EFFECTS OF CLIMATE VARIABILITY ON SMALL-SCALE PRODUCTION OF TOMATOES (*SOLANUM LYCOPERSICUM*) IN MOPANI DISTRICT OF LIMPOPO PROVINCE, SOUTH AFRICA:

By

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DECLARATION

I, Wisani Koza (15013726) hereby declare that this dissertation entitled "Effects of Climate Variability on Small-Scale Production of Tomatoes (*Solanum Lycopersicum*) in Mopani District of Limpopo Province, South Africa" for Master's Degree in Rural Development (MRDV**)** submitted by me to the Institute for Rural Development at the University of Venda has not been submitted previously for any degree at this or another university. It is original in design and in execution, and all reference material contained therein has been duly acknowledged.

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ABSTRACT

Small-scale horticultural producers are the most vulnerable to climate variability effects. The prevailing variabilities are a threat to the survival of small-scale farming. These patterns are predicted to continue in the next imminent future with adverse effects to food security. The extent and nature of these effects of climate variability on small-scale horticultural farmers remain elusive given the changing patterns. The study explored the effects of climate variability on the production of tomatoes (*Solanum lycopersicum)* in Mopani District Municipality of Limpopo Province, South Africa. An exploratory sequentially integrated mixed method research design underpinned the study. Quantitative data were collected using a survey questionnaire and analysed descriptively through Statistical Package for Social Sciences (SPSS) version 26. On the other hand, qualitative data were collected through interviews and thematically analysed with the aid of ATLAS. ti version 8.0. The results revealed several negative effects of climate variability to tomato production. Increased temperatures and pest infestation emerged as the most common and land degradation the least problematic. Moreover, farmers show that individual farmers use different adaptation techniques which were convenient and cost effect to their circumstances. Absence of concrete support and financial constraints inhibited the ability of farmers to adopt efficient adaptation strategies to climate variability effects. The findings of the study are useful in formulating rural agricultural policy and helping farmers to understand deeply the climate variability effects and adapt their adaptation techniques.

Keywords: Climate variability, climate variability adaptability, horticulture, small-scale farmers, production

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ABBREVIATIONS AND ACRONYMS

CO_2	Carbon Dioxide
CH_4	Methane
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
EPA	Environmental Protection Agency
FAO	Food Agricultural Organisation
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
GDP	Gross Domestic Product
GHGs	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
N_2O	Nitrous oxide
RSA	Republic of South Africa
SADC	South African Development Community
StatsSA	Statistics South Africa
SPSS	Statistical Package for Social Sciences
UNECA	United Nations Economic Commission for Africa
USD	United States Dollar
WCG	Western Cape Government

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CHAPTER 1: INTRODUCTION AND BACKGROUND OF THE STUDY

1.1 Background

Tomatoes are considered the most important horticultural crops among the rural small-scale farmers worldwide (Lee, Kim, Lee, Choi & Park, 2016; Arah *et al*., 2015; Ronga *et al.,* 2019). They are an important source of vitamins and minerals; thus, they guarantee food and nutrition security (Rai, 2005). Most rural small-scale farmers in the developing world rely on tomatoes production for income and family sustenance (Karungi*et al.,* 2011). Knapp and Peralta (2016) indicated that tomatoes forms part of daily meal for most families across all social classes. Tomatoes originated from South America, and they are grown as commercial crops around the world (Deter *et al.*, 2012). Their production is amongst the most globalized and advanced horticultural industries, with an annual value exceeding 90 billion USD (Food and Agriculture Organization Corporate Statistical Database (FAOSTAT, 2019).

Countries that lead in tomato production are the United States of America, China, the European Union, Turkey, and India (Kuşçu *et al.,* 2014). In 2017, global tomatoes production was approximately 160 million tons (Costa & Heuvelink, 2018). Tomatoes are generally cultivated in temperate climate zones. About 91% of tomato production is done in the northern hemisphere while only 9% of tomatoes are cultivated in the southern hemisphere (Pathak & Stoddard, 2018). Despite its economic and social importance discussed above, its production is threatened as it is a sensitive crop to random climatic changes. Conditions such as long-term water shortages, unsuitable soil conditions, and floods have significant impact on tomatoes production (Fahim *et al.,* 2010; Pathak *et al.,* 2018).

Climate change is a global concern. It negatively impacts sustainable agriculture and development in general. It poses a significant threat to economic activities and people's wellbeing. In fact, Kotir (2011) indicates that climate change is a serious hazard to environmental, social and economic sustainability. Similarly, Intergovernmental Panel on Climate Change (IPCC) (2014) pronounced that the ongoing climate warming is unequivocal as demonstrated by a rising global average air and sea temperatures, extreme temperatures, prevalent melting of snow and ice, and increasing sea level. United States Department of Defence (2015) claims that due to human emissions of greenhouse gases, the world is facing fluctuating temperatures and rainfall levels

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which adversely affect agricultural sustainability and productivity. This poses risk of food and nutrition security.

Changing climatic conditions imposes limits on horticultural production capacity particularly among the small-scale farmers with limited capital. Moat *et al.* (2019) indicates that due to adverse effects of climate change, horticultural production has become expensive and its production unsustainable. Also, small-scale tomatoes farmers worldwide are witnessing an increase to production costs while the total output is on the decline. Consequently, price hikes for fruits and vegetables including tomatoes are a new norm. Most farmers in Sub-Saharan African countries bear the brunt of effects of climatic changes (Moat *et al*., 2019).

Effects of climate change differ from one region to another, and one country to the next. Geographical location, ability to respond to its impact and available resources are key differentiating factors (Kurukulasuriya & Mendelsohn, 2006). As an important and key economic activity and source of income for most rural communities, decreased agricultural production has the potential to further exacerbate income inequalities between the rural and urban communities. Current prevailing weather conditions are a great risk to agricultural production especially in the rural sub-Saharan Africa (Lee, 2014). Every year, different regions in the sub-Saharan region encounter different types of disasters like water scarcity, hailstorms, heavy rains, floods, frost, cyclone and some abiotic stresses which are clarified as impact of climate change (IPCC, 2007). Such conditions are a great risk to the sustainability of rural small-scale farming and agriculture in general. This necessitates the need for understanding the impact of changing climatic conditions to devise appropriate mitigation strategies.

Rural communities mainly in the developing world are considered the most vulnerable due to their reliance on agriculture. Warmer baseline climates, low precipitation, and limited ability to adapt, expose them to harsh and adverse effects of climate changes (Kotir, 2011; Food and Agriculture Organization (FAO), 2014). Such unstable weather patterns endanger horticultural productivity including tomatoes production because of high and low temperature regimes and increased rainfall variability (Somarriba *et al*., 2013; Srivastava *et al.,* 2014). For instance, Johkan *et al.,* (2011) found that tomato production in India was under serious strain due to its sensitivity variations in temperature and monsoon rainfall. The implication is that as rainfall increases, it potentially causes a reduction in tomatoes yield. Johkan *et al*. (2011) found that excessive rainfall

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and temperature variations are detrimental to production. Thus, every slight change in temperature and rainfall significantly affect the quality and quantity of tomatoes production.

Small-scale farmers in the sub-Saharan Africa are not immune from the effects of climate change. In the last decades, the region reported rising temperatures and unpredictable rainfall patterns which are attributed to climate change (Quaye *et al*., 2012; Descheemaeker *et al*., 2016). In Ghana, increased number of pests and low tomato Fields were recorded per hectare due to changing weather patterns (Robinson & Kolavalli, 2010). For example, water stress escorted by temperature above 28°C prompted about 30-45% decline in tomatoes production. Moreover, high humidity in the ecological zone of Nigeria is accompanied by fungal diseases which attack the tomatoes especially in the months of March to June (Opoku, 2014). High rainfall experienced during this period reduce flowering, fruit-set and total output (Kyei-Mensah *et al.,* 2019). In Kenya, the drought conditions experienced in 2008 adversely affected the production of tomatoes in the country (Guodaar, 2015).

Guodaar (2015) further reveals that extreme temperatures had a negative association with tomatoes yields. Thus, the higher the temperature, the lower the tomatoes yield per growing season. In addition, the currently experienced erratic rainfall patterns, high temperatures, floods and drought in the South African Development Community (SADC) region are having negative effect on the income of small-scale tomatoes farmers and agriculture sector (Bita & Gerats, 2013). This indicates variations in the effects of climate change to tomatoes production within the same region.

South Africa is the dominant tomatoes producer and has ranked 35 in the world based on total tonnage (Malherbe & Marais, 2015). Malherbe and Marais (2015) further reveal that South Africa grows about 54% of tomatoes on 11% of the total cropped area. In Sub-Saharan Africa continent, South Africa remains a major regional tomatoes producer. To maintain this status, there is a need to distil the effects of climate change at micro levels. Understanding its impact on single crops or its family, is key towards developing adaptation measures for sustainable and climate flexible rural small-scale horticultural farming. Food and Agriculture Organisation (2016) emphasizes that extreme weather events are causing a major challenge to agricultural crop production to small-scale farmers in South Africa. Within South Africa, Limpopo Province is the main tomatoes producer (Tshiala, Botai & Olwoch, 2012). It contributes about 66 % of the total annual tonnage of tomatoes. This is since Limpopo Province has warm humid weather conditions which makes it

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suitable for crop production. However, the unstable and extreme high temperatures are a cause for concern among the small-scale tomatoes' farmers (Ayankojo & Morgan, 2020).

Tomatoes are widely produced as a major cash crop in Limpopo Province, with comparative higher market share (Selowa *et al.,* 2015). However, the climatic weather changes are currently threatening tomatoes production in the province. Climate change is directly and negatively impacting on farmers' income and economic sustainability for rural communities. This necessitates the need to unpack the lived direct and indirect effects of climate change on tomatoes production. Moreover, establishing and developing context-based adaptation techniques for sustainable tomatoes production in the province is equally important. Hence, this study explored the climate variability effects on tomatoes production among small-scale producers (*Solanum lycopersicum),* in Mopani District Municipality of Limpopo Province, South Africa.

1.2 Statement of the Research Problem

The tomato plant is sensitive to climatic conditions. Thus, the ongoing unstable weather patterns have resulted in low output, crop failure, pest and disease infestation and reduced quality of the tomatoes (Abewoy, 2018). More so, limited resources and capital among the rural small-scale farmers, limits their ability to adapt to changing climate conditions. Resultantly, output per hectare decreases with direct negative impact to farmer's income and food security. Climate change threatens food and nutrition security. Correspondingly, it increases hunger, poverty and causes dietary challenges to rural communities (Deressa *et al., 2012*). The effects of climate variability on crop production undermine the efforts of adequately address rural food security challenges and rural economic growth. A review of scholarly literature indicates varying effects of climate variability to tomato production per region. Thus, necessitating understanding of context-based effects of climate variability to develop appropriate interventions. Moreover, there is little evidence suggesting studies conducted in Mopani District Municipality, yet the effects of climate variability to tomato production are evident in Limpopo province (Maponya & Mpandeli, 2013). As projected, rural poor small-scale farmers with significant reliance on rainfed agriculture will be the hardest hit by the effects of climate variability (IPCC, 2007). It is against this background that this study explored the effects of climate variability on small-scale tomato farmers (*Solanum lycopersicum)* in Mopani District.

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1.3 Significance of the Study

The prevailing adverse effects unpredictable climate conditions and persistent decrease in agricultural output among the small-scale farmers is threat to rural food and nutrition security. The findings of this study, help to understand the true realities of the impact of climate variability on tomato production. These results of the study also recommend scalable solutions to be used in mitigating climate variability challenges and improve the productivity among small scale tomato farmers. Hence, improving output and ensuring food and nutrition security. In addition, the study contributes to the body knowledge on the effects of climate variability and help guide adaptation of tomato small-holder farmers. In addition, the results also provide useful elements for achieving the Sustainable Development Goals especially goal number one which aims to eradicate extreme poverty and hunger.

1.4 Research Objectives

The major study objective was to determine the perceptions of climate variability effects on small-scale tomatoes (*Solanum lycopersicum)* production in selected villages of Mopani District Limpopo Province, South Africa.

The specific objectives of the study were to,

a) Determine the perceptions of small-scale famers regarding the effects of climate variability on the production of tomatoes,

b) Analyse the current adaptation techniques used by small-scale tomatoes famers to mitigate the effects of climate variability on tomatoes production, and

c) Suggest the possible strategies that can be used to mitigate the effects of climate variability on production of tomatoes.

1.5 Research Questions

a. What are the perceptions of climate variability effects on small-scale famers tomato producers?

b. What methods are currently used by small-scale tomatoes famers to mitigate the effects of climate variability on the production of tomatoes?

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c. What are the possible strategies that can be used mitigate the effects of climate variability on the production of tomatoes?

1.6 Hypothesis

H0: Climate variability effects negatively impact tomato production

1.7 Operational Definition of Key Terms and Concepts

Climate variability - is the variations in the mean state of the climate over a given period usually ranging from a month, season or year to decades with 30 years being the cut-off point (Ahmed, Shahid & Nawaz, 2018). It is a change in the statistical properties of the climate system, when measure over time. In this study climate variability is viewed as a short to medium term shift in global or regional climate patterns.

Climate variability perceptions – hence climate variability in this study refers to the observed and experienced perceptions of farmers about the climate change effects on tomato production.

Small-scale farmer refers to a person who operate a small-scale agricultural production that fails to attract service needed to significantly increase farm productivity (Kirsten & Van Zyl, 1998). In this study, small–scale farmers are defined as individuals who use a small piece of land without using advanced or expensive technologies.

For this study e*ffects* are changes which are the results or consequences of an action or other cause (Patel, 2015).

Climate variability adaptation is the process of transformation to expected climate and its effects (Murray & Ebi 2012).

1.7 Theoretical Framework of the Study

The current study was guided by the Theory of Capability (Nussbaum, 2011; Sen, 2017). The theory unpacks the capacities that are required for individuals to lead operative lives. The functioning of an individual represents a grouping of “beings” and “doings”. It is also viewed as different outcomes an individual may accomplish (Goerne, 2010). A capability approach is concerned with how people own capabilities required to achieve a fully operational life. Such

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capacities depend on natural systems to influence its survival such as a stable climate system. The capability approach outlines concepts that include the current understanding of climate justice. However, its framing is skewed towards and applicable to the development of adaptation policy (Schlosberg, 2011). This approach deals with the basic requirements that are required to support a human life. Given this, it is therefore key to align these adaptation policies and operationalise them in the context of climate justice that protects the basic functioning of individuals, communities, and the environment.

Changes in climate influence what people or farmers can do with the available resources. If climate variability obstructs agricultural production, then tomato farm productivity will be limited. In this case, climate variabilities are a barrier to the functioning of farming activities among small-scale farmers (Schlosberg, 2011). Critically, a capabilities-based approach to adaptation requires that top-down and expert-driven affairs be done away with and focus put on the those directly affected by the changes in climate. Hence, it is required that small-scale farmers are comprehensively engaged to define their own vulnerabilities and design adaptation techniques that can shield them from climate variability effects which threatens their productivity capabilities (Ribot, 2010; Schlosberg, 2011). Thus, the approach offers a way of analysing the needs of small-scale farmers, identifying gaps which hinder them to adapt to climate variability, directing adaptation policy toward preserving or rebuilding the specific capabilities under threat from climate variability, and measuring the success of implemented adaptation policies.

1.8 Organization of the Research Dissertation

This dissertation is presented in three chapters. Chapter 1 provides an exordium and context on the effects of climate variability to crop production. Specifically, the effects of climate variability to tomatoes production. Moreover, topics on the statement of the research problem, significance, research objectives and cognate questions are described. Definition of terms and the theoretical framework are also outlined. Chapter 2 presents the reviewed literature used in this study. It covers topics on climate variability and production in line with the study objectives. Chapters 3 includes the following subsections: study area description, study design, population and sampling procedures, data collection and analysis methods and techniques, and ethical steps to be followed. The last sections of chapter 3 are devoted to the work plan, budget and appendices. Chapter 4 includes the presentation of the results that include the demographic profile of respondents' climate variability effects and the currently used strategies used by small-scale

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tomatoes. Chapter 5 presents the discussions of the findings, conclusion and recommendations of the study.

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CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this Chapter, available literature on the effects of climate variability to crop production is interrogated. Specifically, the aim is to establish knowledge and perception of small-scale farmers on climate variability and the resultant challenges to the success of their operations. Also, the literature on the climate variability adaptation techniques and methods practiced by small-scale horticultural farmers, particularly those in tomato production was reviewed in this chapter. This chapter is divided into nine sections. The first part is devoted to the concept of climate variability followed by factors that influence it. Furthermore, literature on the effects of climate variability to agriculture production in general as well as in the context of the sub-Saharan African continent and South Africa is also discussed. Thereafter, in line with the study objectives, challenges caused by climate variability to crop and tomato production are reviewed. Lastly, this chapter outlines the climate variability adaptation techniques by farmers and supporting legislation in South Africa. Summary of literature review concludes the chapter.

2.2 The Concept of Climate Variability

Climate variability refers to a change in the state of the climatic conditions over a period stretching from months to 30 years (Scheffran *et al.,* 2012). Climate variability differs with climate change on the period with the later referring to change in weather patterns of more than 30 years. Intergovernmental Panel on Climate variability (2014b) points out that climate variability can be identified by persistent and elongated weather pattern changes which are usually decades or longer. it could be caused by either internal processes or external forces. The internal processes are natural causes such as volcanic activity and tectonic earthy movements (Stern & Kaufmann, 2014). On the other hand, external forces are anthropogenic influences such as changes in the atmosphere due to the industrial revolution and population growth (Gemeda & Sima, 2015; Riebeek, 2010; Stern & Kaufmann, 2014). Pillay (2016) claims that the first IPCC report was vague about information regarding the climate. This is because in 1996, the IPCC report that anthropogenic forces were responsible for altering the climate. Later in 2001, the IPCC report suggests that there was a noticeable human influence on the climate which had contributed to the climate variability during the twentieth century.

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European Environment Agency (EEA) (2014) and Schulze (2021) claim that climate is changing due to an increase in concentrations of greenhouse gases (GHGs) mainly CO2, methane and nitrous oxide in the earth's atmosphere. The scholar further posits that the increase in the GHGs has occurred over the past two centuries, and has been accelerating more recently, due to anthropogenic (human driven) factors, particularly through burning of fossil fuels like coal, oils and natural gas for energy generation. Also, unsustainable land use practices, increases in livestock and clearing of forests, all resulting in increasing the concentration of GHGs (Schulze, 2021). Similarly, Mohammed *et al*. (2015) found climate variability as a product of both natural and human causes. The natural factors include; latitude, continental or marine location of an area, altitude, and topography while human factors include burning of fossil fuel, cutting down of vegetation, and industrialization (Bjorn & Hauschild*,* 2018). Human activities like the Industrial Revolutions beginning in the early 1800s, the burning of fossils such as coal, oil, and gasoline have significantly increased the amount of greenhouse gas emissions into the atmosphere. Destruction of vegetation is the second largest anthropogenic basis of CO2 into the atmosphere which range between 6% to 17% (Pooja *et al.,* 2019).

The rise in atmospheric GHGs concentration has resulted in climate variabilities including the warming of the globe. As a result, international governments have signed several agreements to commit to reversing the adverse effects of GHGs. For instance, there is Kyoto Protocol, Paris Agreement on climate change and other initiatives that seeks to reduce the negative effects GHGs (Guo & Vanrolleghem*,* 2014). The impact of greenhouse gases to a warmer climate is commonly expressed in terms of its global warming potential (GWP). This enables scientists to be able to compare the effects of global warming gases and with that of a reference gas like CO2 (IPCC, 2001). Sweetapple *et al.* (2013) postulates that atmospheric CO2 intensities have risen by over 40% since the start of the Industrial Revolution. This represents an increase from about 280 parts per million (ppm) in the 1800s to 400 ppm presently. The CO2 on earth's atmosphere last reached 400 ppm in the Pliocene Epoch, about 5 million to 3 million years ago (Environmental Protection Agency (EPA), 2012). The greenhouse effect, collective with growing levels of greenhouse gases and the resultant global warming, is expected to have profound consequences, per the near-universal consensus of scientists (ElFade *et al.,* 2001). If global warming undergoes unimpeded, it will cause noteworthy climate variability, a rise in ocean levels, increasing ocean acidification, life threatening weather events and other severe natural and societal impacts (Bowen *et al.,* 2015).

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2.3 Factors Influencing Climate variability in the Agriculture Sector

Farmers' climate variability vulnerability in South African agricultural sector differs based on geophysical conditions and region. Thus, small scale farmers in different regions are exposed to varying effects of climate variability. Some of the key determinants to climate variability effects are presented in Figure 2.1. Although these changes pose a risk to local agriculture, it should be viewed as an opportunity for regional integration through trade within sub-Saharan Africa and technology sharing (Department of Environmental Affairs (DEA), 2011).

Rainfall is the most key factor in deciding potential agricultural activities and suitability across the country. Rainfall variability brings about an inherently high risk to climate at many time scales, particularly in transitional zones of widely opposing seasonality and volume of rainfall (Kyei-Mensah, Kyerematen & Adu-Acheampong, 2019). These transitional zones appear particularly sensitive and vulnerable to geographical shifts in climate. Another factor, is temperature. The exceedingly high atmospheric demand, i.e. the potential evaporation, in South Africa at 1 400–3 000 mm/ year coupled with unreliable rainfall often results in semiarid conditions due to high evaporation rates alone, despite often adequate rainfall. Dependence on underground water represents a significant, current vulnerability for almost all agricultural activities (Kim, Devineni, Lall & Kim, 2018). Irrigated agriculture is the biggest single user of surface water accounting for about 60% of total available water, and with all agriculture related activities consuming 65%.

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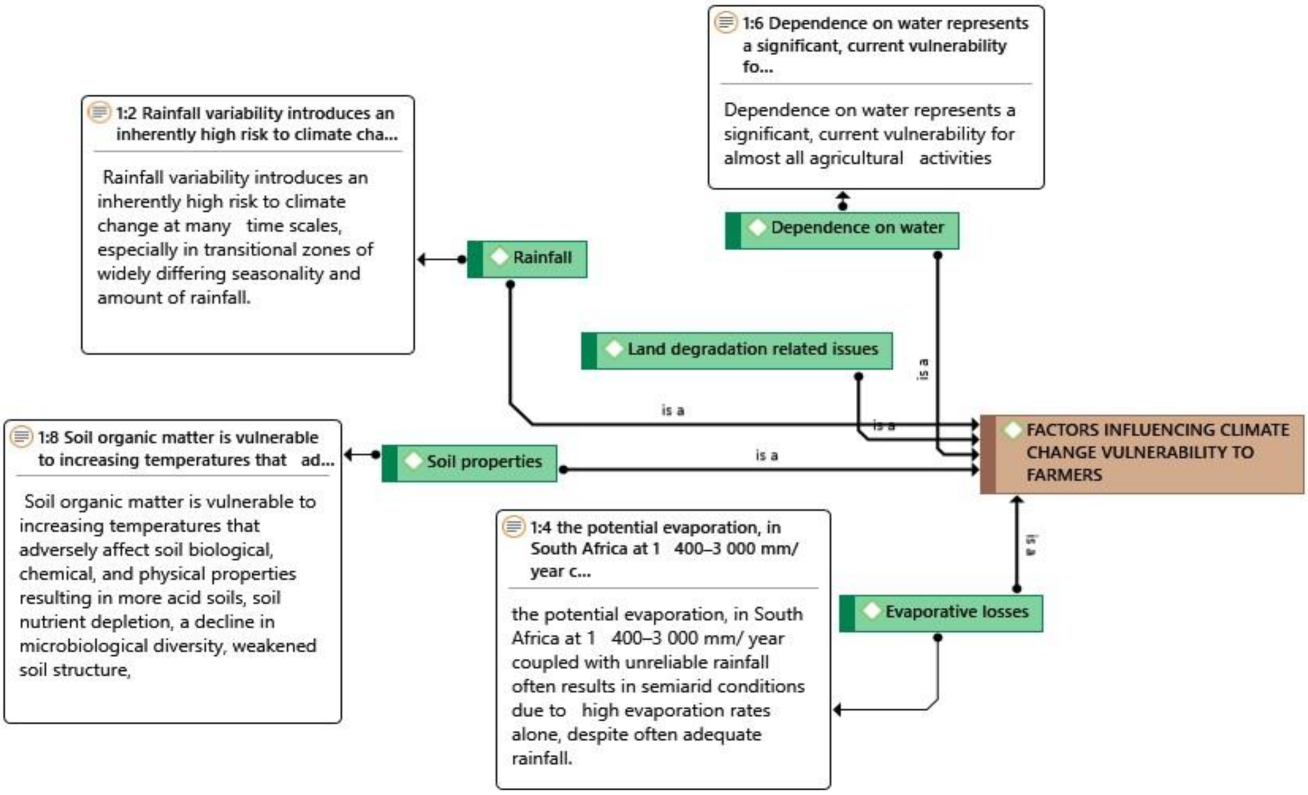

Figure 2.1: Factors influencing climate variability vulnerability to farmers

Source: (DEA, 2011)

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Agriculture's vulnerability is exacerbated by soil properties and topographical constraints that limit intensive crop production. South Africa's has a complex soil mantle that is diverse, often thin and vulnerable to degradation. The organic matter in the soils is also vulnerable to increasing temperatures that negatively affect soil biological, chemical, and physical properties (Nguyen, 2022). This result in more acidic soils, depletion of soil nutrients, a decline in living organism, debilitated soil structure, reduced water-holding capacity, and incr15eased runoff. Increasing population pressure, unsustainable land use and increasing competition for agricultural land, resulting in land use change and poor economic decisions, are leading to land degradation, aggravated by bush encroachment and invasive alien plants.

2.4 Effects of Climate Variability on Agricultural Productivity

2.4.1 Global overview

Globally, the water required to feed the world in 2050 is expected to increase by 4500 km3 /year from the current 7000 km3/year (Kijne *et al.,* 2009). The current trend of climate variability such as decreasing rainfall and increasing temperatures, indicate a bigger problem in the future of water availability for human usage including in agriculture. Currently, it is predicted that due to climate change there will be a rise in water demand with the increasing population further worsening food insecurity. Food insecurity is projected to continue as a serious issue in coming decades despite a projected hunger decrease from about 850 million to about 200-300 million in the end of the 21st century (Tubiello, 2012). The world nations are projected to encounter increasing poverty and food insecurity levels, as a result of localized high population growth rates, poor socioeconomic capacity, and continued depletion of natural resource like water availability particularly to countries that rely on rain fed agriculture.

Rain-fed agriculture covers 80% of the world's farmland and two third of global food production (Oweis & Hachum, 2012). Rain-fed agriculture plays a critical role in food production with about 80% of the agricultural land global which produces low crop yield levels and high on-farm water losses (Zahoor *et al*., 2019). The current climate risks and food insecurity intersect in the most vulnerable areas of the World include West Africa, East Africa, Southern Africa and South Asia (Berhane, 2018). Climate variabilities affect all the scopes of food production, which include security; availability, accessibility, utilization, and systems stability; impacting human health, livelihood assets, food distribution and market.

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2.4.2 Africa Perspective

Agriculture is a key sector in the sub-Saharan African continent. On average, it employs about 70% of the labour force and contributes over 25 % of GDP (UNECA, 2009). Amid climate variability conditions, agricultural sector in the sub-Saharan Africa continent is under threat. Dependence on rainfall and underdeveloped agricultural systems exposes mainly small-scale farmers and the sector to the adverse effects of climate variability in continent. Limited financial resources, capital, inadequate access to infrastructure and disparate access to information by small scale farmers leaves them more vulnerable to the effects of changing weather conditions. Although, experience, importance of farming and existence of generational traditional knowledge offer elements of resilience in the face of climate variability, the current unpredictable weather patterns threaten agriculture sustainability.

Thompson (2010) attests that indeed climate variability is one of the largest constraints limiting farmers in sub-Saharan Africa. Extreme weather conditions such as climate variability are the reason for this development. Verdin *et al.* (2005) note that the region's agricultural sector is extremely sensitive to future climate changes and variabilities. This poses a challenge to food and nutrition security in the continent and to rural communities. Coupled with growing population, climate variability could see the continent failing to meet SDGs of eradicating poverty and zeroing hunger by 2030. Thus, it is necessary to assess the effects of climate variability to agriculture with a view of developing adaptation techniques. It is reported that small scale farming sector in Sub-Saharan Africa is already vulnerable to environmental dilapidation and unreliable rainfall patterns. Climate variability adds to other developmental stresses, notably, poverty, HIV/AIDS and food insecurity (FAO, 2008). Agronomic studies predict a sharp fall in yields for most African crops in the absence of technological change. Without adaptation, increased temperatures will result in the reduction on crop yields, all things constant (Kurukulasuriya & Mendelsohn, 2006). Currently, the continent is experiencing high temperatures and fluctuating rainfall. This is a serious challenge to most small to rural economies which are critically dependent on agriculture (Kruger & Shongwe, 2004).

Climate variability and change present a huge challenge to agricultural productivity in the continent. Tazeze *et al.* (2012) states that the sub-Saharan African continent is the most vulnerable to the current spate of climate inconsistency with severe economic effects. This vulnerability is stressed by socio-development constraints like widespread poverty, ecosystem deprivation and poor access to capital, markets, infrastructure and technology (Aydinalp & Cresser, 2008).

In Benin, agriculture is the second largest contributor to GDP accounting for about 38% and responsible for 70–80% of export earnings. In such economies, the negative effects climate changes cannot be understated (Mudhara, 2010). Tazeze *et al.* (2012) report that weather variability characterized by

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fluctuating period and duration of precipitation, variation in annual rainfall, increasing temperatures, water scarcity, soil dilapidation, random flooding, strong winds and the propagation of diseases and pests is common occurrence in Benin and the rest of the continent. Similarly, Weldegebriel and Prowse (2017), notes that climate variability and variability in Ethiopia poses risks to poor farmers and pastoralists who depend directly on natural systems for their livelihoods and natural resources. Also, Ugandan, small scale pineapple farmers reported reduced yields and increased pest and disease outbreaks in 2012 and these were attributed to prolonged drought and hot temperature (Mugambwa, 2014). Varying effects of climate variability to agricultural productivity are widely reported in most parts of the continent.

2.4.3 South Africa perspective

The South African agricultural sector is highly diverse and it is described as two-tiered (commercial vs. small-holder and subsistence farmers), with activities that cut across a wide variety of climatic conditions. According to DEA (2011), roughly 90% of the South Africa is sub-arid, semi-arid, or sub-humid, and about 10% is considered hyper-arid. Only about 14% of the South African's land is considered arable, and only 1/5 of the arable land has high agricultural potential. Climate plays a significant role as an indicator for potential agricultural activities and suitability across the country. This is true mainly in small-holder farmers and subsistence farming. Irrigation and conservation tillage practices are viewed as suitable strategies that can effectively overcome rainfall challenges, especially in the high-value commercial agricultural sector. Currently, irrigation farming uses about 60% of the country's surface water resources. This has key implications for agricultural exports, and food and water security in the context of climate variability (DEA, 2011).

Projected climate variability effects under an unconstrained emissions situation are generally negative to a variety of agricultural activities over the next few decades, but with some exceptions. Adverse effects are projected for important cereal crop production, high value export agricultural production and intensive animal husbandry practices. However, there are positive effects forecasted for other tropical crops. Deleterious effects would also be felt by the rise in irrigation needs and in the effects of agricultural pests and diseases. Strong international mitigation responses (under a constrained/mitigated emissions scenario) and with the implementation of suitable adaptation measures part of the negative effects could be reduced.

2.5 Climate variability induced challenges on Crop Production

Climate variability affects crop production by altering the biophysical factors such as plants and animal's growth rate and the physical infrastructure associated with food processing and distribution (Aydinalp

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& Cresser, 2008). Literature suggests that some impacts of climate variability are occurring more rapidly than previously anticipated (Parry *et al.*, 2007). Coupled with drought, forecasted maximum and minimum average temperatures for tropical and subtropical regions globally, are set to rise resulting decreased crop yield (Parry *et al*., 2007). This is because of increased vapour transpiration and lower soil moisture level (FAO, 2008). Therefore, the phenomenon would result in some of the agricultural lands in parts of the Sub-Saharan Africa which is in the tropics, becoming unsuitable for cropping and some grassland becoming unsuitable for pasture (Bals *et al.*, 2008).

It is expected that because of climate variability, the temperature in region (wet areas) could become wetter and the dry areas more-drier (FAO, 2008). The intensity of rainstorm could lead to rise in some areas and rainfall could become more inconstant and erratic. The variation in rainfall affects soil erosion rates and soil moisture both of which are key to crop yield (Ziadat & Taimeh, 2013). The rise in temperature together with reduced rainfall result in the loss of arable land in the region as a result of reduced soil moisture, rise in aridity and salinity as well as groundwater depletion (Okur & Örçen, 2020). The combined effects of these changes are expected to result in fall in crop productivity (Parons *et al.,* 2001). Its effect will also be felt in the livestock production. For instance, it is estimated that livestock productivity will decrease by 50% in year 2050 if the current climate variability patterns persist. Increasing temperatures and decreasing rainfall reduce yields of rangelands and contribute to their land degradation (FDRE, 2015). Some of the notably direct challenges of climate variability to crop production are illustrated in Table 2.1.

2.6 Tomato Production

Tomatoes are amongst the most popular vegetables in the world, with an annual value exceeding 90 billion USD (FAOSTAT, 2019). They are the second most important vegetables crop following potatoes in the world. Tomatoes world production in 2009 were about 152 million tons produced on 4.4 M ha (Biratu, 2018). Due to their importance, tomatoes acreage increased by almost threefold in the last 50 years to around five million ha in 2015. EU is one of the most important tomatoes producing regions and of the total, more than 85% of tomatoes are produced outdoors, mainly in Mediterranean Member States (Eurostat, 2019). Between 2010 to 2014, the world witnessed an increase in tomatoes harvested area, however, the yield decreased in this period for the sub-Saharan countries (Biratu, 2018). Desneux *et al.* (2011) reported that due to climate favourability for expansion and damaging potential of tomatoes leaf miner, the world tomatoes production has drastically reduced.

Table 2.1: Challenges posed by climate variability impacts on crop production

Factor	**Challenge caused**

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Average temperature increase Hot days and night.	1. Increase evapo-transpiration resulting in reduced soil moisture and plant wilting 2. Greater destruction of crop and stress by pest
Extreme events such as drought and floods	1. Crop failure or reduced yields 2. Increase land degradation desertification 3. Damage crops and food stores loss of arable land 4. Soil erosion, inability to cultivate land due to water logging
Change in rainfall amount and patterns	1. Shortages of water for irrigation purpose
Sea level rise	1. Loss of cropland and nursery areas for fisheries through salt water instruction 2. Salinization of irrigation water, estuaries and fresh water systems which will threaten irrigated crops and loss of arable land

Source: Adopted from IPCC, 2007

2.6.1 Tomatoes production and climate variability

Tomatoes crops are dependent on climatic factors for their growth. Despite its reputation as a high-value product, tomatoes are susceptible to an array of above and below ground pests and diseases. They are known to have above-average fertilizer requirements, which additionally increases the pest/disease problem in some cases. Tomatoes yield and quality are directly influenced by water and

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nitrogen management. Climate variabilities are a common denominator in many of these challenges faced by the tomato growers. Seasonal climate patterns dictate the onset and severity of pest and disease problems for tomatoes. Extreme weather events such as frost, hail, prolonged rain, excessive wind speed result in catastrophic crop loss on a regular basis. Excess water limits nitrogen availability and crop health. It is not easy to produce tomatoes, and it is even harder to produce high quality tomatoes (Malherbe, 2016).

Tomatoes need suitable soil and climatic condition for growth. Although, tomatoes can be produced on a variety of soil types, they grow optimally in deep, medium textured sandy loam or loamy, fertile and well-drained soil (Kelley & Boyhan, 2010). The soil provides physical support, nutrients and water to the crop. This means that, in the event where there is deficiency in the afore-mentioned factors, crops will not do well, and it will lead to a reduction in yield or production. It is also worth noting that, the provision of support, nutrients and water by soil depends on the topography, soil type, soil structure and soil management practices. For tomatoes production, there is the need for proper tillage to ensure satisfactory soil management and improve crop yields. Land preparation should include adequate tillage operations that make the soil suitable for seed germination or transplantation and to provide the suitable soil structure that allows or promotes root growth and development (Kelley & Boyhan, 2010).

2.6.2 Climate variability induced challenges on tomato production

The production of tomatoes has been decreasing due to production constraints such as biotic and abiotic factors (Asante *et al*., 2013). Abiotic factors look at erratic rainfall, high temperature, and poor soils, among others while the biotic constraints include diseases such as tomato yellow leaf curl virus, bacterial wilt, bacterial spot, early blight, and tomato mosaic viruses (Asante *et al.,* 2013). Climatological extremes, including very high temperatures are predicted to impact negatively on plant growth and development, with an overall effect of catastrophic loss of crop productivity which would have far reaching effects on food production (Bita & Gerats, 2013). On the same wavelength, the IPCC (2007) postulates that increased temperatures are expected to reduce crop yields and increase levels of food insecurity even in the moist tropics. This negative impact of high temperature is expected to increase risks in the agricultural sector (Gornall *et al.,* 2010).

Climate variability is a major challenge to tomatoes production in Africa. For instance, in southwestern Nigeria, rainforest is turning to derived savannah and vegetables usually grown in the savannah are being grown in other areas, leading to the disappearance of tree cash crops in the areas (Adebisi-Adelani & Oyesola, 2014). In Nepal, Marhjan *et al.* (2011) found that flooding at harvest destroyed crops, causing loss. Patterns of seasons have been shifting, and this change may eventually affect production of certain crops. Guodaar (2015) studied the effect of temperature on tomatoes productivity

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in north district of the Ashanti region of Ghana found maximum temperature had statistically significant negative association with tomatoes yield. This means that an increase in temperature resulted in a significant decrease in tomatoes yield with some confounding variables such as soil type, application of agro-chemicals, irrigation, tomatoes variety and regular weeding held constant. Similarly, it was discovered that a statistically significant negative association between rainfall and tomatoes yield. The implication is that as rainfall increases, it potentially causes a reduction in tomatoes yield even though tomatoes need water, excessive rainfall is detrimental to it.

Fahim *et al.* (2010) revealed that the early onset of high temperatures results in an earlier threat of diseases with possible more severe epidemics and increases in pesticides applications needed to control pests. Crop pests are already a major factor influencing farm productivity. Globally about one-sixth of field production is lost due to pests, with further losses in storage. Under climate variability the likelihood of the crop pest prevalence, the frequency of new pest introduction, the occurrence of pest outbreaks, and the risk of pesticide residues in food increase. These events are driven by climate variability and extreme weather (Dhanush *et al.,* 2015). For instance, in Egypt late blight of tomatoes increased to a 6% of its current level of the epidemic because of the projection of climate variability (Biratu, 2018). In support of Biratu, Fahim *et al.* (2013) claim that during warming conditions, late blight outbreaks projected to occur from 10 to 15 days earlier in terms of crop susceptible is lengthened by 10 to 20 days.

In South Africa, Limpopo Province is the major production area with 3 590 ha. The province accounts for over 75% of the total area planted with tomatoes in the republic (DAFF, 2017). In real terms, R630 million was generated from a mere 4,523 hectares. The economic sustainability of the local and national tomatoes industry is vital for the economic and social stability of thousands of rural households and small-scale farmers. Tomatoes are good for people in more than one way. According to Tshiala & Olwoch (2010), high yields in the province are not sustainable as the ripple effects of climate variability are taking toll on its production. The sensitivity of the tomato crops to climate variability and change is the main cause for concern amid fluctuating climatic patterns. Like the rest of the world, it is worth noting that effects of changing weather patterns continue to significantly contribute to the declining in tomatoes productivity in South Africa and in sub-Saharan region as a whole.

2.7 Climate Variability Adaptation

2.7.1 Legislative and policy framework on climate variability in South Africa

Jacobs & Msulwa (2012) enunciate that in the last decade, climate variability has been moving towards the centre of South Africa's agricultural policy landscape, for example in the 2001 Strategic Plan for

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South African Agriculture. The government adopted an overarching policy called the National Climate Variability Response Policy. The core message of this policy statement is South Africa's contribution to the transition of the global economy to a low-carbon economy and climate-resilient society. Policy makers are mindful that this challenge is inseparable from achieving key developmental goals: sustainable development, job creation, poverty eradication, and social equality. South Africa's strategic plan on the alignment of investment in agriculture mirrors the global strategies of policy makers (Tibesigwa & Visser, 2015). Currently, although South Africa is the second biggest economy in Africa with enough food availability at the national level, however not at household level. Statistics shows that about 45.6% of South Africans are considered food secure, 28.3% are at risk of hunger, while 26% are food insecure, i.e., experience hunger (Shisana *et al.,* 2014).

Schulze (2016b) posits that all South Africans, including farmers and ranchers, are currently faced with adverse effects of climate change such as severe floods, high temperature, drought, rise in wildfires as well as disease and pests. For this reason, the South African government has committed to cut the GHGs gases that drives climate variability and protect the atmosphere. Agriculture is a vulnerable sector due to its direct dependence on climate conditions like temperature and rainfall (Ringler, 2010).

Climate variability is influencing the rise in food insecurity, exacerbating poverty among the rural communities in South Africa. It has the potential to impact the key four dimensions of food security namely availability, accessibility, utilization and systems stability (FAO, 2008). In South Africa, an about 21% of the households are involved in agriculture, and 65% of them depend on agriculture as a subsistence strategy to meet household food needs (Republic of South Africa (RSA), 2014). The approach of using small-scale and subsistence farming as a strategy to promote food security remains a huge challenge because of climate variability. Food security or insecurity is multidimensional and remains a significant concern among policy makers. It is increasingly being recognised that more information is needed to guide decision makers (Nelson *et al.,* 2009).

2.7.2 Adaptation to Climate Variability in the South African Agricultural Sector

Smith & Olesen (2010) posit that climate variability is a global phenomenon and its impact on agricultural activities in developing countries has dramatically increased. Thus, many countries and individual farmers battle with finding adaptation techniques to reduce its effect on crop production and agriculture in general. The South African government has implemented various policies at local, provincial and national levels to curb the damaging effect of climate variability and to cushion farmers therefore. According to Schulze (2016), it must be emphasised that climate and climate variability challenges are superimposed upon the many other problems and stressors faced by the South African agricultural sector such as globalisation, environmental degradation, disease outbreaks, market uncertainties,

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machinery costs, policies concerning water, field burning, overgrazing and land redistribution irresponsive support systems. These have worsened the effects of climate variability and made development of appropriate plans and strategies difficult. However, up to a certain point, farming communities are trying to cope and adapt to climate that varies from time to time. To create an enabling environment for farming communities in dealing with uncertain future climatic changes, it is paramount to unpack the challenges and effects that makes them vulnerable. This would enable the development of context-based mitigating measures to cope with the effects of climate variability.

Government's efforts on climate variability adaptability are widely visible. However, they are impactful at a national and provincial level. Thus, climate variability adaptation has so far not been adequately integrated in specific plans and strategies for the agricultural sector at the local and grassroots level. The Western Cape Government (WCG) has recognised the important role played by the agricultural sector in the provincial economy and its growth potential, in job creation, and in the socio-economic development needs of the rural areas. For instance, as one of the intervention strategies, in 2014, the WCG developed a standalone plan namely: The Western Cape Climate Variability Response Framework for the Agricultural Sector. Its main aim was to specifically guard food and nutrition security by focusing on promoting climate-smart agriculture (Zwane & Montmasson-Clair, 2016). It also aligns closely with the current five-year Provincial Strategic Plan and the national DAFF's Strategic Goals. However, the framework lacks details on financing mechanisms to address the specific needs of small-scale agriculture, including the need for investment capital and risk management/transfer.

Kwazulu-Natal Climate Variability Adaptation Plan (2014), predicts that amid climate variability, agricultural productivity in the province is set to change in the coming years and decades. Production areas will shift and productivity will be altered. Agricultural opportunities will be gained in some areas while other areas will become agricultural 'losers. The plan also acknowledges that food insecurity in the coastal and northern parts of the province may be worsened by climate variability impacts. Several solutions to address food security threats, including expanded rainwater harvesting, water storage and conservation techniques, water reuse, desalination, water-use and irrigation efficiency are contained in the plan. The plan further recommends a shift in crop calendars, the switching of crops and a switch to more resilient livestock production systems. However, the plan has not yielded desired results for on the small-scale rural farmers.

Similarly, Eastern Cape Climate Variability Response Strategy has the objective to promote adaptation and mitigation technologies and interventions to minimise current and future adverse effects of climate variability on agricultural production and rural livelihoods (Zwane & Montmasson-Clair, 2016). The strategy supports the use of drip irrigation. However, there is no corresponding funding mechanism on

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the proposed adaptation strategy. The strategy is also silent on policy instruments (such as access to quality climate information, the role of agricultural insurance and investment in technology development, research and development) for adaptation in the agriculture sector.

In 2013, the Gauteng Province launched a climate variability response strategy. The strategy reported that evaporation of water from dams and soil in Gauteng was expected to increase by five to ten% by the 2050s; and 15 to 25% by the 2090s. In response to water scarcity, farmers were encouraged to conserve water by using grey water technology, which is the reuse of water used for domestic activities such as laundry, dishwashing and bathing. In this strategy, no clear support systems by the government were spelt out.

In Limpopo province, climate variability adaptability was incorporated into its Green Economy Plan. Agriculture and food production are among the key focus areas of Limpopo's Green Economy Plan. The plan recommends an awareness raising strategy on raising awareness on the green economy. The Limpopo Department of Agriculture Strategic Plan 2015-2020 acknowledges the acute shortage of extension officers with the necessary skills and resources to support previously disadvantaged farmers and enable them to cope in a technologically advanced and globalised sector. Moreover, it proposes to recruit extension officers to support previously disadvantaged farmers and land reform projects. In this strategy, however, proposed awareness raising strategies outlined in the green economy plan do not form part of the current Limpopo strategic plan. This shows lack of coordination between the planning authorities.

The Green Economy Plan ignores the training and retraining of extension staff to acquire new capacity in climate variability management. The plan also lacks detail on climate variability adaptation strategies for the agricultural sector (Zwane & Montmasson-Clair, 2016). This necessitates the need to understand the challenges and adaptation mechanisms faced by small scale farmer to devise context flexible policies to curb and termed the effect of climate variability to small scale farmers. It is against this backdrop that this study is set.

2.9 Summary of Literature Review

This chapter explored literature review focusing on climate variability and agricultural productivity including tomatoes production. Literature showed that climate variability effects are felt throughout the world however, its impact is heavy on small-scale farmer particularly in the sub-Saharan continent. Although, these effects are widely spread, it is evident that they vary from one region to another even within the same country. This indicates the need to address its effect on regional or local levels. Moreover, it was revealed in literature that climate variability is acknowledged at global, national and

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local level agricultural development planning. For instance, in South Africa, each province has its own climate variability policy which aims to tackle local specific effects. Loss of crops, decreasing yields, and reduced profits are some of the climate variabilities induced challenges. In addition, the past studies indicate rapid changes in weather pattern and are difficult to predict. Given the above findings from literature, it stands to reason that each region develops its context specific understanding of climate variability effects and adaption techniques.

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CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This study was designed to determine the effect of climate variability on small-scale tomato farmers (*Solanum lycopersicum)* production in selected villages of Mopani District Municipality. In this chapter, a comprehensive description of the research methodology is provided. Sileyew (2019) defines methodology as the path through which a study is conducted. The next components of the research methods are presented: study area description, study design, population and sampling, data collection and analysis, and ethics to be followed in the study.

3.2 Description of the Study Area

The study was conducted in Nkomo A and Nkomo B villages in Greater Giyani Local Municipality under Mopani District Municipality of South Africa (Figure 3.1). Mopani District Municipality is situated in the north-eastern part of the Limpopo Province. It is bordered to the north by Vhembe District Municipality, Ehlanzeni District Municipality to the south, Sekhukhune District Municipality to the south-west and in the west by the Capricorn. Nkomo A and B are located about 25 km from Giyani town. The coordinates for Nkomo A and B are 23°24' 0" South & 30°46'0"east, respectively.

Agriculture is the second employing industry after mining in Mopani District thus, majority of households in the district rely on agriculture to sustain their livelihoods. As is the case in Limpopo Province, Greater Giyani Municipality is also adversely affected by the climatic change. Such condition limited to the small-scale farmers' ability to realize their full potential. For instance, small-scale horticultural crop farmers are finding it difficult to sustain operations amid persistent climatic change. Thus, small-scale farmers are the most vulnerable to climate variability due to limited capital and financial resources.

3.3 Research Design

Figure 3.2 presents a schematic diagram of an exploratory sequential mixed methods research design. The design was employed in this study because of its ability to explore the current phenomenon in question.

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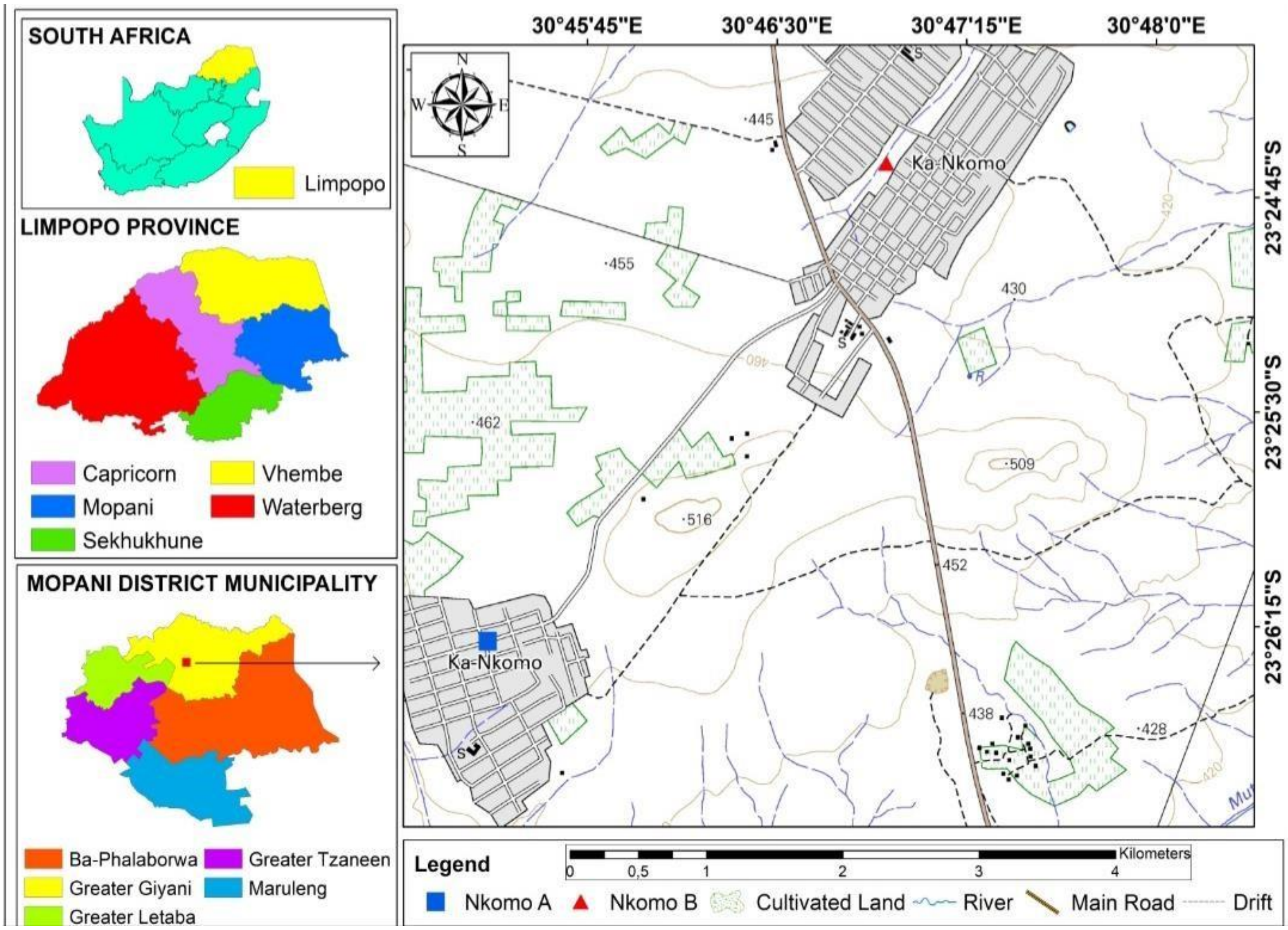

Figure 3.1: The map showing Mopani District Municipality and Giyani Local Municipality**.**

Source: University of Venda, GIS Resource Centre (2020)

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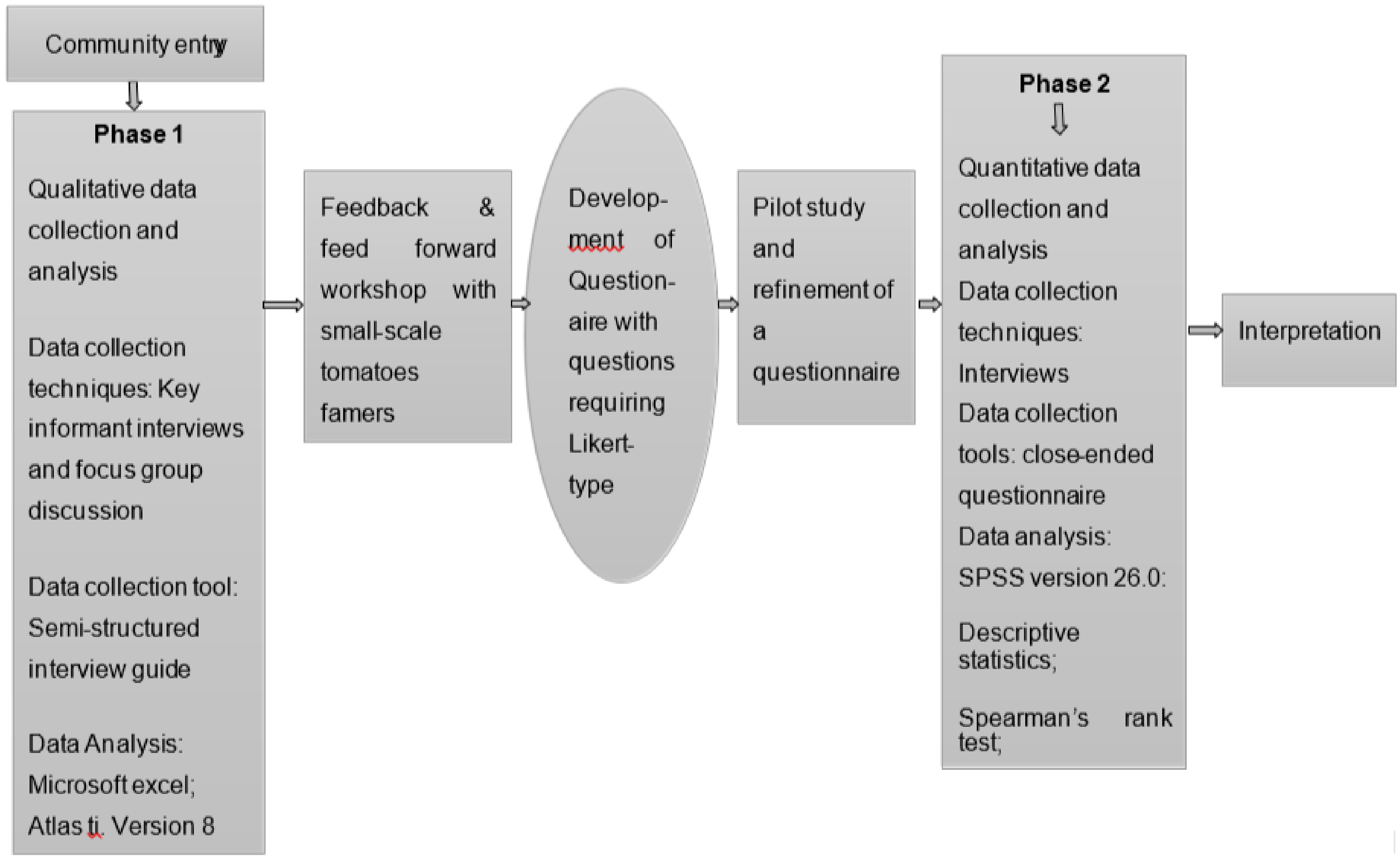

Figure 3.2: Schematic presentation of exploratory sequential mixed methods research design

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This design allows for the collection and analysis of qualitative and quantitative data first during exploring the phenomenon (Creswell, Klassen, Plano Clark & Smith, 2011). The established themes were used to drive the development of a quantitative instrument to further explore the research problem (Creswell & Clark, 2017). Based on the results of this design, three stages of analyses were followed namely: primary qualitative, secondary quantitative and integration. This connects the strands of qualitative and quantitative data and extends the initial qualitative exploratory phase of the findings (Creswell & Clark, 2017). Moreover, the qualitative approach was considered to have an in-depth understanding of climate variability effects on tomato production (Flick, 2009).

3.4 Training in Data Collection Tools

Data collection tools were developed to obtain data that would meet the objective and its associated questions. Semi-structured interview guide and close-ended questionnaire were designed. One university undergraduate student was recruited and served as research assistant. She was chosen based on experience in research processes and to administer data collection tools using local spoken language. The research assistants were trained on data collection tools administration. In addition, the research assistant was orientated on the objectives of the study and her specific roles. Each section and questions raised on data collection tool were explained, including the rationale for its inclusion.

3.5 Population of the study

Study population included small-scale tomato farmers and key informants such as extension services, chairperson of farmers' association committee, and climate variability adaptability experts. Neuman (2006) defines population as the precise set of cases which the researcher wishes to investigate such as individuals, cities, documents and countries.

3.5.1 Sampling procedures and sample size

Purposive sampling technique was employed to select the respondents in the first phase of the study. Purposive sampling technique was deemed appropriate because the researcher wanted to focus on characteristics of a population that were of interest (Palys & Atchison, 2012). Also, purposive sampling relies on the judgement of researcher to choose the members of the study population to participate in the survey. The characteristics of the population as defined by the

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researcher were used to select participants who match the description of the population. Thus, small-scale tomato farmers from Nkomo A and B were identified. Thus, tomato production and location in Nkomo A and B were used as a criterion to select respondents. Furthermore, key stakeholders who work closely with small-scale tomato farmers were also purposively selected for the study. Data saturation was used to determine the total sample. A sample of twenty-seven (27) respondents was provisioned for data saturation based on the previous studies.

During phase two of the study, purposive and random sampling method was used to select (n = 60) farmers in the study area. Purposive sampling technique was deemed appropriate because of its ability to identify farmers who are involved in tomato production in the area. Out of 60 farmers, 30 of them were selected from Nkomo A while the remaining 30 were recruited from Nkomo B.

3.6 Data Collection Methods and Techniques

3.6.1 Data pretesting

The data collection tools were piloted with 10 randomly selected farmers. These were not included in the final survey. Pilot was done to test the applicability and understandability of the questions included in the questionnaires. The results of the pre-test were used to revise the draft questionnaire.

3.6.2 Data collection

Qualitative data were collected through administering a semi-structured interview guide to twenty key informants. These included six extension services, two chairpersons of farmers' association committee, two chiefs of Nkomo A and B, and ten climate variability adaptability experts. To guard against the spread of COVID-19, health guidelines and protocols such as social distancing and wearing of masks were followed as stipulated by the Department of Health, South Africa. Moreover, sanitizers were provided during interviews to wash the hands of the respondents. Thermometer was very crucial during data collection process as it was used to take the body temperatures of the participants. The following uniform set of semi- structured questions was used to guide the key informant interviews: a) What are climate variability induced challenges faced by small-scale tomato famers? b) What techniques are currently used by small-scale tomato farmers to cope with the effects of climate variability? and c) What are possible strategies that could be

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used to address the identified challenges faced by small-scale tomato farmers? The interview guide was used to respond to objective 1, 2 and 3.

Qualitative data obtained through the interviews were used to construct a close-ended survey questionnaire. The survey questionnaire was used to answer objective 1 and 2. The questions required responses on a 5-point Likert-type scale of 1 (strongly disagree) to 5 (strongly agree). The questionnaire was administered to sixty small-scale tomato farmers.

3.7 Data Analysis

Table 3.1 presents the summary of data analysis per objective. Qualitative data obtained from the first phase were analysed using Atlas ti. Version 8 software to perform thematic content analysis. Data was cleaned and captured into Microsoft Excel prior to importation to the software. ATLAS ti.is a sophisticated qualitative data analysis tool suitable for analysing large texts, audios and pictures (Smith, 2002). Moreover, this software uses different techniques such as open coding, In-Vivo coding and quick coding techniques. In this study, open and quick coding techniques were applied to group family of themes and associated quotations. In addition, the software allowed for visual inspection of network of themes and how they relate to each other using diagrams. This further enhanced the analysis of the qualitative data. Quantitative data were analysed using Statistical Package for Social Sciences (SPSS) version 26. Descriptive statistics were used to calculate frequencies, percentages, and mean for scores.

Exploratory factor analysis was used to explore and identify factors in the given data set. Pearson's correlation coefficient (r) was used to determine the relationship between the currently used adaptation techniques and identified climate variability effects. Factors identified in thematic analysis, were further assessed quantitatively using exploratory factor analysis (EFA) in the second phase. Data were firstly screened for EFA suitability using KMO and Bartlett's sphericity tests. KMO > 0.5 indicates sampling adequacy of the data (Kaiser, 1960; Pallant, 2007:181; Tabachnick & Fidell, 2007). Also, Bartlett's test of sphericity ($\alpha < 0.05$ (Bartlett, 1954) is considered significant. Items with factor loadings of 0.4 and above were considered suitable for extraction. Those with a factor coefficient less than 0.4 or predicted a total variance of less than 5%, were suppressed after the inspection of the initial pattern and structure matrices (Pallant, 2007: 192). Also, subjective judgments and theory knowledge were utilised to select items and concretise factors.

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Table 3.1: Summary of data analysis per objective

Objective	Analysis
a) Analyse the challenges faced by small-scale tomatoes famers regarding climate variability on production of tomatoes.	**Qualitative data** Thematic content analysis: Thematic analysis was used to build themes on the effects of climate change variability **Quantitative data** *Factor analysis*: was used to determine or identify or extract the number of factors from the second phase data. *Mean scores*: Mean scores will be used to rank the common factors or climate variability effects in order of importance or impact. Pearson's correlation coefficient (r): Pearson was used to determine the relationship between the currently used adaptation techniques and identified climate variability effects
b) Analyse the current adaptation techniques used by small-scale tomatoes famers to mitigate the effects of climate variability on tomatoes production.	**Qualitative data** Thematic content analysis: Thematic analysis was used to build themes on the currently used techniques to manage or adapt to climate change variability **Quantitative data** Factor analysis: was used to determine or identify or extract the number of factors from the second phase data. Mean scores: Mean scores will be used to rank the common factors or climate variability adaptation technique in order of importance or impact.

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c) Suggest the possible strategies that can be used to mitigate the effects of climate variability on production of tomatoes	Qualitative data: Thematic content analysis was used to build themes on preferred or proposed climate change variability **Quantitative data** *Factor analysis*: was used to determine or identify or extract the number of factors from the second phase data. *Mean scores*: Mean scores was used to rank or identify the most preferred factors or climate variability adaptation technique. *Pearson's correlation coefficient* (r): Pearson will be used to determine the relationship between the currently used adaptation techniques and identified climate variability effects .

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3.8 Ethical Considerations

This study was carried out after getting ethical clearance from the University of Venda Ethics Committee. Permission to interview farm workers was sought from the farmers' Association Committee and Traditional Authority in Nkomo A and B in Giyani Local Municipality. Informed consent and the right to participate were adhered to. Written consent of the farmers was sought, meaning that only those who volunteered to participate were engaged. All participants could ask questions and decided whether to participate or not. Before using tape recorders, consent of the participants was secured to ensure that participants were acquainted in advance with every aspect of the study. For this reason, the participants were assured that the information collected would be confidential and used for the sole purpose of this study. Moreover, once the study has been concluded and reports finalised, data or collect information would be kept in a safe place to protect the identity of the respondents. The participants were also assured that photographs taken during the interviews would be stored in a safe place and used for academic purposes only. Participants were further informed about the objectives of the study and that privacy during the interview would be recognised. The respondents' anonymity and confidentiality were ensured through non-recording of names and using codes to refer to the collected data. In addition, before data collection commences, the purpose of the study, potential harm and nature of the participation were explained. This includes that they were participating in voluntary and for academic purposes only. Lastly, consenting individual farmers was asked to tacitly and expressly indicate their willingness to participate.

3.9 Dissemination Plan

Considering that various individuals and institutions constitute the end users, various methods of dissemination will be used. At least two scholarly papers will be published in a peer reviewed journal. The study findings will also be disseminated through presenting papers in at least one local and one international conference. Where possible, interviews will be given to interested media houses. The policy recommendations will be disseminated to relevant institutions through a policy brief.

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CHAPTER 4: PRESENTATION OF RESULTS

4.1 Introduction

This chapter outlines the results of study. Firstly, the demographic information is presented. Secondly, climate variability effects, currently used adaptation techniques; and proposed or preferred strategies to mitigate climate variability effects on tomato production are outlined in this order. In each case, thematic analysis (explorative study) results are presented first followed by that of descriptive results (quantitative study). Thirdly, Pearson correlation analysis of how adaptation strategies used influence or are likely to influence climate variability effects is shared.

4.2 Results

4.2.1 Demographic profile

Most the respondents (67%) were female (Table 4.1). Equally, those aged between 21-30 years and 41-50 were the most represented at 24% and 34.8%, respectively. This is an indication that farmers in the key age groups take responsibility of ensuring food security for their households and community. In addition, most farmers (43.5%) have been in farming between 3– 4 years. Most of them (39%) were married while 35% were single. About 11 and 15% were widowed and divorced respectively. The majority of the farmers (33%) had tertiary qualification while 28% had primary schooling.

4.2.2 Climate variability effects

Figure 4.1 presents the qualitative results of the farmers lived experiences on the effect of climate variability on tomato production. These were categorised into twelve sub-themes which included stock loss, pest infestation, poor fruit quality, over and under supply of water, unemployment, decrease in output, soil erosion and infertility, unpaid or reduced salaries, decrease in profit margins, loss of clientele, increased production costs and long working hours.

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Table 4.1: Demographic profile of the respondent (46)

	Category	Frequency (%)
Gender	Male	15 (32.6)
	Female	31 (67.4)
Age	21-30	11 (23.9)
	31-40	16 (34.8)
	41-50	11 (23.9)
	51-60	6 (13.0)
	Over 60	2 (4.3)
Edu Level	None	7 (15.2)
	Primary	13 (28.3)
	Secondary	11 (23.9)
	Tertiary	15 (32.6)
Number of years working in farm	≤1	8 (17.4)
	2-3	14 (30.4)
	3-4	20 (43.5)
	5 and above	4 (8.7)
Marital status	Single	16 (34.8)
	Married	18 (39.1)
	Divorced	7 (15.2)
	Widowed	5 (10.9)

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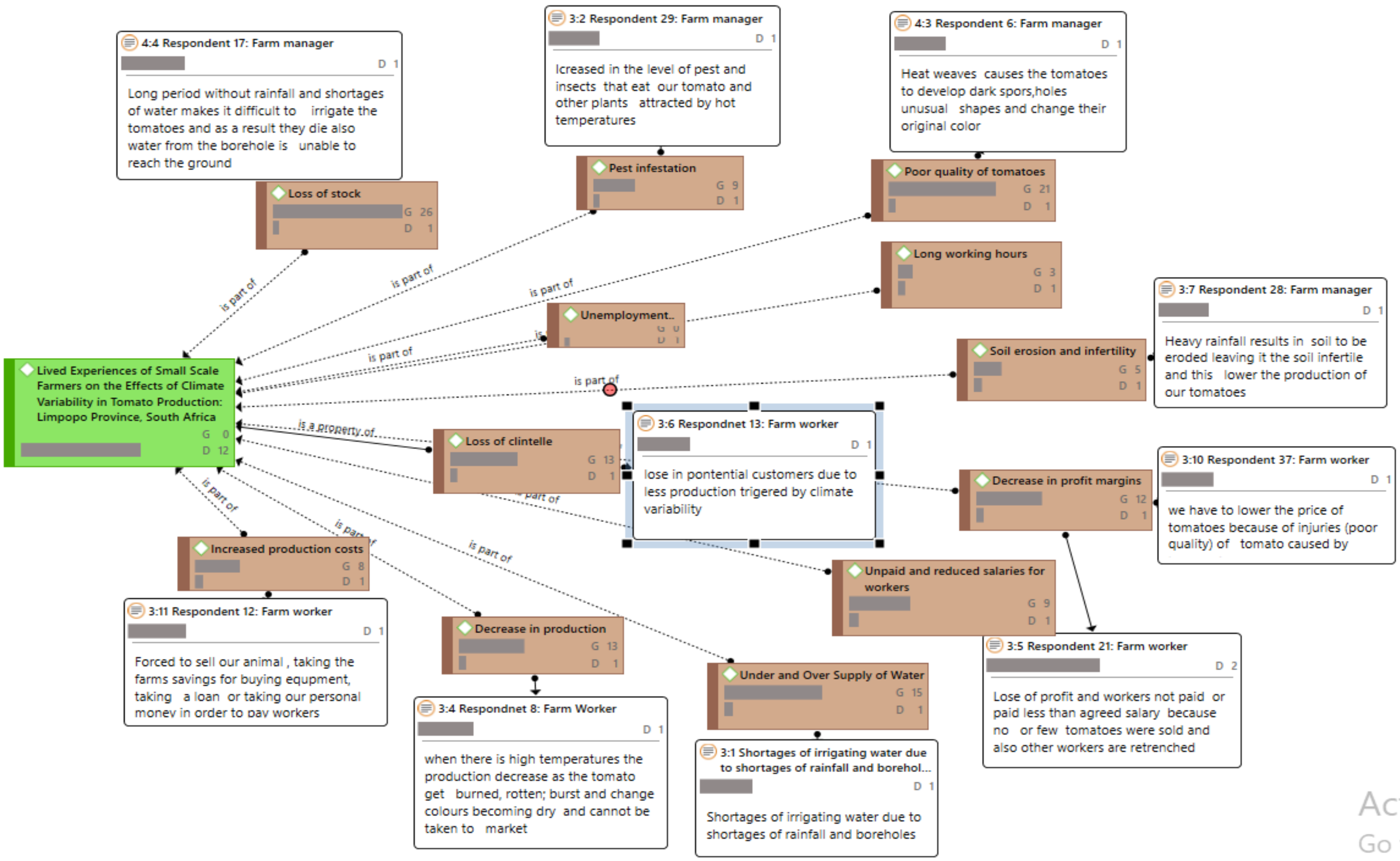

Figure 4.1: Climate variability effects in tomato production: Limpopo Province, South Africa

Key: G = groundedness of the thematic code **D =** density of the thematic code'

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As shown, in Figure 4.1, the most common effect of climate change revealed by respondents was loss of stock. For example, a farmer indicated that:

> *Long period without rain and shortage of water makes it difficult to irrigate the tomatoes and they ended up dying.*

Another effect of climate change was poor quality of tomatoes. For instance, one farmer revealed that:

> *Heat waves caused tomatoes to develop dark spots, change shapes and the original colour.*

Another farm worker had this to say:

We must lower the price of tomatoes because of injuries (poor quality) of tomato caused by heavy rains.

Water scarcity was also mentioned as a challenge in tomato production by the respondents in this study under and over supply of water. The respondents indicated that:

There is limited water for irrigation due to shortage of rainfall and boreholes.

A farm manager indicated that:

I used to produce tomatoes on 4 hectares. However, for the past 3 years I was no longer using the whole field because of shortage of water.

Small-scale tomato farmers also complained of loss of clientele. The reason advanced was:

> *We failed to maintain clientele such as big shops and supermarkets. This was because most of us find it difficult to consistently supply the agreed tonnes of tomatoes due to less output or no production because of climate problems*.

The effects which were least mentioned were long working hours and unemployment.

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4.2.2.1 Descriptive Analysis

Principal Component Analysis and Kaiser Normalisation rotation method were used to extract the factors based on Total Eigen values and Oblique Rotation for a simple structure. This was done to explore structural validity and reliability of the identified factors. The analysis was pegged at a 95 % level of significance and factors with Eigen values of > 1 were considered. As shown in Table 4.2, seven factors were extracted. From twenty-five items the PCA isolated seven components accounted for 71.4% of the variability. For example, Factor 1 had an Eigen value of 8.326 while Factor 7 named "Lower wages and profits" scored 1. 018. Also, scree plot was observed to enhance the accuracy in factor selection. As stated in the data analysis section, items with factor loadings of 0.4 and above were considered suitable for extraction. Those with a factor coefficient less than 0.4 were suppressed after the inspection of the initial pattern and structure matrices.

Out of the 25 items, only item E2 had a factor loading of less than 0.4, hence it was eliminated for further analysis. After systematic assessment of factors, each factor was named as depicted in Table 4.3. For instance, Factor 1 was named "Increased Temperatures & Pest Infestation" and its loading items were "In extreme heat tomatoes are attacked by worms and perish"; "In recent years, our plants are increasingly attacked by insects that eat tomatoes fruits"; "There has been an increase in the level of pest and insects eating our tomato and "Increasing pest attack has made us to purchase more expensive chemicals (pesticides) for killing pests". The identified themes describe seven factors that can be reliable used to describe the effects of climate change variabilities in tomato production for Limpopo small scale farmers. The level of importance for each factor, was assessed and ranked using mean scores in SPSS. Results reveal that factor name called, "Increased Temperatures and Pest Infestation" is the most common and problematic climate variability effect to tomato producers while "Land degradation" was the least ranked (Table 4.4).

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Table 4.2: Factor extraction using Eigen values and total variance explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	8.326	33.304	33.304	8.326	33.304	33.304	5.906
2	2.353	9.412	42.716	2.353	9.412	42.716	4.781
3	1.847	7.387	50.102	1.847	7.387	50.102	4.457
4	1.802	7.209	57.312	1.802	7.209	57.312	1.704
5	1.367	5.467	62.778	1.367	5.467	62.778	1.891
6	1.139	4.554	67.333	1.139	4.554	67.333	2.804
7	1.018	4.071	71.403	1.018	4.071	71.403	2.726

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

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Table 4.3: Factor loadings for factor analysis of Climate variability effects to tomato production among small scale farmers

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
E4. In extreme heat tomatoes are attacked by worms and perish	.703						
E12. In recent years, our plants are increasingly attacked by insects that eat tomatoes fruits	.460						
E13. There has been an increase in the level of pest and insects eating our tomato	.663						
E14 Increasing pest attack has made us to purchase more expensive chemicals (pesticides) for killing pests	.848						
E16. High rainfall experienced sometimes affect our farm operations to the extent that we must wait for longer periods to plant.		.774					
E18. In recent years, production has decreased due to water challenges		.704					
E22. Long working hours are increasingly becoming a common occurrence to monitor plants from water stress and pest attack.		.540					
E25. We find ourselves selling our possessions, dipping into the farm savings, taking a loan and taking personal money to buy irrigation equipment and pay workers		.886					
E7. Extreme heat results in tomatoes fruits changing shapes and original colour			.732				
E17. We are experiencing high temperatures recently that cause the tomato fruit to burn, burst, rot and change colour.			.475				
E23. It is common to now produce dry tomatoes			.879				
E5. Very cold weather conditions reduce the amount of juice in the tomato fruit			.411				
E24. Compared to the past, sometimes our tomatoes are of poor quality and gets rejected or attract lower price in the market.			.413				
E6. Heat weaves causes the tomatoes to develop dark sports and holes,			.522				
E8. Longer dry seasons are experienced causing water scarcity for the farmers?				.481			
E21. We can no longer manage to till the whole farm due to water problems or fear of stock loss				.787			
E3. When it is very hot, tomato trees burn and wilts					.816		
E11. Water inside the irrigation pipes heats up in very high temperatures and burn the tomato tree causing it to die					.412		
E9. We experience frequent flooding that erodes and washes away our tomato plants					.701		
E10. When it's very hot the leaves of the tomato tree turn dusty white and shrink					.796		
E15. Soil infertility caused by water shortage and flooding require us to now buy fertilisers or apply manure frequently						.641	
E1. High temperatures harden the soil and makes it difficult for tillage						.777	
E19. Workers now are increasingly subjected reduced salaries due to low output caused by water problems or environmental conditions environmental conditions							.547
E20. Workers have been and are likely to be retrenched because of decreased output from the farm							.830
Eigen values Explained	**8.326**	**2.353**	**1.847**	**1.802**	**1.367**	**1.139**	**1.018**

KEY: Factor 1 = Increased Temperatures & Pest Infestation; Factor 2 = Disruption /changes of normal production process, Factor 3 = Poor quality of tomato crop; Factor 4 = Water shortages; Factor 5 = Loss of tomato crop; Factor 6 = Land degradation; Factor 7 = Lower wages and profits.

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Table 4.4: Mean factor ranking of climate variability effects to tomato production among small scale farmers

Factor No & Name	Sum	Mean	Std. Deviation
Factor 1: Increased Temperatures & Pest Infestation	1294.00	28.1	5.32
Factor 2: Disruption /changes of normal production process	907.00	19.7	3.83
Factor 3: Poor quality of tomato crop	602.00	13.1	1.67
Factor 7: Lose in profit	540.00	11.7	2.19
Factor 5: Loss of stock	391.00	8.5	1.00
Factor 4: Water shortages	389.00	8.4	1.26
Factor 6: Land degradation	364.00	7.9	1.75

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4.2.3 Adaptation techniques currently used by small-scale tomato farmers

Figure 4.2 presents the qualitative results of the adaptation techniques currently used by small-scale farmers to adapt to climate variabilities in tomato production. Nine themes that described the adaptation techniques were categorised into intercropping, mulching, plant covering, seasonal planting, crop rotation, use of pesticides, water optimisation, application of manure, and use of water storage facilities. As highlighted in Figure 4.2, seasonal planting was revealed as the most common adaptation technique practiced by famers to address climate variability. For instance, farm worker expounded that:

We usually plant tomatoes during winter season to lower the risk of climate variability

Application of manure as well as use pesticides and water from boreholes were second and third commonly used current adaptation techniques by small scale farmers respectively (Figure 4.2). Farmers also employed watering optimisation to minimise water loss. For example, a farmer stated that:

We water the tomato plants during the morning hours and late evenings to give plants enough time to absorb water before it escapes the soil through sunlight.

This was also confirmed by another farmer who indicated that:

We shelter or cover tomatoes plants with plastic or sail to reduce water loss through evapo-transpiration and prevent water from escaping the soil quickly

Respondents further claimed that they practice plants covering technique to deal with excessive heat and sunlight that causes evapotranspiration. This was highlighted by a farm worker who said:

We are planting more trees that would provide shadow and protect tomatoes from extreme weather conditions.

Other adaptation techniques to climate variability revealed by the respondents were intercropping, crop rotation, use of manure, pesticide, and water storage facilities.

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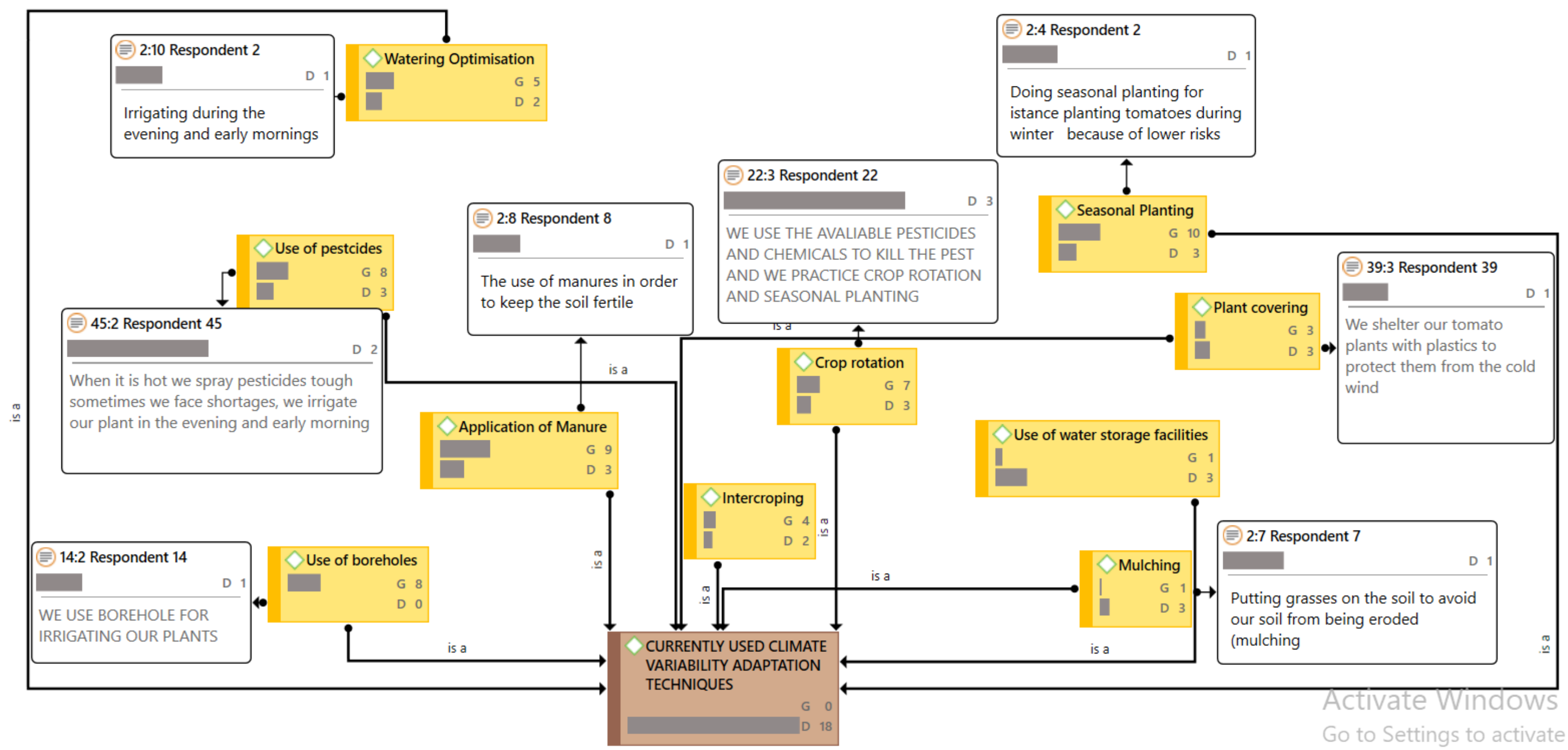

Figure 4.2: Adaptation techniques used by farmers in tomato production in Mopani District of Limpopo Province, South Africa

Key: G = groundedness of the thematic code **D =** density of the thematic code

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The least mentioned technique by tomato farmers was mulching. For instance, one farmer reported that:

> *We cover the soil between plants with a layer of grasses to keeps roots cool in summer and warm in winter*

4.3.3.1 Descriptive analysis

Two factors with Eigen values of greater than 1 were extracted as shown in Table 4.5. Unlike in the qualitative data where 10 factors were identified, only two factors were extracted. Observation of factor matrixes showed that items of techniques that relate to effects of high temperatures such as soil covering, tree shading, intercropping, and saving water were associated or grouped together. Hence, the first factor is named “Water Saving Techniques”. The second factor is named Crop Rotation and Seasonal Planting Techniques (Table 4.7). All items in this category loaded sufficiently ($\alpha > 0.4$). For example, the lowest factor loading is 0.505 for CT5 and highest is 0.870 for CT2 (Table 4.6). Thus, the two-identified factors sum up the commonly used strategies to mitigate climate variability changes. Water saving related techniques were the most common adaptation strategies utilised by farmers (Table 4.7).

4.3.4 Proposed adaptation strategies used to address the effect of climate variability

Figure 4.3 shows the results of the proposed adaptation strategies/techniques that can be used to reduce effect of climate variabilities. These were categorised into tunnel farming, deficit irrigation, tree shadow planting, drought resistant seed variabilities borehole drilling, alternative efficient pest control methods, drip irrigation and use of big water pipes. As shown in Figure 4.3, borehole drilling was the most proposed strategy by farmers.

Installing greenhouses was the second mentioned strategy proposed by small scale tomato farmers. An extension officer for example said,

> *Erecting greenhouses is urgently needed to help tomato farmers manage climate induced adverse effects to production*

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Table 4.5: Factor extraction for currently used climate variability adaptation techniques

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.233	40.417	40.417	3.233	40.417	40.417	2.803
2	1.387	17.332	57.749	1.387	17.332	57.749	2.317

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

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Table 4.6: Factor loadings from factor analysis of coping techniques (CT) to climate variability effects in tomato production

	Factor 1	Factor 2
CT1: We practice intercropping such as planting different crops in same row for shading and to provide enough soil cover	.507	
CT4: Excessive sunlight and heat is managed by planting more trees around the farm and sheltering plants with plastic covering	.801	
CT5: To manage water shortages, we resort to water storage tanks	.505	
CT6: Soil covering with tree leaves and grass is currently used as a method to reduce soil moisture loss and erosion	.543	
CT7: In recent times, more and more manure is a must to keep the soil fertile	.692	
CT8: To save and manage water available, plants are watered or irrigated during the evening and early mornings	.754	
CT2: Practicing crop rotation is one of the methods we use to address pest infestation and soil fertility		.870
CT3: Seasonal planting such as growing tomatoes in winter is practiced to lower the risks.		.861
Eigen Values Explained	**3.233**	**1.387**

Extraction Method: Principal Component Analysis.

Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Key: Factor 1 = Water Saving Techniques; Factor 2 = Crop Rotation and Seasonal Planting Techniques

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Table 4.7: Mean factor ranking for currently used climate variability adaptation techniques

	Sum	Mean	Std. Deviation
Factor 1: Water Saving Techniques	1143.00	24.8	4.01
Factor 2: Crop Rotation and Seasonal Planting Techniques	582.00	12.6	2.02

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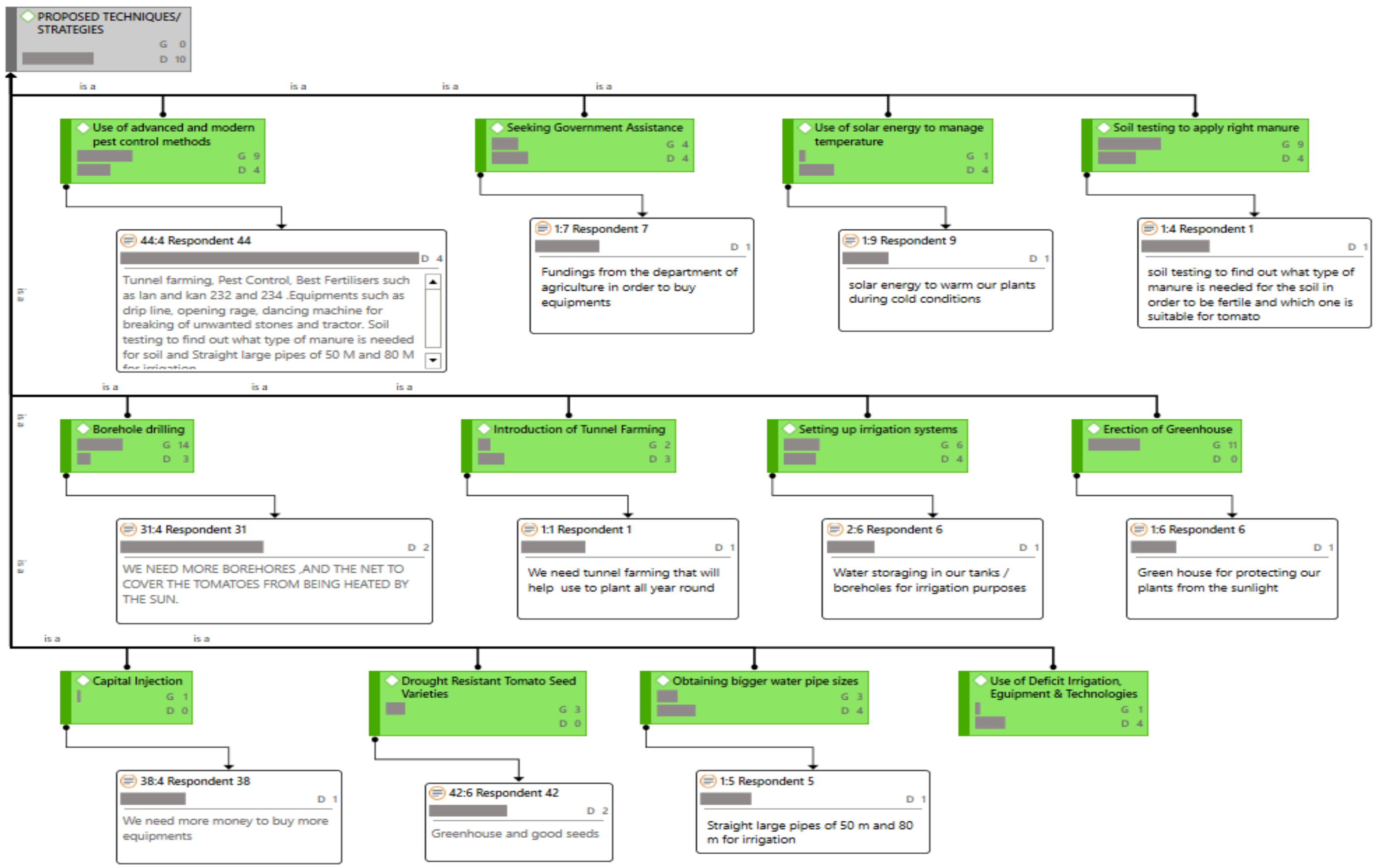

Figure 4.3: Proposed adaptation strategies to mitigate climate variability effects of on the production of tomatoes in Mopani district of Limpopo Province, South Africa.

Key: G = groundedness of the thematic code **D =** density of the thematic code

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The use of advanced pest control methods and soil testing for accurate manure/fertiliser application were the third most mentioned proposed techniques with the same number of quotations. For instance, a farmer worker said,

Soil testing to find out or know in real time which manure is suitable for tomatoes at a given stage is important for right and timeous manure application.

It also emerged that improvement and or erection of drip irrigation could also help the farmer to reduce the effects of climate variability. For example, a farm worker indicated that:

Our irrigation system is broken and now we rely on flooding the entire field. We need support to buy a new system that will help us save on water

In a similar vein, famers said purchasing and using pipes with bigger width could also improve water availability in the farms. For a farm manager had this to say:

We need straight large pipes of 50 to 80 m for irrigation.

Use of drought resistant plant varieties was also mentioned as a viable option for mitigating the effects of climate variability by tomato farmers. A farm worker highlighted that:

> *We need new type of seeds that can with stand heat and low rainfall otherwise our production will keep decreasing if the situation continues the same way*

Farmers also stated that soil testing to know soil properties and nutrient composition was crucial to the survival of tomatoes. A farm manager is of the view that:

[as tomato farmers] We need soil testing to find out what type of manure is needed for the soil to be fertile, and which one is suitable for tomato.

Finding and using alternative efficient pest control methods was also stated as potential strategy for reducing climate variability effect of increasing pest attack and chemical resistance by pests.

Deficit irrigation emerged as the least potential strategy for reducing climate variability problems to small scale tomato farmers. For example, a farm worker lamented that:

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We need to learn about the amount of water needed at different stages of tomato growth. This will help us to know when to put the plant under water stress to manage water scarcity.

4.3.4.1 Descriptive analysis

Factors were extracted using Eigen values of greater than 1. Resultantly, three factors were extracted. Factor 1 had Eigen value of 4.525, factor 2 had Eigen value of 1.319 and factor had a value of 1.041 (Table 4.8). The rest of the items were lower than 1 hence were eliminated for further analysis. All items loaded adequately at $\alpha > 0.4$ (Table 4.9). Matrix observation revealed that items were not related and violated theory. Thus, factors were further analysed using subjective judgements to identify factors. Hence, four factors were identified namely, Irrigation Set Up, Water use management systems, crop, soil and climate relationship and advanced pest control methods (Table 4.10). The number of factors is lesser than the 12 themes identified in thematic analysis. Thus, thematic analysis provided more specific factors compared to factor analysis where items are summed together.

4.3.5 Pearson correlation of climate variability effects and adaptation strategies

Table 4.11 shows the correlation analysis between the climate variability effects and adaptation strategies. There are negative relationships between water saving related techniques with most climate variability effects. For instance, loss of stock (α = -.622**; p = .000), decrease in profits (α = -.374*; p = .010) and disruption in normal production processes (α = -.637**; p = .000) is negatively related to water saving related adaptation strategies. This means, applying the water saving techniques decreases the chances of losing profits among farmers for example. Equally, when water saving techniques are used more, the loss of stock and disruption of production of process is decreased. There is no significant relation between water saving techniques and increased temperature and pest infestation. Moreover, the results show that crop rotation and seasonal planting techniques were negatively related to all climate variability effects except for water shortages and poor quality of tomato crop. This means that using crop rotation and seasonal plating techniques reduces the effects where the relationship is significant.

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Table 4.8: Factor extraction using Eigen values and total variance explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% Of Variance	Cumulative %	Total	% Of Variance	Cumulative %
1	4.525	45.249	45.249	4.525	45.249	45.249
2	1.319	13.189	58.439	1.319	13.189	58.439
3	1.041	10.412	68.851	1.041	10.412	68.851

Extraction Method: Principal Component Analysis.

Table 4.9: Factor loadings through Exploratory Factor Analysis for proposed climate variability adaptation strategies (PS)

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	Factor 1	Factor 2	Factor 3	Factor 4
PS1: Drilling boreholes for irrigation purposes is one of the methods we would like to use to address water challenges in the farm	.609			
PS8: Large water pipes are required to draw water for irrigation	.499			
PS7: Erecting an irrigation system	.678			
PS3: There is a need for tunnel farming to be able to plant tomatoes all year around	.707			
PS4: Setting up an efficient water use management equipment such as timed drip irrigation and watering monitoring technology		.743		
PS10: Use of solar energy and green house to manage temperature will help us mitigate the effects of climate variabilities		.666		
PS5: A greenhouse is required for protecting plants from the direct sunlight.		655		
PS2: Assistance with drought resistant seeds, manure and chemicals from the department of agriculture and other organisations helps us to cope with challenges			.612	
PS9: Our soil needs testing to select the manure in correcting soil infertility			.731	
PS6: We would like to use advanced and modern pest control methods and chemicals				.799

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 9 iterations

KEY: Factor 1: Irrigation Set Up**; Factor 2:** Water use management systems**; Factor 3:** Crop, Soil and Climate relationship**; Factor 4:** Advanced pest control methods

Table 4.10: Mean Score ranking of proposed adaptation strategies

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	Sum	Mean	Std. Deviation
Factor 1: Irrigation Set Up	968.00	21.5	3.02
Factor 2: Water use management systems	600.00	13.0	1.79
Factor 3: Crop, Soil & Climate relationship	397.00	8.6	1.42
Factor 4: Advanced pest control methods	231.00	5.3	0.98

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The results show that some climate variability effects are negatively related to proposed strategies while some are positively related. For example, the use of advanced pest control methods will reduce the crop pest attack (α = -.472**; p= .001). However, this is also likely to increase the effect of and degradation (α = .378**; p = .010).

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Table 4.11: Pearson correlation of climate variability effects and adaptation strategies

		1	2	3	4	5	6	7	8	9	10	11	12	13
1. Increased Temperatures & Pest Infestation	Pearson Correlation	1												
	Sig. (2-tailed)													
2. Disruption /changes of normal production process	Pearson Correlation	.363*	1											
	Sig. (2-tailed)	.013												
3. Poor quality of tomato crop	Pearson Correlation	.652**	.471**	1										
	Sig. (2-tailed)	.000	.001											
4. Water shortages	Pearson Correlation	.302*	.519**	.281	1									
	Sig. (2-tailed)	.041	.000	.058										
5. Loss of stock	Pearson Correlation	.507**	.583**	.499**	.188	1								
	Sig. (2-tailed)	.000	.000	.000	.211									
6. Land degradation	Pearson Correlation	.610**	.425**	.587**	.476**	.425**	1							
	Sig. (2-tailed)	.000	.003	.000	.001	.003								
7. Lose in profit	Pearson Correlation	.858**	.359*	.626**	.349*	.479**	.687**	1						
	Sig. (2-tailed)	.000	.014	.000	.018	.001	.000							
8. Water Saving Techniques	Pearson Correlation	.433	-.637**	-.522**	-.305*	-.622**	.388	-.374*	1					
	Sig. (2-tailed)	.073	.000	.000	.039	.000	.088	.010						
9. Crop Rotation and Seasonal Planting Techniques	Pearson Correlation	-.566**	-.315*	.194	.169	-.414**	-.574**	-.571**	.401**	1				
	Sig. (2-tailed)	.000	.033	.197	.261	.004	.025	.000	.006					
10. Irrigation Set Up	Pearson Correlation	.548	-.532**	.595	-.396**	-.593**	.637	.616**	.578**	.192	1			
	Sig. (2-tailed)	.230	.000	.073	.007	.000	.089	.000	.000	.207				
11. Water use management systems	Pearson Correlation	.471	-.505**	.565	-.273**	-.623**	.558	.522**	.733**	.401**	-.562**	1		
	Sig. (2-tailed)	.111	.000	.454	.066	.000	.271	.000	.000	.006	.000			
12. Crop, Soil & Climate relationship	Pearson Correlation	.692	-.573**	-.557**	.260	-.686**	.595**	.692**	.698**	-.580**	.678**	.618**	1	.
	Sig. (2-tailed)	.321	.000	.000	.082	.000	.000	.000	.000	.000	.000	.000		
13. Advanced pest control methods	Pearson Correlation	-.472**	.322	-.513**	.114	-.620**	.378**	.461**	.637**	.375*	.628**	.680**	.557**	1
	Sig. (2-tailed)	.001	.291	.000	.450	.000	.010	.001	.000	.010	.000	.000	.000	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

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CHAPTER 5: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The chapter presents the discussion of the findings based on the study objectives. However, the demographic profile of respondents is discussed first. Also, the conclusions drawn from the study findings are outlined to synthesise the results. Lastly, the recommendations on what could be done to mitigate the effects of climate variabilities on tomatoes are also given.

5.2 Discussions

In general, respondents in the current study were predominantly women. This could be explained by the fact that more men leave rural communities to urban big cities such as Pretoria or Johannesburg in Gauteng Province in search of Jobs (Mbiyozo, 2018). This is also supported by most studies that men migrate further than women in developing countries (Amrith, & Sahraoui, 2018; Schäfer, 2018). Moreover, the last statistics of South Africa in 2011, shows that there are more women in the country than men. The farmers aged between 21-30 years and 41-50 were equally represented and were the majority groups. This is an indication that farmers in the key age groups (the youth and adults) take responsibility of ensuring food security for their households and community. In addition, most farmers were more experienced with over 3 years of farming while a significant percentage had over 5 years in practices. This highlights that farmers have experienced enough variabilities in weather conditions to report accurately on effects of climate variability.

In this study, the effects of climate variability on tomato production in Limpopo province, South Africa were investigated. It emerged from the study that there are various climate variability effects to tomato production. This included increased temperatures and pest Infestation; disruption /changes of normal production processes; poor quality of tomato crop; water shortages; loss of stock; land degradation and lose in profits for farmers.

Increasing temperatures are among the most mentioned effects of climate variability by different farmers including crops (Eruola *et al.,* 2013), vegetable (Tanyi *et al.,* 2018), fruit (Williams *et al.,* 2017) and tomato (Guodaar *et al.,* 2020) farmers. In South African particularly in Limpopo province, the rising temperature has been reported as early as a decade ago (Tshiala, & Olwoch, 2010). Due to climate change in the last decades, extreme weather events such as heavy rainfall, droughts and heat waves are increasing and they are linked to increased temperatures (Gornall *et al.,* 2010;

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Mirza, 2011). Another study in Limpopo found that there is a significant increase in temperature in Bela Bela, Polokwane and Musina in northeastern of South Africa (Kruger & Shongwe, 2004). This has had adverse effects to agricultural productivity.

High temperatures and frequent heat waves are also linked to negative vices to crop production as also mentioned in this study. In support of the current study findings, Tshiala (2014) highlights that when crops are exposed to heat stress, they become more susceptible to attack by pests and diseases. This observation was also made by Porter *et al.* (1991). Pest infestation caused by the effects of climate variability has been observed global and has been on the rise. Greenslade (2008) reports similar results in Australia. Tanyi *et al*. (2018) in Cameron claim that climate change has caused frequent attack to horticultural crop particularly to cabbage producers which led to farmers to adapt their planting dates as mitigating strategy. The results and literature show that pest and insect attack is a common problem of climate variability which small-scale farmers must brace themselves for and find alternative adaptation strategies to manage the challenge.

Farmers in the current study also reported water scarcity as the common challenge caused by climate variability. As water stressed country, rising temperatures worsen the problem of water scarcity. Rising temperatures are responsible for the water scarcity/droughts in the country and it is the most challenge faced by small-holder farmers (Riva *et al.,* 2021). Farmers reported that due to water scarce they either rely on or require artificial waters supply systems like irrigation and water storage tanks. Farmers further stated that although water scarcity and shortage of rain was a norm, they also experienced frequent flooding which washed away their plants. This observation is similar to the one observed in a recent study carried out in Nigeria.

The study revealed that 80% of the farmers' experience floods occurrences during rainy season and water deficit between January and March each year (Adegbehin *et al.,* 2021). For instance, an increase in temperature causes intensification of the hydrological cycle that results in increased evapo-transportation in plants (Creed *et al.,* 2015). High levels of evapo-transpiration coupled with water scarcity causes plants to wilt and have stunted growth. This results in what farmers described as loss in stock and poor quality of tomatoes.

It emerged from the results that the soil is losing its capacity to support crop production in the area. Also, farmers reported loss of nutrients and poor performance of the soil. This is attributed to high temperatures and low rainfall. As noted by Fagariba *et al.* (2018) that, higher temperatures have

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knock on effect to soil characteristics that leads to soil losing its structure leading to soil degradation. Studies show that high temperatures and low precipitation in the dry lands result in reduced organic matter production and quick oxidation (Yiran *et al.,* 2012; Sivakumar & Stefanski, 2007). Lower organic matter result in reduced aggregation that leads high possibility of wind and water erosion occurrence in the area. Thus, causing unimaginable damage to agricultural soils. Sivakumar & Stefanski (2007) conclude that severity, frequency, and extent of erosion depend on changes in rainfall amount and intensity and changes in wind. Moreover, climate variability effects such as droughts, sand and dust storms, floods, heat waves, wildfires also have adverse effects on land causing its degradation.

The results show that majority of farmers are aware of the climate variability effects and are in the inroads to adapt their farming practices to copy with these effects. Intercropping, mulching, plant covering, seasonal planting, crop rotation, use of pesticides, water optimisation, application of manure, and use of water storage facilities were some of the strategies employed by farmers to manage the effects of climate variabilities. Similarly, Antwi-Agyei *et al.* (2012) reveal that farmers employed various techniques in dealing with climate variability effects such as crop diversification, planting date adjustment, soil and water conservation and management, increasing the intensity of input use, integrating crop with livestock, and tree planting.

In line with the results of the present study, a recent study in Cameroon, in Santa region, revealed that there are farm and non-farm level adaptation options to tomato production. Farm level adaptation options used in Santa included use of new varieties, advanced pesticides, and agro-chemicals, new farming techniques and irrigation methods (Malyse, 2021). In this study, farmers also engaged in re-afforestation and planting of trees to provide shade, and control flooding as well as provide wind breaks to tomatoes plants. Like this study, other studies also reveal that due to limited forestry cover, farmers are compelled to intensify climate change adaptation capability to curb biophysical challenges (Kusakari *et al.,* 2014).

Contrary to the present study, farmers in Santa utilised off-farm options such as trading, bike riding, and dress making as alternatives for survival. Also, some farmers shut down their operations and moved to bigger cities in search of jobs and greener pastures (Malyse, 2021). The studies by Zorom *et al*. (2013) and Rodriguez-Solorzano (2014) on climate variability and adaptation practices by farmers show strategies adopted by farmers includes cultivation of dry season irrigated vegetables and diversification of farm activities or products like reduction of food intake, selling of poultry and

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rearing of livestock. In this way farmers are likely to distribute climate variability risks over different activities; hence, their financial capacities are strengthened. Thus, tomato farmers in Limpopo Province could also learn or adapt some of these techniques in literature to improve their resilience to climate variability effects and can therefore stay in business.

It also emerged in the study that farmers faced challenges in adapting to climate variabilities. Other studies show that in the Sub-Saharan countries, small-scale farmers are the most vulnerable to climate change effects. Poverty, weather extremes, and minimal or no government support are some of the factors that exposed farmers to these vulnerabilities. This is unlike with large scale commercial farmers who can adapt swiftly using their resources. Other researchers suggest that financial, limited or no education, socio-cultural, institutional, and technological barriers worsen the ability of small-scale farmers to protect themselves from climate variability effects (UNFCCC, 2007; Antwi-Agyei, *et al*., 2012). Reportedly, the most affected farmers are those that heavily depend on rainfed agriculture for their livelihoods.

Also, poor extension services and access information made it difficult for the farmers to navigate the effect of climate variability to crop production. Fosu-Mensah, Vlek & MacCarthy (2012) state that access to weather information, enables farmers to plan and adopt measures that can be used to curb climate variability effects. Armah *et al.* (2010) add that access to weather information increases farmer preparedness for heat stress, drought, pest and weed invasion. The results also showed that most farmers had lower education level. Only a handful had tertiary education. Studies show that education is strongly correlated to climate change.

Farmers with high levels of education mostly understand and can easily apply new technologies and skills acquired to improve farm productivity compared to those with low level of education (Owusu-Sekyere et al., 2011; Nyantakyi-Frimpong, & Bezner-Kerr, 2015). Although, those with low level of education can also apply or innovate new adaptation technology, those that require calibration, reading, and precision are best applied or are more easily utilized by educated farmers. Niang *et al.* (2014) points out that in developing countries like South Africa, adapting to changing climate is important for ensuring livelihoods of the poor communities. To achieve this, it will require the involvement of multiple stakeholders, such as policymakers, extension agents, NGOs, researchers, communities, farmers, and especially local stakeholders to address location-specific effects Morton *et al.,* (2007).

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5.3 Conclusions

The study investigated the effects of climate variability on tomato production in Limpopo Province, South Africa. The results showed that climate variability is considered a serious environmental challenge affecting the food security and livelihood of farmers. These included increased temperatures and pest Infestation; disruption/changes of normal production processes; poor quality of tomato crop; water shortages; loss of stock; land degradation and lose in profits for farmers. These effects were mainly caused by temperature changes and scant rainfall distribution throughout the season. The effect of temperature changes, caused pests and disease, water scarcity, and soil degradation. Also, the result shows that temperature is the main cause and will continue to affect the agriculture sector as the results demonstrated a correlation between temperature and tomato production in Limpopo Province. Moreover, it emerged that farmers are taking necessary steps to mitigate these challenges however, due to poverty, financial constraints, and low level of education, it was difficult for them to fully adapt to their desired level. Given adequate resources, farmers wished to upgrade their adaptation strategies at the farm level such as improving irrigation systems and using advanced fertilisers. To fully, adapt to the climate variability effects, it is crucial that these effects together with the current or proposed adaptation strategies are studied, observed, and analysed to introduce appropriate interventions for small-scale tomato farmers. Involving local level stakeholder network of support, is critical in improving the conditions of tomato farmers in Mopani district of Limpopo province, South Africa.

5.4 Recommendations of the study

Based on the results of the study, the following recommendations are made:

a) It is important to strengthen the local knowledge and activities of small-scale tomato farmers through the support of the government and other local institutions for effective and successful adaptation to minimize the effects of climate variability and create growth opportunities for small-scale farmers.

b) Adequate policy, institutional, technological and research support is needed to adapt the climate to market-oriented and capital-intensive horticultural production and resource-limited farmers. Studies support that successful adaptation can be achieved through context-specific approaches and strategies particularly for small-scale farmers with limited resources.

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c) There is a need for stakeholders (including farmers and researchers) to further explore the effectiveness of adopted adaptation practices to improve decision-making on the methods to use and resource allocation. For example, there is a need to conduct an economic analysis of the strategies currently used and envisaged for decision-making on adaptation measures to be adopted that are effective in terms of cost, and time. Moreover, it is vital that more work and more efficient methods are created to help farmers improve their managed financial problems. Another area to study is the development of more climate-resistant tomato plant varieties to protect the social environment and adapt to conditions such as creative conditions and drought tolerance.

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APPENDICES

Appendix 1: Permission letter

University of Venda

X5050 Thohoyandou

Limpopo, South Africa

Nkomo Tribal Office

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Giyani, Limpopo 0826

25 October 2021

To the Traditional Authority

RE: REQUEST FOR PERMISSION TO CONDUCT A STUDY IN NKOMO VILLAGE

My name is Koza Wisani a student from the University of Venda currently enrolling Masters degree in Rural Development.

I wish to conduct a research study for my Masters dissertation, which aims to better understand The effects of climate change on the production of tomatoes *Solanum lycorpersicum*. This study is conducted under the supervision of Dr Mathaulula and approved by the University of Venda Higher degrees committee and by the Ethics committee.

I hereby request your permission to enter your community to present the study and approach a group of small- scale es farmers, farm workers. In addition, I will liaise with extension officers from the Limpopo Department of Agriculture and Rural Development who are currently working closely with the farmers in your area.

I will appreciate your permission to conduct the study.

Yours Sincerely,

Koza Wisani

____

Appendix 2: Information to Respondents

Title of the Research Study : Perceived effects of climate change on the production of small-scale tomatoes *(Solanum lycopersicum*), in Mopani District Municipality of Limpopo Province, South Africa.

Principal Investigator/s/ researcher : Koza Wisani (Maters in Rural Development)

Supervisor/s : Dr M. A. Mathaulula (Supervisor).

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Co-Investigator/s : Dr F. Ravhuhali (Co-supervisor).

Brief Introduction and Purpose of the Study: Tomatoes are considered the most important horticultural crops among the rural small-scale farmers worldwide (Lee, 2013; Arah *et al*., 2015). They are an important source of vitamins and minerals; thus, they guarantee food and nutrition security as Rai (2005) indicates. Most rural small-scale farmers in the developing world rely on tomatoes production for income and family sustenance (Karungi*et al.,* 2011). Knapp & Peralta (2016) reiterated that tomatoes forms part of daily meal for most families across all social classes. Tomatoes originated from South America and currently they are grown as commercial crops around the world (Deter *et al.*, 2012). Their production is amongst the most globalized and advanced horticultural industries, with an annual value exceeding 90 billion USD (Food and Agriculture Organization Corporate Statistical Database (FAOSTAT, 2019).

The purpose of the study is: To determine the perceived effects of climate variability on smallscale tomatoes (*Solanum lycopersicum)* production in selected villages of Mopani District Municipality of Limpopo Province, South Africa.

Outline of the Procedures : (*Responsibilities of the participant, consultation/interview/survey details, venue details, inclusion/exclusion criteria, explanation of tools and measurement outcomes, any follow-ups, any placebo or no treatment, how much time required of participant, what is expected of participants, randomization/ group allocation*). Data collection tools will be developed to obtain data that will meet the objective and its associated questions. Semistructured interview guide and close-ended questionnaire will be designed. One university postgraduate student will be recruited to serve as research assistant. He/she will be chosen based on experience in research processes and to administer data collection tools using local spoken language. The research assistant will be trained to administer the data collection tools. The researcher will be responsible for securing of the venue for training. In addition, the research assistant will be orientated on the objectives of the study and specific roles. Each question in the data collection tool will be explained, including the rationale for its inclusion. The study will consist of 120 farm workers. Covid-19 measures and protocols will be followed especially wearing of masks, social distancing, and hand sanitising. Before its use in data collection, the data collection tool will be pre-tested with 10 farmers to ensure validity and to determine the time that will be

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required to complete each questionnaire. The results obtained will be used to improve the final data collection tools.

Risks or Discomforts to the Participant: (*Description of foreseeable risks or discomforts to for participants if applicable e.g. Transient muscle pain, VBAI, post-needle soreness, other adverse reactions, etc.)* The study will have no risk or discomfort to the participant.

Benefits: (*To the participant and to the researcher/s e.g. Publications*)

The results of this study will provide useful elements for achieving the Sustainable Development Goals especially goal number one which aims to eradicate extreme poverty and hunger. Secondly, the findings of this study will enrich the existing body of knowledge on rural development and give a basis for further research in related fields.

Reason/s why the Participant May Be Withdrawn from the Study: (Non-compliance, illness, adverse reactions, etc. Need to state that there will be no adverse consequences for the participant should they choose to withdraw) if the participant no longer wants to participate in the study.

Remuneration: (*Will the participant receive any monetary or other types of remuneration?)* No

Costs of the Study : (*Will the participant be expected to cover any costs towards the study?)* No

Confidentiality: (*Description of the extent to which confidentiality will be maintained and how will this be maintained*) Yes, the importance of privacy, anonymity, and confidentially in interviews will be highly considered by making use of codes instead of participants' names. The respondents will be assured that the collected data will be solely used for this study only and will not be shared with anyone. Data collected sheets will be stored in a locked locker and will be stored until the dissertation is examined.

Research-related Injury : (*What will happen should there be a research- related injury or adverse reaction? Will there be any compensation*?) NA

Persons to Contact in the Event of Any Problems or Queries:

(Dr M. A. Mathaulula (Supervisor). Contact number 015 962 8008 Or 0765352313. The University Research Ethics Committee Secretariat may also be contacted at 015 962 9058.

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Complaints can be reported to the Director: Research and Innovation, Prof GE Ekosse on 015 962 8313 or Georges Ivo.Ekosse@univen.ac.za

General:

Potential participants must be assured that participation is voluntary and the approximate number of participants to be included should be disclosed. A copy of the information letter should be issued to participants. The information letter and consent form must be translated and provided in the primary spoken language of the research population

Appendix 3: Consent Form

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, (*name of researcher*) , Koza Wisani, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number:

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- I have also received, read and understood the above written information (*Participant Letter of information*) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during this research which may relate to my participation will be made available to me.

Full Name of Participant Date Time Signature

I, ……………………. …………… ………… …………………..

(*Name of researcher*) herewith confirm that the above participant has been fully Informed about the nature, conduct and risks of the above study.

Full Name of Researcher

……………………. Date**……………….** Signature**…………………** Full Name of Witness (If applicable)

……………………. Date **……………….** Signature**…………………..**

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Appendix 4: Participant Register

The effects of climate change on the production of es *Solanum lycopersicum* in Mopani District Limpopo

Date:____________________

Place:______________________

Name of the farm	Male or Female	Respondents	Phone numbers	Email	Marital status	Signature
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						

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Appendix 5: Semi-structured interview Guide

Step by step guide to data collection

1. Structured interview guide of each objective

Objective 1: Establish the knowledge of the small- scale es farmers on climate change.

1. What do you understand by the term climate change?
2. What do you refer to as climate change?
3. Do you understand what is meant by climate change Yes or No, if yes explain your answer?

Objective 2: Determine the climate change induced challenges faced by small scale es famers.

4. What are the climate change induced challenges faced by small scale es famers?
5. Is there any influence of climate variability on es production over Mopani district?
6. How has climate variability affected the production of tomatoes over the years?

Objective 3: identify climate change adaptation techniques and Strategies used by small scale-es famers

1. What are the proposed intervention strategies that could be used by small-scale es farmers to adapt es production to climate change variability?

2. How effective are the mitigation strategies that you are currently

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