder irrigation

Intensification of the smallholder furrow and sprinkler irrigation systems was one of the vital methods employed by household farmers to adapt to the current decline in rainfall and the increase in temperature in the past 30 years, most of the respondents in Tshiombo use furrow irrigation activities (see Figures 5.4 and 5.5). The Tshiombo Irrigation Scheme was initiated in June 1962. The Chiefs and the government allocated each resident of Tshiombo a plot of 1.286 hectares as agreed upon by the government and the local people, however, some residents were able to register for more than one plot because of nepotism. The irrigation technique was carried-out along the rivers, streams and a few recently constructed water reservoirs. In Tshiombo, farmers irrigate their plots of vegetable and maize gardens. The findings agree with the study in Oman, where smallholder farmers have taken the decision to plant their crops with the aid of drip irrigation before the onset of the rainy period (Choudri *et al*., 2013). On the other hand, studies in Vietnam show that, local farmers plant their rice in the dry season to avoid salinity (Bastakoti *et al*., 2014).

The results of this study show that farmers who have water produce better agricultural products as compared to those who are farming in dry areas.These findings agrees with Alam *et al*., (2017), which noted that smallholder farmers take advantage of the rainy season and planted most of their crops during the wet seasons. The result of the findings has also shown that irrigation techniques are important for improving and better-managing crop production, reducing food insecurity, and enhancing livelihoods in the district. The finding results are in line with studies conducted in Bangladesh (Alam *et al*., 2017; Tripathi & Mishra, 2017).

As indicated in Table 5.3, although all the farmers rely on rain water, Levubu and Tshiombo areas have a high number of respondents also using the furrow irrigation method at 88.7% and 89.7% respectively. It is also worthwhile to note that local farmers in Levubu area are farming in a microclimatic zone compared to farmers in Nwanedi and Tshiombo. Nwanedi has the lowest users of the furrow irrigation system. In Nwanedi most farmers prefer the sprinkler as a source of irrigation. Most of the crops grown there are for household consumption with the surplus sold at Thohoyandou and beyond. The results of Mpandeli *et al*., (2015), resonate with the current findings that, lack of water and prolong dry spells in the periods 1988/1989, 1991/92, 2004/2005 and lately in 2014/2015 have had substantial negative effects on crops and livestock production and consequently on food security and livelihood. Varieties of crops are cultivated such as maize, cabbage, swill chard, chilies, beans, sweet potatoes and varieties of vegetable because of the irrigation scheme. According to the farmers, it was a high risk to entirely depend on rain-fed cultivation in the years 1990 – 2015; however, since the installation of the irrigation scheme, crop production has improved among the farmers. Findings have also shown that some areas have adopted the irrigation strategy more successfully than others and are better adapted to climate change through the irrigation system as is reflected in the comment below:

> "*Farmers in Tshiombo have mostly relied on the irrigation farming, instead of depending entirely on rain-fed farming for the past years. Now the farmers rely much on irrigation, unlike those years when they had a dry spell and poor rainfall. Now the farmers can cultivate irrigate crops like cabbage, swill chard, and beans, they never used to grow before irrigation*" (Agricultural extension officer).

Figure. 5.4. Preparing farm for smallholder irrigation in Tshiombo (field survey, 2018)

Figure. 5.5. Smallholder irrigation in Tshiombo (field survey, 2018)

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Table 5.3. Water sources for irrigation

Sources of Irrigations	Levubu		Nwanedi		Tshiombo	
River (furrow-irrigation)	55	88.7%	33	46.5%	61	89.7%
Rain-fed	62	100%	71	100%	68	100%
Sprinkler	10	16.1%	58	81.7%	5	7.4%
Tanks	12	19.4%	15	21.1%	6	8.8%

5.4. Off-farm household adaptation/coping strategies to climate change

The uncertainty of climate trend and poor farm harvest for the past decades, have resulted in significant income instability of smallholder farmers in the study area, therefore, the majority of farmers have diversified their sources of income activities to earn extra capital.

The study reveals that, smallholder farmers in Vhembe District, as elsewhere in Limpopo Province, use a variety of strategies to cope with and adapt to the challenges imposed by climate variability and change. Most of the smallholder farmers were struggling to adapt to these effects, as they are vulnerable and with little or low adaptive capacity, hence, crops production in the farms may be discouraging. Small household farmers are trying to mitigate the effects of the climatic changes and poor crop yields by opting for alternative activities, such as small business, keeping animals and depending on remittance from relatives.

Due to the perceived impacts of climate change, smallholder farmers have adopted both on-farm and off-farm activities as a means of enhancing their resilience to climate variability and change. These individual farmer's responses, however, need to be complemented by other external interventions to improve adaptation within communities. Such intervention activities include, working on commercial farms to be paid a wage, rural-urban migration to look for jobs, getting involved in small business activities, obtaining remittance from relatives and keeping animals such as poultry. Similar findings were obtained from a study by Adegnandjou & Banjolle (2018), in the Central Highlands of Ethiopia. These, therefore, have been common complementary activities by smallholder farmers in response to climate change.

The findings of this study identified remittance from relatives as one of the most significant income sources which enhanced their livelihoods beyond farming for most household farmers. This concurs with results of the study done by Rahut & Ali (2018), however, many of the respondents who indicated remittances as the main source of income were the elderly farmers. Many of the older farmers' children and relatives who had migrated to urban towns, acted as the alternative means of support for them. These findings are identical to those of Pandey *et al*. (2018). A comment by one of the elderly farmers indicated that:

> *"In recent years, the rain has reduced and unpredictable too. Prolong drought occurs. As a result, I mostly depend on my relatives and children who work in Thohoyandou, Louis Trichardt, Musina and as far as Gauteng province to support me as the farms are no longer giving me enough good harvest for my family"* (Mr. Lufuno, an elderly farmer in Nwanedi area).

A few of the smallholder farmers are involved in commercial farm as labourers in adjacent towns and commercial farms, such as commercial plantations along the road, from Levubu to Louis Trichardt and Nwanedi to Louis Trichardt. The income from such activities is used to support their families, particularly, during poor harvests or winter seasons, since their agricultural activities depend on rainfall. These findings are in line with those of Cyan & Shackleton (2005), on the link between precipitation inconsistency and food insecurity when they were making a case on the matter of out-migration in response to changes and variability of the local climate; they concluded that climate change causes poor yields, henceforth, food shortage.

In the study area, during the focus group discussions and interviews, participants reported that they have set-up small businesses as an alternative income source to combat poor harvest. These businesses were mostly small kiosks or tuck shops for selling small consumables to their communities. Cyan & Shackleton (2005) conducted a similar study in Bushbuckridge, South Africa, and they highlighted that smallholder farmers are engaging in natural product trading for income generation due to deteriorating socio-economic and changing climate. These have encouraged some of the smallholder farmers to start up small business as coping and adaptation strategies. One of the farmers mentioned:

> *"Using some money I got from children and selling sweet potatoes and maize previous years, I set-up a small business kiosk where I sell small foodstuffs such as bread, snacks, cold drinks, cooking oil, salt, sugar etc. The sales were very supportive because past years*

I do not make a good harvest due to unpredictable rainfall but was able to buy food items and buy clothes for my children using this small business." (During focus group discussion).

Generally, only a few smallholder farmers in all the study sites responded to the adverse climate conditions by keeping poultry and animals, such as goats, pigs, and sheep in different stalls as part of their livestock diversification. Some farmers sell some of the animals to cover basic family expenses, such as foodstuff and school needs for their children. From the qualitative interviews and focus group discussion and the analysis of the quantitative data, alternative adaptation strategies were identified in the various study areas; according to percentages, these are as indicated in Table 5.4 below.

The results revealed that goats were kept by the highest number of respondents, 34.2%, chickens were second at 34%, sheep and cows were kept by 20% and 10% of participants, respectively, while pig keeping was the least employed with only 6.1%. One farmer had this to report:

"Livestock keeping support me too, especially during poor harvest. I keep some chicken, but it is not a serious business, they are only a few, I sell few and pay some food items for the family, such as buying some maize meal etc." (Mr. Chauke, farmer in Tshiombo).

Table 5.4. Distribution of livestock per site of study

Common /English name	**Tshivenda/Local name**	**Tshiombo No: 68**		**Nwanedi No: 71**		**Levubu No: 62**		**Total Percent %**
Goats	Mbudzi	6	8.8%	10	14.1%	7	11.3%	**34.2%**
Sheep	Nngu	3	4.4%	6	8.5%	5	8.1%	**21%**
Pig	Nguluvhe	2	2.9%	0	3%	2	3.2%	**6.1%**
Chickens	Khuhu	15	22.1%	7	9.9%	13	21%	**34%**
Cows	Kholomo	4	5.9%	1	1.4%	2	3.2%	**10.5%**

5.5. Indicators used to estimate choice of farmers' adaptation strategies to climate change

This study used Multinomial Logit (MNL) frameworks to estimate the drivers affecting choice of climate change adaptation strategies by farmers. The MNL framework is necessary in this study as it is useful for analysing decisions due to its interchangeable nature. Multinomial Logit Framework and marginal effects of this study are indicated in Tables 5.5, 5.6 and 5.7. Table 5.5 shows results for MNL regression model indicating the factors of using the different climate change adaptation strategies used by smallholder farmers to combat climate variation for the past years, using explanatory variables. Using the Multinomial Logit Framework analysis, it was shown in Table 5.6 that the following indicators have significant influence on farmers' adaptation to climate change. These, indicators include, educational background, gender of household head, off-farm income, farm size in hectares, access to climate knowledge, and decline in rainfall and temperature increase.

In this study, gender variation represents a significance of 0.01 levels in response to change in climate. The result further indicated that out of the 224 respondents, 55.2% were female and only 44.8% were male. As indicated earlier on, female farmers were more likely to employ new crops as a strategy of adaptation to climate change, this is in lines with a study by Nhemachena & Hassan (2007). A possible reason is that most of the farm's works are done by women, while men are busy in off-farm activities like seeking for jobs in urban areas. This finding disagrees with that of Adegnandjou *et al*., (2018), which found that men are the majority of smallholder farmers, while women were involved in processing activities like trade in *zou*, in Benin. Farm size in this study, has a positive effect on climate change, with larger farms playing a positive role in decisions on climate variability and change adaptation. An increase in farm size encourages farmers to practice diversification to suitable crop activities and animal husbandry (Lemma, 2016; Alemayehu & Bewket, 2017).

The overall results of the Multinomial logit analysis in Table 5.7 revealed that a significance of 1% of farm size is an adaptation determinant to climate change. These results confirmed that in the context of this study, 0.05 significance effect of off-farm employment brings about a change in adaptation to climate variability. The findings also showed that remittance was one of the most significant income sources which enhanced their livelihoods beyond farming for most smallholder farmers. The findings further reveal that knowledge about climate plays a vital role in farmers' awareness on decreasing precipitation and increased temperatures. Higher levels of education were complementing drivers that impact on the implementation of different techniques that could improve resilience against climate variability and change.

Table 5.5. Indicator estimates of the Multinomial logit framework climate change adaptation decisions

	Mixed crop		Changing planting dates		Drought crop		Diversification of crop		Improved variety		Irrigation (furrow)	
	Coef	**P-level**	**Coe**	**P-level**	**Coef**	**P-level**	**Coef**	**P-level**	**Coef**	**P-level**	**Coef**	**Pe-level**
Explanatory Variables												
Age	-003	0.440	- 003	0.440	-003	0.440	-003	0.440	-003	0.440	-003	0.440
Gender	- 206*	0.067	- 206*	0.067	- 206*	0.067	- 206*	0.067	- 206	0.067	- 206	0.067
Education	.26	0.26**	.26	0.26**	.26**	.26	0.26**	.26	0.26**	.26	0.26**	.26
Marital	0.57	0.153	0.57	0.153	0.57	0.153	0.57	0.153	0.57	0.153	0.57	0.153
Household size	-004	0.154	-004	0.154	-004	0.154	-004	0.154	-004	0.154	004	0.154
Farm size	.095***	0.000	.095***	0.000	.095***	0.000	.095***	0.000	.095***	0.000	.095***	0.000
Farmer experience	-003**	0.150	-003**	0.150	-003**	0.150	-003**	0.150	-003**	0.150	-003**	0.150
Household income	.031	0.269	.031	0.269	.031	0.269	.031	0.269	.031	0.269	.031	0.269
Non-farm income	-340***	0.000	-340***	0.000	-340***	0.000	-340***	0.000	-340***	0.000	-340***	0.000
Access to climate knowledge	-133**	0.015	-133**	0.015	-133**	0.015	-133**	0.015	-133**	0.015	-133**	0.015
Decreasing rainfall	-379***	0.000	-379***	0.000	-379***	0.000	-379***	0.000	-379***	0.000	-379***	0.000
High Temperature	- 137**	0.026	- 137**	0.026	- 137**	0.026	- 137**	0.026	- 137**	0.026	- 137**	0.026

Noted **** Significant at 1% (0.1 level) ** Significant at 5%, (0.05 level) * Significant at 10% probability level. (0.01 level)*

Table 5.6. Factors with marginal effects from Multinomial logit framework climate change adaptation decisions

	Mixed crop		Changing planting dates		Drought crop		Diversification of crop		Improved variety		Irrigation (furrow)	
	dy/dz	**P > y**	**dy/dz**	**P > y**	**dy/dx**	**P > y**	**dy/dz**	**P > y**	**dy/dz**	**P > y**	**dy/dz**	**P > y**
Explanatory Variables												
Age	-003	0.440	-003	0.440	-003	0.440	-003	0.440	-003	0.440	-003	0.440
Gender	--206**	0.067	- 206**	0.067	- 206**	0.067	- 206**	0.067	- 206**	0.067	- 206**	0.067
Education	-026**	0.26	-026**	0.26	-026**	0.26	-026**	0.26	-026**	0.26	-026**	0.26
Household size	-004	0.154	-004	0.154	-004	0.154	-004	0.154	-004	0.154	-004	0.154
Farm size	.095***	0.000	.095***	0.000	.095***	0.000	.095***	0.000	.095***	0.000	.095***	0.000
Farmer experience	-003**	0.150	-003**	0.150	-003**	0.150	-003**	0.150	-003**	0.150	-003**	0.150
Household income	.031	0.269	.031	0.269	.031	0.269	.031	0.269	.031	0.269	.031	0.269
Non-farm income	- 340***	0.000	-340***	0.000	- 340***	0.000	-340***	0.000	- 340***	0.000	- 340***	0.000
Access to climate knowledge	-133**	0.015	133**	0.015	133**	0.015	133**	0.015	133**	0.015	133**	0.015
Decreasing rainfall	379***		379***		379***		379***		379***		379***	
High Temperature	-137**	0.026	137**	0.026	137**	0.026	137**	0.026	137**	0.026	137**	0.026

Notes: * Significant at 10% probability level. ** Significant at 5%, and *** Significant at 1%

Table 5.7: Factors with Significant effects on adaptation to climate change effect Multinomial logit and marginal effect analysis

	Mixed crop		**Changing planting dates**		**Drought crop**		**Diversification of crop**		**Improved variety**		**Irrigation (furrow)**	
	Coef	**P-level**	**Coe**	**P-level**	**Coef**	**P-level**	**Coef**	**P-level**	**Coef**	**P-level**	**Coef**	**Pe-level**
Explanatory Variables												
Gender	- 206*	0.067	- 206*	0.067	- 206*	0.067	- 206*	0.067	- 206	0.067	- 206	0.067
Education	.26**	0.26	.26**	0.26	.26**	.26	0.26**	.26	0.26**	.26	0.26**	.26
Farm size	.095***	0.000	.095***	0.000	.095***	0.000	.095***	0.000	.095***	0.000	.095***	0.000
Farmer experience	-003**	0.150	-003**	0.150	-003**	0.150	-003**	0.150	-003**	0.150	-003**	0.150
Non-farm income	-340***	0.000	-340***	0.000	-340***	0.000	-340***	0.000	-340***	0.000	-340***	0.000
Access to climate knowledge	-133**	0.015	-133**	0.015	-133**	0.015	-133**	0.015	-133**	0.015	-133**	0.015
Decreasing rainfall	-379***	0.000	-379***	0.000	-379***	0.000	-379***	0.000	-379***	0.000	-379***	0.000
High Temperature	- 137**	0.026	- 137**	0.026	- 137**	0.026	- 137**	0.026	- 137**	0.026	- 137**	0.026

Noted **** Significant at 1% (0.1 level) ** Significant at 5%, (0.05 level) * Significant at 10% probability level. (0.01 level*

Further, from data analysis, it was revealed that as much as there are some similarities in terms of adaptation strategies, the study areas were dominated by slightly different climatic conditions and crops, characterising not only farmers' favourites, but also socio-economic status, local climatic conditions and irrigation systems in operation. Looking at the conditions in Levubu and Tshiombo, genetically modified maize has been [i]widely adopted as the main crop because of its capability to severe weather conditions, particularly prolonged dry spells. A similar situation in Zimbabwe documented by Cairns *et al*., (2013) reported that the recurrence of dry spells and lack of access to irrigation resources led to the development of drought-resistant maize varieties and its widespread adoption. In a similar study conducted in Brazil, maize was considered as the crop with the highest yield and could be grown in both tropics and sub-tropics and to a certain extent in the semi-arid areas under harsh climatic conditions with inadequate water (FAO, 2016). Kakumanu *et al*., (2016), thus conclude that farmers in China and Bangladesh used supplemental irrigation to boost crop production during long drought spells. Studies conducted in Asia, reported that, smallholder farmers cultivated their crops near water bodies as the nearby water sources can reduce a lot of cost and make for easy crops irrigation (Masud *et al*., 2017; Keshavarz *et al*., 2014). The results of this study agree with Yin *et al*., (2016), which stated that smallholder households' farmers with well-advance irrigation scheme have a better chance to adapt to drought spell than those farmers still depending on out-dated irrigation method. Farmers in Tshiombo rely on the old traditional irrigation system, which results in poor crop production.

The findings further revealed significant similarities between the different areas, as most farmers have resorted to new and diverse crop varieties instead of the common varieties, due to differences in the ecological zones. However, a dissimilar situation was reported for Nwanedi, as most farmers have always been producing tomatoes and watermelons. On the other hand, traditional crops such as maize and sweet potatoes are under no threat from the perceived impacts of climate change as farmers in Nwanedi, have been proactive. Most smallholder farmers were able to adapt timeously and have selected more resistant, higher-yield and shorter-cycle crop varieties. These results are in line with the findings of Garcia de Jalon *et al*., (2018), that, in East Africa, local farmers were introducing resistant varieties as a common adaptation measure, whereas in West Africa, changing planting dates was a measure of frequent adoption. A strategy concerning maize cultivation was implemented through the introduction of new hybrid maize varieties, which are believed to have shortened cycle from planting to harvesting in reaction to the increases in temperature. This finding disagrees with Olesen *et al*., (2011), who state that, the expected increase in temperature in the future will bring about growth of grain crops, as these crops grow and develop faster in such conditions. This latter finding is in line with research which stated that, maize production in Scandinavian nations indicates a great increase in production, as a result of increase in temperature conditions (Odgraad *et al*., 2011; Rasmussen *et al*., 2018). In this study, one of the extension officers clarified about this issue during the interview and focus-group discussion, and stated that most farmers have adopted new and better maize varieties which are more tolerant to the unfavourable weather conditions, especially, increase in temperature. In addition, the new maize varieties have shorter cycles than the traditional crops (Ramesh *et al*., 2017). Several studies in Southern Africa and South Asia have yielded similar results. Tesfaye *et al*., (2018), stated in their studies of possible benefits of drought-tolerant maize for adapting to climate change in tropical regions.

Another finding on adaptation strategy by the smallholder farmers, across the three ecological, was crops diversification. The findings show that there are four main crops been cultivated in the study sites, - maize (improved varieties), Irish potatoes, vegetables, and tomatoes. According to Maddison (2006), the cultivation of multiple crops is regarded as the most widespread adaptation strategy across Africa. Although, the strategy was not evenly spread across regions, for instance, crop with shorter cycles were more preferable in West Africa (Olubode, 2019). Findings from South Africa indicated that this adaptation strategy is not differentially demarcated spatially, with exceptions only in the type of crops preferred. Li *et al*., (2018), highlighted that crop diversification methods helped farmers to overcome the challenges of poor productivity, while generating extra resources and reducing the impact of the failure of one particular crop.

Furthermore, this study discussed the techniques aimed at diversifying income sources from farmers' activities from the farms, to off-farm, to combat climate variability and change. According to the heterogeneous nature of the study area, farmers participated in various income-generating activities. A similar study by Bryceson (2004 & 2019), revealed that diversification of households' livelihood activities, management arrangements, altering farming activities, income generation schemes, trading of labour and the shifting to non-farm incomes were the more prominent adaptation strategy within Sub Sahara Africa, however, it varied from one study area to another. In this study, 76.6(%) percent of the respondents in Levubu were engaged in various alternative income-generating activities; in Tshiombo it was 79.6 percent, while in Nwanedi it was 72.6 percent. The study showed that most smallholders farming have been evolving in response to climate variability and change. The determinants choice of farmers' adaptation to climate change was significant as the computed P-value is greater than the significance level alpha = 0.05.

5.6. Summary

Climate variability and change influenced smallholder farmers to employ coping and adaptation strategies at farm levels. This study revealed the changes that farmers, within the study sites have been making in adapting to climate change. FGDs, questionnaires, and interviews were used as data collection techniques. The success of adaptation methods is mainly a function of various socio-economic and interrelating factors. The adaptation methods include; changing to short-cycle crop varieties, changing dates of planting, diversification of indigenous crops to newly-improved crops and using drought-resistant crop varieties.

The adaptation strategies selected depend upon understanding significant determinants of smallholder farmers' desire to design impactful strategies in the study area. The relationship between the exploratory variable and dependent variable was analysed using Multinomial logit Regression Framework. These adaptation strategies to climate variability and change indicated that socio-economic and physical variables influence the choice of farmers. The significant determinant drivers affecting households' choice of adaptation methods include; educational level of household head, landholding size, available information to climate change, off-farm activities, decrease and increase of rainfall and temperature respectively.

Due to the negative effects of change on agricultural activities, it is important to reduce this calamity of changes in climate. After accessing and analysing farmers' perception and adaptation approaches to climate variations for the past three decades, the national and the local authority need to improve farmers' methods of adaptation; they need to encourage farmers to exploit institutional and indigenous knowledge system in the study area to improve local farmers' livelihoods.

CHAPTER SIX: STAKEHOLDER INTERVENTION TO CLIMATE CHANGE AND FRAMEWORK FOR LIVELIHOOD SUSTAINABILITY

6.1. Introduction

This chapter focuses on climate change as a multi-stakeholder and multi-dimensional discourse, which lies in multi-sectoral adaptation approaches. Therefore, the determination of stakeholders' roles and their effectiveness in climate change adaptive capacity is of great concern in this study. This section of this chapter examines a sustainable livelihood framework for assessing climate change vulnerability, which depends upon several drivers to sustain farmers during climatic shocks.

The first section of this chapter, hence, reflects on stakeholders and their responses to adverse climate change, mainly, to adaptation strategies at the local community level. In the literature review, the role of institutions in adaptation was well-defined and in practice several drivers come into action and they tend to support these roles. Ospina & Heeks (2010) reported that institutions play an important role in adaptive strategies to climate change trends, while capacity to adapt relies on two additional drivers, namely; availability of resources to cope with exposure and the dissemination of these resources across the system. Several bodies made-up institutions, which may include formal or informal, government departments, NGOs and indigenous knowledge of the local farmers, however, not only were climate change interventions and support systems not accessible to smallholder farmers, but access to agricultural support systems was also a big challenge. The farmers indicated that some of the challenges include the fact that they receive inputs after planting seasons have passed. Thus, they have to rely mainly on their indigenous knowledge and each other for making decisions on when to plant? how to plant and when to spray chemicals? Several sources of information and opportunities have always been employed by institutions to design and promote proactivity in adaptation methods. This sub-section reveals the role of institutions in supporting smallholder farmers to adapt to adverse changing climate. Although, institutional support relies on decision made at individual or household level in some cases.

6.2. The role of stakeholders in response to climate change

Multi - stakeholders' roles on climate challenges vary internationally and at household levels. They are normally hinged on access to assets for a better livelihood. Several researches have been conducted and they confirmed that climate change is occurring and the community must engage in necessary steps to adjust to the impacts for an improved community livelihood. As revealed in Chapter Three, there were multiple stakeholders who were directly or indirectly involved in adaptation strategies in response to climatic risk issues in the Vhembe District Assessment of the knowledge and activities of the smallholder farmers relies on the role of major institutions such as, the South African Weather Service (SAWS), Agricultural Research Council (ARC), Vhembe Department of Agriculture (Vhembe District), Agricultural Extension Officers and Indigenous Knowledge Systems (IKS), and expert staff working in the various organizations. Some of their roles in combating climate change are indicated in the following sub-sections.

6.2.1 The role of extension services in promoting farmers adaptation strategies to climate change

Smallholder farmers have been experiencing negative effects of climate variability and change on their agricultural production, for example reduction in crop yields, frequent outbreaks of diseases and pests. These factors affected mostly agronomic crops, such as maize, tomatoes, and onions. It is important to note that maize is regarded as a staple crop in the various communities in the Vhembe District, when there is drought, maize crop is mostly affected because it is sensitive to high temperature and heatwave.

The results of the study indicated that the Government seems not to be doing enough to assist farmers to adapt to climate change; 95% of the farmers suggested that they need to be assisted and protected against adverse climatic conditions. The farmers further said there is a need for more boreholes, training and capacity building, modern farming implements, as well as financing of agricultural inputs. The finding also reveals that changes in climatic conditions affect crop production; however, farmers are hopeful that if they get adequate guidance and support, they will adapt enough to keep their farming activities going on, as well as securing their livelihoods.

The results of the study indicated that extension services need to support on-farm and off-farm activities through new knowledge, in an adequate and timely manner. Accordingly, 85% of the farmer respondents confirmed that they have received support service from extension officers. This narrative is also consistent with results by Brow *et al*. (2018), who stated that extension officers were seeking a better mandate to bring services to developing countries. These services are based on the use of improved (hybrid) seed, natural resources conservation and inorganic fertilizers.

This has a vital implication for promotion of practices that aim to increase crop yield. Furthermore, farmers complained that some agriculture officers were not well qualified to do the job, while the extension officers put the blame on the Vhembe Department of Agriculture for not organizing relevant training courses on agriculture production and climate change. There is, therefore, a need for extension officers to attend training courses in order for them to capacitate themselves and be able to transfer their knowledge to smallholder farmers as part of capacity building and technology transfer. Several studies reported that extension services were necessary to assist smallholder farmers to acquire new technical knowledge, new skills, smart agricultural techniques, production support systems (Maponya & Mpandeli, 2013).

Shah *et al*. (2019) conducted a study in Pakistan where smallholder farmers used ecosystem-based adaptation services. The farmers stressed that there were challenges, such as lack of publicity and sharing of climatic information among farmers, lack of managing strategies during dry-spell seasons and long-term adaptation approach to the issues. During the focus group discussions (FGDs) at the district and local areas, agricultural professionals produced no different opinions from the NCCRP and Climate change Monitoring and Evaluation policy framework on climate change. Issues which are dealt with at the national and provincial levels were not cascaded to the local and farm levels.

The farmers during FGDs reported that Government has in some instances implemented measures to support them, such as the periodic supply of inputs to their farms. Farmers also revealed that in some instances, they did receive seeds from the Government through the Department of Agriculture, but this did not have any direct impact in terms of them adapting to climate change. The results further reveal that farmers still feel the Government has not done enough to support their efforts to continue farming, as no technical awareness programmes have been done to educate farmers on what climate change really entails. This finding is in line with the studies conducted by Simtowe *et al*., (2016) and Ayelazuno *et al*., (2019).

6.2.2. Agricultural Research Institutional role in combat climate change risks

The results showed that there is a great association among farmers, information of climate change, adaptation to climate change, information received through extension services, food scarcity, food security and agricultural production (Maponya & Mpandeli, 2013) he study area, there was evidence that rainfall is unevenly distributed and temperature increase was the major crises of smallholder farmers of the study sites, hence, this demands the generation of smart agriculture support that can combat adverse climatic shocks.

From the results, the majority of farmers (85.8%) stated that credit is needed to purchase fertilizers and drought-resistant seed and the remaining 14.2% mentioned the credit being used for livestock fattening. The farmers have requested that the Department of Agriculture should set aside special financial capital that could be available and accessible by poor farmers in the study area during drought and floods periods, so that they may engage in livelihood diversification and enhance their adaptive capacity to harsh climate. This concurs with the results of a study done by Lemma (2016), which analysed smallholder farmers' perceptions and adaptation strategies in Western Amhara Region of Ethiopia. The existence of credit service providers depends mainly on government decision at several levels. For example, the availability of local agricultural agent depends on financial policy from the Department of Agriculture, Land Reform and Rural Development.

The results reveal that weather-conditions data play a key role for smallholder farmers whose activities depend on rain for better crop yield and livelihood. Nadi (2014) confirmed that meteorological information is necessary to subsistence household farmers who depend on rain for high agriculture production. The South Africa Weather Service is the main body concerned with meteorological knowledge, therefore, it is expected to organise and circulated weather forecast information across seasons to various organisations in Vhembe District The Water Research Commission has developed a Hydrosoft Climate Adaptation Framework (HCCAF) as a Geographical Information System (GIS) tool, which monitors the water situation of various localities located in areas of climate changes and analyses as a single-integrated scenario. The baseline objective of this scenario is to determine the level of vulnerabilities and adaptation strategies best suitable for each area.

The findings of the study indicated that, the success of institutional support depends on decisions made at the national down to households' levels, which involve both coping and adaptation strategies. Households' level is usually supported by local institutions, by support structures which target the adaptation processes and parameters associated with decisions made by the local population (DAFF, 2014). It was revealed that, smallholder farmers required some support to change agricultural activities, such as information on predictable weather patterns. Accepting that present-day farming activities are no longer profitable; the majority of farmers have developed several appropriate alternatives measures in order to cope with and adapt to the drought periods. During the interviews, it was clear that farmers are aware about issues, such as book balance, market prices, crops, which have high value, inputs prices such as those for seeds and fertilizer; this was in addition to information on threat-reduction mechanism such as insurance for agricultural production.

The farmers confirmed that the Vhembe District Department of Agriculture have been supporting through providing them with fertilizers on credit base, since 2005. The study additionally, highlighted that institutional loans to farmers play a vital role. This helps the farmers to cultivate news crop varieties as adaptation strategies to combat the changing climate's impacts, particularly in semi-arid zones. Institutional loans have been given to respondent farmers in the study sites for buying of farm inputs, such as chemical fertilizer and pesticide and to engage in small-scale commercial ventures.

6.2.3 Local community organisation level

The study revealed that, at the grass root level, there is a need to establish the role of municipalities, using a bottom-up approach. Local farmers provide the baseline input for decision on adaptation issues both for current and future strategies. It was indicated during the field survey and interviews that local institutions have an important role in planning how rural household respond to natural environment challenges. For adaptation at the local level, it is essential to understand the role of local institutions in recognising and enhancing capacity of the most vulnerable farming groups. It was noticed that there exists a local-level network of monitoring of the changing climate, to enhance decisions and support systems. The Non-governmental organisations (NGOs) provide local farmers with appropriate information on climate variations by developing mechanisms sensitive to climate change issues. Furthermore, NGOs have established frameworks to share, educate and exchange at the farm-level, knowledge and experiences on climate risks and adaptation strategies for household members. To structure these frameworks, household members' educational levels and skills were used together with their experience on the effects of their adapting strategies.

The data from the FGDs with farmers revealed that most smallholder farmers get available climate change information mainly from local and national radio broadcasts, as well as from agricultural extension officers. Tangible climatic-related information is better disseminated through these avenues rather than other sources.

6.2.4. South Africa Weather Service in response to climate change risks

The participating farmers reported that, SAWS is expected to organise, update and circulate timely weather forecasts among farmers and stakeholders. Furthermore, developing early weather warning and forecasts by the meteorological stations is essential for adaptive capacity. Household farmers need an early warning system as one of their drivers against climate change effects on rain-fed agriculture.

During the focus-group discussions, farmers reported that there exist little or no activities to gather meteorological data to aid them to decide when to start planting. The findings indicated that farmers need weather information before the planting season starts in order to minimise risks. When extreme weather conditions are expected, weather information is needed to support farmers plan for what to do in the season. The result of the study reveal that such types of services have not been established to boost the farmers. The circulation of climate knowledge is not timely and reliable because of poor communication network among respondents.

The findings revealed that, it is not only climate change interventions and financial support systems, which were not accessible to farmers, but access to agricultural support systems was also a big challenge to the farmers. These findings are similar to those outlined by Ubisi (2016).

6.3. Indigenous Knowledge System (IKS) use in managing climate change

Most of the farmers are of Venda and Tsonga origins; they have traditional beliefs and sense of mythological guidance in certain climate-related matters. The manner in which traditional farmers understand climate changes is materially different from the theoretical and western knowledge (scientific approach), which has been highlighted in different sections in Chapter two. Traditional awareness of what constitutes climate variations in rural Vhembe District might have been influencing, in many ways, the manner in which the majority of smallholder farmers responded to the different impacts of climate change.

This sub-section examines the role of traditional knowledge practices in climate change strategies. As noted in the preceeding chapters, smallholder farmers are aware of the concept of climate variability and change as they have observed and experienced changes such as decrease in rainfall, early cessation of rainfall, increase in temperature, frequency of drought, shorter growing season. These changes have had adverse influence on crops production for the past decades. Despite these huge challenges resulting from these climatic changes, local farmers still use their indigenous knowledge techniques to cope and adapt. Indigenous farmers, however, are highly vulnerable to the effect of climate change and have low adaptive capacity (Jiri *et al*., 2016). These smallholder farmers have developed a variety of methods and socio-economic responses that creates the basis of their resilience to climate change. Therefore, a strong argument can be made for revamping indigenous-based resilience as a root for adaptation technique.

The concept of Indigenous Knowledge System (IKS) is also known as "traditional knowledge". Chanza (2014), explains climate-based IKS as the assembly of knowledge, skills, technologies and practices of local indigenous communities, which they have developed from observing and experiencing changes in climatic phenomena over a long period. Applying this local knowledge, smallholder farmers have developed several solutions to the challenges affecting crops production for the past decades. One of the best strategies of managing impacts of climate variation is to produce crops, which can easily adapt or withstand high temperature; in other words, taking measures in response to climatic stimuli.

The findings of the study revealed that indigenous knowledge play a major role in weather forecast and farming decisions in crop planting. This concurs with results of studies carried out in Limpopo and Western Cape Provinces in South Africa (Ncube & Lagardien, 2015; Jiri *et al*., 2016). The results of the current study indicated that smallholder farmers in Vhembe District use a combination of indigenous weather indicators and forecast, such as wind movement, flower and fruit productions, star and moon movement, black and red ants' appearance, behaviour of certain plants, germination of new leaves and mist-covered mountains as weather indicators of the beginning of planting season. The findings from this study revealed that out of 224 respondents only 75, which is equivalent to 37.3% were using IKS to predict seasonal climate for planting. Similar studies have highlighted that smallholder farmers have been found using lunar cycles, behaviour of animals and birds to predict planting season (Mpandeli, 2006; Akullo *et al*., 2007; Masinde & Bagula, 2012).

The study also showed that the level of awareness of traditional knowledge on weather forecast was high among the age group above 60. Younger farmers said that they have little or no interest in this system of weather forecast, as that type of farming methods are based on trial and error. This finding agrees with that of Egeru (2012), which stated that younger farmers were more interested in western knowledge than Indigenous Knowledge System. Furthermore, increasing levels of educational level among farmers and heterogeneity in the population make people less dependent and interested in their local knowledge for weather forecast. These findings are in line with a study conducted by Nganzi *et al*., (2015) in Kampala, which noted that many of the indicators that their ancestors usually used to forecast weather is slowly disappearing, hence, the younger generation are more responsive to western information. Jiri *et al*. (2016) argue that phenology, animal behaviour and atmospheric indicators have also altered to an extent that they may also mislead smallholder farmers in their decision-making. Table 6.1 shows the use of Indigenous knowledge indicators of weather forecast and planting crops in Vhembe District by smallholder farmers.

Table 6. 1. Indigenous knowledge indicators of weather forecast and planting crops in Vhembe District**.**

Indicators	Meaning according to the smallholder farmers
Flower and fruit production of local trees	Many local trees produce flower and fruit at the beginning of season, which is a good sign of good raining season
Star and moon movement	Movement of star from west to east at night under clear skies means rain will fall in few days to come/ good raining days
Winds movement	Winds moving from west to east shows beginning rainfall
Behavior of certain plants germination of new leaves on baobab tree	This tree is common in the Limpopo province, germination of new leaves on the baobab tree is an indication of heavy raining season
Mist-covered mountains	Showing sign of good rains in few days to come
Appearance of red ants	A lot of rainfall is coming
Black ants	Appearance of too many black ants it a sign that it was a good raining season, so farmers can start planting.
Cloud formation	Present of dark cloud indication of rainfall

6.4. Employing Indigenous Knowledge System (IKS) to determine seasons and predict weather conditions

Several studies have considered IKS as social capital for the poor; relied upon for local food production and livelihood security. Scientific knowledge and traditional knowledge system are portrayed as competing knowledge systems, characterized by a binary divide. This divide has arguably evolved out of the epistemological foundation of the two knowledge systems. Therefore, these systems may be treated as discreet entities separable from each other in space, which precludes dialogue and learning between them (Mohan & Stokke, 2000). Western science is seen to be open, systematic, objective and very much dependent on a detached centre of rationality and intelligence. Indigenous Knowledge is seen to be closed, parochial, unintellectual, primitive and emotional (Elia *et al*., 2014).

Just like scientific forecast, indigenous smallholder farmers rely on observation and interpretation of specific weather phenomena; it suggests an alternative to modern scientific prediction. Environmental technical indicators that farmers use to forecast the coming season become available for observation at different times of the year, starting immediately after harvest and continuing into the new season. The Indigenous Knowledge System indicators shown in Table 6.1 indicate that farmers mostly rely on wind behaviour, cloud formation, temperature observation, animal behaviour, birds' appearance on trees, surveillance of the moon and stars, fruit production of certain trees, temperature during the dry season and throughout the year. This narrative is also consistent with results by Mpandeli, (2006), Ncube & Lagardien, (2015) and Jiri *et al*., (2016).

Climate variability and change pose problem in the provision of accurate and reliable seasonally predictions and forecast information, however, effective coping and adaptation strategies can only be attained through accurate weather and climate predictions, as this will help farmers in making informed decisions on their farming activities leading to increased food productivity (Kijazi *et al*., 2013). For smallholder farmers to make various decisions for adaptation, therefore, they need climate knowledge, whatever the source of information (Gukurume, 2014).

The findings of this study show that, smallholder farmers rely on rain-fed farming, but in the context of increasing variability of the rain, production is affected. During the FGDs, it was revealed that smallholder farmers stand specifically to benefit from climate change information because of the link between climatic patterns and crop production. This has generated hope that accurate weather predictions may boost food security for highly vulnerable groups, in less-developed countries. Interpretation of climate forecast depends on the way people think about climate variability and crops yield. These observations are in line with our results and studies by Naganzi *et al*. (2015). Traditional smallholder farmers predict the future by depending on factors like, ancestral divinations, Islamic scripture as well as spiritual ritual for rainmaking.

The process of forecasting in the indigenous system is just like scientific forecast, which relies on observation and interpretation of specific phenomena. The results of the study indicated that indigenous farmers often use the present of dark cloud formation to forecasts rainfall occurrence. An estimated 75% of the local farmers observed in the study sites perceive cloud formation as one of the important instruments to monitor climate change. During the focus-group discussion, local farmers reported that the appearance of too many black ants is a sign that it will be a good rainy season, so farmers can start planting. The findings revealed that more than 58% of farmers in the Levubu, Tshiombo and Nwanedi area were using the presence of black ants as the beginning of the planting season. This finding is in line with various studies conducted in Tshiombo, Rabali and Tshakhuma areas and in other regions on the continent (Mpandeli, 2006; Nganzi *et al*., 2015). Most of the indigenous farmers in Levubu area indicated that the present of mist on the Soutpansberg Mountain is a sign of good rain in a few days to come, hence, the farmers prepare the farms for planting. Similar findings were obtained from the studies conducted in Vhembe District (Mpandeli, 2006; Maponya & Mpandeli, 2013).

However, more than 70% of farmers in Nwanedi use tree characteristics as indicators within traditional forecasting system and 18% indicated that they used other indicators, such as the movement of stars. This movement of stars under clear skies meant rain will fall in a few days to come. The results show that germinations of new leaves on the baobab tree is an indication of a heavy rainy season. This concurs with studies done in Southern Africa (Kaland-Joshua *et al*., 2011). Older farmers in Nwanedi and Tshiombo reported that winds moving from West to East show the occurring of rain within 12 hours. During the focus-group discussion, farmers also cited the behaviour of insects sometimes predict to them the occurrence of crop disease challenges during planting season. This study, therefore concluded that in order to cope and adapt, local farmers employed a variety of indicators to plan and manage crop production practices (Biggs & Moya, 2012; Jiri *et al*., 2016).

6.5. Developing a conceptual framework for Sustainable livelihood

Sustainable livelihood frameworks can be used as a tool for reducing smallholder farmers' vulnerability. One of the approaches to reduced vulnerability is to start practicing adaptation options, although, the availabilty of farmers' assets and capabilities often define poverty levels and their capacity to improve their lives.

The present study links sustainable livelihood to smallholder farmers' role and capital assets. The farmers' activities and capital assets measured as independent variables and the livelihood as the dependent variable. The changes in the capital assets and farmers' activities may affect the livelihood, if the farmers develop positive adaptive strategies, and capital assets, they may accomplish a positive change in their sustainable livelihood. The livelihood strategies, institutional policies and processes will help the farmers to attain the livelihood promotion and help to reduce farmers' vulnerability to on crop production. In this way, farmers can manage livelihood's outcomes, like more revenue, increased social status and empowerment, reduced vulnerability, more sustainable base from natural environmental resources. This study presents a conceptual framework that disaggregates the various ways and structures that affect the farmers in their struggle for livelihood. The conceptual framework developed in this study consists of farmers and capital assets-based response to impacts of climate change on crops. In focusing on the livelihood of the farmers, the intent of this study was to provide an understanding of how to attain sustainable livelihood promotion. Figure 6.1 indicate a sustainable livelihood framework.

The study further reveals that farmers' livelihoods do not depend mainly on crop production; therefore, there is limited knowledge on how farmers are vulnerable to climate impacts on crop production. The exposure of smallholder farmers to climate change and extremes, particularly, heatwaves, increased temperature, drought and decreasing rainfall poses substantial negative effects on farmers' livelihoods in the study area. This study used a sustainable livelihoods framework as one of the drivers relevant to understand vulnerability to climate change, it provides a framework for analysing major components that make up livelihoods. Eakin & Luers (2006) concluded that an association with factors that make smallholder farmers sensitive to the impacts of climate trends could disrupt natural ecological systems, which reduces crop yield.

6.5.1. Smallholder farmers' alternative strategies in response to climate change

Livelihood diversification has been used as a coping and recovering strategies in many agricultural areas in response to changes in climate. The majority of farmers diversify their livelihoods activities because of insufficient resources from their agricultural production, as a baseline livelihood income. Their sole dependence on their land for crop production do not provide sufficient means for their survival. Hence, diversification of livelihood capital assets has the capacity to spread the risk over a portfolio of activities and to reduce the vulnerability of farmers in case of crop production failure.

Alternative livelihood strategies used by smallholder farmers in the Vhembe District are varied as illustrated in Figure 6.1. These are strategies aimed at diversifying the assets of smallholder farmers, hence, making them less vulnerable to the impact of climate variability and change. The choice to engage in an alternative livelihood activity, for most of the smallholder farmers in the Vhembe District, is influenced by current crop-yield trends as more than half (61%) of farmer have resorted to alternative livelihood activities due to either crop failure or low yield. Accordingly, 24% of participants were engaged in these livelihood activities without any climate-related reason, while only 15% of the respondents do not engage in any alternative livelihood activity. This latter group are farmers who depend solely on agriculture as a livelihood and rely on remittances and other forms of social support. The NGOs and extension officers who assist to support farmers, particularly women, to engage in alternative income-generating activities explained that off-farm income-generating activities, in the Vhembe District have increased in the last fifteen years and have been skewed towards trading, becoming domestic workers and small-scale mining; the latter however did not receive much focus. This could be because those who engaged in these activities may not have acquired the legal rights to undertake such activities and hence do not feel safe giving out such information about them. Interactions with the farmers, informally, revealed that it is one of the major alternative engagements that has emerged in recent years. One of the farmers added: "in view of weather changes, farmers have increasingly engaged in other livelihood activities, particularly petty trading, processing and little-animals keeping".

The study revealed that most smallholder farmers in the Vhembe District (28%) are into petty trading. This, as observed in the communities, includes the sale of cooked food, small household appliances and accessories, and clothes among many others on table tops and stores; others carried these from one community to another on head pans. The framework serves as the basis for understanding how farmers can build coping strategies against extreme events and diversify their activities to increase resilience to unforeseen future climate change. The finding of the research in relation to farmers' capacity, opportunities and threats to optimise crop production to support changing climate are indicated in Table 6.2.

During focus-group discussions, one of the coping elements used by farmers was diversifying livelihood through aquaculture, businesses, seeking job (formal and informal) and intensification of agricultural activity; the majority of farmers, however, chose a combination of all these elements. Farmers from the different household groups may differ with respect to which element they prefer.

The results also revealed that 68% of smallholder farmers have been affected by local crime on crop yield, hence, younger farmers, especially men, turned to formal and informal wage employment in nearby urban areas. Similar findings obtained from the studies conducted by Pandey *et al*. (2017) show that a sustainable livelihood framework based on social capital was used in response to climate change in Himalayan communities. The coping method employed by these farmers was the same, as they received remittance from relative and friends employed in urban areas. Further, during extreme weather events farmers received loans from formal and informal institution, such as the banks. Farmers' sensitivity was higher as 1.5% percentage had access to climate knowledge through social network, therefore, only a small proportion of farmers were not taking advantage of, or exploiting their relationships with government institutions and the NGOs. During the FGDs, smallholders indicated high vulnerability and lower adaptive capacity in term of social asset.

Smallholder farmers have witnessed prolonged dry spells, decreased rainfall, longer dry spells, and disease outbreaks like malaria, livestock deaths and poor crop harvest over the past three decades. Temperature increased has been noticed by 78.5% of participants, heatwave by 18.1%, but only a negligible portion of about 8.3% had perceived increase in floods.

Like social asset, physical capital consists of infrastructure and local services needed to sustain livelihoods. Farmers reported that crops have been attacked by many diseases in the farms as a result of climate change. About 28.7% of households had experienced some new diseases as compared to previous decades. These finding are similar to those from different regions. For example, increasing temperature and changes in rainfall pattern has resulted in invasion of crop by pest (aphids attack) and diseases (IPCC, 2007; Pandey *et al*., 2017). Increasing heatwave, therefore, results in huge losses of households' crop yield, and further reduction in poor farmers' livelihoods.

Human assets play an essential role in farmers' livelihood, including the skill and knowledge ability that support farmers to pursue different livelihood approaches. This finding revealed that inadequate human capital in the study area meant that farmers were very exposed to climatic variability and changes, hence, a high section of smallholder farmers were reliant on poor crop harvest, resulting in only 8.2% of households with sufficient harvest obtained from the farms. These findings are in line with previous work by Pandey *et al*., (2016) and Macchi *et al*., (2013).

Natural assets include natural resources on which smallholder farmers depend for livelihood, as this involves a variety of tangible and intangible amenities. During the FGDs farmers reported that there is a close relationship between natural asset and vulnerability; natural processes are some risks that affect the livelihoods of poor farmers. Smallholder farmers were more exposed to natural assets due to their dependent on rain-fed agriculture production. The study in Africa by Lerchenko & Brien (2016) analyses the dynamics of rural farmers' vulnerability to global change in South Africa.

Table 6.2. Livelihood capitals and vulnerability dimension

Livelihood capital	Description of Vulnerability dimensions		
	Exposure	**Sensitivity**	**Adaptive capacity**
Social	*Households affected by criminality	* Farmers households without access to climate information.	8* farmers receiving support, remittance or loans. *8 household receiving help from social network.
Natural	*Farmers with lack of nature resources. *Households with poor crop harvest. *Smallholder experiencing problems with irrigation water.	*Farmers relying solely on crop production as a source of revenue. Farmers Households dependent on farming activity for food.	*smallholder farmers not practicing crop diversification * Household reporting changing planting date. * Natural resource diversification.
Financial	* Farmers with farm-size less than 2ha. * Household with loss of crop production due to climate change	*Local farmers using pesticide. *Farmers households' not receiving support from family members and friends.	*Smallholder farmers receiving support from NGOs, government. *Households exchanging money between social network *Farmers using chemical fertilizer.
Human	*farmers with insufficient harvest from farm. *farmers with inadequate nutrition.	*Household members migrating to urban areas. * Farmers reporting stress due to climate variation. * Farmers reporting crop disease due to climate effects.	* Households whose head is educated (decision). * Household with farming experience more than 15 years. * Households labour skills.
Physical	* Households farms attached by climate change diseases	*Farmers without irrigation water. * Farmers with suitable agricultural land.	* Farmers with land-size more than 2h *Households with livestock.

6.5.2. Farmers' sustainable livelihood framework assets

Presently, sustainable livelihood frameworks have been widely used in research and international development, and existing frameworks are mainly proposed by the Department for International Development (DFID), United Nations Development Program (UNDP), and CARE International (CARE). Among the above, the most widely used framework is the Sustainable Livelihood Approach (SLA) analysis framework proposed by DFID, which has been adopted by many organisations and scholars. In this context, "A livelihood comprises the capabilities, capital including (human, social, natural, physical and financial) required for a mean of living and "A sustainable livelihood is when the system can cope with and recover from stresses and shocks and maintain or enhance its capabilities and capital now and in the future, while not undermining the natural resource base" (Chambers & Conway, 1992).

In this study and in the framework, farmers also make a living in a particular context of vulnerability. In this context, livelihood assets are "the fundamental content of the sustainable livelihood framework". The results of this study revealed how smallholder farmers act under specific livelihood assets and farmers vulnerability to changes in climate. Smallholder farmers employed various mechanisms in the study area to reduce their vulnerability (Thorlakson & Neufeldt, 2012). For effective adaptive capacity for farmers in the semi-arid Vhembe District, a high level of households' financial resources is required to support social and human capital against climate risks. Studies conducted on climate change vulnerability and adaptation for Himalayan communities, natural capital was identified as a dominant factor among the livelihood capitals (Pandey *et al*., 2015; Gerlitz *et al*., 2016). The study is based on sustainable livelihood framework and the five forms of asset used for sustainable livelihood. The linkage is between the five forms of livelihood asset, smallholder farmer and climate change (Figure 6.1). Therefore, the identified means and ways for enhancing farmers' assets can help the smallholder farmers in the Vhembe District become more resilient to climatic shocks. The analysis has shown the role each sustainable livelihood assets has played in achieving a resilient smallholder farmer by outlining the specific impact on the assets upon climate change.

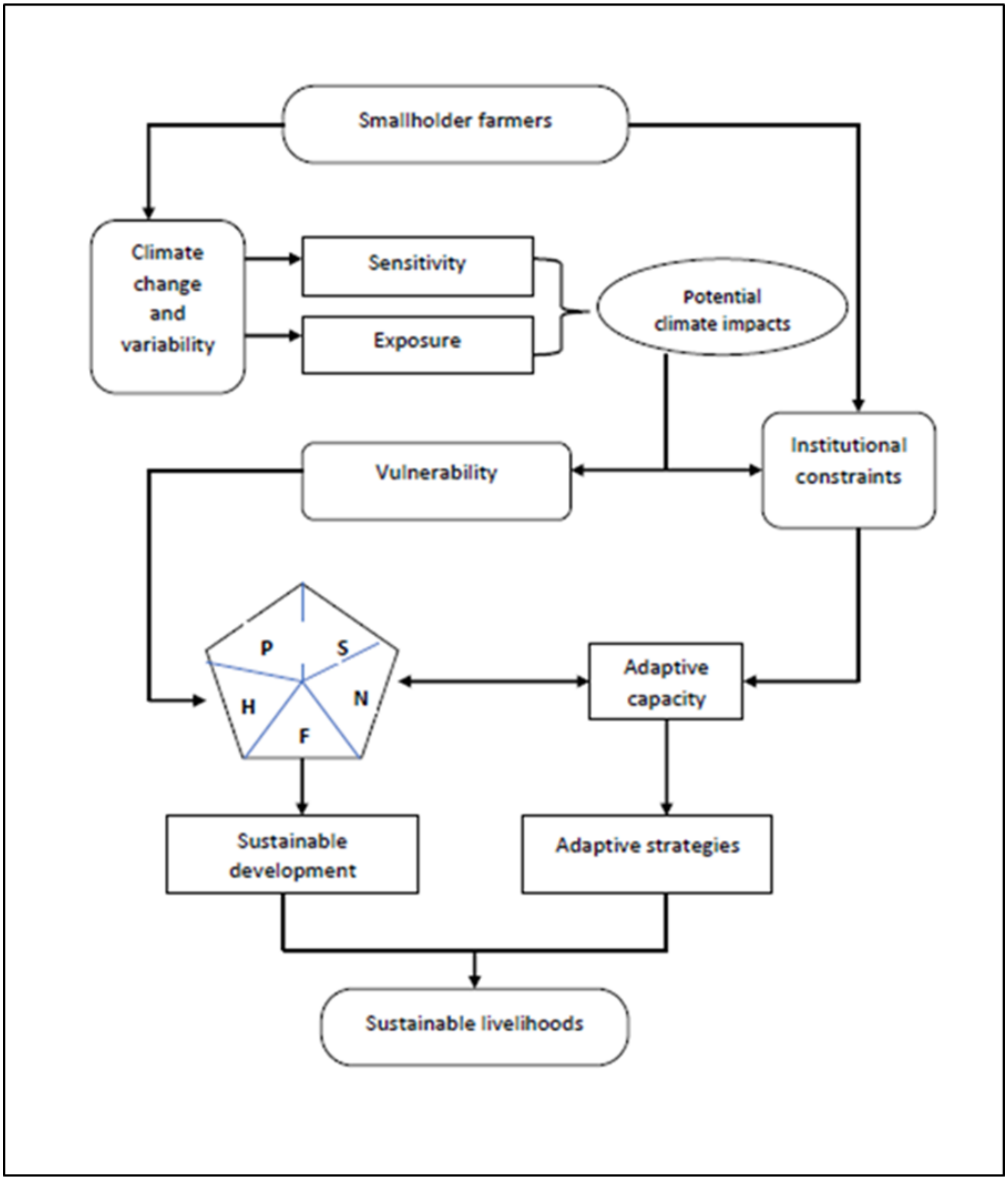

Figure. 6.1. Sustainable livelihood conceptual framework (Adopted and modified from UK DFID Sustainable Livelihoods framework (1999)

6.6. Summary

This study revealed how climate change negatively impacted the smallholder farmers. Hence, smallholder farmers need some practical effective coping and adaptive strategies. To achieve these, a multiple system, farm extension officers, agricultural research centre, institutional organisation, District Department of Agriculture, climate weather services, local community, indigenous knowledge systems (IKS), politicians and administrators have to put their hands together. These coping and adaptive capacity tasks are being practiced at local level, the institutional organisations and integration of Indigenous Knowledge Systems mandate helps to booster the activities. There was minimal effort by the institution to strengthen smallholder farmers in respond to climate variability and change.

Therefore, this study has demonstrated lack of integration of stakeholders' organisation in charge of climate change issues strongly reduces an effective adaptive capacity strategy and increase negative climate change effects on crop production. Hence, adaptation strategies without indigenous knowledge and institutional organisation are surely likely to fail to achieve its goal. Other strategies that farmers have employed include alternative off-farm revenue sources, for instances out-migration, remittance, doing small businesses and animal husbandry to support livelihoods of the farmers' household.

The closing chapter of the study highlights findings of the study, before stating the conclusions and recommendations.

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CHAPTER SEVEN: CONCLUSIONS AND RECOMMENDATIONS

7.1. Introduction

Climate change and its challenges are common phenomena which affect all sector of the economy, however, this study dealt with climate change impacts on crop production and adaptation strategies employed by smallholder farmers to combat these changes. The objectives of the study were to examine farmers' perceptions and knowledge of the local climate trends from 1980 to 2015, adaptation strategies and institutional attempts to react to climate variability and change adaptation methods. In addition, indicators of how farmers' address these issues were assessed. The results from all the analyses are to be used to assess a sustainable livelihood framework. This last chapter of the study seeks to integrate findings and further provide recommendations for practical application of the findings and for future research thrusts.

7.2. Conclusions

The study conclusions were derived from the findings of the objectives as indicated in chapter one as follows;

- South Africa has been one of the countries highly affected by changes in climatic conditions. The Vhembe District has not been spared by the natural environmental conditions on crops production. Local farmers were asked to compare the recent local climate conditions with those of the past 20 to 30 years. The findings showed that for the past three decades, most of the smallholder farmers in the study sites had knowledge that rainfall is decreasing and erratic, while the temperature is constantly increasing. Furthermore, there exists a link between changing climatic conditions and crop production at the study sites, as climate changes have impacted negatively on agricultural production.
- Conclusion drawn from this study is that agricultural activities in the study area depend extensively on rainfall. The farmers have employed smallholder furrow and sprinkler irrigation as vital methods for adapting to declining rainfall and increasing temperature for the past 30 years.
- This study showed the educational level of the farmers. Knowledge and perceptions of farmers about climate change in the study area has been an asset in the effort to adapt to climate change and improve household livelihoods. Better education levels in the local community open up better employment opportunity

and enable farmers to get involved in off-farmers activities and to abandon the unsustainable smallholder farming.

- Farmers still employed their indigenous knowledge and practices in managing agricultural production; however, these play minimum roles, while more emphasis was placed on western scientific technology. There is a decreased_concern with traditional knowledge of smallholder farmers as they are losing confidence in their indigenous knowledge system.
- Lastly, lack of interest by the government about traditional practices has made the implementation of some of the coping and adaptation techniques a problem. This study revealed that local knowledge has been abandoned, which might lead to its disappearance and no measures employed to research its possible contribution to the current adaptation techniques to the adverse climate changes.

7.3 Recommendations

Grounded on the findings of this study, the following recommendations were suggested:

- Focus should be put on capacity building for farmers to enhance their climate adaptation strategies.
- Climate change adaptation techniques success should largely rely on the accessibility of a strong and well-designed instuitional planning characterised by a combination of all stakeholders. These stakeholders should play an essential role in establishing the extent to which farmers and societies are vulnerable to different climatic hazards. Based on this, the tactical and strategic planning that is fashioned at the national level should be from grass-roots level (farm-level) to national-level. The designed approached will then have clear instructions, accountability and the provision of sufficient financial capital.
- The national and districts-level departments to improve water supply to local farmers so that they could invest rain-fed and irrigation systems and in higher levels of technology. There is high precipitation unpredictability in the study area and different types of dry spells posing major threats to crop production and harvest, however, lack of proper storage structure for rainfall harvesting often resulted in rainwater wastage. At national and local levels, municipalities should employ rainwater harvesting equipment to manage seasonal drought through supplemental smallholder irrigation, therefore, rainwater harvesting, and conservation should be considered as the primary adaptation technique.

- The findings of the study revealed that farmers are engaged in different diversification and adaptation techniques, but farmers' efforts are limited by lack of capital asset and limited access to credit and farm input products. Availability of credit would support smallholder farmers to employ their human labour and tangible goods to better their livelihoods. Farmers stated that lack of asset is the major obstacle for not increasing their capital-resource-generating activities; therefore, it is vital to enlarge local micro-credit facilities and make them accessible to smallholder farmers during planting seasons. Limiting obstacles to households' mobility, increasing countryside infrastructure and creating local employment opportunities will provide smallholder farmers a chance to participate in different revenue-generating activities.
- The government and NGOs should provide skills development workshops and seminars in diverse skills that will increase farmers' choices so that they can engage in various activities and earn income from different sources such as, carpentry, metalwork and masonry. It is, therefore, necessary to support farmers to advance their already existing skills to allow them to be more productive.
- Department of agriculuture in Vhembe District needs to play an important role in ensuring that smallholder farmers record their yearly crop production. However, a good farm record system would provide accurate and updated information, which will be enough to provide information in a variety of ways needed for future studies.
- Lastly, the integration of indigenous knowledge system with western climate change policies is likely to boost the legitimacy of any decision-making processes of the local farmers. This may demand that adaptation intervention designers search for solutions together with farmers rather than prescribing solutions, which farmers may not view as feasible or attractive.

7.4. Limitations of the study

One of the limitations of the study was in securing data for most of the study's variables and the absence of well-classified meteorological information for the period of three decades in many of the meteorological stations in Vhembe District It was a problem, therefore, to give an adequate account of climatic variations.

Secondly and lastly, the majority of local farmers were Tshivenda speakers and the questionnaire used for the study were prepared in English; hence, most of the farmers could not react to the questionnaires. (See the discussions on research assistants in Chapter three, section 3: 6.6). Also, a few participants were unable to provide accurate response in filling in the questions on farmers' perceptions of climate change as there were no accurate historical data recorded about climate variations for the past three decades.

The findings of the study may, therefore, not be generalised, due to the results being time-specific and area-specific, as analysing impacts of changes in climate on smallholder farming and adaptation strategies study was survey in Vhembe District with micro-scale climatic variations.

7.5. Suggestions for further research

This concluding chapter of the study has clearly illustrated that the specific objectives have been achieved after rigorous assessing and analyses of the impacts of climate change and adaptive strategies employed by smallholder farmers in rural Vhembe District The global challenges of climate change are cross-cutting issues which impact the human and natural environment. The overall, empirical evidence has revealed that climate change has a negative effect on the smallholder farmers' crop production and hence, farmers' livelihoods among the rural communities. These findings, however, are limited by the fact that the study was confined to climate change and smallholder farmers' crop production in Vhembe District, for a limited period. These analyses and results form a major contribution to existing knowledge. To the knowledge of the investigator, there are several studies conducted on a larger scale, such as at regional or provincial scale addressing related challenges. This study adds value to studies conducted previously addressing constraints and challenges faced by smallholder farmers across the globe and this includes the Vhembe District. The key recommendation is that, there is need for more studies to pursue the impacts of climate change on other sectors of the economy which affect local farmers' livelihoods and inequality at a macro level.

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APPENDICES

SECTION 1

THESIS OUTPUT

My role in each of the papers and presentations is * indicated. As a corresponding author, my roles were data collections, analysis and writing up the papers. The co-authors of the manuscript publications directed and supervised the research that forms the basis for the thesis.

Chapter Four

1. Kom, Z*, Nethengwe, N.S., Mpandeli, S., & Chikoore, H. 2019. Climate Change Grounded on Empirical Evidence as Compared with the Perceptions of Smallholder Farmers in Vhembe District, South Africa. Journal of Asian and African Studies (SAGE). https://doi.org/10.1177/0021909619891757

Chapter Five

2. Kom, Z*, Nethengwe, N.S., Mpandeli, S., & Chikoore, H. 2019. Determinant of small-scale farmers' choice and adaptive strategies in response to climatic shocks in Vhembe District, South Africa. GeoJournal. DOI: 10.1007/s10708-020-10272-7

Chapter Six

3. Kom, Z*, Nethengwe, N.S., Mpandeli, S., & Chikoore, H. 2019. Ref: GEC_2020_71

Title: Indigenous knowledge indicators employed by smallholders' farmers in adaptation to climate change in Vhembe District, South Africa.

Journal: Global Environmental Change

4. Kom, Z*, Nethengwe, N.S., Mpandeli, S., & Chikoore, H. (In preparation). Stakeholder Engagement on Climate Change Adaptation Strategies in Limpopo Province, South Africa.

My roles were data collections, analysis, writing up of thesis and submission of papers for publications.

Academic Conferences and Training Attended

Kom, Z; N.S., Mpandeli, S., & Chikoore, H. 2017. Climatic Shocks and Crop production: A Case Study of Smallholder Farmers in Vhembe District, South Africa. Hosted by the American Association of Geographers (AAG) Conference, April 4th to 9th, 2017. Boston, United States of America.

SECTION 2

Appendix A: Questionnaire

PRIVATE BAG X5050 THOHOYANDOU 0950 SOUTH AFRICA

SCHOOL OF ENVIRONMENTAL SCIENCES

DEPARTMENT OF GEOGRAPHY & GEO-INFORMATION SCIENCES

I am Mr. Zongho Kom. A student from the University of Venda. I am conducting a study title **"Analysing *the Impacts of Climate Change and Adaptive Strategies on Smallholder Farming of Farmers in Vhembe District, South Africa*"**. The study is for academic purpose and your information will be kept strictly confidential. Your assistance with the completion of this questionnaire and interview will be highly appreciated.

QUESTIONNAIRE FOR CLIMATE CHANGE AND IT POTENTIALS IMPACTS ON SMALLHOLDER FARMERS IN VHEMBE DISTRICT

The aim of this research instrument is to analyses the potentials impacts of climate change affecting smallholder agriculture production for the past three decades and adaptation strategies employed by smallholder farmers to improve crop production and their livelihood in Levubu, Tshiombo and Nwanedi, Vhembe District Various data collection instruments are designed and used to address the objectives of the study.

Research Instrument 1: Questionnaire

Questionnaire No ………….:

Date: / / /

Day/month/year

Study sites	Levubu Nwanedi Tshiombo	
Vhembe District	Municipality	

Part One: Demographic attributes and Characteristics of farmer's households

1. Size of your household

1 – 4 ▭ 5 - 8 ▭ 9 and above ▭

2. Gender of farmer's household head.

Female ▭ Male ▭

3. Age of Farmer's household head in years.

21 – 30 ▭1 – 40 ▭41 – 50 ▭ 51 – 60 ▭ 60 and above ▭

4. Marital status of the Farmer's household head.

Single ▭ Married ▭ Widowed ▭ Divorced ▭

5. Education background of Farmer's household head.

Cannot read and write ▭ read only ▭ Grade 1 – 8 ▭ Grade 9 – 12 ▭

Certificate and diploma ▭ First Degree (university) and above ▭

6. What is your average yearly household income in Rand?

Part Two: Evaluating major impacts of Climate Change

7. Have you experiencing climate variability and change in your farm for the past 30 years?

Yes ▭ No ▭

8. If yes, how do you designate such climate change indicators?

Increasing temperature for the past 15 years and above ▭

Decreasing temperature for the past 15years and above. ▭

Rain fall is below normal ▭

Rain fall has increased above normal ▭

Rain fall amount has increasing for the past 15 years and above ▭

Rain fall commence earlier for the past 15 years and above ▭

Deaths of livestock ▭

Crop yield declined ▭

Crop variety changed ☐

Others, specify if any ……

9. Do you realize any impact from the climate variability and change on your crop yield from 1980s to 2015s?

Yes ☐ No ☐

10. If your answer is affirmative for the above question (4), what kind of effect do you realize?

Crops productions are sometimes decreasing ☐

Crops production is increasing ☐

Crops are totally dying ☐

Crop disease and weeds are increasing ☐

Crops production is declining ☐

Other, specify, if any ______________

11. For the past 15 - 35 years, how can you describe the level of temperature & rainfall?

Temperature increasing ☐

Rainfall is increasing ☐

Rainfall is declining ☐

Temperature is declining ☐

No change in rainfall ☐

No change in temperature ☐

I have no ideas about it ☐

12. What is the main drivers of climate change in your community?

Inappropriate farming system ☐

Lack of the implementation of soil and water conservation activities ☐

Deforestation ☐

Mining activities ☐

Population boom ☐

Others (specify)…………………………………………………………………

13. Do you get information on impact of climate change? Yes ☐ No ☐

14. Which is the source of information on impact of climate change?

Electronic media (TV, Radio,) ☐

Print media (books, magazines newspaper, wall-writing, billboards, etc.) ☐

Interpersonal communication ☐

Informal education ☐

Formal education (primary, secondary and higher education) ☐

Local clubs ☐

Messages in daily life ☐

Others (specify)

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

15. Do you receive information on climate variability and change effects through extension officers?

Yes ☐ No ☐

16. Through what network did you receive information about climate change impacts on crop production?

Extension officers ☐

Farmer to farmer ☐

Relative ☐

Neighbours ☐

Other (specify)

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

17. What kind other support do you receive for climate change effects?

Extension officers ☐

Farmer to farmer ☐

Credit ☐

Relative in Levubu or Nwanedi ☐

Other (specify

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

…..

18. Does the support you get make any changes in climate adaptation techniques?

Yes ☐ No ☐

19. If yes, what kind of change did you get in relation to climate adaptation techniques?

Part Three: Assessing Climate Change Adaptations Practices

What is the size of your farm in hectares?

Less than 2hectares ☐ 2.-4 hectares ☐ 5-7 hectares ☐ 6-8hectares ☐

9 hectares and above ☐

20. What kind of farming system do you practice?

Rain fed ☐ Irrigation ☐ Mixed (both) ☐

Others (specify) ---

21. How many times do you harvest annually?

One ☐ Two times ☐ Three times ☐ 4 times and above ☐

22. What techniques of adaptation have you adopted to deal with these changes in climate?

Retailing of household assets ☐

Using irrigation /ground water methods ☐

Planting trees for shading ☐

Implement soil conservation methods ☐

Construct a water-harvesting system ☐

Assistance from Government and NGOs ☐

Reduced socialization for saving ☐

Change planting dates ☐

Migrate from villages to urban area with better conditions ☐

Plant Diversify crops ☐

Planting crops diversity ☐

Change from crop to livestock farming ☐

Marketing of forest products ☐

Local artisan work ☐

Increase your ritual sacrifice to traditional rainmakers ☐

Changing from farming to non-farming activities ☐

Others (specify) ---

23. If you did not adapt, what made you not to adopt adaptation methods to climate change?

Lack of knowledge about climate change ☐

Little or lack of information ☐

Do not know what to do ☐

No credit or savings ☐

Lack of technology (agricultural inputs) ☐

No support from technical expert ☐

Lack of agricultural Extension service ☐

Lack of local climate knowledge ☐

Agricultural policy barrier or insecure property right ☐

Others (specify) ---

24. Have your household any policies and strategies that aims at ensuring effective climate change adaptation techniques on your farm?

Yes ☐ No ☐

25. If affirmative to question number **24**, what are the policies and techniques?

26. Are the policies takes into account the indigenous knowledge and practices of climate change adaptation?

Yes ☐ No ☐

To what magnitude that the policies takes the indigenous knowledge and practices of climate adaptation into consideration?

27. What do you consider should be done in order to reinforce climate change adaptation techniques on your farm?

28. What policies and strategies are currently in place to assurance effective climate change adaptation approach in your farm?

29. What are the major challenges in dealing with climate change adaptations techniques?

Thank you very much for your time!

Appendix B: Key Informant Interviews

Checklists to Guide Key Informant Interviews

1. What are the major impacts of changes in climate on agricultural practices of smallholder farmers in Nwanedi, Tshiombo and Levubu?

2. What are the ongoing practices and strategies toward climate change adaptations being employed by smallholder farmers of Nwanedi, Tshiombo and Levubu?

3. What are the major reasons of smallholder farmers' adaptation strategies to climate change in this Nwanedi, Tshiombo and Levubu?

4. How and to what possibility do climate change policies and strategies are integrated into development planning and ongoing sectoral decision-making by the Government?

5. How and to what level do climate change adaptation strategies are mainstreamed into District Climate Change Response Policy and the District Climate Change Adaptation Strategies?

6. What policies are currently in place to ensure effective climate change adaptation practices in study area? How their influence on agricultural production?

7. How and to what extent do local communities, governmental institutions and nongovernmental organizations participate in practicing climate change adaptations in this study area?

Thank you very much for answering these questions!

Appendix C: Climate Change Information

1. What are the driving forces and the impacts of climate change induced-hazards on your household livelihoods?

2. What are the major current climate change adaptation strategies being practiced on your farm (associated to crop production and livelihoods)?

3. Do you have expert assistance while you are practicing adaptation techniques? If yes, How?

4. What are the key challenges that you have encounter in practicing climate change adaptation strategies?

5. To what extent do smallholder farmers, government and non-government agencies working on climate change are interacting?

6. Do your collaboration with government and non-government agencies working on climate change adaptation strategies? How?

7. Who is accountable for future guidelines and policy actions to support climate change adaptation strategies in Nwanedi or Levubu?

Thank you very much for answering this questionnaire!!

Section B: **Use of climate knowledge**

1. Do you consider your farm drier to do farming? 1. Yes ☐ 2. No ☐

2. Is this yours farm drier than that of your neighbours? 1. Yes ☐ 2. No ☐

3. Is there any significant difference between rainfalls for different years? 1. Yes ☐ 2. No ☐

4. *'Standard rain is expected this season'*

a. Do you comprehend this sentence? 1- Yes ☐ 2- No ☐ 3- vaguely ☐

b. What does it mean to you as a farmer?

1- Rainfall is going to be good; ☐ 2- average over a long period of ☐e; 3-☐ ☐ low rainfall or drought; 4- chance of highest rainfall

5. Before you planted this season, have you information how the weather would be like?

1. Rainfall assured to be above standard	
2. Rainfall might be above standard	
3. Rainfall expected to be standard	
4. Rainfall might be below standard	
5. Rainfall likely to be uneven	
6. Heard information but did not pay attention	
7.Nothing information received	

6. What do you think the rainfall has been like this season so far?

a. Overall Seasonal Rainfall:

1. Good	
2. Standard	
3. Bad	
4. Don't know	

b. Time of start of rainfall:

1. Beneficial	
2. Standard	
3. Bad	

4. Don't know	

7. How has this season been compared to that year in question 3?

Temperature: 1. warmer ….☐ 2. Cooler…. ☐ 3. No difference ☐ .4.can't remember ……..☐

Rainfall: 1. wetter …..☐ 2. Drier ..☐ 3. No difference…☐ 4. Can't remember ☐ ……..

8. Do you have a radio? 1. Yes ☐ 2. No ☐ 3.Have, but not functional ☐

9. Do you listen to the weather forecast daily? 1. Yes ☐ 2. No ☐ 3. Sometimes ☐

10. Did you receive any information in the last 6 months on what rainfall to expect this season?

1. Yes ☐ 2. No, ☐

if yes: ……………………………………………………………………………………………………

11. Who provided you with this information?

(Please check all that apply)

Source	***Details***
Meteorological bulletins	
Newspaper	
Radio (specify station & program)	
Television	
Agricultural extension officer/agency	
Neighbours (farmers)	
Aid organizations	
Religious organizations	

Internet	
Village meeting	
School or other education institution	
Other, please specify	

12. Please describe the forecast (probability? total seasonal amount? time of onset?)

……

13. Did the forecast contain enough information to make planning decisions?

Yes ☐ No ☐

If no, explain…………………………………………………………………………………………

…………………………………………………..

14. If yes, a) what decisions did the information help with?

……

15. Have you been given instruction on how to prepare for the expected weather? If so, specify instruction, from whom received and if you followed it.

……

16. Would you like to receive a forecast for what the chances of a good, bad or normal rains might be for the season? 1. Yes ☐ 2. No ☐ 3. Don't know ☐

If yes,

17. What would be your chosen method of receiving it?

1. Radio……… ☐ 2. Extension agent…… ☐ 3. Co-operation… ☐
4, other (specify)……….

18. Which month would you like to receive? ………………………………….

19. Which of the following pieces of forecast information would you find the most useful?

Total amount of seasonal rainfall ☐

Time of rain's onset ☐

Other ……………………………………………………………………

20. What modifications would you like to be able to make if you receive it?

…………………………………………………………………………………………………

21. Indicators of farmers' perception of climate change during the past 30 year (tick the box below from 1 – 5) according to the statement of weather indicators.

Weather indicators variables	1	2	3	4	5	Grand score	Total Percent (%)
Summer rainfall amount has increased							
Summer rainfall amount seem to be decreasing							
Rainfall amount has not change for the past 30 years							
Early cessation of rain							
Late start of rain fall							
temperature Increased							
temperature Decreased							
Shorter growing season							
Weather seems to be unpredictable							
Frequently drought							

Highly agree =1 Agree = 2. Not certain = 3. Disagree = 4. Highly disagree = 5

Appendix D: Indigenous knowledge, external knowledge and approaches

Section D 1. Weather forecasts

1. Indigenous knowledge systems (IKS) & climate forecast

What are the indigenous techniques used by indigenous smallholder farmers to prediction the upcoming rainfall or drought? Mention all & please provide detail as to how the technique works. *(– let farmers respond openly)*

Technique	How does it function?	Do you use this technique?	Do you think this technique is reliable?
Wind behaviour			
Cloud formation			
Observation of temperature			
Animal behaviour only			
Behaviour of birds only			
Behaviour of insects only			
Surveillance of the stars			
Surveillance of the moon			
Appearances of plants and trees			
Others:			

2. Do you have greater assurance in forecast from indigenous sources or from external sources?

Yes ☐

No ☐

Explain……………………………………………………………………………………………

3. How often do you use this indigenous knowledge of information and do you combine this information with sciences sources. Example 20% ☐ ☐and 80% external) ☐ or 50-50?

Explain……………………………………………………………………………………………

4. When planning your cultivation practices, do you use

a. science forecast only ☐

b. indigenous forecast only ☐

c. .both forecast sources ☐

d. .none ☐

Explain……………………………………………………………………………………………

(Science forecast it comes from outside – usually South African Weather Service)

5. Did you hold or attend any farmer's meeting with other farmers to share some ideas about the conditions? For example, meetings with other stake holders to discuss about water shortage in the areas or meeting about planting resistant varieties

Yes ☐ (specify)

……………………………………………………………………………………..

NO ☐

6. Are you planning to hold ritual sacrifice or prayer during this period?

Yes ☐

No ☐

Explain……………………………………………………………………………………………

7. Do you see local information of weather pattern obtained from seniors is appropriate for your farming systems?

Yes ☐

No ☐

Explain...

Section D-2: **Indigenous Knowledge & Agricultural techniques**

1. What are the local techniques used by your farmers households in agricultural techniques? Indication all & please provide detail as to how the technique works. (If case of any problem with the questio*n, give some examples to easy the interviewee understands the question)*

Technique	**How does it function?**	**Do you use this technique**	**Do you think this technique is reli**
For example Slash-and burn technique. Eliminating weeds manual instead of Chemicals.			

2. If you use indigenous techniques in agriculture, is it:

(a) Because it is easy to used

(b) Because of inheritance from inherited or traditional beliefs

Others..

3. In some societies if the head of households or chief passed away, you are not allow to go to work in the farm. Do you practiced this kind of thing in Venda?

Yes ☐

No ☐

Reason………………………………………………………………………………………………………

4. What kind of seeds do you normally use when planting, recycled local seeds or hybrid seed?

(a) Indigenous seeds ☐

(b) Hybrid seeds ☐

(c) Both ☐

5. If you heard that this season will be wet, do you know which crop performs better or grows easily?

Yes ☐

No ☐

Explain

……

Appendix E: Focus Group Discussions

FOCUS GROUP DISCUSSIONS

Research Instrument: Focus Group Discussions Panel Guiding Themes

1. Composition of stakeholder group and identification

Interview facilitator: …………………………………

Address: ………………………………………………

Date: …………………………………… Hour: …………………………………………………

District Municipality: ………………… Local Municipality: …………………………………

2. Study sites:

Levubu	
Nwanedi	
Tshiombo	

3. Smallholder farm

Age intervals of participants	
Gender	
Number of participants	

1. State of the local climate:

a) The state of the local climate in the past 30 year's to-date

b) Any changes so far (good/bad ones)

c) Why those changes (if any)?

d) The state of the climate to change further in the future? Good or bad?

2 Key changes in the farming practices and their sustainability.

a) What are these changes (specifically) e.g. type and characteristics of crops, soil management techniques, water harvesting and storage etc.

b) Timing of the changes c) Alternative income sources and whether they are sustainable

3. Motivating factors for changes in the farming practices and adoption of alternative income sources

a) Climatic conditions

b) Economic factors

c) Policy changes

d) Any other

4. Socio-economic implications of the changes in the local climate.

Identification of the effects of the changes, e.g.

 Incomes Water availability Food production and security Social conflicts Health status Household conflicts etc.

5. Policy and strategic interventions for enhanced adaptive capacity and long term resilience.

………

University of Venda
Creating Future Leaders

Appendix F: Research Ethics Letter

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Mr Z Kom

Student No:
11607100

PROJECT TITLE: **ASSESSING THE IMPACTS OF CLIMATECHANGE AND ADAPTATION STRATEGIES ON SMALL-SCALE FARMING IN VHEMBE DISTRICT, SOUTH AFRICA**

PROJECT NO: SES/17/GGIS/08/1412

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Dr NS Nethengwe	University of Venda	Promoter
Prof SN Mpandeli	University of Venda Water Research Commission	Co- Promoter
Dr H Chikoore	University of Venda	Co- Promoter
Mr Z Kom	University of Venda	Investigator – Student

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: February 2018
Decision by Ethical Clearance Committee Granted
Signature of Chairperson of the Committee: ....
Name of the Chairperson of the Committee: Senior Prof. G.E. Ekosse

UNIVERSITY OF VENDA
DIRECTOR
RESEARCH AND INNOVATION
2018 -02- 07
Private Bag X5050
Thohoyandou 0950

University of Venda
PRIVATE BAG X5050, THOHOYANDOU, 0950, LIMPOPO PROVINCE, SOUTH AFRICA
TELEPHONE (015) 962 8504/8313 FAX (015) 962 9060
"A quality driven financially sustainable, rural-based Comprehensive University"

Appendix G: Permission letter to conduct fieldwork and survey

SCHOOL OF ENVIRONMENTAL SCIENCES

Department of Geography & Geo-Information Sciences

12 December 2017

TO WHOM IT MAY CONCERN

This is to certify that ZONGHO KOM student number, 1107100 is a Ph.D. candidate, in the Department of Geography & Geo-Information Sciences, School of Environmental Sciences. His research thesis is entitled **"Assessing the impacts of climate change and adaptation strategies on small-scale farming in Vhembe District, South Africa"**

I would therefore appreciate it if due assistance is given to him. Currently, the student is involved in data collection phase and therefore requires permission to conduct field work and survey in Levubu, Tshiombo and Nwanedi and their environs from 27th November 2017 to the 30th June 2018. The information collected is for academic purposes and will be analysed and presented as such.

In my capacity as the supervisor I am hopeful that you will afford Mr. Kom support during this critical phase of his research process. For further information and/or clarification, please do not hesitate to contact me at (015) 9628593

Kind Regards

Dr. N.S. Nethengwe
HOD: Department of Geography & Geo-Information Sciences

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FOR YOUR INFORMATION
2017 -12- 0 6
OFFICE OF THE DEAN
UNIVERS..Y OF VEN.A

University of Venda

PRIVATE BAG X5050 THOHOYANDOU 0950 SOUTH AFRICA
TEL: +27 15 962 8593; Fax: +27 15 962 8597/4749 E-mail: nthaduleni.nethengwe2@univen.ac.za

University of Venda
Creating Future Leaders

SCHOOL OF ENVIRONMENTAL SCIENCES

Department of Geography & Geo-Information Sciences

12 December 2017

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Kind Regards

Dr. N.S. Nethengwe
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FOR YOUR INFORMATION
2017 -12- 06
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UNIVERSITY OF VENDA

University of Venda

PRIVATE BAG X5050 THOHOYANDOU 0950 SOUTH AFRICA
TEL: +27 15 962 8593; Fax: +27 15 962 8597/47-49 E-mail: nlhaduleni.nethengwe2@univen.ac.za