EFFECTS OF CLIMATE VARIABILITY ON CITRUS PRODUCTION AND RURAL LIVELIHOODS IN MOPANI DISTRICT MUNICIPALITY, SOUTH AFRICA

By

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DECLARATION

I, **TANGANEDZANI TSHITAVHE,** hereby declare that this dissertation for Master of Environmental Sciences Degree in Geography at the University of Venda, hereby submitted by me, has not been submitted previously for a degree at this or any other university, that this is my own work in design and execution, and that all reference material contained therein has been duly acknowledged.

Signature: ___________________________ Date: 25/02/2022

DEDICATION

This study is dedicated to me, for not giving up. This journey has been quite an experience. It is an evidence of my perseverance, resilience, and eagerness to become a researcher, and a hallmark of my capacity to fight for my ambitions. I have genuinely learned that in challenging times and difficult moments of life, only the determined and committed breed succeed.

And to the memory of my late father, Tshitavhe Ntshengedzeni Samuel, an epitome of endurance, hope, and inspiration.

"No matter where I am, your spirit will be beside me. For I know that no matter what, you will always be in my heart because in there you are still alive. Till we meet again and part no more" I love you deeply Daddy.

ABSTRACT

Climate variability has always had an impact on citrus production in South Africa. Climate models have projected increases in temperature and changes in rainfall patterns. These changes are likely to present a risk to farmers and rural individuals who depend on citrus production for their livelihoods at district level. Rural livelihoods are subjected to multiple climatic shocks and stresses that can increase household vulnerability. It is important to assess and understand the negative impacts of climate variability on citrus production and rural livelihoods to provide the best adaptive measures and strategies. This study, therefore, analyses the influence of climate variability on citrus production and rural livelihoods in Mopani District Municipality. To achieve this aim, quantitative and qualitative research methodologies were employed. Climate data from 1987 to 2017 was obtained from the South African Weather Service. Citrus production data, citrus farm net revenue, and citrus market chain statistics for the study period were obtained from citrus farms and government records such as the Department of Agriculture and Rural Development. Mann-Kendall trend analysis was applied to analyse temperature, rainfall, and citrus production trends. Standardized Precipitation Index (SPI) was applied to analyse precipitation anomalies in the study area. Multiple linear regression analysis was utilised to establish the relationship between climate variability and citrus production. Whilst simple linear regression was used to determine the influence of citrus production on farmers' income and rural livelihood by establishing the relationship between citrus production and farm net revenue. The relationships were consistent at a 95% confidence level showing a ±5% margin of error (confidence interval). Semi-structured questionnaires were administered to citrus farmers, citrus workers, and citrus vendors to elicit data on climate variability impacts, perceptions, and adaptation strategies to deal with climatic shocks and stresses. Statistical Package for Social Science (SPSS version 22) was used for its bivariate and univariate analysis capabilities. The findings show a variable significant relationship between climate variability and citrus production. Results indicated a very strong positive significant relationship between citrus production and farm net revenue. The study shows a significant relationship between livelihood variables and climate variability variables. Furthermore, the perceptions of citrus farmers, citrus workers, and citrus vendors correspond well with climatic trends that indicated flood and drought cycles. Due to the considerable climate variability over the study period, citrus farmers, citrus workers, and citrus vendors have adopted various coping strategies at on-farm and off-farm levels. The study concludes that climate variability and citrus production influence farmers' income and rural livelihoods. The study recommends a framework that includes water conservation, investment in irrigation systems, and other climate-smart agricultural technologies that would merge modern scientific knowledge and indigenous knowledge systems to maximise citrus productivity and improve rural livelihoods.

Key Words: Climate Variability, Standardized Precipitation Index, Citrus Production, Rural Livelihoods, Adaptive Measures

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LIST OF ABBREVIATIONS AND ACRONYMS

CGA	Citrus Growers Association
CO2	Carbon Dioxide
CPWF R4D	Challenges Program on Water and Food Research for Development
CSAG	Climate System Analysis Group
DAFF	Department of Agriculture, Forestry, and Fisheries
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
FAO	Food and Agriculture Organisation
GDD	Growing Degree Days
GDP	Gross Domestic Product
GTEDA	Greater Tzaneen Economic Development Agency
IAASTD	International Assessment of Agricultural Science Technology for Development
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
LDA	Limpopo Department of Agriculture
LDP	Limpopo Development Plan
LGCCS	Local Government Climate Change Support
LTAS	Long-Term Adaptation Scenarios Flagship Research Program
MDM	Mopani District Municipality
NAC	National Agro-meteorological Committee
NDA	National Development Agency
NDP	National Development Plan
NFPM	National Fresh Product Market
R/tons	Rands per Tons

SADC	Southern African Development Community
SARPN	Southern African Regional Poverty Network
SAWS	South African Weather Service
SMME	Small Medium Micro Enterprises
StatsSA	Statistics South Africa
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USDA-FAS	United States Department of Agriculture – Foreign Agricultural Service
WMO	World Meteorological Organization

CHAPTER 1: BACKGROUND TO THE STUDY

1.1 Introduction

The Intergovernmental Panel on Climate Change (IPCC, 2014) defines climate change as statistically significant variations in global and regional climatic patterns that continue over an extended period. The changes may extend for several decades or longer. Climate change is caused by many factors, including human activities and natural processes (IPCC, 2014). Climate change results in changes in climate variability and the extent, duration, frequency, intensity, spatial, and timing of extreme climate and weather events (IPCC, 2012).

Climate variability refers to short-term changes in climate, precipitation, and weather patterns of a place over months, seasons, and years (Thornton *et al.,* 2014). Climate and weather variability will increase as the planet warms up. Climate variability is anticipated to affect agricultural production in Africa (Ringer *et al.,* 2010). This is because about 80% of agricultural production in the continent depends on natural rainfall (Thornton *et al.,* 2011). Agricultural production is vulnerable to weather variability with variations in the distribution of rainfall throughout the African continent (Peter, 2015). Weather variability is as equally important as climate change in farmers' decision making, especially in countries that have no weather insurance such as South Africa.

South Africa has diverse weather and soil conditions that enable the country to produce and cultivate a variety of crops, including fruits (Potelwa *et al.,* 2016). One of the major fruits produced in South Africa is citrus. According to Citrus Growers Association (CGA, 2012), citrus fruits are categorised as grapefruit, kumquat, lemons, limes, and oranges. Citrus is one of the major export sub-sectors in the agricultural economy of South Africa, with oranges contributing 70% of the total output of citrus export (Ntombela and Moobi, 2013; Nahman and de Lange, 2013). Citrus is grown in a range of regions, including Eastern Cape, Kwazulu-Natal, Limpopo, and Western Cape provinces in South Africa (CGA, 2012). There are about 58.102 hectares of cultivated land under citrus production in South Africa with most of the production concentrated in Limpopo province, with about 18.146 hectares (CGA, 2016).

Citrus production is a major economic activity in Mopani District Municipality (CGA, 2012), with Hoedspruit and Letsitele the major production areas. The areas produce high volumes of grapefruits and oranges (Potelwa *et al.,* 2016). However, weather conditions in the areas adversely affect citrus productivity. Declining rainfall and increasing temperatures in these areas have reduced the length of the growing season and the onset of the harvesting season with a consequent adverse effect on citrus productivity (Potelwa *et al.,* 2016; Le Roux, 2017). Moreover, climate variability in recent years frequently causes heavy rains, flooding, and intense droughts which devastate agricultural land and plunge farmers into economic hardships.

Citrus production is influenced by many factors, including climatic conditions and production practices. Ziervogel *et al.* (2014) opined that precipitation and temperature are the most critical climate variables to measure regarding production because of the intensity of the events and the frequency at which these extremes occur. Hlalele *et al.* (2016) emphasised that fluctuations in global climate variables could present a risky future for households that depend on rain-fed agricultural production for their livelihoods considering shifts in temperature and rainfall patterns. According to Hlalele *et al.* (2016), weather variability could affect farmers' income from agricultural production and increase costs to customers.

1.2 Problem Statement

Citrus production is one of the key livelihood activities that is sensitive to changes in weather and climate. The changes have devastating effects on citrus productivity leading to reduced yields. Citrus is also known to be tremendously sensitive to moisture stress during flowering and fruit set. Thus, any water shortage during this time adversely affects yield (Hutton *et al.,* 2007). Changes in weather conditions affect the timing of citrus development and growth (Joshi *et al.,* 2011). Temperature increases associated with hot and dry winds have detrimental effects on citrus production. Rising temperatures reduce citrus production in the long-term through a reduction in the number of reliable growing days while changes in precipitation increase short-term citrus fruit failure and long-term production declines (Joshi *et al.,* 2011).

Besides temperature changes, rainfall patterns have changed over the years (Birech *et al.,* 2008) with cases of heavy rainfall at fruit maturity and drought occurring in critical stages of fruit growth. Weather variability increases the population and growth of pests, insects, weeds, and diseases making citrus management difficult and expensive. This affects the optimal conditions required at each stage of citrus development and growth. Consequently, the quantity and quality of harvested fruits is severely compromised with greater economic consequences (Gbetibouo *et al.,* 2010).

According to Acquah (2011), the lack of investments in agricultural infrastructure results in limited use of irrigation facilities during dry seasons posing an additional threat to farmers who rely on rain-fed agriculture for their livelihoods. Hence, citrus farmers remain more vulnerable to weather and climate variability because the frequency of citrus fruit failures forces farmers to depend on low input and low-risk technologies (Shafqat *et al.,* 2021). The frequency of weather and climate shocks is likely to increase in the future, straining farmers' adaptation measures (IPCC, 2014). The study addresses the lack of empirical evidence of the impacts of climate variability on citrus production and rural livelihoods in Mopani District Municipality. The study attempts to close the research gaps in climate variability associated with citrus production and its livelihoods. It illustrates farmer's mitigation measures to the effects of climate variability on citrus production in Mopani District Municipality.

Climate variability is a national problem by its nature. Oremo (2013) emphasised that climate variability affects rainfall patterns and temperature trends. Crop production is intimately linked to changes in climate. Seasonal shifts in climate and weather have serious repercussions on citrus production in South Africa (DAFF, 2013). Mopani District Municipality is in the semi-arid region and amongst the most vulnerable districts to drought in Limpopo Province, South Africa (DAFF, 2016). The district was chosen because of its extensive citrus production in the province. The phenomenon of climate variability has resulted in erratic, unpredictable, and depressed crop yields. The topic was chosen because crop production is the leading sector of agriculture in South Africa.

Climate variability is acknowledged worldwide (IPCC, 2012). However, country-level analysis and understanding of climate variability is limited (Guloba, 2014). Kasimba (2014) stated that the changing climate patterns have resulted in food insecurity and price increases of crops such as maize. Climate variability has negative impacts on citrus production, and it is important to assess and understand them to provide the best adaptive measures and strategies (DAFF, 2016; Maponya and Mpandeli, 2012). Climate variability adaptive measures are an effective way to promote crop production during seasons of unanticipated weather and climate.

1.3 Research Aim and Objectives

1.3.1 Research Aim

The aim of the study is to analyse the influence of climate variability on citrus production and rural livelihoods in Mopani District Municipality.

1.3.2 Research Objectives

The specific objectives of this study are to:

- examine the effects of climate variability on citrus production in Mopani District Municipality for the period 1987 to 2017.
- establish the influence of citrus production on farmers’ income and rural livelihood in Mopani District Municipality.
- evaluate farmers’ adaptive measures to climate variability on citrus production farm income and livelihood in Mopani District Municipality.

1.4 Research Questions

The study seeks to address the following questions:

1. What is the influence of climate variability in citrus production?
2. To what extent do citrus production influence farmers' income and rural livelihood in Mopani District Municipality?
3. What are the farmers' adaptive measures to climate variability on citrus production?

1.5 Delimitation of the Study and Study Area

1.5.1 Focus of the Study

The study investigates the relationship between climate variability and citrus production on rural livelihoods in Mopani District Municipality. The study focuses on determining precipitation and temperature trends and how they affect citrus productivity and rural livelihoods. Mopani District Municipality was purposively chosen due to its fragility and sensitivity to climate and weather and because citrus is the major fruit production activity practiced in the area.

Rainfall and temperature are essential elements in fruit production. It is difficult for plants to reach maximum productivity with inadequate rainfall and unfavourable temperatures. The study establishes the influence of citrus production on farmers' income and rural livelihood and subsequently evaluates farmers' adaptive measures to climate variability. The study was limited to irrigated and rain-fed citrus trees.

1.6. Description of the Study Area

The study will be carried out in Mopani District Municipality (MDM). Mopani District Municipality (Figure 1.1) is situated in the north-eastern part of Limpopo Province (Ubisi, 2016). The area is located within 23°19'S and 30°43'E geographical coordinates, it covers an area of 20 011 km^2 with a population of about 1 092 507 people, 296 320 households, and 118 wards (Lehohla, 2015). Mopani is one of the five district municipalities in Limpopo province. The district contains five local municipalities namely Ba-Phalaborwa, Greater Giyani, Greater Letaba, Greater Tzaneen, and Maruleng. However, only two of the five municipalities were studied in this research namely, the Greater Maruleng and the Greater Tzaneen local municipalities, due to many citrus farms in the district.

According to Mopani Integrated Development Plan (Mopani IDP, 2012), Mopani District Municipality contains 14 urban areas and 352 rural settlements constituting approximately 80% of poor unemployed people. The district has been named Mopani due to the abundance of Mopani worms found in the area (Mopani IDP, 2012). The district is regarded as the most affected by climate change and variability in Limpopo province (LDA, 2012), receiving an annual average rainfall of between 400 mm to 900 mm. This results in inadequate water resources, causing consistent drought conditions and water shortages in the low-lying areas of the district (Ubisi, 2016).

Agriculture is a vital economic sector and source of livelihood in Mopani. The Lowveld region in the area contributes significantly towards agricultural activities at the provincial level. Climate change and variability are some of the crucial developing challenges confronting district in agriculture. The district is characterised by extensive and intensive farming activities, with about 26% of the population employed in farming (Ubisi, 2016). Citrus, subtropical fruits and vegetables are the most important crops in the district in terms of monetary value. Approximately 50% of the farm revenue in

Limpopo's horticulture is earned in the district. Farming in this district, mostly depends on irrigation and natural rainfall. About 6.7% of land in the region is considered arable of which 43% is under irrigation. The Blyde irrigation, lower Letaba and middle Letaba are the most important irrigation schemes in the district. Exotic and indigenous plants are also found in the subtropical areas of the district (GTEDA, 2010).

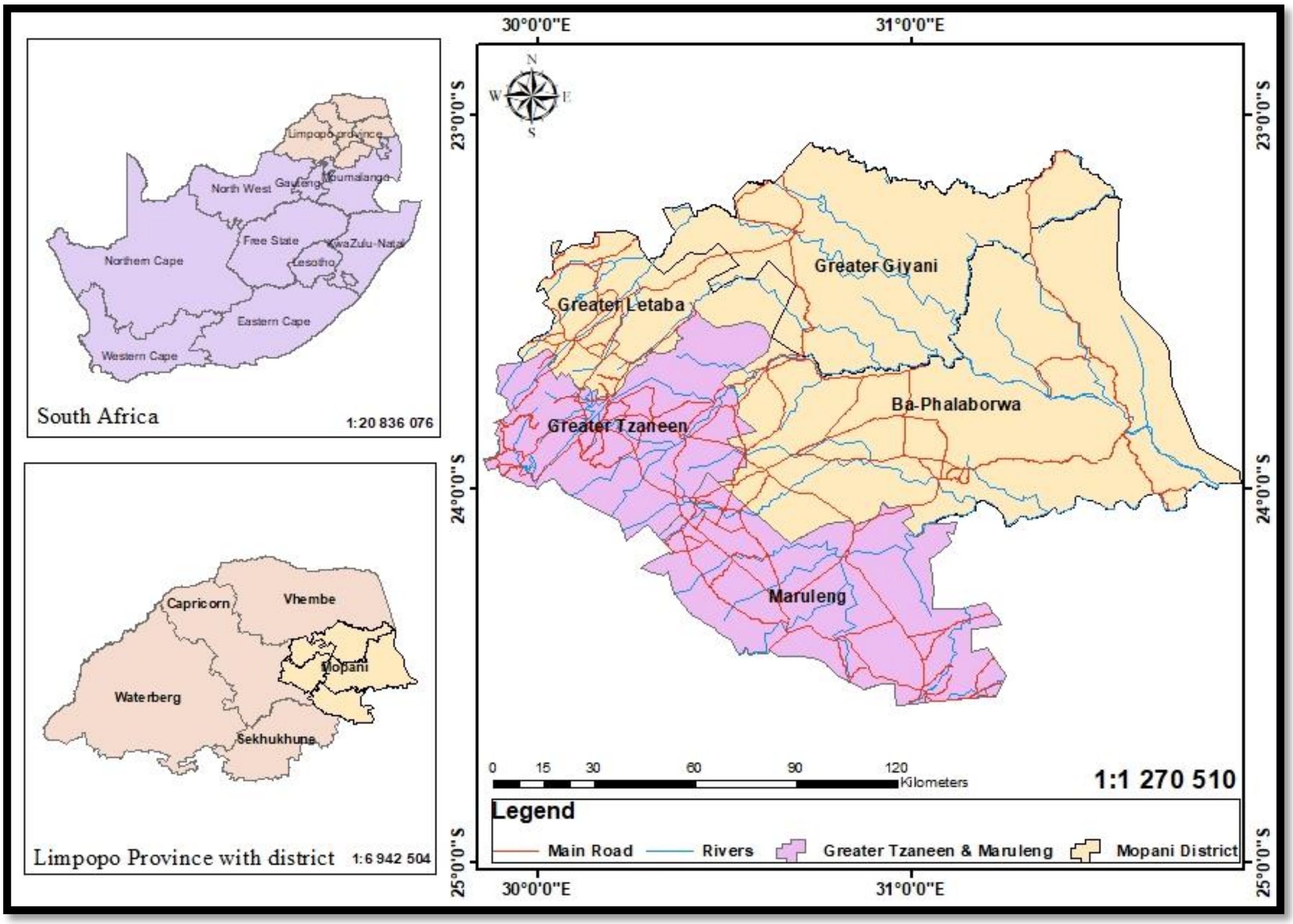


Figure 1. 1: Mopani District Municipality

1.6.1 Climate

Mopani receives most of its rainfall during summer, about 85% of the rain (Mopani IDP, 2012). Rainfall in the area varies from 2000 mm per annum in the mountainous zones of Drakensberg to 400 mm per annum in the dry, low veld of the Kruger National Park (Mopani IDP, 2012). The district has a mean annual rainfall of 612 mm. Temperature in the district range from a high average of 21°C to a remarkably high average of 25°C in both mountainous areas and dry low veld areas of the Kruger National Park. Frost rarely occurs in Mopani. The district falls within the Letaba Catchment Area which is approximately 13 779 km^2. The climatic variation experienced in Mopani allows the district to produce a range of agricultural produce including citrus fruits.

1.6.2 Geomorphology and Geology

According to Mopani Integrated Development Plan (Mopani IDP, 2012), the geomorphology of the Mopani district is characterised by a variety of landscapes including undulating terrains, plains, and lowlands with low to moderate relief. The geology of the area is not uniform and is underlain by basalt, conglomerate, grit, sandstone, shale, and quartzite (GTEDA, 2010). The area is highly favourable for minerals such as copper, gold, and manganese, among others. This is confirmed by the existence of several mining activities taking place around Ba-Phalaborwa local municipality (Mopani IDP, 2012).

1.6.3 Natural Water Bodies (Dams and Rivers)

Mopani district has several main rivers which include rivers such as Debengeni, Great Letaba, Letsitele, Politsi, and Thabina. Tributaries of the Great Letaba include Klein Letaba, Middle Letaba, Molototsi, and Nsama rivers. Most of these rivers flow across the Kruger National Park, where they join the Olifants River (Lepelle River) which is a short distance upstream of the Mozambiquan border (Mopani IDP, 2012). Several dams within the district are being used for primary consumption, such as commercial, domestic, industrial, and irrigation purposes. The district also has additional small dams within private properties. The total yield from the dams for primary usage is 273 million m^3 per annum (GTEDA, 2010). The agricultural sector uses the greatest portion of the available yield in the district, which is estimated at 70% leaving 30% for other water users.

1.6.4 Agriculture and Forestry

Agriculture and forestry play a key role in the economic growth of Mopani District Municipality (Mopani IDP, 2012). Mopani District Municipality (MDM, 2016) stated that crop production in Mopani contributes about 3.2% to the district's economy and is considered one of the major industries after mining. There are several forestry plantations in Mopani district, especially in Greater Letaba and Tzaneen local municipalities that are dominated by exotic plant species such as Eucalyptus, Mahoganies, and Pines. The mountain ranges' foothill zones contain tea estates. The Letsitele and Tzaneen areas of the Letaba catchment areas produce citrus, bananas, mangoes, and avocados (Mopani IDP, 2012). The Klein Letaba, Molototsi, and Nsama river catchments are dominated by the rural settlements and subsistence farming (GTEDA, 2010). Mopani District Municipality is also a major producer of tomatoes in Limpopo province and South Africa. Tomatoes are produced in Mooketsi ZZ2 within Letaba local municipality.

1.7 Justification for the Study

According to Iglesias *et al.* (2007) fruits have become a research matter in recent years because of their importance in agriculture and human diet. However, previous research in Limpopo has focused primarily on maize, and vegetables such as tomatoes and potatoes while other vegetable variants and fruits are not so well researched on. This research focuses on citrus production.

South Africa is experiencing the effects of climate variability with crop yields declining due to unpredictable rainfall and prolonged droughts. Yet little research has been done to establish the effects of climate variability on crop production and rural livelihoods (Ochieng *et al.,* 2016; Kolawole, 2016; Araro *et al.,* 2020) This study, therefore, considers the effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality. The study also addresses farmers' mitigation measures to the changing climate. Uncertainty on future weather and climate variability is posing challenges and preventing farmers from making critical decisions that are necessary to adapt. Policymakers have articulated concerns about the possible effects of climate variability on crop production (Oremo, 2013).

Therefore, investigations on the extent and intensity of the changes will help inform policy to enable crop production systems to adapt to future climate variability. Improving responses to climate variability together with ongoing farmers' adaptive measures is important in informing policies aimed at promoting successful adaptation and coping strategies for the agricultural sector. This is important in identifying the gaps that exist between climate and agricultural adaptation strategies and recommendations for various crop production in other regions. These will lead to increasing citrus yields and improve the rural livelihoods of the area. The study seeks to significantly benefit policy implementers and policymakers, to further acknowledge climate variability and to adjust to annual and seasonal climate and weather variations in South Africa. Policymakers may use the recommendations from the study to advise farmers about weather variability and adaptive practices required to reduce its risks.

1.8 Dissertation Outline

This section shows the logical structure of the dissertation.

Chapter 1 establishes the introduction, background to the study, research problem, research aim, specific objectives, research questions, delimitation of the study area, and description of the study area. The justification for the study area is also presented in this section.

Chapter 2 provides an in-depth review of the literature on previous studies done for climate variability, citrus production, and rural livelihoods.

Chapter 3 presents the materials and methods of analysis that were employed in this study.

Chapter 4 presents the results and discusses the effects of climate variability on citrus production in Mopani District Municipality. Annual precipitation anomalies, variability of climatic parameters, and citrus production trends are also presented. The chapter also establishes the relationship between climate variability and citrus production and the relationship between citrus production and farm net revenue.

Chapter 5 deals with the influence of climate variability and citrus production on citrus workers' livelihoods. The sustainable livelihood framework approach indicators, namely, financial assets, social assets, human assets, physical assets, and natural assets were explored together with issues relating to climate variability, citrus production, and livelihood conditions of citrus workers.

Chapter 6 presents and discusses the influence of climate variability and citrus production on citrus vendors' livelihoods. The sustainable livelihood framework approach indicators, namely, financial assets, social assets, human assets, physical assets, and natural assets were explored together with issues relating to climate variability, citrus production, and livelihood conditions of citrus vendors.

Chapter 7 provides farmers’ adaptive measures to climate variability, citrus production and livelihoods, and the determinants of adoption choice towards climate variability and change.

Chapter 8 gives conclusions and recommendations on climate variability impacts and effects on citrus production and the livelihoods of the rural people. The recommendations were based on the major findings of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

According to IPCC (2014) the scientific community widely agrees that climate change is a reality. This chapter aims to place the study under a scholarly context by reviewing various contributions made by several authorities and researchers on weather variability and citrus production. This chapter reviews related literature on the effects of climate variability on crop production and farmer's livelihoods. It precisely focuses on what other scholars have done and their findings. This enables the researcher to put the problem in its right perspective and provide a better understanding and appreciation of the problem under investigation. Issues and concepts of weather variability and citrus production are theoretically and empirically reviewed.

2.2 Climate Change

Human activities directly and indirectly influence the changes in climate (Protocol, 1997). Eregha *et al.* (2014) opined that the global climate has increased by 0.74°C on average with the period 1990s and 2000s being the warmest. There is evidence of increased effects of climate and weather variability (Ajala, 2017), mostly in the least developed and developing countries where crop production is rain-fed with the people having limited mitigation measures and adaptation strategies to acclimatize (Easterling *et al.,* 2000; Traerup and Mertz, 2011). Mandleni (2011) emphasised that climate change will be exhibited in changes in the climatic conditions that are prolonged, inter-annual and seasonal variability that is increased, the extreme events of changes that are spread, and catastrophic alterations of the ecosystems.

Oduniyi (2018) noted climate change as global warming. This is because of increasing temperatures and levels of carbon dioxide in the atmosphere due to the use of fossil fuels globally. The rapid increase in greenhouse gases causes global warming that weakens the ozone layer, in the quest for comfort and livelihood of human beings (Ajala, 2017). Mandleni (2011) mentioned climate change as a market failure the world has ever experienced because it is a public area that any country can pollute. Ayinde *et al.* (2010) argued that the changing climate has become more alarming to the sustainable crop production of most countries. The consequence of the changing climate is that the world will continue to experience changes in rainfall patterns and higher temperatures than what we experience.

Climate change affects every country in the world and is likely to widen the gap between poor and rich countries (Ayinde *et al.,* 2010; Coster and Adeoti, 2015; Mandleni, 2011). According to Mendelsohn *et al.* (2006), third-world countries will tend to experience the most suffering in the future because of the negative impacts of climate change. Climate change in these countries poses a notable risk and increases the vulnerability of the underprivileged since they mostly depend on ecosystems. Apata *et al.* (2009) concluded that crop production in Africa is vulnerable and negatively affected due to erratic and unpredictable weather conditions, making farmers aware of the destructive impacts of climate change on crop production.

2.3 Weather and Climate Variability

The global climate is constantly changing at rates that are projected to be extraordinary in recent human history. The Intergovernmental Panel on Climate Change (IPCC, 2012) highlighted that most of the observed increase in the global average temperature since the mid-20th century is due to the increase in anthropogenic greenhouse gas concentrations. When climate changes and variability occur, there is a high possibility of damages, danger, and disasters to humankind. Kazoka (2013) stated that events such as droughts, floods, hurricanes, storms, and spells of enormously high or low temperatures are known as major risks associated with climate and weather variability.

Changes in long-term patterns of climatic variables such as rainfall and temperature are referred to as climate variability (Ngaira, 2007; Huho *et al.,* 2012). It is the variation around the average climate, including seasonal variations in atmospheric and oceanic circulation such as El Nino. Climate variability is the shift from the normal experienced rainfall pattern of seasons to the abnormal rainfall patterns (Amsalu and Adem, 2009; Omambia and Gu, 2010). Climate variability can therefore be thought of as a long-term summing up of weather conditions (Mwabumba *et al.,* 2022), taking account of average conditions and variations including fluctuations that occur from year to year and extreme conditions such as severe storms and unusually hot seasons.

Climate change is the long-term influence of global food production. Karanja (2014) opined that extreme weather events and their year-to-year variability pose a significant risk to food security globally. Historically, reductions in crop production have been accredited to low rainfall and elevated temperature events. Nevertheless, even insignificant changes in the mean annual rainfall can impact productivity. Lobell *et al.* (2008) investigating the impact of climate variability on millet production in South Asia, reported that a change in seasonal rainfall of the growing period by one standard deviation can be associated with as much as 10% change in production.

Asada and Matsumoto (2009) studied the relationship between rainfall and district level crop production data (wet season Kharif rice) for the period 1960 to 2000. The results of the study showed that different regions were sensitive to rainfall extremes in numerous ways. In the upper Ganges basin, crop production is linked to total rainfall during the short growing period and is consequently sensitive to drought (Karanja, 2014). Likewise, the lower Ganges basin was sensitive to pluvial flooding and the Brahmaputra basin established an increasing effect of weather variability on crop production mostly for drought. The relationships were not consistent through time due to weather trends. Karanja (2014) concluded that the variation between the districts implied the importance of social factors and the introduction of irrigation techniques.

Stone *et al.* (2013) refer to weather as the atmospheric conditions over a short period. Weather variability executes a wide range of direct and indirect impacts on crop production. Hence, weather fluctuations play a significant role in crop growth, development, and production. Any changes in local weather conditions, especially during critical development stages of crops, could adversely impact growth and result in enormous yield reductions (Karanja, 2014). Such situations make weather variability a threat to production with serious economic implications at local, regional, national, and global scales.

Weather variability is already exerting control over development progress, poverty alleviation and efforts to address food security in sub-Saharan Africa (Sokona and Denton, 2001; Ndlovu *et al.,* 2020). Karanja (2014) stated that extreme events of weather variability leave people vulnerable in Africa and other parts of the world impoverished and unable to cope. The adverse impact of weather variability is further visualised on natural resources such as land and water. These resources are exposed to the impact of weather variability and threatened by poor and unsustainable use of resources and management. Crop production in Africa is a weather dependent activity and is most vulnerable to weather variability and its effects (Ehiakpor *et al.,* 2016).

According to McCartney and Smakhtin (2010) weather variability is a key constraint to crop production and economic growth in many developing countries. This is likely to worsen in many regions as weather variability is amplified because of the changing climate. Weather changes will also increase variability in groundwater recharge and river flow, thus affecting all water sources (McCartney and Smakhtin, 2010).

2.4 Limpopo Province Climate

Climate models indicate that Limpopo's future temperatures are predicted to increase by as much as 2°C by 2035, 1-2°C between 2040 and 2060 (or 2-5°C in high-end scenarios) and 3-6°C between 2080 and 2100 (or 4-7°C in high-end scenarios) (DAFF, 2016). Rainfall forecasts are less certain in the province, with some climate models suggesting increases in rainfall and others projecting reductions in precipitation. Limpopo province will experience greater variations in climate. Increases in natural disasters such as floods and fires are some of the foreseen impacts of the changing climate (DAFF, 2015).

According to Maluleke and Mokwena (2017) Limpopo province was the worst affected by drought between the years 2004 to 2012. This was when dams were only 50% full, compared to 84% below the capacity in the late 1990s. The agricultural sector is an important source of livelihood for Limpopo, especially in the rural areas. Extreme weather and climate events make it difficult for crop production and livestock farmers to cope with all the various financial implications and challenges.

Increasing variability in rainfall and temperatures are predicted to result in shrinking of land that is suitable for certain crops such as citrus (Tubiello *et al.,* 2002; Armah *et al.,* 2011). Temperature increases will correspondingly result in the need for increased water for irrigation, and this may have unfavourable impact on livestock and profits. According to the Department of Agriculture, Forestry and Fisheries (DAFF, 2017) Limpopo is recognised as the most vulnerable district in South Africa in terms of climate variability impact on crop production, particularly citrus due to the high percentage of large-scale and small-scale farmers.

2.5 Climate Variability and Crop Production

According to Mubaya *et al.* (2017) climate variability is hastily emerging as one of the utmost serious global problems affecting many sectors in the world. It is one of the most serious threats to sustainable development with an adverse impact on economic activities, environment, food security, human health, natural resources, and physical infrastructure. Mubaya *et al.* (2017) emphasised that southern Africa is one of the most vulnerable regions to climate variability in the world, particularly because of frequent droughts, inequitable land distribution, widespread poverty, over-dependence on rain-fed agriculture, and low adaptive capacity. However, rural farmers have managed to survive the inconsistency of climate variability over the years.

In many less developed countries agriculture is the biggest industry, with crop production as its top sector. It plays a significant role in contributing to the national food security, national social and economic stability, and to the environmental protection of a country. It provides food and raw materials for most manufacturing industries in many countries. Diao *et al.* (2010) specified that many countries export and import substantial amounts of agricultural products that bring about the economic development of the world. Crop production is an activity involved in producing, preparing, and processing crops. It is an integral part of agriculture dealing with the cultivation, harvesting, protection, and storage of cultivated plants for human use (Yahaya and Tsado, 2014; Akanbi, 2019).

Crop production is sensitive and vulnerable to climate variability (Maponya and Mpandeli, 2012; Idowu *et al.,* 2011). A small change in climate can have a direct impact or influence on the quality and quantity of crop production. The climate of a region is highly correlated toits vegetation and the extension type of crop that can be cultivated. South Africa’s agriculture, therefore depends highly on climate and weather because temperature, rainfall, sunlight, and relative humidity are the main drivers of crop growth, development, and production (Maponya and Mpandeli, 2012). Calzadila *et al.* (2013) recognised five factors that climate variability will impact on crop productivity, which are changes in carbon dioxide, rainfall, surface-water runoff, and temperature. Climate variability is predicted to have an adverse effect on crop production in the poorer regions of the world including sub-Saharan Africa. Low technology-based crops are produced in this area and are therefore heavily susceptible to environmental factors (Odekunle and Adejuwon, 2007).

Variation in climate and weather conditions has affected crop productivity in many countries, including South Africa (Ayinde *et al.,* 2010; IPCC, 2014; Maponya and Mpandeli, 2012; Oduniyi, 2013). According to Oremo (2013) projections on climate are uncertain, especially concerning scenarios of future rainfall, temperature, floods, and droughts. However, projections on temperature are more reliable. Lee (2008) stated that warming in the whole of sub-Saharan Africa is projected to be larger than the global annual average. Rainfall prediction models indicate that East Africa will have increased rainfall events (Lee, 2007; Gautam *et al.,* 2013; Seitz and Nyangena, 2009). Current research suggests that local circulation will result in erratic rainfall instead (Funk *et al.,* 2015). However, climate variability is already a striking consent that future weather is unlikely to be the same as the present (Oremo, 2013). Therefore, there is a need to apply the precautionary principle because the costs of not acting on the changing climate are likely to be inestimably high. Nyamwanza *et al.* (2017) opined that spatial and temporal variation of rainfall and increased temperatures are the main weather variability related drivers that impact crop production.

Boruru *et al.* (2011) suggested that increased temperature levels will cause crop damage, crop diseases, soil moisture deficits, more intense and unpredictable rainfall, higher frequency, and severity of extreme weather events. Equally, climate variability drivers have the potential to alter crop growth and production through carbon dioxide (CO2) fertilization effects (UNDP, 2012). Lotze-Campen and Schellnhuber (2009) experiments on Free Air Carbon Enrichment (FACE) for C3 crops (rice, soya beans, and wheat) indicate a productivity increase in a range of 15-25% and 5-10% of the C4 crops (maize, sorghum, and sugarcane). Higher levels of carbon dioxide also improve the water use efficiency of both C3 and C4 crops (Lotze-Campen and Schellnhuber, 2009). Nevertheless, there is uncertainty about the magnitude of the positive effects of higher carbon dioxide concentrations.

Climate variability will interlock with farmers and their livelihoods differently for varied reasons. Moderate local increases in temperature can have small beneficial impacts on crop productivity in mid to high latitude regions, while such moderate temperature increases are likely to have negative production effects in low latitude regions (Aydinahlp and Cresser, 2008; Scoones, 2009; Iglesias *et al.,* 2006). This will significantly increase yield variability in many areas around the world and result in the polarisation of effects with substantial increases in prices (UNDP, 2012). However, due to the advanced preparation and careful management of crop production, these risks could be substantially reduced. Current studies show that for each 1°C rise in average temperature in Africa dryland farm profits will drop by 10% (Alexandratos, 2009). Cabré (2011) revealed that rain-fed crop yields could be halved by 2020 and the crops net revenue could fall by 90% by 2100 in some African countries.

Extreme climate events of droughts and floods are a risk to crop production and could bring chronic and transitory food insecurity. This is because many crops have annual cycles and yields that fluctuate with climate variability, particularly rainfall and temperature (FAO, 2009). Because of climate variability, farmers that depend on rain-fed agriculture will become more vulnerable to food security. The global drivers of crop production and its variability include climate, crop management practices, genetics, soil, and associated decisions such as crop hybrid selection, fertilizer applications, irrigation management, and tillage (Kukal and Irmak, 2018). Climate variability plays a key role in determining yields in crop production (Michler and Shively, 2016).

2.5.1 Climate Variability and Crop Production in Mopani District Municipality

Mopani District Municipality is one of the richest agricultural areas in Limpopo province, South Africa (Musetha, 2016). It is a major producer of fruits and vegetables. The subtropical climate gives rise to the cultivation of coffee, macadamia nuts, tea, and fruits such as citrus and avocados. Mopani District Municipality is particularly vulnerable to climate variability as crop production depends on climatic conditions and on the quality of the wet season. Climate variability in Mopani District is taking place in the context of other developmental stresses, food insecurity, unemployment, and notably poverty which is feared that will exceed the limits of adaptation in other parts of the district (Letsatsi-Duba, 2009). The Department of Agriculture, Forestry and Fisheries (DAFF, 2013) emphasised that climate variability in Mopani district is increasing temperatures, reducing rainfall and its timing. This puts pressure on the district's scarce resources with implications on crop production.

Tshiala and Olwoch (2010) opined that crop production farmers in Mopani are facing possible negative impacts on crop yields, mostly farmers without advanced technology and decent modern crop production practices. Therefore, less food is directly available to households. Mopani District Municipality is the main citrus growing area in Limpopo province (DAFF, 2013). According to the Citrus Growers Association (CGA, 2016) there have been increases and decreases in citrus production in Mopani District Municipality because of the sensitivity of citrus trees to weather variability.

The average annual rainfall in Mopani district is 612 mm (Mopani IDP, 2017). The wet season starts in October in this district. Rainfall patterns peak in January and February months, this is when floods are anticipated. During December and January, rainfall exceeds the potential evapotranspiration. Wilhite and Svoboda (2000) noted that the meteorological drought in the district is a result of the rainfall's negative deviation from the mean and is usually the utmost common indicator of extreme events of drought. Mopani District Municipality regularly experiences extreme temperatures. When there are increased temperatures, there is also an increased probability of evaporation during that period. Temperatures can reach more than 35°C during summer.

According to Limpopo Department of Agriculture (LDA, 2012) drought is a severe problem in Mopani because the district is a semi-arid area with low unreliable rainfall. Extreme events of drought are some of the main challenges farmers in Mopani will have to face for many decades to come (Senyolo *et al.*, 2004). Drought could become a major threat to crop price increases and food insecurity, as it has a strong impact on crop production, its access, and distribution. In South Africa, there are about 3 million farmers who produce food primarily to meet their family needs (StatsSA, 2011), rural poverty in Mopani could worsen. Mendelsohn *et al.* (2000) and Dinar *et al.* (2012) projected that farmers with low income, technologies, and capital stocks are likely to have limited options to adapt to the changing weather patterns such as drought.

Mopani District Municipality is characterised by low rainfall, particularly in areas that are low lying such as Ba-Phalaborwa and Greater Giyani (LDA, 2012). This results in inadequate water resources, severe water shortages, and regular drought conditions as the district is currently experiencing issues of water scarcity and quality. Low rainfall has negative impacts on citrus production and results in reduced citrus yields and a shortage of irrigation water (CGA, 2016). Climate models projected a 28% reduction of the suitable area for citrus production and deciduous fruit productions such as apples and pears in the district. These products are important to the local livelihoods and the economy. Citrus productivity differs depending on wet, dry, and dry-wet climate. Climate models also projected an increased area for commercial and forestry plantations along the eastern part of the district and adjacent areas.

2.5.2 Effects of Temperature on Citrus Production

The Intergovernmental Panel on Climate Change (IPCC, 2014) emphasised that the average surface temperature of the earth has increased throughout the twentieth century by approximately 0.6 ± 0.2°C. The Intergovernmental Panel on Climate Change (IPCC, 2012) reported that nowadays it is warmer around the world than at any time during the past 1000 years. Extreme climate variability events are on the rise globally and more likely to happen in the future (Seneviratne *et al.,* 2012). The climate in terms of extreme temperature is rising from time to time. Musetha (2016) stated that most of the world's poor people are rural and food insecure. These people directly and indirectly depend on crop production and income for their livelihoods and are therefore directly exposed to any risk that would impact crop production.

According to Mamo and Abavisenga (2015) global warming affects crop production due to rises in atmospheric carbon dioxide concentrations resulting in food security and shortages. Temperature increases are already affecting citrus growth and development rate. This is enhanced by rising temperatures, which reduce the window opportunity for photosynthesis since the life cycle is shortened. Mamo and Abavisenga (2015) further emphasised that the effects of increased temperatures depend on the net result of the effects on photosynthetic rates of leaves, the rate of crop growth, and development. Additionally, drought and heat stress directly inhibit citrus growth and development at a metabolic level (Zandalinas *et al.,* 2016). However, Abayisenga (2018) stated that the harvest index may decrease if reproductive processes are impaired by stress that occurs at critical growth phases. Attri and Rathore (2003) study on wheat indicated that increasing temperature leads to a rapid accumulation of Growing Degree Days (GDD). Hence, the growth and development of the crop is faster, resulting in the reduction of phenophase duration. In response to high temperatures, the number of wheat tillers decreases particularly in high night time temperatures (Masahumi *et al.,* 2011; Wilby, 2010).

Increased temperature and increases in the frequency and severity of storm events will impact crops that can be grown and potentially result in a loss of livelihoods. Musetha (2016) conveyed that temperature stress is severe under late crop sowing causing a reduction in the late growth phase. During the citrus growth phase, high temperatures have a negative effect on the quantity and quality of citrus productivity (CGA, 2016). High temperatures can negatively affect citrus production as well as reduce the yield. Similarly, Ziska *et al.* (1997)'s study on rice in Malaysia revealed that most of the rice farmers recorded a decrease in the yield of rice because of an increase in temperature. In addition, farmers reported that they were experiencing droughts and long dry spells resulting in low yield and total crop failure as these conditions restrict the suitability of land for cultivation.

High temperatures are likely to increase pest and disease pressure on citrus production (Turral *et al.,* 2011). According to Mandal and Singh (2020) farmers have perceived that there has been a rise in pest and disease due to warming because of the changing climate, for instance, stalk borers (*Calidea dregii*) which attack maize and sorghum. Ants were also reported to be the chief problem in crops such as groundnuts and maize. Temperature changes could increase pest reproductive rates and virulence, shift the distribution and pests' range size, and lead to greater frequency of new emerging diseases and invasive alien species (Turral *et al.,* 2011).

2.5.3 Drought Impacts on Citrus production

Drought has been identified to be a major driver of global food insecurity (IPCC, 2014). Due to climate change and variability, drought conditions are expected to become even more important in the future leading to significant crop losses (IPCC, 2014). The citrus industry is one of the agriculture sectors that have been hit hardest by drought (Dlikilili, 2018; Bezuidenhout *et al.,* 2020). Drought causes devastating impacts on citrus because of the effects on the production chain. Drought is a fundamental problem in Mopani considering that it is in a semi-arid area with low unreliable rainfall (LDA, 2012). Due to drought, the district experience reduced grazing land, water for livestock, and irrigation (Maponya and Mpandeli, 2013; Hartley *et al.,* 2021).

Large scale commercial agriculture in Mopani exists mainly in citrus, mangoes, and vegetables for the export market (Mokgalabone, 2015). The commercial citrus farms are dominated by white farmers who feature prominently at the top of the supplier list. The effects of climate and weather changes are characterised by changes in rainfall variability, increasing the number of seasons without enough rainfall, and increased temperatures which lead to extensive droughts and heat stress lowering crop productivity (Mandleni and Anim, 2010; Aune, 2012; Komba and Muchapondwa, 2012). This is likely to shift optimum growing areas for citrus and other key crops and generate an increase in the frequency and severity of extreme and moderate events and result in pests and diseases finding new ranges (DAFF, 2017).

Drought has negatively affected the well-being of most citrus farmers through its adverse impacts (CGA, 2016; DAFF, 2017; Ubisi *et al.,* 2017). Citrus farmers have been experiencing low productivity, crop failure, pest and diseases, and lack of water (DAFF, 2017). These impacts have posed a huge threat to food security and livelihoods of most farmers around the world, compromising their well-being as most depend on natural climatic sensitive resources such as crop production for their livelihoods (Hurni *et al.,* 2015). Therefore, drought has been a threat to crop production which is mostly rain-fed (Mpandeli *et al.,* 2015). Kurukulasuriya *et al.* (2006) revealed that Africa is most likely to be affected by climate variability with prolonged droughts, reduced rainfall, and increased temperatures.

Citrus farmers in Limpopo province, including Mopani district and other northern areas of South Africa experienced a localised drought in 2016 which saw their export oranges and grapefruits crop volumes shrink while soft citrus. Lemons and navel oranges which are grown in the Eastern and Western Cape were not much affected by drought in 2016 (CGA, 2016). Oranges and grapefruits managed to bounce back to their 2015 production levels when the area recovered from drought (CGA, 2016).

Citrus trees experience water stress even before any visual symptom of drought appear and the effects depend on the severity of water stress, citrus, and weather conditions during the period of water shortage (Johnson *et al.,* 2003; CGA, 2016). Lack of rainfall forces fruit producers to spend more. Citrus production in the 2015/2016 season was estimated to decline by 7.5 million cartons compared to the previous 2014/2015 season (CGA, 2016). Drought often creates economic and financial difficulties for agricultural producers (Johnson *et al.,* 2003). Drought that persists for several years can create substantial and devastating agronomic difficulties and genuine economic hardships for rural agricultural producers (DAFF, 2017).

2.5.4 Influence of Rainfall on Citrus Production

Rainfall projections are less certain than projections for temperature (IPCC, 2014). Water is vital to plant growth; hence varying rainfall patterns have a significant impact on agriculture. As over 80% of total agriculture globally is rain-fed, projections of future rainfall changes often influence the magnitude and direction of climate impacts on crop production (Karanja, 2014). A climate with moderate rainfall and sunshine is good for citrus trees. It promotes good flower differentiation, flower and fruit quality, and development. High rainfall areas are less suitable for citrus (CGA, 2012) because they have higher pest and disease burden, lower yields, and poor fruit quality. Citrus growers consider rainfall distribution, rainfall intensity, duration, and frequency.

Citrus fruit crops require water in specific quantities for their optimum growth. An excessive and deficit amount of rainfall can retard crop growth and lower crop productivity. For example, under climatic conditions, citrus requires different amounts of water during its stage of growth and development (DAFF, 2017). Changing rainfall patterns lead to imbalances in crop water needs. Such have a robust impact on yields and the quality of agricultural products. The quantity of water required for citrus production differs depending on the variety and soil conditions (CGA, 2016).

The influence of rainfall on citrus production can be related to its total seasonal amount and annual distribution. During the extreme case of droughts with very low total annual rainfall amounts, citrus production suffers the most (Sivakumar and Motha, 2007; Woldeamlak *et al.,* 2009; Kumar *et al.,* 2021). Citrus yields are often constrained by insufficient water. This proves that the number of wet days during the growing phase is as important as that of the total annual rainfall. However, the effects of rainfall on citrus production vary with weather conditions, properties, topography, and the type of soils and varieties grown.

Chelong and Sdoodee (2013) stated that environmental variables particularly temperature and rainfall are key factors that affect plant growth, development, and productivity. Differences in the citrus growth phase, yield, and quality of fruit attributes in varying seasons and locations are due to the different weather conditions that are based on the rainfall prevailing during the crop life cycle (Chelong and Sdoodee, 2012). An adequate amount of rainfall is interrelated with citrus quantity and quality in the subtropical region (Albrigo, 1999; Davies and Albrigo, 1999; Nawaz *et al.,* 2020). Citrus responds best to inputs at certain stages of plant development. It is important to understand the citrus growth phase for the timely application of water, fertilizers, pesticides, and other inputs to offset the seasonal stress periods (CGA, 2016). Citrus trees progress through three growth stages, which are the flowering, growth, and harvest stage. Rainfall is important during each stage of citrus growth and development.

Crop production is the most weather dependent of all human activities (Hansen, 2002). The main weather parameters affecting crop growth are rainfall and temperature (Hadgu *et al.,* 2015). Hence, knowledge of rainfall variability sequences and extreme weather events can assist in acquiring specific information for crop production planning (Mandal *et al.,* 2015). According to Molla *et al.* (2020) understanding the events of the occurrence of rainfall features within variable seasonal rainfall patterns such as the onset and offset of the rainy season as well as dry spells are crucial to decrease the adverse effects and exploit opportunities. According to Mzezewa *et al.* (2010) the amount and pattern of rainfall are amongst the utmost important factors that affect crop production. Lázaro *et al.* (2001) further emphasised that the analysis of temperature and rainfall records for long time periods provides information about weather variability. The variability of citrus yields depends on variations in weather in Mopani District Municipality where citrus is mostly irrigated and rain-fed (DAFF, 2013).

2.6 Climate Variability Impact on Crop Yields

The negative impacts of climate variability on crop yields are pronounced in Africa, as crop production sector accounts for a large share of gross domestic product, employment, and export earnings. According to Haggblade (2009) the crop model indicates that in most parts of Africa in 2050, average maize, rice, and wheat yields will decline by up to 30%. Udie (2019) opined that climate variability will reduce the production of five staple crops (cassava, groundnut, maize, millet, and sorghum) in Africa by a mean of between 8% and 22%. In all cases, there is a 5% chance that yields could drop by more than 27% except cassava. Lobell and Burke (2010) further emphasised that Africa could face a 30% decline in maize production in the next two decades because temperature and rainfall in Africa are changing quite fast.

According to Rowhani *et al.* (2011) the impact of climate variability is highly variable on different crop types. Declines in production of 27% for maize and 25% for wheat in the absence of any agricultural mitigation measures to climate variability have been projected in southern Africa. Farmers have already felt the effects of the changing climate and weather conditions. Oyieng (2014) stated that in 2006, the production of maize which is the main staple crop in southern Africa fell short by 2.18 million metric tonnes due to droughts in Mozambique, Namibia, South Africa, Swaziland, and Zimbabwe. Yamba *et al.* (2011) further emphasised that flooding in the Zambezi River basin has been affecting countries like Angola, Botswana, Namibia, Zambia, and Zimbabwe. Southern African countries have been experiencing a mixture of increased droughts and floods. According to Kusangaya *et al.* (2014) in southern Africa, preliminary analysis demonstrates that the amount and timing of rainfall is a good predictor for yields. Similarly, the potential future decrease in total rainfall in the early winter months will have a negative impact of between 5% and 70% on yields, depending on the area and eventual weather variability scenario.

According to Vogel *et al.* (2010) temperature has been projected to increase in South Africa. This will cause approximately 28% constraint of some areas suitable for crop production as early as 2020 (Vogel and Olivier, 2019). The above scenario is consistent with observed trends of reduced production and exports partly attributed to adverse conditions (Midgley *et al.,* 2005; Midgley *et al.,* 2006). The eastern part of South Africa is seen afflicted with increasingly severe storms while the west part is becoming much drier. As the western areas of South Africa dry out, the country would turn to more drought resistant strains of staple crops and rely more on the role of genetically modified strains. In January and February 2011, the abnormally high rainfall resulted in significant losses to both dry grapes and wine in the Northern Cape (Musetha, 2016). The effects of lower dry grape and wine production resulted in a R300 million loss to farmers in the province. Maize is also predicted to fall from 635 000 tonnes from the previous season to 575 000 tons in 2011, due to floods (Musetha, 2016).

Limpopo province is the main tomato growing area in South Africa, producing 66% of the total annual tonnage of tomatoes (Tshiala and Olwoch, 2010). There is an increase in tomato production in Limpopo province for certain years and a decrease in production in a certain period due to the sensitivity of the tomato to climate variability. The reduction in tomato production in some of the years was mainly due to droughts experienced in the region. Farmers in Mopani District Municipality are facing a possible negative impact on crop yields, especially farmers without advanced technology and good modern agricultural practices (Tshiala and Olwoch, 2010). Consequently, less food is directly available to the households. People in the province linked changes in crop production and availability to decreased health, which is in turn linked to climate, water, financial or economic stresses. Some communities are moving away from agriculture and are instead seeking to engage in wage-earning activities as an adaptation to water and climate stresses. According to Tshiala and Olwoch (2010) as heavy rains continue to wreak havoc on the crops, tomato farmers in Limpopo province have lost between R10 million and R50 million. Tshiala and Olwoch (2010) warned that some crops may experience difficulties as the rate of variations in climate increases.

2.7 Climate Variability Impact on Crop Prices and Income

According to the Food and Agriculture Organisation (FAO, 2010) African countries make up 36 of the 50 countries whose food supplies are most at risk. High poverty rates, extreme droughts, as well as poor infrastructure for transporting agricultural products, make Africa vulnerable to high food prices. Due to climate variability, Africa is struggling in terms of crop prices. The price increases have been most noticeable with the cereal crops (maize, millet, rice, sorghum, and wheat) which comprises the basic diet of billions of people (FAO, 2010). Feed for cattle, chicken, and other meat producing animals has also been hit hard by the rising crop prices (FAO, 2010). Food and Agriculture Organisation (2009)noted that the food price index rose by 47% between January 2007 and January 2008, led by increases in the prices of cereals by 62%, dairy by 69%, and vegetable oils by 85%.

According to Maponya (2012) since 2007 erratic and unpredictable rainfall has led to increased food shortages in Southern Africa where droughts damaged and destroyed maize crops in Lesotho, Mozambique, Namibia, South Africa, Swaziland, and Zimbabwe. As a result, Southern Africa fell short of 2.18 million metric tonnes of maize in 2007 and 2008, hence an increase in maize prices due to scarcity. Ncube *et al.* (2016) stated that escalations in food prices between 2007 and 2008 led to riots in some Southern African countries and subsequent shortages.. The situation was further elaborated by World Bank which released its food index data in March 2011, the data showed higher food prices for maize, edible oils, sugars, and wheat. This has pushed about 44 million people in developing countries including Southern Africa into extreme poverty since 2010 due to climate variability.

A severe cold and frost also hit Southern Africa in 2010. This erratic and unpredictable climate and weather pattern has proved to be very costly to fruit and vegetable farmers. The situation was worse in South Africa’s KwaZulu-Natal province where according to De Bruin *et al.* (2010) sugarcane did not perform very well because of the severe cold. It was confirmed that 124 000 tons of cane were affected by the first 5th stage damage and is one of the reasons the price of sugar has increased as shown by the food price index released by the World Bank in March 2011. According to the Department of Agriculture Forestry and Fisheries (DAFF, 2013) South Africa’s total maize output and the yield per hectare have fluctuated dramatically over the past three decades due to drought. This has led to increases in maize prices because of its scarcity. Even though yields per hectare have improved in recent years, this is partly because of intensive energy inputs which will become increasingly expensive and scarce as oil progressively runs out. In 2010 there were continuous adverse climate and weather patterns particularly during the heavy rain period which resulted in major delays in crop harvesting such as sweet potatoes and potatoes. This led to increases in potatoes prices because of scarcity (Hanekom *et al.,* 2010).

According to Tshiala *et al.* (2012) Limpopo Province is the main tomato growing area in South Africa, producing 66% of the total annual tonnage of tomatoes. The total annual production of tomatoes is approximately 227 990 tons of the total South African production, which is 345 440 tons about two-thirds of the national tomato production (Tshiala *et al.*, 2012)). De Bruin *et al.* (2010) opines that in Limpopo province frost damage is extensive and a large area in Mopani, Capricorn, and Sekhukhune districts was badly hit. Maponya (2012) further emphasised that the situation is going to be very terrible since some fruits and vegetables are now very expensive. For example, green beans is already up to R50/Kg from R6/Kg and tomatoes R100/bag.

The rising temperature in Africa might reduce the income of large-scale farmers by as much as 35% or US$20 billion a year (Seo and Mendelssohn, 2007). Increased rainfall would reduce livestock revenue for both large and small farms. Agricultural production is projected to be halved due to climate variability. This will threaten the livelihoods and income of farmers in the region where most of the population are smallholder farmers. Farmers are already feeling the impact of climate variability on their income. In 2006, the production of maize fell short by 2.18 million metric tonnes due to drought in some parts of Africa (Mendelsson *et al.,* 2000). Musvoto *et al.* (2018) emphasised that farmers should diversify their income if they want to survive and if possible, farmers should seek work elsewhere because they cannot rely on agriculture anymore.

Southern Africa is already experiencing declining incomes and an increased likelihood of food insecurity. Climate variability is likely to make things worse for the farmers' income. Southern Africa's vulnerability is in good part a function of it having higher weather variability than other regions of the world, such as Central Africa and Europe (Arslan, 2018). Musvoto *et al.* (2009) stated that farmers have already felt the first impact of changing weather conditions in 2006 when their income fell dramatically due to drought in Mozambique, Namibia, South Africa, Swaziland, and Zimbabwe.

According to Blignaut *et al.* (2009) South Africa is getting hotter and dryer, and this has major implications for South African agriculture. Notably, there is very little scope for the expansion of irrigation, given the limited supply of water and the pressing socio-economic needs. This implies that farmers are likely to rely more on water saving techniques. This might increase the costs even further in a sector that has a small net income margin, and which is already facing rapid cost increases due to weather variability. This is likely to make it increasingly difficult for farmers to improve their income from crop production. Blignaut *et al.* (2009) further emphasised that net agricultural income in the provinces contributing 10% or more to the total production of both field crops and horticulture is likely to be negatively affected by a decline in rainfall. In South Africa, every

1% decrease in rainfall is likely to lead to a 1.1% decline in the production of corn and a 0.5% in wheat consequently reducing farmers' incomes (Blignaut *et al.,* 2009).

Ziervogel and Taylor (2008) and Singh *et al.* (2018) indicated that there is sparse rainfall and high evaporation rates in Limpopo province that limits the success of farming activities, such as the growing of maize and pumpkins as well as rearing of goats, chickens, and cattles. This situation will in turn affect farmers' income. Further, Ziervogel and Taylor (2008) emphasised that in Limpopo province agricultural incomes are lowest due to climate variability as compared to non-agricultural incomes. This is mainly because climate variability affects crop production directly. It is also noted that climate variability will have a major impact on the farm workers' income, particularly in rural areas of Limpopo province where agricultural production is the major source of income and employment (Maponya, 2012). Limpopo province is further vulnerable because of its limited ability to adapt to climate variability due to the dependence of rain-fed agriculture in some areas, low levels of human capital, physical capital, and poor infrastructure.

2.8 Citrus Commodity Profile, Market Distribution, Industry Performance, and Trends

Citrus is the most economically important fruit crop in the world and has a tremendous cultural and social impact on our society (Iglesias *et al.,* 2007; Tadeo *et al.,* 2008). It is grown in most developed and developing countries and constitutes one of the main sources of vitamin C (Hussain *et al.,* 2018). Citrus is one of South Africa's important fruit groups by value and volume. Citrus production in South Africa mostly occurs in Eastern Cape, Kwazulu-Natal, Limpopo, Mpumalanga, Northern Cape, and Western Cape provinces.

There are significant variations between citrus production areas in South Africa based on climate. The Limpopo, Kwazulu-Natal, and Mpumalanga provinces are considered warmer and better suited to the cultivation of grapefruits and oranges. In the Eastern Cape and Western Cape, the climate is cooler and citrus production is primarily focused on lemons and navel oranges (DAFF, 2017). According to the Citrus Growers Association (CGA, 2016) most citrus production takes place in Limpopo province on 835 hectares which contributed 59% of oranges planted in 2015. The major citrus production areas in Limpopo province are found in Mopani District Municipality namely Hoedspruit and Letsitele (DAFF, 2017).

The citrus industry is the third largest industry in South Africa after vegetables and deciduous fruits in terms of gross value (DAFF, 2016). The citrus industry is labour intensive and is estimated to employ 100 000 individuals, with many employees in orchards and packing houses. It is estimated that more than a million households in South Africa depend on the citrus industry for their livelihoods (DAFF, 2016). The industry contributed about R11.0 billion (20.6%) to the total gross value of South Africa's agricultural production during the 2014/2015 production season.

Citrus production is dependent on climatic conditions and can be partially manipulated by man through irrigation (DAFF, 2016). Distinct differences in climatic conditions affect the growth phase, and there is also a significant relationship between yield and climate conditions (Duane *et al.*, 2019). Moisture is a limiting factor in citrus production because rainfall is often poorly distributed and, in most cases, deficient. Therefore, it is necessary to supplement moisture by irrigation to ensure that moisture stress does not suppress growth and production. Rosenzweig *et al.* (2002) examined the potential impact of weather variability on citrus production. According to the Limpopo Department of Agriculture (LDA, 2012) the citrus industry is export orientated and requires well developed infrastructure along the value chain. The highest revenue in the citrus industry is earned through exports and the processing of fruits (DAFF, 2012). The citrus industry contributed about R5, 8 million to the total gross value of South Africa's crop production in the 2008/2009 season (CGA, 2016; LDA, 2012).

Citrus production is a vital foreign exchange earner and mostly aimed at South Africa's export market (CGA, 2016). Locally, citrus produces are traded through different marketing channels such as National Fresh Produce Markets (NFPMs) with oranges being the highest sold commodity followed by nartjies, lemons, and limes (LDA, 2012). The domestic market is also made up of informal markets (street hawkers), processors of juice, and dried fruit production. The fruits are also directly sold to wholesalers and retailers through signed contracts (CGA, 2016). South Africa exported a total combined volume of 1 782 583 tonnes of citrus products in 2015, the volume was higher than that of the previous year by 2.9%. The major citrus exporting area in Limpopo province is Mopani district. The region recorded R986 million worth of citrus product exports in 2015 (DAFF, 2016). The implication for local citrus producers is that they need to target export markets and ensure the quality of produce meets export requirements (LDA, 2012). The focus for local citrus producers should be improving the quality and quantity of citrus fruits through technical assistance and training.

According to the Citrus Growers Association (CGA, 2012) a notable increase in the citrus export market was 746 963 tonnes in 2005 to 1 045 254 tonnes in 2010. Most of the citrus fruits are exported, approximately 70% of citrus volumes, 22% is used for the local market and 8% is processed. South Africa's major export destination for all citrus fruit is Northern Europe with 27%, followed by the Middle East with 21% and Russia with 13% (CGA, 2012).

Most of the citrus exports are from export provinces such as the Western Cape and Gauteng, despite the Limpopo, Eastern Cape, and Mpumalanga provinces being the leading producers of citrus fruits (DAFF, 2016; CGA, 2012). This is due to the Western Cape and Gauteng being the registered exporters which are based in their separate provinces and serve as exit points for citrus exports. The proximity of the Limpopo Province to neighbouring countries and the Southern African Development Community (SADC) region provides an opportunity to act as an exit point to export citrus (DAFF, 2016; CGA, 2012). Export districts in Limpopo Province are Mopani, Sekhukhune, and Vhembe district.

2.8.1 Overview of the South African Citrus Industry

This section focuses on the performance of the South African citrus industry. As stated earlier, the citrus industry is one of the most important agricultural industries that contribute to the GDP of South Africa. The citrus industry is guided by the Citrus Growers Association (CGA), which protects the interests of the relevant stakeholders. The CGA provides membership to more than 1 000 growers throughout the country, a few others in Zimbabwe and Swaziland. Supporting the CGA are various institutions, such as the Grower Development Company, that targets transformation in the industry by currently supporting and developing more than 100 black citrus farmers in the country, which is aimed at increasing equity in the sub-sector across the value chain (Dlikilili, 2018). Other key organisations supporting the citrus industry in various forms include the Agricultural Research Council (ARC), Citrus Research International (CRI), the Perishable Products Exporters Control Board (PPECB), the Fresh Produce Exporters Forum (FPEF), the Citrus Academy, learning institutions such as Stellenbosch University and the University of Pretoria, and the Department of Agriculture, Forestry and Fisheries (DAFF).

The citrus industry is the third largest horticultural industry after deciduous fruits and vegetables. During the 2013/2014 production season the industry contributed R9.69 billion to the total gross value of the South African agricultural production. This represented 15% of the total gross value (R53.2 billion) of horticulture during the same period. The industry is also an important foreign exchange earner and comprises of four broad categories namely oranges, grapefruits, soft citrus (tangerines, mandarins, clementines, and satsumas), and lemons and limes.

2.8.2 Orange Production Trends

Figure 2.1 shows annual production and area harvested estimates for oranges over a period of 31 years (1987 to 2017). Results show a fluctuating but increasing trend. The increase was mainly due to increased exports, and the weakening of the rand (ZAR) against major currencies of South Africa's trading partners (CGA, 2012). Results indicate that orange production experienced successive good years starting from 1987 to 1990, 1992 to 1994, 1996 to 2003, 2005 to 2008, 2010 to 2013, and 2017. However, there were exceptions in 1991, 1995, 1998, 2004, 2009, and 2016 season where there was a decrease in production due to droughts and floods that affected the quality and size of the fruit. Orange production and the area harvested have been on the increase since the 1996 production season. The area harvested for oranges reached its peak of 53 000 ha in 2001, the lowest was 35 500 ha experienced in 1987. The production of oranges totalling 1 810 559 tonnes was harvested in 2013. This was the highest quantity with an area of 47 022 ha, the lowest was experienced in 1987. The increase has been mainly due to good climatic conditions in leading production areas.

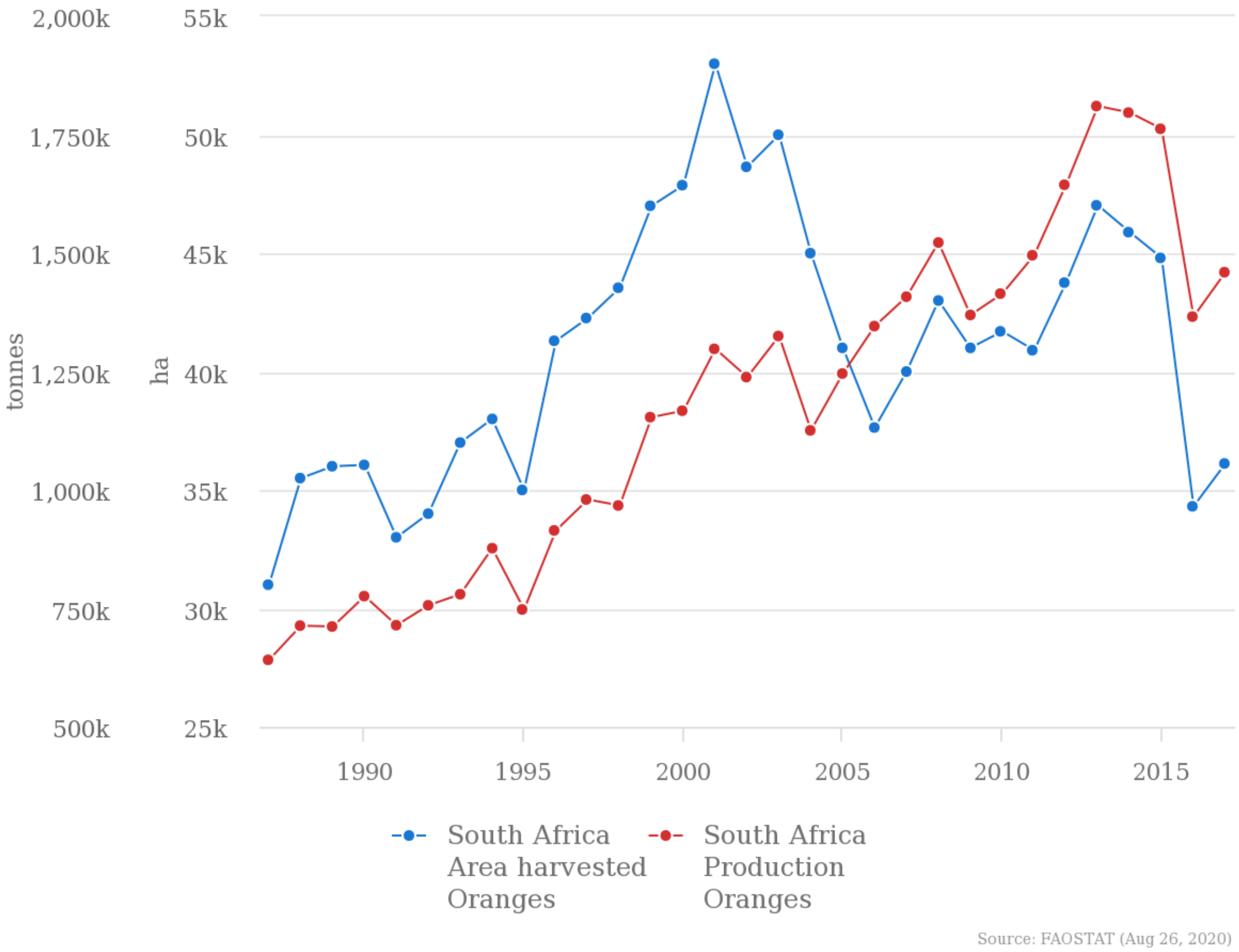


Figure 2. 1: Orange Production and Area Harvested in South Africa

Source: Own calculations based on FAOSTAT (2020) data.

2.8.3 Lemons and Limes Production Trends

Figure 2.2 shows annual production and area harvested estimates for lemons and limes over a period of 31 years. Results show a fluctuating increasing trend. However, the production and area harvested of lemons and limes remained stable from 1987 to 1988, again between 1990 and 1995 with production between 61 252 tonnes and 74 259 tonnes and area harvested between 3 250 ha and 3 800 ha. Lemons and limes show a fairly increase in production and area harvested from 1996 (with area harvested of 4 200 ha and production of 86 663 tonnes) to 2004 (with area harvested of 10 896 ha and production of 212 955 tonnes). The production and area harvested decreased in 2005, 2007, 2009, and 2012. The area harvested and production of lemons and limes reached its highest peak of 21 999 ha and 446 340 tonnes in 2017. The area harvested was at its lowest in 1990 with 3 200 ha. Similarly, the production of lemons and limes was at its lowest in 1993 with a volume of 61 252 tonnes.

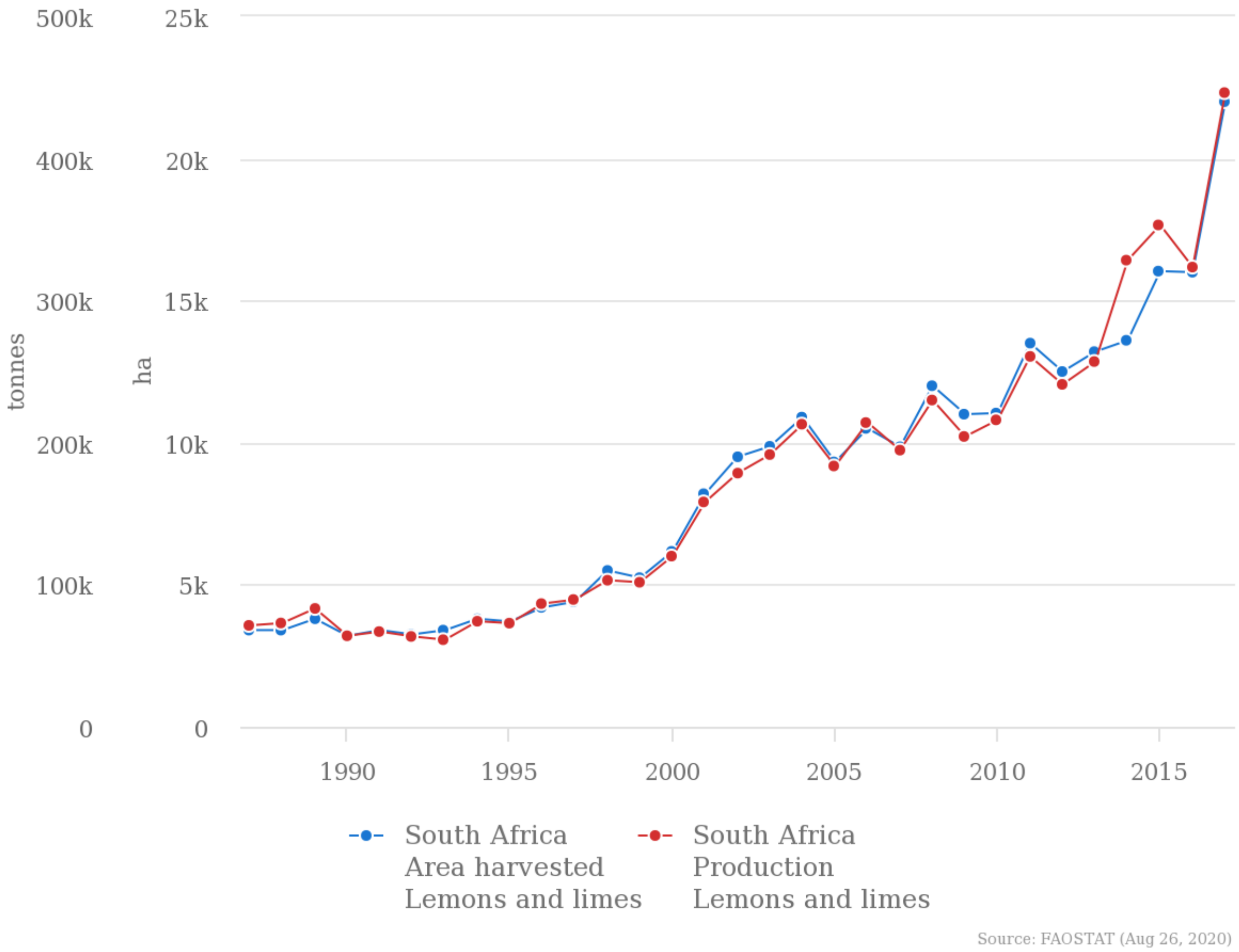


Figure 2. 2: Lemons and Limes Production and Area Harvested in South Africa

Source: Own calculations based on FAOSTAT (2020) data.

2.8.4 Grapefruit Production Trends

Figure 2.3 shows annual production and area harvested estimates for grapefruits over a period of 31 years. The production and area harvested of grapefruits show an increasing trend. In 2013, grapefruits reached its production and area harvested peak of 442 847 tonnes and 14 648 ha. The production and area harvested show a strong fluctuating trend starting from 2000 to 2017. The cause of this rise and fall can be due to droughts, floods, pests, and diseases that affected the quality and quantity of the fruits. Grapefruit production was at its lowest in 1993 with the volume of 89 675 tonnes. Similarly, the area harvested was at its lowest in 1987 with 3 350 ha.

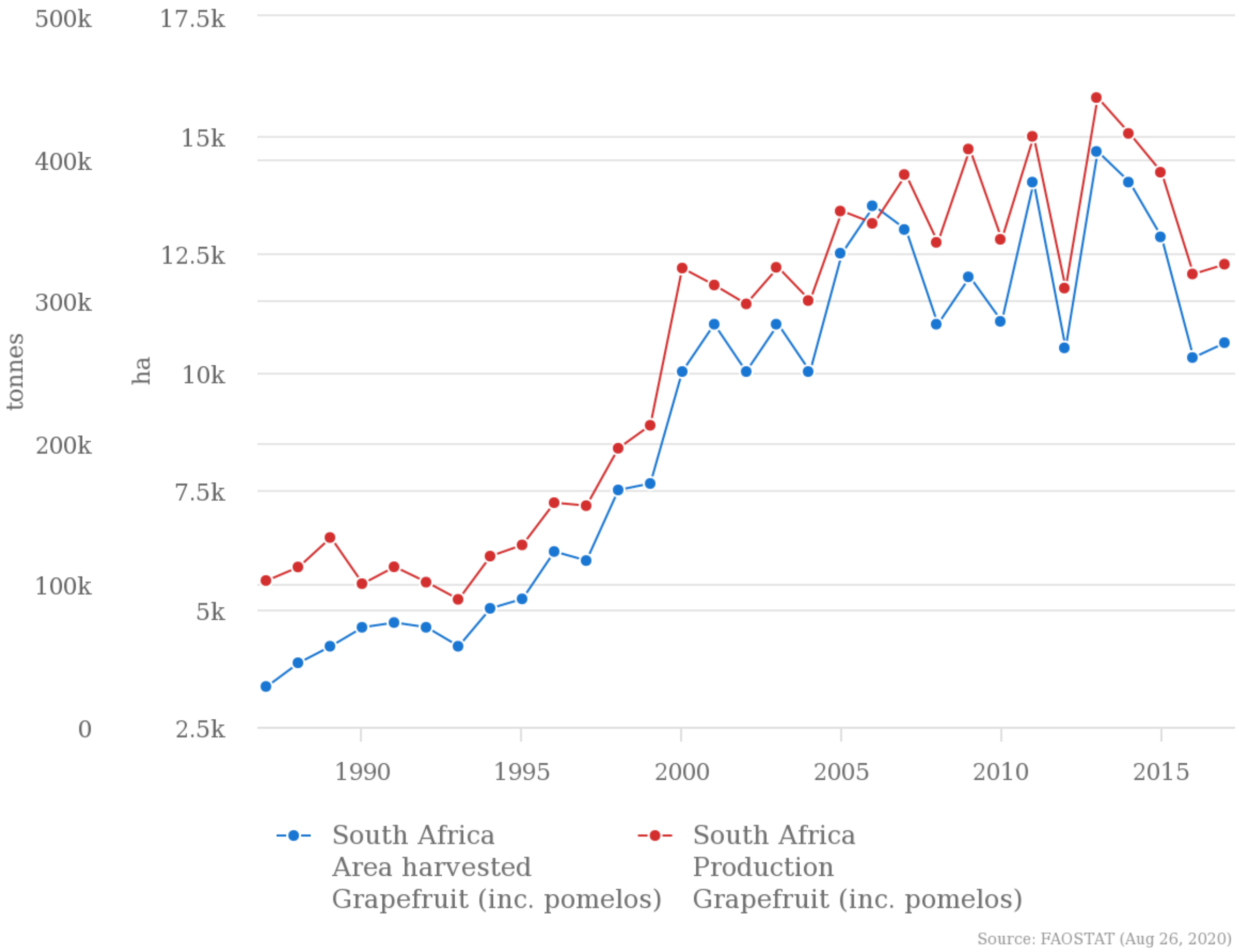


Figure 2. 3: Grapefruit Production and Area Harvested in South Africa

Source: Own calculations based on FAOSTAT (2020) data.

2.8.5 Tangerines, Mandarins, Clementines, and Satsumas Production and Area Harvested Production Trends

Figure 2.4 shows annual production and area harvested estimates of tangerines, mandarins, clementines, and satsumas (soft citrus) over a period of 31 years. The production and area harvested of soft citrus show an increasing trend. However, there were exceptions in 1991, 1994, 2000, and 2002 seasons where there was a decrease in production and area harvested. Soft citrus reached its production and area harvested peak of 189 505 tonnes and 6 436 ha in 2017. The dip in production and area harvested of soft citrus was experienced in 1987 with 28 638 tonnes and 1 700 ha.

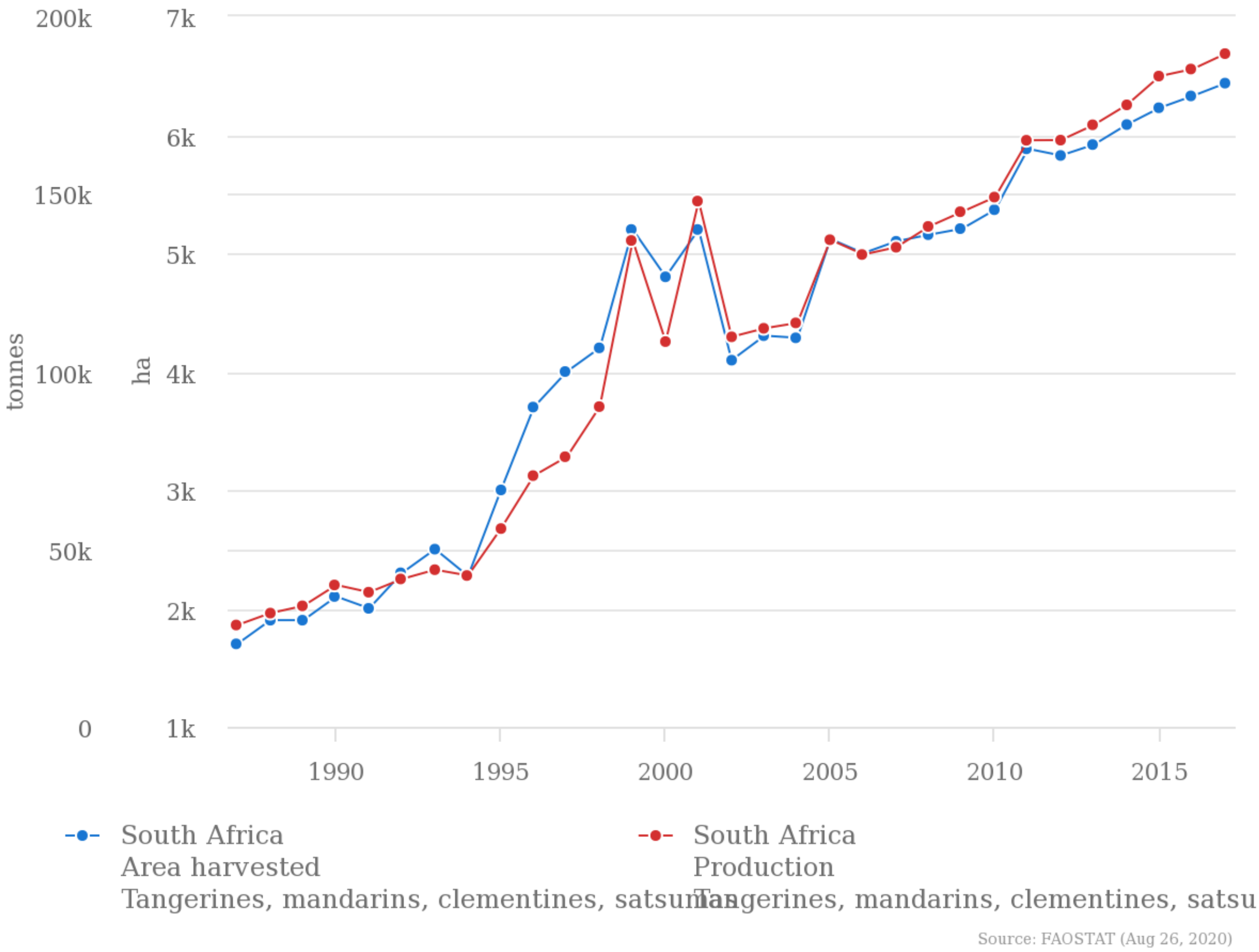


Figure 2. 4: Tangerines, Mandarins, Clementines, Satsumas Production and Area Harvested in South Africa

Source: Own calculations based on FAOSTAT (2020) data.

2.8.6 Citrus Fruits Historical Producer Price Trends in South Africa

The citrus industry is export orientated, the reason for this includes the high revenues per ton obtained from the export markets. Figure 2.5 below shows the producer price annual values in standard local currency (SLC/tonne) of oranges, lemons and limes, grapefruits, and soft citrus (tangerines, mandarins, clementines, and satsumas) from 1991 to 2017 when sold locally, exported, and sold to the processing industries. The producer price of all citrus varieties shows an increasing trend during the period under review. However, in 1991 all citrus varieties were at their lowest producer prices with annual values ranging between R499.00 and R986.00 SLC/tonne. As can be seen in Figure 2.5, soft citrus fetched higher returns in the market, while grapefruits fetched the lowest price, whereas oranges, lemons, and limes were sold at an average price. The prices fluctuated sturdily from 2001 to 2017. The producer price of soft citrus and grapefruits in 2001 were equal at R1 079.00 SLC/tonne. Soft citrus reached its producer price peak at R8 660.00 SLC/tonne in 2014, lemons and limes in 2016 at R8 271.00 SLC/tonne, grapefruit in 2016 at R5 200.00 SLC/tonne and oranges in 2014 at R4 025.00 SLC/tonne. The producer price of all citrus varieties in 2009 decreased with an annual value ranging between R1 100.00 and R3 684.00 SLC/tonne. In 2015, all citrus varieties decreased in prices except for grapefruit showing a hasty increase of R3 938.00 SLC/tonne from that of the previous year of R2 975.00 SLC/tonne.

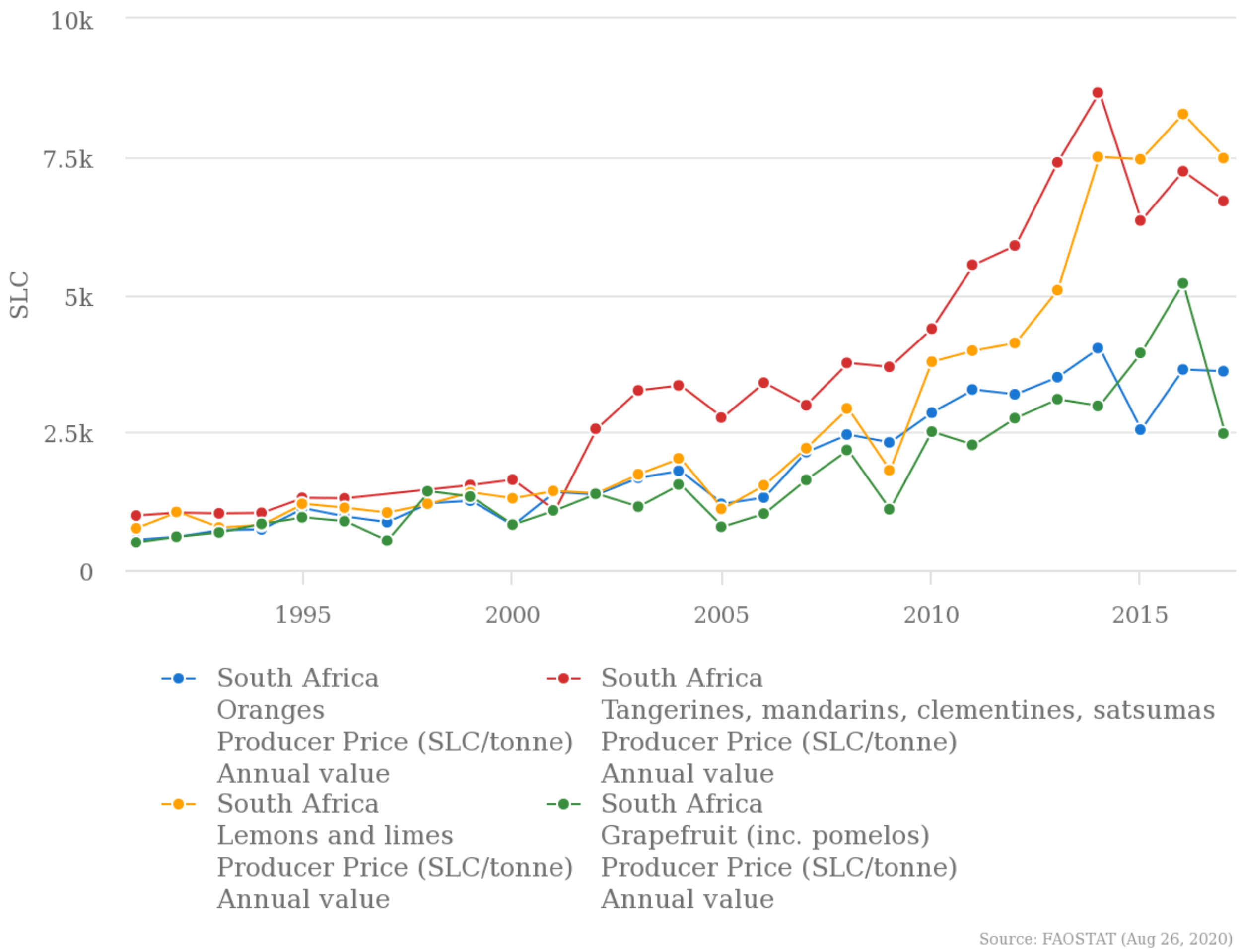


Figure 2. 5: Annual Comparison of Citrus Historical Price Trends in South Africa

Source: Own calculations based on FAOSTAT (2020) data.

2.8.7 Oranges Trades

Figure 2.6 below shows South Africa's import quality, import value, export quality, and export value of oranges from 1987 to 2017 in 1000 US$ per tonne. The export quantity and export value of oranges show a positive annual growth over the study period. The import quantity and import value of oranges show a constant growth from 1987 to 2017 with a slight increase of import quantity in 2014 of 12 782 tonnes. The export quantity value of oranges had the highest annual growth in 2013 totalling 1 173 359 tonnes worth 591 713 US$. Meanwhile, the export value growth reached its peak in 2017 of 752 509 US$. Similarly, the export quantity and export value of oranges equally show a declining growth in 1993 to 1994, 1996, 2000, 2009, 2011, and 2016. This indicates the importance of export markets to South Africa's production of oranges.

The export quantity and export value of oranges has gradually increased since 2001, except for 2009, 2011, and 2016 when it experienced a decrease in tonnes and prices. According to Citrus Growers Association (CGA, 2016), the decrease in import and export market was caused by the rough international financial conditions that were felt at the end of the 2008 production season and had a heavy impact on the 2009 citrus trade season. Further, the CGA (2016) report elucidates that the major markets for local citrus experienced a tough trading environment, leading to "recession economics" of low supply, experiencing low prices across all citrus varieties.

Figure 2. 6: Orange Trade Trends in South Africa

Source: Own calculations based on FAOSTAT (2020) data.

2.8.8 Lemons and Limes Trades

Figure 2.7 shows South Africa's import quality, import value, export quality, and export value of lemons and limes from 1987 to 2017 in 1000 US$ per tonne. The export quantity and export value of lemons and limes show an increasing trend in annual production over the study period. The import quantity and import value of lemons and limes show a continuous growth from 1987 to 2017 with a slight increase of import quantity of 2 062 tonnes and import value of 2 535 US$ in 2016. The export quantity of lemons and limes had the highest annual growth in 2017 where it reached 299 260 tonnes worth 292 216 US$. Likewise, the export quantity and export value of lemons and limes equally show a continuous growth from 1987 to 1991 and 1993 to 1996 except for 1992 when there was an increase in price per tonnes. The quantities of lemons and limes sent to the export market have been increasing throughout the years while the import market has been stagnant. The prices per tonnes realised in the lemons and limes export markets fluctuated greatly between 2006 to 2012, when prices decreased to their lowest of 54 389 US$ (export value) in 2007 and 52 219 US$ (export value) in 2006.

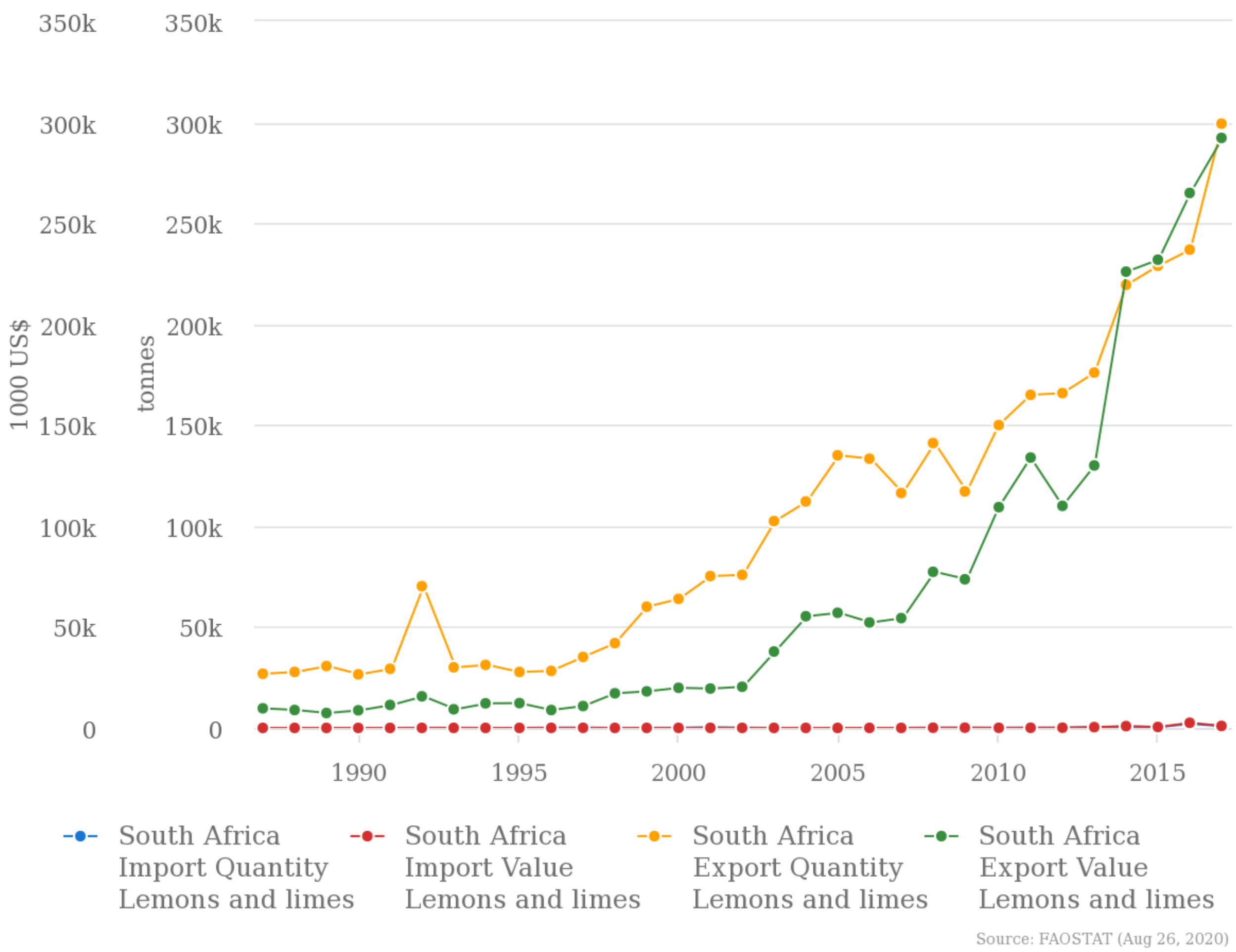


Figure 2. 7: Lemons and Limes Trade Trends in South Africa

Source: Own calculations based on FAOSTAT (2020) data.

2.8.9 Grapefruits Trades

Figure 2.8 shows South Africa's import quality, import value, export quality, and export value of grapefruits from 1987 to 2017 in 1 000 US$ per tonne. The export quantity and export value of grapefruits show an increasing trend in annual production over the study period. The price per tonne realised in the grapefruits export markets fluctuated greatly between 2005 to 2017. Grapefruits totalling 262 939 tonnes were exported in 2013, this was the highest export quantity from 1987 to 2017, the lowest was experienced in 1993 with the volume of 58 000 tonnes. The import quantity and import value of grapefruits show a constant growth from 1987 to 2017, with a slight increase in import value in 2013 and import quantity in 2004, 2005, 2006, and 2014. The export value of grapefruits had the highest annual growth in 2017 where it reached 132 055 US$. The leading market for South Africa's grapefruits is the export market. The increase was primarily the result of a huge increase in the demand for South African grapefruit exports in Asia during the same period.

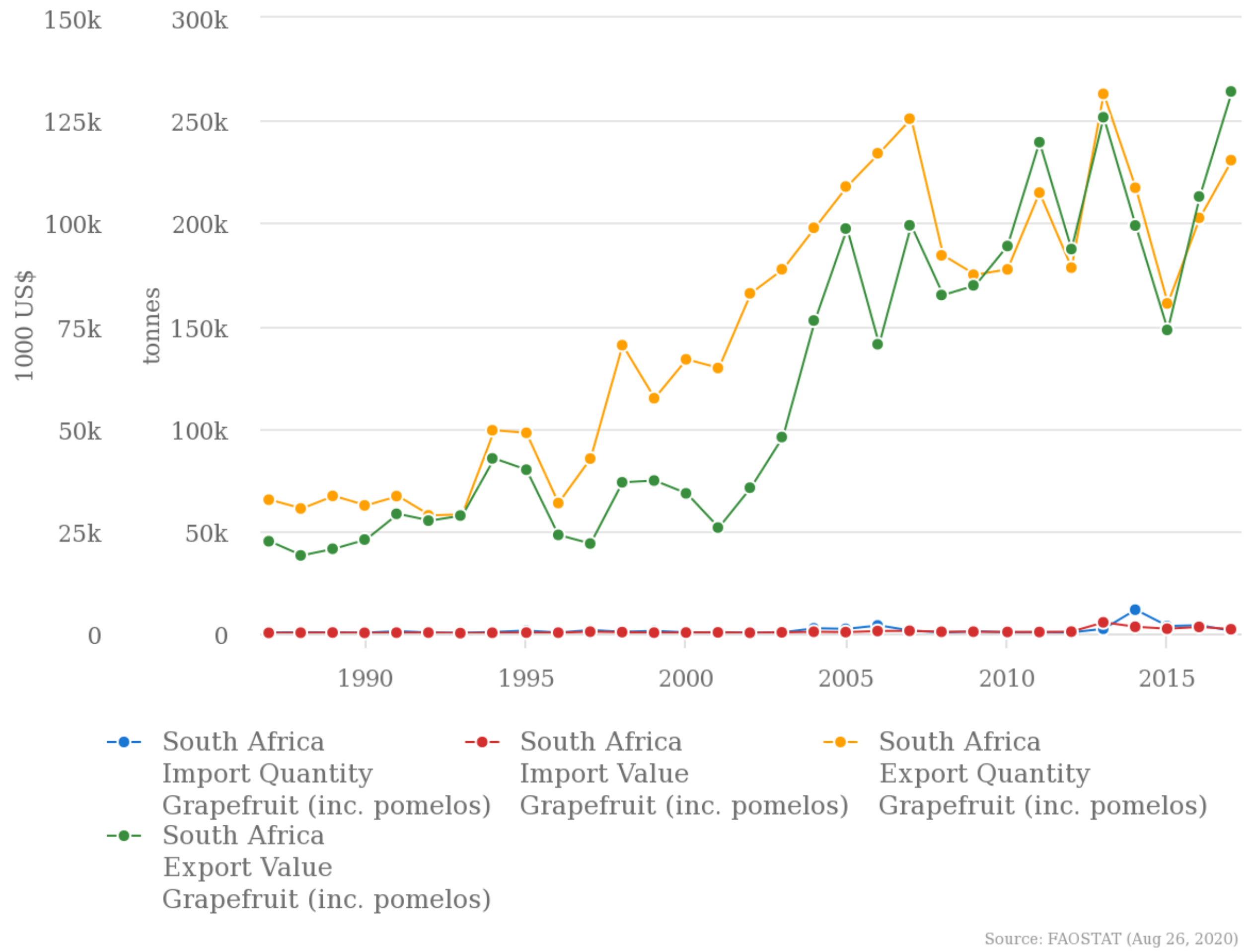


Figure 2. 8: Grapefruit Trade Trends in South Africa

Source: Own calculations based on FAOSTAT (2020) data.

2.8.10 Tangerines, Mandarins, Clementines, and Satsumas (soft citrus) Trades

Figure 2.9 shows South Africa's import quality, import value, export quality, and export value of tangerines, mandarins, clementines, and satsumas (soft citrus) from 1987 to 2017 in 1 000 US$ per tonne. The export quantity and export value of soft citrus show an increasing trend in annual production and price over the study period. The price and tonnes realised in the soft citrus export markets fluctuated greatly between 1999 to 2002, 2014, and 2015 seasons. Soft citrus totalling 209 825 tonnes were exported in 2017, this was the highest export quantity from 1987 to 2017, the lowest was experienced in 1987 with the volume of 300 tonnes worth 169 US$. Most of the South African annual soft citrus crop is absorbed by the export market. This can be explained by the highest annual growth in the export price, which stood at 215 204 US$ in 2017. The export quantity and export value of soft citrus show a constant growth from 1987 to 1990. The import quantity and import value of soft citrus made their first appearance in the import market in 1995 with an import quantity of 52 tonnes worth 35 US$. The import quantity and import value of soft citrus show a constant growth from 1995 to 2017. This is due to the low demand for soft citrus in the South African import market.

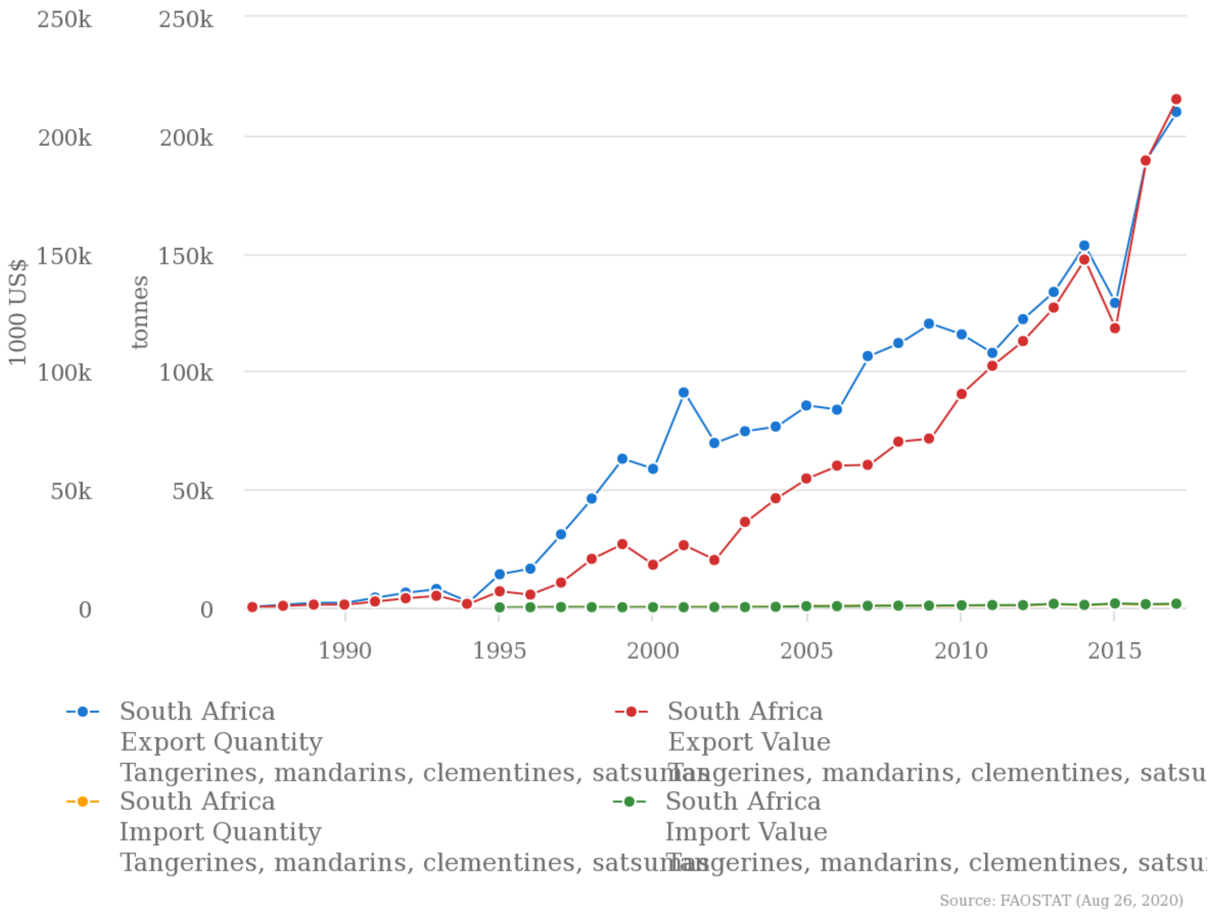


Figure 2. 9: Tangerines, Mandarins, Clementines and Satsumas Trade Trends in South Africa

Source: Own calculations based on FAOSTAT (2020) data.

2.8.11 A Comparison of All Citrus Varieties Trades

Citrus production in South Africa is predominantly aimed at the export market. As can be seen in Figure 2.10 below, the biggest contributor to the total volume of South African citrus exports is oranges, followed by grapefruits, soft citrus, lemons, and limes. South Africa is ranked amongst the top three exporting countries of citrus by value and has shown an impressive and positive trend in competitive performance over the study period. This is highlighted by the increasing trends in export value and export quantity. South Africa imports a small number of citrus fruits. Most of these imports come from neighbouring countries such as Swaziland (CGA, 2016). The South African imports represent less than 1% of world imports for citrus and the country is ranked number 86 in overall citrus imports. South Africa’s value of imported citrus increased from 2015 to 2016, mostly due to the drought that hit the country in that period, resulting in lower quantities of citrus produced. The annual growth in value of imports between 2008 to 2017 has also shown a positive trend.

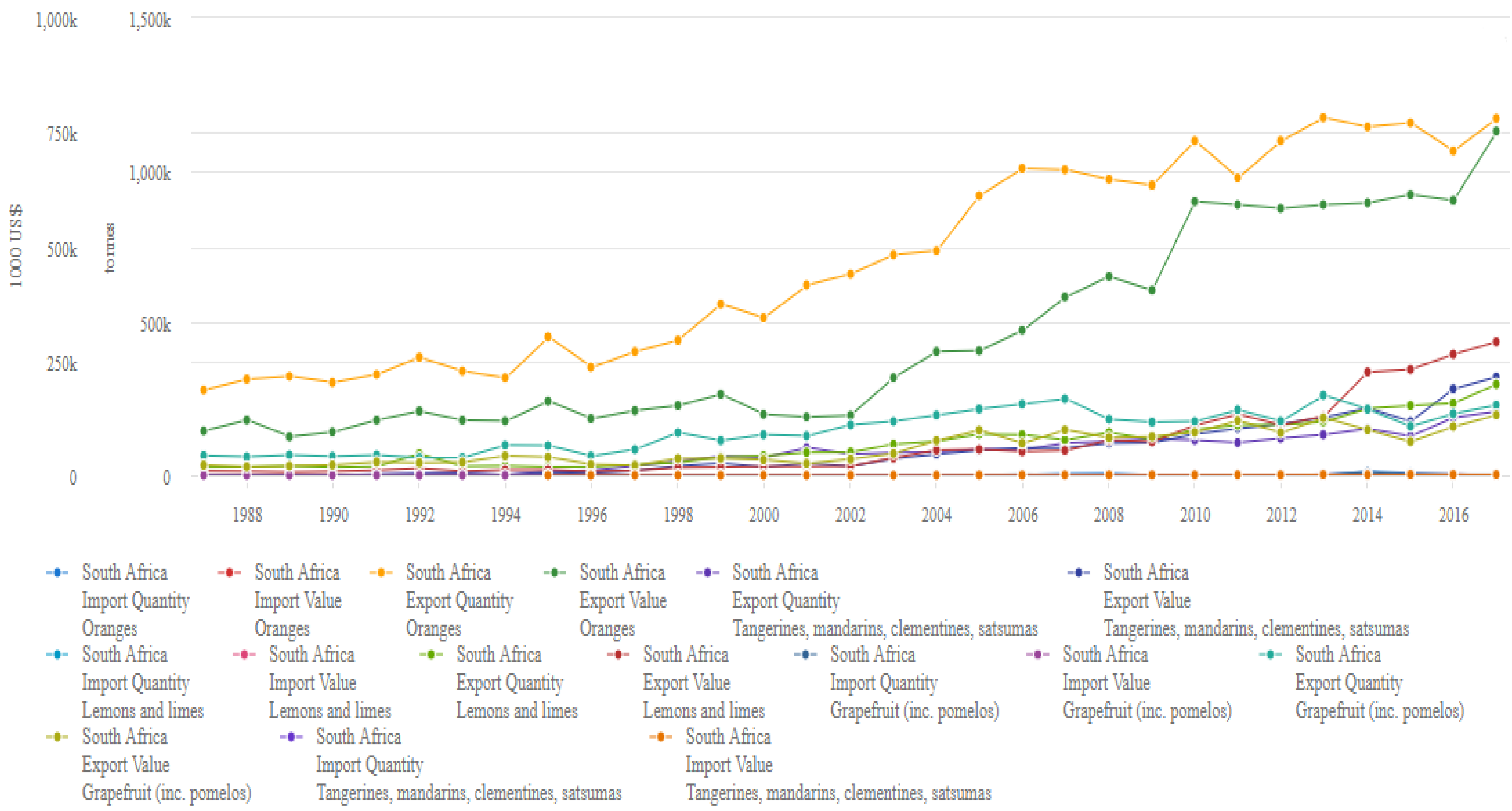


Figure 2. 10: Annual Comparison of All Citrus Trades in South Africa from 1987 to 2017

Source: Own calculations based on FAOSTAT (2020) data.

2.9 Sustainable Livelihood Approach

According to Department for International Development (DFID, 2000) livelihoods are the capabilities, assets including both material and social resources (farms, resources, supplies, claims and access) and activities required for a means of living. Thus, a livelihood is sustainable when it can cope with and recover from stresses, shocks and maintain or enhance its capabilities and assets both in the present and in the future, while not undermining the natural resource base (Chambers and Conway, 1992; Krantz, 2001; Ncube, 2012). The Department for International Development (DFID, 2000) identified and integrated the vulnerability context to the key aspects of livelihood to make it sustainable.

The sustainable livelihood approach works intensively with people to find long term secure sources of income and to become resilient to life shocks. Sustainable livelihood approach helps people identify the strength they already have and the assets they can build on to help support themselves. These strengths fall into five categories, human assets (skills and knowledge), social assets (family and community groups), physical assets (decent housing, transport, and tools for work), public assets (nearby community centre, supermarket, and library) and financial assets (wages, benefits, and savings) (Ellis, 2000; Scoones, 1998; Chambers and Conway, 1992). This holistic people centred approach is the best way to help people help themselves, boosting self-worth, empowering people, inspiring friends, and family and in turn strengthening the community (DFID, 2000).

Sustainable livelihood approach helps people escape poverty and bring about lasting change for all. Also, a livelihood is environmentally sustainable when it contributes to the stability of environmental assets and has a sustainable positive net benefit effects on other livelihood sources (Morse and McNamara, 2013). People undertake livelihood strategies using assets owned to transform their lives. Assets owned are key in implementing livelihood strategies such as crop production and livestock rearing which are necessary for the realisation of desired livelihood outcomes (Davies *et al.,* 2008; LaFlamme, 2011; McLean, 2015).

This approach is usually used to design development programs at the community level and is especially useful for assessing the ability of households to withstand shocks such as epidemics or civil conflicts (Chambers and Conway, 1992). Therefore, changes in weather and climate add complexity to household livelihood security. The sustainable livelihood approach is restricted to the issues of adaptive capacity and sensitivity to climate change and variability (Hahn *et al.*, 2009). For this reason, an innovative approach for evaluating livelihood risks resulting from climate variability integrating the climate exposures and household adaptation practices are needed.

2.10 Sustainable Livelihood Framework

The livelihoods framework is a way of looking at the complexity of people's livelihoods, especially the livelihoods of the poor (Lee, 2008; Scoones, 1998). It seeks to understand the various dimensions of a person's livelihood, the strategies and objectives pursued and associated opportunities and constraints. The sustainable livelihoods framework takes an integrated approach to poverty than just a narrow set of indicators such as income and productivity (Solesbury, 2003). The framework provides a checklist of prominent issues and emphasises the multiple interactions between the numerous factors that affect livelihoods and is centred on people. It is used for planning new development activities and assessing the contribution to livelihood sustainability made by development interventions. It also draws attention to core influences, processes, and emphasises the multiple interactions between the numerous factors that affect livelihoods.

Figure 2.11 outlines the Sustainable Livelihood Framework where the vulnerability context directly influences the livelihood strategies, livelihood outcomes, structures, and processes of the community, and is a determinant of livelihood sustainability.

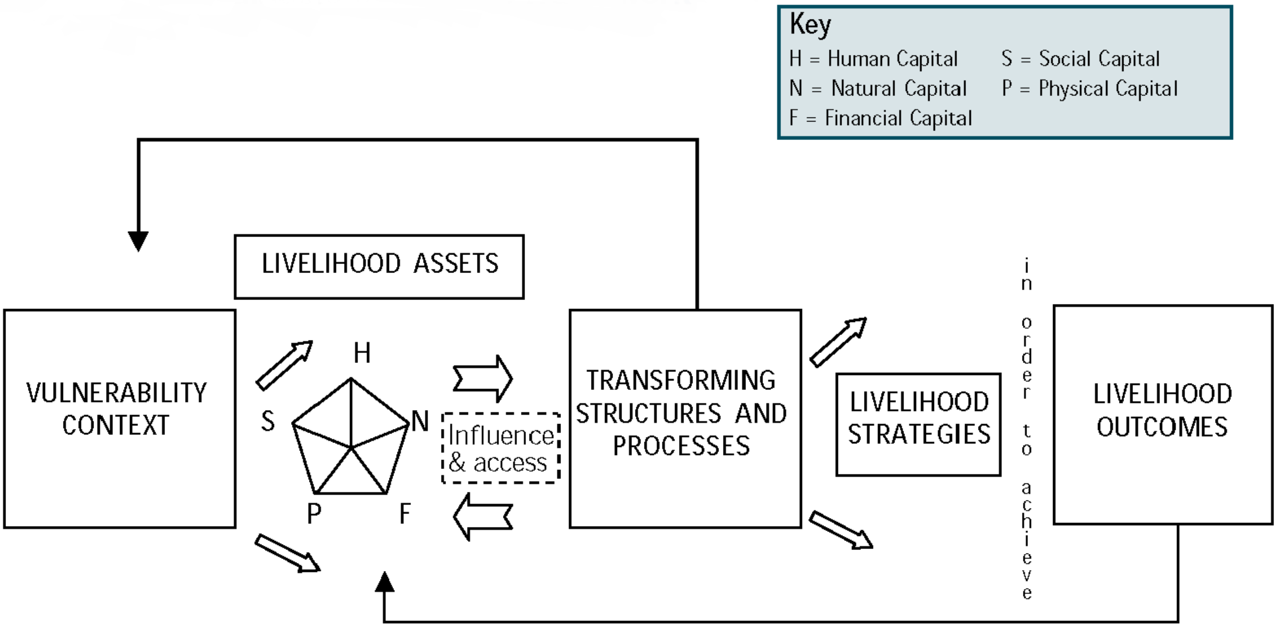


Figure 2. 11: The Sustainable Livelihood Framework

Source: Scoones (1998) and DFID (2002).

The vulnerability context as defined by the framework frames the external environment in which households and farms exist. People's livelihoods are fundamentally affected by critical trends as well as by shocks and seasonality over which they have limited or no control (Niehof, 2004; Jessup-Varnum, 2018). Trends such as changes in population size, trends in natural or human resources, national or international policies, changing trends in governance, growth or replacement of technological trends are significant changes that influence livelihood decisions (Tao and Wall, 2009). Trends can be positive, for example, economic indicators can move in a favourable direction, diseases can be eradicated.

Shocks are sudden, happening over short periods such as natural disasters for example extreme weather events, economic shocks, crop or livestock health shocks, human health shocks or accidents, conflicts, and earthquakes (Jessup-Varnum, 2018; Woyesa and Kumar, 2021). They can destroy assets result in loss of crops and human lives. Seasonality is a periodic change such as fall of prices in a certain season. Seasonality can affect production and employment opportunities for labourers, for example, seasonality of rainfall determines livelihood strategies of subsistence farmers in dry periods (Feuerbacher and Grethe, 2018).

The use of the term "vulnerability context" draws attention to the fact that this complex of influences is directly or indirectly responsible for many of the hardships faced by the poor and vulnerable people in the world. If the trend moves in a positive direction, some people can gain from it, but some are unable to benefit as they lack assets and strong institutions working in their favour (Feuerbacher and Grethe, 2018). For example, if the demand for citrus products in the world market increases, the marginal citrus farmers cannot gain from it as they do not have the necessary resources to market on a large scale. The vulnerability context can be changed by modifying institutions and policies (Carney, 1999; DFID, 2000). For example, increasing people's access to appropriate financial services (insurance) is one way of reducing shocks. Compensation for crop losses by the government helps reduce the severity of shock.

The livelihood approach seeks to gain an accurate and realistic understanding of people's strengths (assets or capital endowments) and how they attempt to convert these into positive livelihood outcomes (Carney, 1999). The people need a range of assets to achieve positive livelihood outcomes (Ncube, 2012). Rural poor individuals' access to any given category of assets tends to be extremely limited. It is seen that people find ways of nurturing and combining the assets they do have in ingenious ways to ensure survival. The asset pentagon is a contribution of the framework. It lies at the core of the livelihoods framework and depicts important inter-relationships between the various assets. Poverty studies have shown that people's ability to escape from poverty is critically dependent upon their access to assets.

2.11 The Livelihood of Citrus Farmers and the Sustainable Livelihood Framework

Citrus production is gaining popularity among farmers due to good economic prospects (Chiphang, 2018). Citrus production is the major source of livelihood in Mopani district for most rural people, who need considerable assets or capital for it to be considered sustainable. Although citrus is not a major fruit and widely produced due to climate, soil conditions, expanding market and export potential, there is a sharp rise in the production of commercial citrus (Liebenberg, 2013; Dlikilili, 2018; Genis, 2018). Livelihood sustainability is an evolving issue especially in the developing economies given the increasing level of poverty, hunger, starvation, economic backwardness, and poor agricultural system prevalent in the region (Ashley, 2000; Turton, 2000; Nicol, 2000; Udoh *et al.,* 2017).

Homestead cultivation, community cultivation and commercial production could be an important contributor in the total citrus production (Genis, 2015). Consequently, it could be a potential source of livelihood for many rural poor people (Simbi and Aliber, 2000; Du Toit and Ally, 2003; Glenn, 2012; Theron, 2012; Visser and Ferrer, 2015). For example, previous studies on small-scale agriculture show a positive impact on the improvement of the livelihood of rural poor farmers. Sarker *et al.* (2017) shows how small entrepreneurs in the agricultural sector can achieve sustainable livelihood through access to a range of livelihood assets. Kabir *et al.* (2012) found a positive significant relationship between small agriculture enterprises with an improvement of livelihood. Salehin *et al.* (2009) showed a significant increase in annual income, food consumption expenditure, housing environment and family status of the farmers due to the adoption of new agricultural technologies.

According to Kabir *et al.* (2016) citrus production improves the livelihoods of farmers in terms of access to land, social networks, health, education, income, decision -making ability and saving patterns. The occupation of the household head is an important socio-economic indicator to measure livelihood status (Sarker, 2016; Sarker *et al.,* 2017; Sarker *et al.,* 2020). Sarker *et al.* (2017) noted a significant increase in income, household assets and other livelihood components due to the adoption of modern agricultural technology in Bangladesh. According to Kabir *et al.* (2016) citrus production improves the living conditions of the poor and their household status.

Citrus production is one of the most significant impact of the conversion of uncultivated land into productive citrus orchards, consequently adding an unemployed labour force into the productive wheel (Kabir *et al.,* 2012; Kabir *et al.,* 2016; Genis, 2018). Most rural people who are engaged in citrus production are landless, day labour and unemployed, hence are considered as marginal population. The involvement of the marginal farmers in citrus production brings fortune to the people (Bhorat *et al.,* 2014; Bhorat *et al.,* 2016). A study by Kabir *et al.* (2016) suggested that before citrus production, people of Kathalia in Bangladesh suffered in several ways. They lived in poor conditions, but due to the involvement in citrus production, the annual income of the households has increased in countless ways. Their yearly income reached up to 50 000 to 60 000 takas from one-acre citrus field, deducting all types of production costs.

Kabir *et al.* (2016) explained every component of the sustainable livelihood framework to determine whether lemon farmers have achieved sustainability in their livelihood. The natural capital consists of resource stocks such as water, soil, fertilisers, and genetic resources. That is used to support the livelihood activities of citrus farmers and labourers. Natural assets (access to lemon land) in the study area showed limited access to natural assets like forest land and public water bodies. When landless people got access to land by registering under the government department, they were instantly entitled to the same (Kabir *et al.,* 2016; Sarker *et al.,* 2017). They are currently using this land property for their livelihood to make better income and increase employment opportunities.

Within the context of farm livelihood, physical capital comprises the basic infrastructures and producer goods needed to support livelihoods (Selvaraju *et al.,* 2006). They are items of economic, commercial or exchange value that has a tangible or material existence. For instance, farm's income, farm tools and equipment, farm inventory and other properties owned by the farmers. Physical assets include improved irrigation systems, farm buildings and housing. Since rural people are engaged in citrus production, their labour force has given them the opportunity of earning and thus helping them to meet their basic needs (Sarker *et al.,* 2017). Most citrus growers are now self-employed and have improved housing, sanitation, and better physical assets.

Social capital in the context of sustainable livelihood means the social resources upon which people built or form in pursuit of their livelihood objectives. These are developed through networks and connectedness, membership of more formalized groups and relationship of trust, reciprocity, and exchange. Social assets (social networks), rural farmers can be connected to multiple networks and stakeholders due to their involvement in citrus production (Kabir *et al.,* 2016; Sarker *et al.,* 2017). Citrus cultivation links citrus businessperson, intermediary and local market (USDA-FAS, 2016). Thus, they are incorporated into the market and supply chain. Yet, these social networks are still extremely limited within the local areas.

Human capital represents the skills, knowledge, experience and ability of human labour or other intangible assets of individuals that can be used to create economic value for the individuals, families, employers, communities, society, and the nation. At a farm level, human capital represents the amount and quality of farm labour available, this varies according to farm size, skill level, leadership potential, health status, among others. Citrus growers today are more skilled than before due to experience in the field of citrus production (Kabir *et al.,* 2012; Kabir *et al.,* 2016; Sarker *et al.,* 2017). Their knowledge and awareness have also increased. They are now getting better education, healthcare, and other livelihood facilities.

Another important form of sustainable capital is financial capital. This refers to the financial resources such as cash, liquid assets, pension, and remittances (Scoones, 1998; Morse *et al.,* 2009). Financial capital denotes resources that people use to achieve their livelihood objectives. Some of these capitals are straight forward for example land, buildings, machinery, cash, while some are less obvious such as social networks, knowledge, and good health. All are important although clearly the balance in the used of these capitals' changes from one citrus farm to another over time.

Once the balance has been identified using capital pentagon, it will be easier to assess the contribution of each capital and explore the vulnerability context (trend, shocks, and stresses) in which they exist at the citrus farms. Each of the capital assets discussed previously has an index or indicator that reveals its accessibility, availability and other vital information that could be used to access individual farms. It is also worth to note, that a single citrus farm asset such as land can generate multiple or stream of benefits. For example, if a citrus farmer has secure access to land, they are likely to be well endowed with financial assets as they can use the land for productive purposes and to secure loans (Chambers, 1995; DFID, 2000).

Literature has also provided evidence that farm capitals show varying degrees of resilience with respect to shock or stress intensity (Odero 2006). For instance, some assets do not change much over time while others such as cash and social network can be volatile and depend on human movement patterns. Also, climate conditions such as drought, impact natural capital and in turn reduce yields but may have negligible effect on other capitals. In the longer term, severe drought could impact a wide range of capital including social and human capital while having minor impact on others (Scoones, 1998). Financial assets (capital or income credit), citrus production is a year-round enterprise that requires workforce throughout the year. Thus, rural people get regular earning from citrus production as well as by selling labour in the same enterprise. The financial assets of citrus producers have been increasing for the past decade.

2.12 Sustainable Livelihood in Rural Areas

It has been observed that despite the abundant natural, physical, and human resources that South Africa is endowed with, there is still a high incidence of poverty and poor livelihood potential especially in the rural areas (Liebenberg, 2013; Nwagwu, 2014). The deteriorating physical assets in the rural areas have aggravated the incidence of poverty and stamped growth in the human assets as well as the social assets (Ziervogel and Calder, 2003; Paudel Khatiwada *et al.,* 2017). The major source of livelihood activity of the rural dwellers in South Africa is agriculture. However, evidence abounds that small-scale agriculture, practiced by most of these rural dwellers, lacks sufficient incentives needed for optimal household livelihood sustainability.

According to Liebenberg (2013) South Africa’s agricultural sector is faced with several challenges such as poor land ownership structure, low level of irrigation development, limited adoption of research findings, excessive cost of farm inputs, poor access to credit, inefficient fertilizer procurement and distribution, inadequate storage facilities and poor access to markets have all combined to keep agricultural productivity low with high postharvest losses and waste (Akpan *et al.,* 2016). In Mopani District Municipality, the picture of the agricultural sector is not far different from the national scenario. For instance, most of the population still reside in rural areas and they rely on citrus production for their livelihood sustenance. The poor land tenure system leads to fragmented and marginal farm holdings while those residing along the water bodies engage in highly contracted artisanal fishing and crop irrigation (Pimbert *et al.,* 2001; Udoh *et al.,* 2017). However, for most rural dwellers, income earned from these occupations does not meet the needs of the household, hence households are often faced with the option of occupation diversification.

Literature has shown that most rural farmers in South Africa are poor, implying that they have a poor asset base that cannot sustain them (Barrientos and Visser, 2013; Akpan *et al.,* 2016). Henceforth given a strong correlation between poverty and assets owned. Therefore, there is an overwhelming need to assess the asset profile of these rural farmers. Household livelihood options are influenced by access to a bundle of assets owned by it. According to Chambers and Conway (1992), these enable the household to respond to shocks such as changes in climate and weather, poverty, price fluctuations, flood, and drought, among others.

Due to changes in climate, price or risk, poverty, and inflation, some households are unable to live sustainably. However, Haddad *et al.* (1997), found out that a household can only survive changes based on the assets owned by them and how they can utilise these assets to cope with and enable them to have a sustainable living. A household with a higher level of education has a higher potential to adopt sustainable livelihood strategies associated with better food security (Savath *et al.,* 2014).

As noted by Odero (2006), the five principal assets mentioned previously are important to a sustainable livelihood in rural farming households. He presented these assets in the form of a pentagon and asserted that their balance changes from household to household and over time. Following this scholarly work, it is observed that, once these assets have been identified and assessed in terms of their contributions to household livelihood sustainability and presented in a pentagonal graph, it is quite easy to analyse the household vulnerability (for example, shock, trend, and stresses) to any category of asset with respect to household sustainable livelihood (Odero, 2006; Zoomers, 2014). In this manner, as one of the ways to ascertain the sustainability of farming household livelihoods, it is important to access the availability of these principal assets in a bit to proffer solutions during shocks or stresses.

When responding to shocks, as well as during life transformations, households deploy their assets in different combinations to try to meet livelihood goals (Moench, 2005; Bharwani *et al*., 2008; Liu *et al.,* 2018). It implies that the knowledge of the asset profile of a group can help government and donor agents to decide on the magnitude of intervention or help during or after a major disaster. Therefore, an accurate and realistic understanding of people's assets is crucial to be able to analyse how they endeavour to convert their assets into positive livelihood outcomes (Bebbington, 1999; Pimbert *et al.,* 2001). Hence, farmers being the most vulnerable group to shocks and the persistence of these shocks in the rural areas as well as the need to generate reliable data base for the future and interventions in times of shocks (Udoh *et al.,* 2017).

2.13 Employment in Citrus Production

According to Limpopo Department of Agriculture (LDA, 2012), agriculture in Mopani District Municipality contributes about 3.6% to the local economy. Citrus production in Mopani District Municipality contributes a high percentage of employment, particularly in improving rural farmers' income (DAFF, 2016). Citrus for many years provided more substantial income for farmers and salary for the rural poor who directly and indirectly depend on citrus for their livelihoods (DAFF, 2017). The value of citrus production is in the quality of fruit as large volumes are exported. On-farm value addition and citrus processing facilities can reduce wastage faced by emerging farmers and contribute to income regeneration (DAFF, 2016).

It is estimated that each hectare of citrus results in one on-farm job, meaning that on-farm employment in the citrus industry is 60 000 workers. Further, it is estimated that 40 000 are employed in packhouses, processing plants, transport, and other service sectors (CGA, 2012). The opportunity for growth in employment exists due to the increase of area planted for citrus production over the years. Citrus production also has a strong background and forward linkages that local small-medium micro enterprises (SMMEs) can take advantage of. There are numerous pack houses with cold storage facilities in the Limpopo Province (LDA, 2012). Most of these pack houses belong to commercial citrus farmers. Thus, they can partake in the vertical integration of produce from farm to market. A high number of packhouses are in Mopani District Municipality. The area has citrus processing factories such as Granor Passi, HFP, and Letaba Citrus Processors and produces high volumes of citrus. These factories combine other fruits such as guava, mango, and peaches in their manufacturing to ensure in and out of season production.

According to Ateeq-Ur-Rehman *et al.* (2018), agriculture is a major source of employment for poor people and farmers as it accounts for around 41% of the labour force and 67.5% of the population that is living in rural areas and is directly and indirectly linked with agriculture to sustain their livelihood and the country's economy. Rural livelihoods depend on income from producing agricultural commodities and raising livestock(Ateeq-Ur-Rehman *et al.,* 2018).

2.14 Effects of Climate Variability on Citrus Production and Livelihoods

Climate variability presents many pervasive strains that individuals and communities in rural areas must cope with (DAFF, 2016; Dev and Venkatanarayana, 2011; Ziervogel and Calder, 2003). Most of the rural poor in Mopani District Municipality heavily depend on citrus production for their food needs and livelihood (DAFF, 2016; CGA, 2016). Rural livelihoods are subjected to multiple shock and stresses that can increase household vulnerability. While citrus production plays a vital role in the lives of rural poor in Mopani, their livelihoods typically consist of on-farm and off-farm activities. Many seek paid employment and off-farm income sources to increase their livelihood support base (Scoones, 1998; Ellis, 2000). Although most rural families maintain some involvement in citrus production, the importance of alternative livelihood strategies is growing due to increased variability in weather (Turner *et al.,* 2001).

Climate variability is already evident in several ways. According to Maponya and Mpandeli (2013) consistent warming trends, more frequent and intense extreme weather, and climate events such as drought, floods and heatwaves have been observed across Limpopo Province, including Mopani district. Droughts threaten income and salary with a variety of immediate effects such as reduced citrus productivity and citrus failure, which will serve as assets to the future income (Barrett *et al.,* 2001). Livelihood security depends upon adequate, sustainable access to resources and income so that one can meet essential needs for crop producers, including citrus farmers and workers. Climate changes do not only interrupt the livelihoods of rural people, but also reduce the national development of developing countries around the world (Barrett *et al.,* 2001). The heavy rainfall patterns during citrus flowering and maturity destroy citrus fruit quality and pose the worst impact on livelihoods (CGA, 2016). Changes in climate affect different types of capital assets such as financial, human, natural, social, and physical capitals upon which farm households draw to build their livelihoods (Akudugu *et al.,* 2012).

2.15 Climate Variability Impacts on Food Security

Climate variability is projected to severely compromise crop production, food insecurity and exacerbate poverty in many sub-regions of Africa. Niasse *et al.* (2004) stated that Africa is considered the most vulnerable region worldwide in terms of climate variability. The physical and socio-economic characteristics of Africa such as the fragility of its economy predispose it to be disproportionately affected by adverse effects of weather variability. Food and Agriculture Organisation (FAO, 2009) emphasised that African countries will be hit hardest in terms of future food security. According to Midgley (2007) by 2080 variations in climate would render Africa and certain parts of Asia the most food insecure, with about 75% of the world's poor desperate for food. Due to ongoing climate variability, extreme climate and weather events in Africa are likely to become of higher intensity and more frequent, this situation is expected to worsen. Countries in Africa are likely to continue dominating the food security risk index for some time and businesses with operations and supply chains in Africa should plan for ongoing uncertainty around food and all its related problems.

Climate variability affects southern Africa crop production through the availability, access, and utilisation of food (Ziervogel *et al.,* 2008). Further, the changing climate patterns and extreme events such as droughts and floods will have a negative consequence for crop production in Southern Africa (Ziervogel *et al.,* 2008). As a result, people will have less access to food resulting in food insecurity. Lobell *et al.* (2008) emphasised that increasing temperatures and declining rainfall over Southern Africa are likely to reduce yields for primary crops such as maize and wheat in the next two decades. These changes will have a substantial impact on regional food security. This food crisis in Southern Africa has been caused by low and unseasonal rainfall in Malawi, Zambia, and Zimbabwe.

Some regions in Southern Africa, crop failure has been as high as 90% and maize prices have risen by up to 400%. Weather variability has not only impinged on the cultivation of crops, but the fishing industry is also being threatened as well (Ziervogel *et al.,* 2008). Fish stocks in large lakes across Southern Africa have declined not only because of overfishing but because of declining water levels due to evaporation because of rising temperatures.

Vogel *et al.* (2010) emphasised that there is chronic and persistent food insecurity in Southern Africa. The 2002/2003 drought in Southern Africa contributed to food shortages for an estimated 14 million individuals. This was because of below normal rainfall for two to three agricultural seasons which had an impact in many parts of Southern Africa. The mentioned crisis triggered the United Nations to issue an appeal for US$611 million to address the crisis especially in Lesotho, Malawi, Mozambique, Swaziland, Zambia, and Zimbabwe (Vogel *et al.*, 2010).

According to the Department of Environmental Affairs and Tourism (DEAT, 2004), South Africa's staple food could drop by as much as 30% in the next decades as weather variability brings more intense droughts. The rural areas of KwaZulu-Natal province on the east coast are the largest agricultural contributor to South Africa's gross domestic product (GDP). Small-scale farmers who depend on rain-fed agriculture are found to be among the least resistant to climate variability. Farmers in Limpopo, Eastern Cape and Northwest provinces are also vulnerable to the changing climate patterns (Gbetibouo *et al.,* 2010). Farmers in these provinces have less resilience because the areas they reside in are underdeveloped with no means to access drought-tolerant crop varieties. Further, Molewa (2011)notes that climate variability is threatening food security and increasing food prices. Climate variability effects are continuing to impact negatively on our food security and the recent price increases are mainly because of variations in climate patterns.

Molope (2006) emphasised that food security in South Africa is particularly vulnerable to climate and weather as agricultural production depends on climatic conditions and on the quality of the wet season. The food security threat posed by climate variability is one of the greatest challenges facing South Africa (Van den Heever *et al.,* 2011). Extreme events such as severe droughts, floods and dreadful diseases are obstacles to food security. According to Van den Heever *et al.* (2011) the agricultural sector is facing impacts that include reductions in the amount of land suitable for both arable and pastoral agriculture, shortening of the growing season and a decrease in yields particularly along the margins of semi-arid and arid areas. This will compromise food insecurity badly and climate variability impacts will further reduce the sector's contribution to the gross domestic product, which has already been declining over the years. According to Mastrorillo *et al.* (2016) impact of climate variability on the agricultural sector does not only have implications for the national and household food security but the economy as well.

Limpopo province constitutes 18% of the 40% (approximately 16 million) people of South Africa living in outright poverty or continuing vulnerability to being poor and food shortages (Nesamvuni, 2014). Ncube *et al.* (2009) opined that farmers in Limpopo province will experience rain more than a month later within the next three decades. The province is also experiencing fewer cold days and more hot days because of weather variability. Since 2007, erratic and unpredictable rainfall has led to increased food shortages in some parts of the province due to droughts (Musetha, 2016). It is also estimated that maize yields in Limpopo province will decrease by about 9% between now and 2045

(Manyatsi *et al.,* 2010). This predicted decline will pose a major problem of food insecurity in Southern Africa especially the main staple food.

2.16 Farmers Adaptive Measures to Climate Variability in Citrus Production

Mopani District Municipality is one of the poorest districts in Limpopo province, characterised by poverty, high unemployment rate and lack of access to a range of resources that frustrate most individual’s ability to secure their livelihoods. It is assumed that farmers in Mopani district are using different adaptation strategies, coping and mitigation measures to increase their crop yields. Literature studies show that climate variability mitigation measures vary from region to region due to agro-ecological zones and the harshness of the effects of climate variability. It has been noted that climate variability is fast pushing the most marginalized and poorest communities beyond their capacity to respond to the changing climate. Farmers in Mopani are aware that the area is getting warmer and drier with changes in the timing of rains, increased frequency of droughts, observed trends if precipitation and temperature.

2.17 Chapter Summary

This chapter introduced empirical and theoretical studies relating to climate variability, citrus production, adaptation, and mitigation measures to the changing climate patterns. Climate variability is fast pushing the poorest and marginalized communities beyond their capacity to respond. Climate variability is a cutting issue, it affects and threatens several sectors including agriculture. Crop yields and prices are affected by climate variability thus resulting in food insecurity. The negative impacts of climate variability on crop yields are pronounced in South Africa, as crop production accounts for a large share of gross domestic product, exporting and employment.

Reductions in citrus productivity have been attributed to low rainfall events and more drought. Rainfall patterns and temperature trends are important in understanding extreme climate and weather events. However, rainfall projections are uncertain, with a range of studies using different models producing different results, changes in rainfall patterns are hard to detect due to its greater variability. Different adaptation strategies such as irrigation and integration of crops can limit the adverse effects of rainfall variability. Climate variability will have a negative impact on citrus farmers’ income because it affects citrus production through the shortening of the growing season and a decrease in yields. Such a situation compromises citrus productivity and further reduces the industry’s contribution to the gross domestic product, which has already been declining over the years.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the tools employed to achieve the objectives of this study. Quantitative and qualitative research methods were utilised for the collection and presentation of data. Secondary data was obtained from government records such as South African Weather Service, Department of Agriculture and Rural Development, and records from farm owners. Livelihood activities and indicators were obtained from the survey of participants (citrus farmers, citrus workers, and citrus vendors). The research design, data needed and collection methods, sampling, reliability and validity, ethical consideration, data analysis methods, data presentation methods and limitations of the study are also discussed and justified.

3.2 Research Design

The research is based on a correlational research design, using Mopani District Municipality as a case study. However, this research focuses on two local municipalities in Mopani District Municipality namely the Greater Maruleng and Greater Tzaneen due to extensive commercial citrus farming in the district. The study employed a mixed method approach which is both quantitative and qualitative research. The mixed method approach sought to ensure maximum data capturing which might have been compromised by using a single method (Kumar, 2018). Therefore, both methods were integrated to infer reliability of data, add value to the theoretical debate and to overcome bias inherent in single method designs.

Secondary data of monthly rainfall, monthly temperature, annual citrus production, and citrus market chain statistics were collected. The study needed vital rainfall, temperature, citrus production data and citrus market chain statistics from relevant government departments and farm records from 1987 to 2017. Primary data was collected using semi-structured questionnaires for citrus farmers, citrus workers, and citrus vendors to assess the livelihood statuses, activities, and adaptation strategies to climate change. The study investigates the effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality.

3.3 Sampling Procedure

- **Sampling of Citrus Farms**

The study targeted citrus farms in Maruleng (Hoedspruit) and Greater Tzaneen (Letsitele) local municipalities. The two local municipalities were selected because large-scale farmers in the areas have been experiencing extreme climate risk and high climate variability (LDA, 2012). No sampling was done for citrus farms. This was because the exact population of citrus farms in Mopani District Municipality is unknown. The Limpopo Department of Agriculture and Rural Development and the Mopani District Municipality Department of Agriculture and Rural Development were unable to provide a list of citrus farms in the area, the departments also did not have citrus farm records in their crop production database. Therefore, the study was limited to five citrus farms that were associated with the Mopani Department of Agriculture and Rural Development. These were the farms that were available and willing to participate in the study. The participants were individual or a group of large-scale farmers, practicing citrus production with more than 500 citrus trees, producing for commercial purposes and the surplus for local sales, with a prominent level of dependency on rainfall and irrigation for production and land size ranging from 40 to 250 hectares.

- **Sampling of Citrus Workers**

The survey for citrus workers was determined by an online sample size calculator (https://www.checkmarket.com/sample-size-calculator/). The total population size of citrus workers was 597, at 95% confidence level, 5% margin of error (confidence interval) and at an estimated response rate of 80%. The sample size required to administer the questionnaire was 234. The proportionate stratified random sampling method was used to calculate the number of citrus workers in which the questionnaire was administered. The sample size was then proportionally apportioned between the two local municipalities. Table 3.1 shows the proportions of citrus workers per farm that were interviewed.

Table 3. 1: Proportion of Citrus Workers to Administer the Questionnaire

Local Municipality	Farms found in the MDM	Total citrus farm workers	Questionnaire distribution per farm
Greater Tzaneen	Farm 1	85	33
	Farm 2	94	37
	Farm 3	160	63
Maruleng	Farm 4	108	42
	Farm 5	150	59
Total	5	597	234

- **Sampling of Citrus Vendors**

Purposive sampling was used to select citrus vendors. Purposive sampling is a non-probability type of sampling wherein the samples are selected out of convenience (Acharya *et al.,* 2013). It is applicable under both quantitative and qualitative research approaches (Tongco, 2007). Samples are chosen based on the qualities they possess in relation to the matter under discussion and there is no limit on the number of participants (Palinkas *et al.,* 2015; Tongco, 2007). However, after conducting a series of purposive samples under different sample sizes, Seidler (1974) postulated that at least five participants are required to make the data reliable. Purposive sampling was chosen as it is straight forward and there is no need to sample population, making it suitable in the selection of citrus vendors.

The sampled citrus vendors were from Maruleng and Greater Tzaneen local municipalities. The purposively selected cluster for citrus vendors were made as to be close to 10 km radius from the citrus farms. This was done because most citrus vendors were found within the 10 km radius and the population of citrus vendors in the area is unknown. Twenty-five questionnaires for citrus vendors were distributed to the respondents who were willing to participate, available to communicate information effectively, have knowledge and good understanding of the phenomenon of interest. These were people who purchase their citrus produce directly from the farms.

The justification for choosing a purposive sampling technique is that it allows the researcher to select areas that suit the study's objectives and address the research problem. Further, high dispersion of samples may lead to high costs (accommodation, research assistants, transport, coding, data entry and time) of the research. Therefore, selecting the best sample size involves balancing these factors. Purposive sampling is one of the most cost effective and time effective sampling methods available. It can be the only appropriate method available when there is only a limited number of primary data sources that can contribute to the study. The different approaches within a purposive sample makes it a versatile technique that can be tailored to maximise the effectiveness of the study.

3.4 Data Needed and Data Collection Methods

The study made use of both primary and secondary data collected to address the objectives of this study as detailed here under.

3.4.1 Climate Data

Monthly rainfall and temperature data were obtained from the South African Weather Service to analyse the effects of climate variability on citrus production. Rainfall and temperature data for the period 1987 to 2017 was used to assess climatic trends in Mopani District Municipality. This was done using the Mann-Kendall trend analysis. The Mann-Kendall trend analysis assesses whether rainfall and temperature are decreasing or increasing during the time under review.

Annual rainfall data for the period 1987 to 2017 was used to calculate the Standardized Precipitation Index (SPI), which measures precipitation anomalies of the study area. The SPI is the most used indicator worldwide for detecting and characterising meteorological droughts. The SPI and temperature were also used as indicators of climate variability and to describe the climate characteristics of Mopani District Municipality. Due to some missing rainfall data, temperature data and weather stations name changes, the study used data from four weather stations, namely Tzaneen-Grenshoek (data from 1987 to 2017), Hoedspruit Air Force Base (data from 1994 to 2017), Tzaneen-Westafalia Estate (data from 2007 to 2017) and Letsitele-La Gratitude (data from 2011 to 2017). The four weather stations have climate data that at least covers the period under review.

3.4.2 Citrus Production Data

Annual citrus production data, citrus farm net revenue and citrus market chain statistics were obtained from irrigated and rain-fed citrus farmers', and the Department of Agriculture and Rural Development. The Man-Kendall trend analysis was used to assess the monotonic trends of citrus production over the study period. Citrus production data was regressed against SPI and temperature to determine the relationship between climate variability and citrus production. Citrus farm net revenue was regressed against citrus production for the period 1987 to 2017 to determine the relationship between citrus production and farm income at district level. Due to the confidentiality of production data, farm names remained confidential. Each of the farms was identified by a number.

3.4.3 Semi-Structured Questionnaires

The sustainable livelihood framework approach indicators, namely, financial capital, social capital, human capital, physical capital, and natural capital were used as a guide in designing questionnaires (DFID, 2000). These indicators were explored together with issues relating to climate variability, citrus production, and livelihood conditions in the study area. The five segment questionnaires were used to assess the appropriateness of the project design, efficiency, and effectiveness. The sections of the questionnaires dealt with financial assets, social assets, human assets, physical assets, and natural assets. The questionnaires addressed the objectives; to establish the influence of citrus production on farmers' income and rural livelihood and to evaluate farmer's adaptive measures to climate variability on citrus production farm income and livelihood. The designed questionnaires were self-administered to citrus workers (234), citrus vendors (25) and citrus farmers' (5) that are knowledgeable about the specific subjects.

The questionnaire was opted for because it is cost effective and allows a large amount of information to be captured from participants in a short period. Self-administered questionnaires gave the research many advantages as the questions were explained when it was necessary in case the participants failed to understand the questions and made sure that the questions were completed. The other advantage was that information was gathered even if the participants were illiterate. The disadvantages were that the researcher travelled to the participants, and this was expensive since the participants were sparsely distributed geographically.

- **The First Questionnaire**

The first questionnaire was aimed at citrus farmers' (Appendix A). The questionnaire aimed to obtain data on farmer's adaptive measures to climate variability on citrus production farm income and livelihood in Mopani District Municipality. The questionnaire was designed to include open-ended and closed-ended questions. The themes in this questionnaire include land characteristics and climate variability information, citrus production factors, livelihood variables, economic viability, and marketing information. The questions asked include farmland size, income, factors influencing citrus farming, insurance against climate variability, adjustments to farming due to long-term effects of climate change and famers adaptation to climate variability, among others.

- **The Second Questionnaire**

The second questionnaire was aimed at citrus farm workers (Appendix B). The questionnaire aimed to obtain data on the influence of climate variability and citrus production on citrus workers livelihoods. The themes in this questionnaire include socio-economic information, citrus production and climate variability factors, and livelihood variables. The questions asked include employment contract type, income, remittances, climate variability observations and perceptions, and access to basic necessities such as food, security, clothing, electricity, transport, security, policies, credits, and medical insurance, among others.

- **The Third Questionnaire**

The third questionnaire was aimed at citrus vendors (Appendix C). The questionnaire aimed to obtain data on the influence of climate variability and citrus production on citrus vendors livelihoods. The themes in this questionnaire include socio-economic information, citrus production and climate variability factors, and livelihood variables. The questions asked include number of years in citrus vending, income, standard of living, climate variability observations and perceptions, access to community infrastructures such as water supply, electricity, transport, market facilities, storage facilities, education facilities, health facilities, credit, and social security, among others.

The participants in this study were selected on basis of being available, willing to participate and provided useful information, and dependence on citrus production for their livelihood. A written informed consent detailing the aim of the study and the potential benefits to the participants was sought prior to commencement. The participants were assured that their privacy and confidentiality will be protected.

3.5 Validity and Reliability

The validity and reliability were very crucial in the study. A pilot study was done before the actual data collection process. The aim of the pilot study was to verify whether the questions on the questionnaires were clear and that there was not any ambiguity. Questionnaires were physically administered to the intended respondents. The questionnaires were written and interpreted in a language that the respondents understand. The research assistant was trained to understand the questions and to probe for additional information where necessary. Citrus production data and climate statistics was acquired from the relevant sources.

3.6 Ethical Consideration

Throughout the study, the researcher conformed to ethical issues. The research proposal was successfully presented to the University Higher Degrees Committee and passed. The University Research Ethics Committee also cleared the research before data collection and permission was sought from gatekeepers in this case (Appendix F). To gain entry of the study area, permission to conduct this research was sought from the citrus farm owners (Appendix G), the provincial Department of Agriculture and Rural Development (Appendix H) and the district officers in Mopani District Municipality to avoid violation of privacy and as a way of observing good ethical procedures. Permission sought allowed the researcher to conduct the research in all relevant areas.

Information supplied by the participant farms and government departments that is not for public consumption was treated with utmost confidentiality and the data collected was used exclusively for the main purpose of this research. The purpose of the study was explained to the participants to encourage them to give their full cooperation. Consent forms (Appendix E) were administered and fully explained to the participants. The participants were free to withdraw from participation when they feel the need to do so. The study targeted farms in Greater Maruleng and Greater Tzaneen local municipalities.

3.7 Data Analysis Methods

3.7.1 Standardized Precipitation Index

Annual rainfall data from 1987 to 2017 was analysed to classify anomalously wet and dry conditions of Mopani District Municipality using the Standardized Precipitation Index (SPI). Trends of wet and dry years decided by SPI were detected by the trend analysis technique. The SPI provided an indication of rainfall conditions based on the historical distribution of rainfall in Mopani District Municipality. Microsoft Excel 2016 software was used to analyse the SPI.

The Standardized Precipitation Index was developed by McKee *et al.* (1993) to monitor the occurrence of droughts and to quantify the precipitation deficit from rainfall data and is determined at different time scales (1, 3, 6, 12, 24, 48 months etc) (Hayes *et al.,* 1999; Paltineanu, 2008; Potop, 2011). The time scales reflect drought's impact on the availability of different water resources. The

SPI measures meteorological events and is normalised to identify both dry and wet periods (Bordi *et al.*, 2009) for any location with a long-term precipitation record, typically 30 years. Although SPI is more suitable for monitoring meteorological and hydrological droughts than agricultural droughts, its flexibility in selecting time periods that correspond with growing seasons and crop times makes it useful to inform on some aspects of agricultural droughts (White and Walcott, 2009).

Drought is characterised by rainfall event with low probability while flood event is indicated by high probability on the transformed cumulative probability function (Bordi and Sutera, 2007; Moreira *et al.,* 2012; Jayanthi *et al.,* 2013). The SPI is the number of standard deviations that the observed value would deviate from the long-term mean. Drought is represented by a value less than zero. Greater negative numbers indicate severe drought. The SPI is a tool developed for the identification, and monitoring of the severity and persistence, of drought derived from the long-term historical rainfall records in each place (McKee *et al.,* 1993). The SPI is interpreted as shown in Table 3.2.

The following equation by McKee *et al.* (1993) was used to calculate the Standardized Precipitation Index (SPI):

$$SPI = \frac{x_i - \bar{x}}{s}$$

Where

SPI= Standardized precipitation index

x_i= Annual rainfall amount

$\bar{x}$= Mean rainfall

s = Standard deviation of rainfall

(Calculated from time series of annual values)

Table 3. 2: The Standardized Precipitation Index Category based on the initial classification of SPI values

Category	SPI	Index Value (SPI)
Extremely wet	Non-drought	2.00 and above
Severely wet		1.50 to 1.99
Moderately wet		1.00 to 1.49
Near normal		-0.99 to 0.99
Moderately dry	Drought	-1.00 to -1.49
Severely dry		-1.50 to -1.99
Extremely dry		-2.00 and less

The SPI values greater than median precipitation is denoted by positive values whereas negative values indicate less than median precipitation. A drought event is considered to start when SPI values reach -1.0 and ends when SPI values become positive. The SPI range in the categories; extremely wet (2.00 and above), severely wet (1.50 to 1.99), moderately wet (1.00 to 1.49), near normal (-0.99 to 0.99), moderately dry (-1.00 to -1.49), severely dry (-1.50 to -1.99) and extremely dry conditions (-2.00 and less).

3.7.2 Mann-Kendall Trend Analysis

Annual rainfall, annual minimum, and maximum temperature data for the period 1987 to 2017 was used to analyse climatic trends through the Mann-Kendall test. The Mann-Kendall test was used to statistically assess if there is a monotonic upward or downward trends of annual citrus production over the study period. The trends were consistent and performed at 95% confidence level.

The Mann-Kendall test is a statistical test widely used for analysis in climatological and hydrological time series (Mavromatis and Stathis, 2011). The Mann-Kendall test is a non-parametric test that identifies trends in time series data. The test compares the relative magnitudes of the sample data rather than data values (Gilbert, 1987). The Mann-Kendall test is a statistical procedure performed to evaluate linear and nonlinear relationships between two or more quantitative variables. The trend line, equation, and degree of variation within the Microsoft Excel 2016 function was used to determine the direction, nature, and strength of the trend of variables under investigation. The r-square (r^2) in Mann-Kendall test shows the strength and direction of the trend.

3.7.3 Regression Analysis

Multiple linear regression analysis in Microsoft Office Excel 2016 was used to establish the influence of citrus production on farm income and rural livelihoods in Mopani District Municipality. Citrus production was regressed against climate variables (minimum SPI, maximum SPI, minimum temperature, and maximum temperature) to determine the relationship between climate variability and citrus production for the period 1987 to 2017. The SPI was used as a rainfall variability indicator.

Multiple linear regression is a statistical procedure that is used to explain the relationship between one continuous dependent variable and two or more independent variables (Tranmer and Elliot, 2008). Multiple linear regression was used for this study because it provides the direction, strength, and significance of the relationship between the variables which are being predicted. Multiple linear regression analysis allows the examination of the relationship between multiple variables in a quantifiable manner (Uyanık and Güler, 2013; Olive, 2017). This technique is often used where there are multiple explanations (independent variables or co-variates) for an outcome (dependent variable usually denoted by Y).

Simple linear regression analysis is used to model the relationship between one independent variable and one dependent variable (Montgomery *et al.,* 2021). Simple linear regression analysis in

Microsoft Office Excel 2016 was used to establish the relationship between citrus production and farm income at district level. This was done by regressing farm net revenue and citrus production from 1987 to 2017. Farm net revenue was used as a livelihood indicator.

The r-square (r^2) is an important statistic in regression. The r^2 is known as the coefficient of determination. It is the proportion of the variance in the response variable that can be explained by the exploratory variables (Mason and Perreault, 1991). The r^2 statistic determines how well the regression line approximates the real data. R-square is between 0 and 1. Zero percent indicates that the model explains none of the variability of the response data around its mean, an r^2 of 1 indicates that the regression line perfectly fits the data and that the model explains all the variability of the response data around its mean.

The sign of the regression equation indicates whether the variables have a negative (-) or positive (+) relationship. The strength and direction of the relationship is shown by the coefficients. The strength of the relationship is either very strong, strong, very weak, or weak and the direction is either positive or negative. The adjusted r-square (r^2) represents the r-square value adjusted for the number of predictor variables in the model. The value of the adjusted r-square (r^2) is less than the value of the r-square (r^2) and penalises models that use too many predictor variables in the model.

The Significant-F is the *p*-value associated with the overall F statistic. The Significant-F indicates whether or not the regression model is statistically significant (Mason and Perreault, 1991). The individual *p*-values indicates whether or not each explanatory variable is statistically significant. The *p*-value of ≤ 0.05, means the relationship is significant and the *p*-value of ≥ 0.05, then the relationship is insignificant. The *p*-value was used to determine the statistically significance of the relationship between climate variability and citrus production, and the relationship between citrus production and farm net revenue. The coefficients for each of the explanatory variable indicates the average expected change in the responsive variable, assuming the explanatory variable remains constant.

3.7.4 Descriptive Statistics and Chi-Square Test

Descriptive statistics and Chi-Square test in Statistical Package for Social Science (SPSS version 22) were used to establish the influence of citrus production on farmers' income and rural livelihood in Mopani District Municipality. SPSS was used for its bivariate and univariate analysis capabilities. Descriptive statistics uses the data to provide descriptions of the population through numerical calculations and tables or graphs. Descriptive statistics such as the measures of central tendency and measures of dispersion were used to gain better understanding of gathered survey data.

Chi-Square test, Cramer's V, *p*-value, odds ratio, and relative risk were used to test the level of association or correlation between climate variability related variables, citrus production related variables, citrus workers and citrus vendors related variables (livelihood variables). The results established the influence of climate variability and citrus production on citrus workers and citrus vendors livelihoods. Due to a small number of citrus farms participating in the study and to avoid being biased, only descriptive statistics was used to evaluate farmer's adaptive measures to climate variability on citrus production farm income and livelihood in Mopani District Municipality. Tables were used to describe and summarise the results.

The Chi-Square statistic is commonly used for testing the relationship between categorial variables. The null hypothesis of the Chi-Square test is that no relationship exists on the categorial variables in the population (they are independent) (Bolboacă, 2011). The Chi-Square statistic evaluate tests of independence when using a cross-tabulation (bivariate table). Cross-tabulation presents the distributions of two categorical variables simultaneously, with the intersections of the categories of the variables appearing in the cells of the table. The test of the independence assesses whether an association exists between the two variables by comparing the observed pattern of the responses in the cells to the pattern that would be expected if the variables were truly independent of each other. Calculating the Chi-Square statistic and comparing it against a critical value from the Chi-Square distribution allows the researcher to assess whether the observed cell counts are significantly different from the expected cell counts.

The *p*-value was used to determine whether the association between the categorical variables is statistically significant. The *p*-value of ≤ 0.05, means the association is significant and the *p*-value of ≥ 0.05, then the association is insignificant (Montgomery *et al.,* 2021). The Cramer's V is an effect size measurement for Chi-Square test of independence (Akoglu, 2018). The Cramer's V is a number between 0 and 1, it measures the strength of association between two categorial variables. The Cramer's V effect size of ≤ 0.2 indicates a weak association between the variables, however, the association is statistically significant. The Cramer's V effect size of 0.2 < to ≤ 0.6 indicates a moderate association between the variables. The Cramer's V effect size of > 0.6 indicates a strong association between the variables.

The relative risk is the risk of the event in an experimental group relative to that in a control group (Lumley *et al.,* 2006). The odds ratio is the odds of an event in an experimental group relative to that in a control group (Prentice and Farewell, 1986; Pang *et al.,* 2016). A relative risk or odds ratio of 1.00 indicates that the risk is comparable in the two groups. A value greater than 1.00 indicates increased risk, a value lower than 1.00 indicates decreased risk. The 95% confidence intervals and statistical significance accompany values for the relative risk and odds ratio. The relative risk and odds ratio convey useful information about the effect of a risk factor on the categorical outcome of interest.

3.8 Data Presentation

Data was presented according to each specific objective and the method of analysis used. Data was presented in the form of graphs and tables. The SPI calculations were done using Microsoft Office Excel 2016 and the results are shown by worksheets in the form of tables and graphs. Rainfall, temperature, and citrus production trends were analysed using Mann-Kendall trend analysis and the data was presented in the form of graphs. Multiple and simple linear regression analysis against climate variability and citrus production, and citrus production and farm net revenue was done using tables.

Descriptive statistics in SPSS such as frequencies, standard deviations, percentages, mean, cross tabulation and Chi-square tests were used to establish the influence of citrus production on farmers' income and rural livelihood and to evaluate farmer's adaptive measures to climate variability on citrus production farm income. The data was presented in tables and themed narratives. Table 3.3 shows a mixed method approach (The Research Matrix) with objectives, research questions, data needed, data sources, data collection and analysis methods and key deliverables.

3.9 Limitations of the Study

The following are some of the limitations faced by the researcher during data collection:

- The total number of citrus farms in Mopani District Municipality is unknown. Therefore, the study used citrus farms that were available to participate in the study and that were referred by the Mopani Department of Agriculture and Rural Development.
- Some citrus farmers' were not interested in participating in the study indicating that their citrus production and farm net revenue/income were confidential. Some farmers' insisted that the researcher should leave the questionnaires and come another day for collection, but the researcher found some questionnaires unanswered and some even lost.
- Some citrus workers and vendors could not complete the questionnaires because they were old and could not read or write, whereas some did not show any interest in participating even if the researcher were to read for them.

Table 3. 3: The Research Matrix Showing a Mixed Methods Approach

Objectives	Research Questions	Data Needed	Data Sources	Data Collection Method	Data Analysis Method	Key Deliverables
To examine the effects of climate variability on citrus production in Mopani District Municipality for the period 1987 to 2017	What is the influence of climate changes on citrus production?	• Rainfall data (1987-2017) • Temperature data (1987-2017) • Citrus production data (1987-2017)	• South African Weather Service (SAWS) • Farm owners	• Electronic request (SAWS) • Data request from farm owners	• Standardized Precipitation Index (SPI) • Mann-Kendall Trend Analysis • Multiple liner regression analysis	• Precipitation anomalies • Temperature trends • Rainfall trends • Citrus production trends • The relationship between climate variability and citrus production
To establish the influence of citrus production on farmers' income and rural livelihood in Mopani	To what extent does citrus production influence farmer's income and livelihood in Mopani	• Citrus production data (1987-2017) • Farm net revenue (1987-2017) • Citrus market chain statistics	• Farm owners • Department of Agriculture and Rural Development. • Citrus workers and citrus vendors	• Data request from farm owners and the Department of Agriculture and Rural Development • Questionnaires	• Simple linear regression analysis • Descriptive statistics and Chi-Square test	• The relationship between citrus production and farm net income • The influence of climate variability and citrus production on citrus workers livelihoods

District Municipality	District Municipality?	• Demographic factors, socio-economic factors, livelihood factors, climate variability awareness and perceptions				• The influence of climate variability and citrus vendors livelihoods
To evaluate farmer's adaptive measures to climate variability on citrus production farm income and livelihood in Mopani District Municipality	What are farmer's adaptive measures to climate variability on citrus production?	• Citrus production factors, economic viability, and marketing information • Citrus mitigation measures to climate variability	• Farm owners	• Questionnaire	• Descriptive statistics	• Adaptive measures to climate variability on citrus production farm income and livelihood

3.10 Chapter Summary

This chapter illustrated the methodologies that were employed to achieve the objectives and to answer the questions of the study. The study was based on correlational research design and adopted both quantitative and qualitative inquiry approach. The objectives of the study were to examine the effects of climate variability on citrus production in Mopani District Municipality, to establish the influence of citrus production on farmers' income and rural livelihood and to evaluate farmer's adaptive measures to climate variability on citrus production farm income and livelihood.

To achieve that, secondary rainfall and temperature data was obtained from South African Weather Service. Secondary citrus production data, farm net revenue and citrus market chain statistics was obtained from citrus farms and government records. Precipitation anomalies were assessed through the SPI, trend analysis was done through the Mann-Kendall test, the relationships between climate variability and citrus production, and citrus production and farm net revenue were assessed through multiple linear and simple linear regression analysis. Citrus vendors were purposively selected, while farmers' were provided by the Department of Agriculture and Rural Development. Semi-structured questionnaires were administered to citrus farmers', citrus workers, and citrus vendors. The sustainable livelihood framework approach was used as a guide in formulating the questionnaires. Descriptive statistics and Chi-Square test in SPSS were used to establish the influence of citrus production on farmers' income and rural and to evaluate farmer's adaptive measures to climate variability on citrus production farm income and livelihood.

CHAPTER 4: EFFECTS OF CLIMATE VARIABILITY ON CITRUS PRODUCTION

4.1 Introduction

This chapter presents, interprets, and analyses findings on the effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality, South Africa. The aim of the research was to analyse the influence of climate variability on citrus production and rural livelihoods in Mopani District Municipality from 1987 to 2017. This chapter presents the outcomes of the specific objectives, thus, to examine the effects of climate variability on citrus production and to establish the influence of citrus production on farmer's income and rural livelihood. The Standardized Precipitation Index (SPI), Mann-Kendall trend analysis, multiple and simple linear regression analysis were tools employed to analyse the data.

4.2 Annual Precipitation Anomalies of Mopani District Municipality

The annual precipitation anomalies of Mopani District Municipality were analysed using the Standardized Precipitation Index (SPI) from 1987 to 2017. The SPI was determined using Microsoft Excel 2016 for a period of 12 months. Rainfall statistics of Tzaneen-Grenshoek, Hoedspruit Air Force Base, Tzaneen-Westafalia Estate and Letsitele-La Gratitude weather stations were considered. The SPI is commonly used as a meteorological drought indicator as it is solely based on precipitation (Jayanthi *et al.,* 2013). It facilitates comparison of precipitation deficits at multiple time and spatial scales. It is to be noted that reliable SPI data series needs at least 30 years of continuous precipitation records (Svoboda, 2009). The SPI represents precipitation anomalies. The initial classification of annual SPI values is extremely wet, severely wet, moderately wet, near normal, moderate drought, severe drought, or extreme drought.

The SPI values in Table 4.1 and Figure 4.1 indicate rainfall conditions and describe the annual climate characteristics of Tzaneen-Grenshoek Weather Station for 12 months' time scale. The 12 months' time scale avoids intra-annual frequency variations and allows the identification of the main hydrological droughts and dry or wet period (Vicente-Serrano, 2005), that is suitable to describe the long-term drought conditions. Extremely wet conditions were recorded in the years 1987, 1988, 1995, 1996, 1997, 2000, 2001, 2004, 2006, 2011 and 2013 with the maximum SPI reaching above 2.00 and the highest value at 8.93. This indicates that there were heavy precipitation events over the years. The minimum SPI in Tzaneen-Grenshoek Weather Station falls within the near normal category, with SPI values ranging from -0.99 to 0.99. Results indicate that Mopani District Municipality falls within the near normal category with events of extremely wet conditions. Results agree with that of Kumar *et al.* (2016) who analysed the use of SPI index for drought intensity assessment in Andhra Pradesh state, India. The results of the study indicated normal distribution of precipitation, the scatter plots revealed that the cumulative probability distribution of SPI deviates from normal probability in the lower and upper categories.

Pramudya and Onishi (2018) pointed out that SPI analysis contributes in an improvement to characterize unpredictable rainfall and weather anomalies conditions by quantifying severity levels and proclaiming drought start and end. Moreover, SPI as a normalised index can be used to present excess rainfall or wet conditions, in the same way as it is used to present drought or dry conditions. As a result, it is suggested that using SPI as a stand-alone indicator to assess the severity of drought should be interpreted with caution.

Table 4.1: Rainfall Season Classification under SPI 12 and its Categories for Tzaneen-Grenshoek Weather Station from 1987 to 2017

Year	Number of Months	Minimum SPI	Category	Maximum SPI	Category
1987	12	-0,71	Near normal	2,15	Extremely wet
1988	12	-0,66	Near normal	3	Extremely wet
1989	12	-0,71	Near normal	0,74	Near normal
1990	12	-0,7	Near normal	1,41	Moderately wet
1991	12	-0,69	Near normal	1,44	Moderately wet
1992	12	-0,71	Near normal	1,32	Moderately wet
1993	12	-0,71	Near normal	1,37	Moderately wet
1994	12	-0,7	Near normal	1,5	Severely wet
1995	12	-0,71	Near normal	2,07	Extremely wet
1996	12	-0,57	Near normal	6,03	Extremely wet
1997	12	-0,71	Near normal	3,81	Extremely wet
1998	12	-0,71	Near normal	1,98	Severely wet
1999	12	-0,71	Near normal	1,24	Moderately wet
2000	12	-0,71	Near normal	8,93	Extremely wet
2001	12	-0,7	Near normal	2,39	Extremely wet
2002	12	-0,7	Near normal	0,16	Near normal
2003	12	-0,71	Near normal	0,55	Near normal
2004	12	-0,66	Near normal	2,03	Extremely wet
2005	12	-0,71	Near normal	0,67	Near normal
2006	12	-0,7	Near normal	3,14	Extremely wet
2007	12	-0,71	Near normal	1	Moderately wet
2008	12	-0,69	Near normal	1,01	Moderately wet
2009	12	-0,7	Near normal	1,38	Moderately wet
2010	12	-0,71	Near normal	1,57	Severely wet
2011	12	-0,69	Near normal	3,04	Extremely wet
2012	12	-0,7	Near normal	0,79	Near normal
2013	12	-0,71	Near normal	3,97	Extremely wet
2014	12	-0,68	Near normal	1,21	Moderately wet
2015	12	-0,71	Near normal	0,07	Near normal
2016	12	-0,71	Near normal	0,55	Near normal
2017	12	-0,71	Near normal	1,92	Severely wet

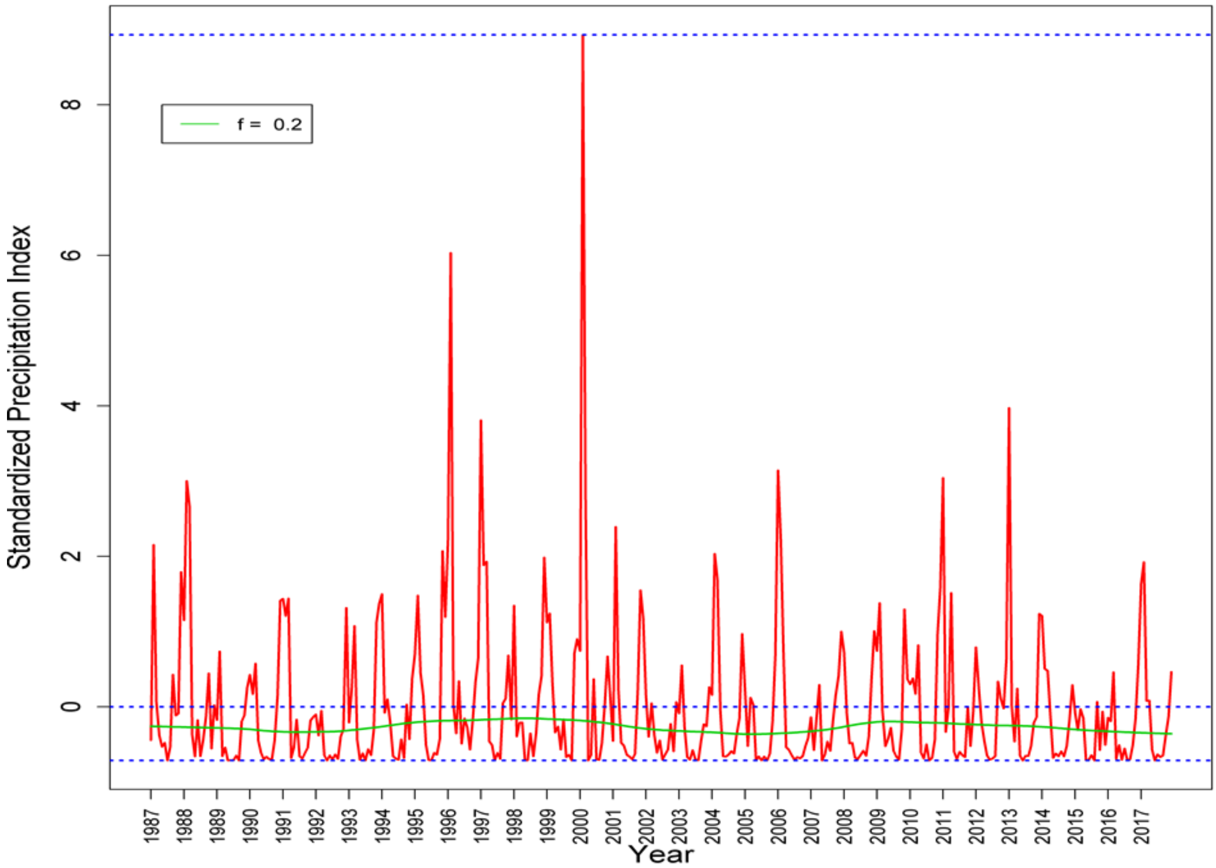


Figure 4. 1: SPI Values of 12 Months' Time Scale for Tzaneen-Grenshoek Weather Station

Table 4.2 and Figure 4.2 show the results of the SPI values for the 12 months' time scale in Hoedspruit Air Force Base Weather Station. Near normal conditions were recorded from 1994 to 2017 with the minimum SPI at -0.67 in all the years under review. Results show that moderately wet conditions were experienced in 1994, 2004, 2007 and 2016. Moderately wet conditions indicate that there were normal precipitation events over the years specified. Maximum SPI values between 1.00 to 1.49 falls under the non-drought category and has the probability of 2.3. The study shows that Hoedspruit Air Force Base Weather Station falls within the mild drought range with minimum SPI values between 0 and -0.99. The area tends to be drier in winter seasons and wetter in summer seasons. According to Angelidis *et al.* (2012) SPI provides a macroscopic insight of the impacts of precipitation deficiency upon different water resources (groundwater, soil moisture, reservoir storage and streamflow) which is extremely difficult to estimate. The SPI is less complex than many other indices (such as the Palmer index) as its calculation is based on the long-term precipitation records for a desired period and can be applied to any location.

Table 4. 2: Rainfall Season Classification under SPI 12 and its Categories for Hoedspruit Air Force Base Weather Station from 1994 to 2017

Year	Number of Months	Minimum SPI	Category	Maximum SPI	Category
1994	12	-0,67	Near normal	1,34	Moderately wet
1995	12	-0,67	Near normal	1,87	Severely wet
1996	12	-0,67	Near normal	4,97	Extremely wet
1997	12	-0,67	Near normal	0,92	Near normal
1998	12	-0,67	Near normal	2,51	Extremely wet
1999	12	-0,67	Near normal	1,54	Severely wet
2000	12	-0,67	Near normal	5,94	Extremely wet
2001	12	-0,67	Near normal	2,44	Extremely wet
2002	12	-0,67	Near normal	0,85	Near normal
2003	12	-0,67	Near normal	0,53	Near normal
2004	12	-0,66	Near normal	1,08	Moderately wet
2005	12	-0,67	Near normal	0,71	Near normal
2006	12	-0,67	Near normal	3,77	Extremely wet
2007	12	-0,67	Near normal	1,32	Moderately wet
2008	12	-0,67	Near normal	0,15	Near normal
2009	12	-0,67	Near normal	1,93	Severely wet
2010	12	-0,67	Near normal	2,02	Extremely wet
2011	12	-0,67	Near normal	3,22	Extremely wet
2012	12	-0,67	Near normal	6,99	Extremely wet
2013	12	-0,67	Near normal	2,77	Extremely wet
2014	12	-0,67	Near normal	2,96	Extremely wet
2015	12	-0,67	Near normal	0,37	Near normal
2016	12	-0,67	Near normal	1,11	Moderately wet
2017	12	-0,67	Near normal	0,57	Near normal

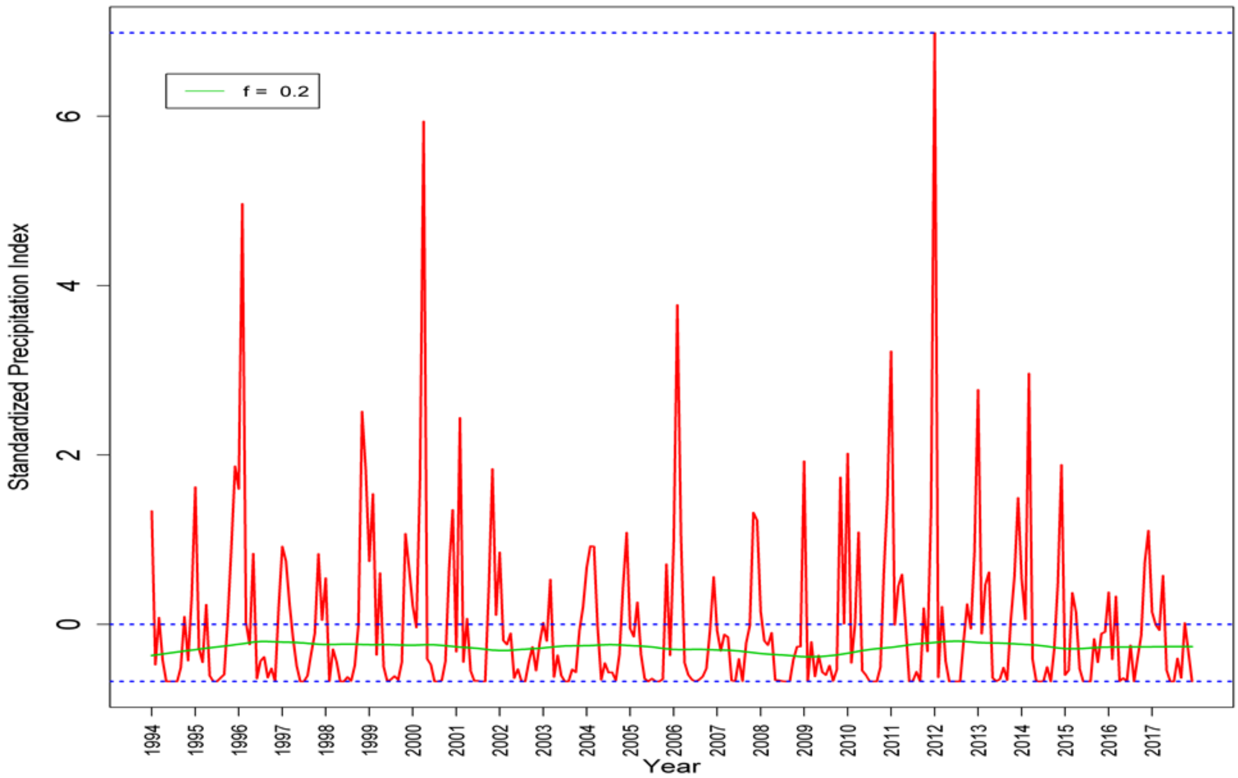


Figure 4. 2: SPI Values of 12 Months' Time Scale for Hoedspruit Air Force Base Weather Station

Table 4.3 and Figure 4.3 show the results of the SPI values for the 12 months' time scale in Tzaneen-Westafalia Estate Weather Station. Near normal conditions were recorded for minimum SPI from 2007 to 2017 with values ranging from -0.99 to 0.99. Results show moderately wet conditions experienced in 2007, 2008 and 2012. Extremely wet conditions were experienced in 2010, 2011, 2013 and 2017 with the highest value of 5.35. Extremely wet conditions indicate that heavy precipitation events were received for the period specified. Such conditions lead to numerous hazards such as severe flooding and loss of crops. Positive SPI values indicate precipitation greater than median and negative values indicate precipitation less than median. Drier and wetter climates can be depicted in the same way using the SPI because it is normalised, and wet periods can also be monitored using SPI (Lloyd-Hughes and Saunders, 2002; Subash *et al.,* 2011; Guenang and Kamga, 2014). Wu *et al.* (2007) revealed that the application of SPI on short time periods in regions with distinct dry season and arid areas fail to detect the onset of droughts. This SPI behaviour is linked to its non-normal distribution caused by greater incidence of no rainfall events. Morid *et al.* (2006) showed that normal rainfall percent deviation is more common in extreme and severe droughts, while SPI is more common in the normal category. The results demonstrated that when there is low normal rainfall percent deviation, the SPI values tend to be greater, indicating a normal distribution.

Table 4. 3: Rainfall Season Classification under SPI 12 and its Categories for Tzaneen-Westafalia Estate Weather Station from 2007 to 2017

Year	Number of Months	Minimum SPI	Category	Maximum SPI	Category
2007	12	-0,82	Near normal	1,44	Moderately wet
2008	12	-0,79	Near normal	1,45	Moderately wet
2009	12	-0,8	Near normal	1,94	Severely wet
2010	12	-0,82	Near normal	2,19	Extremely wet
2011	12	-0,79	Near normal	4,13	Extremely wet
2012	12	-0,81	Near normal	1,16	Moderately wet
2013	12	-0,82	Near normal	5,35	Extremely wet
2014	12	-0,77	Near normal	1,71	Severely wet
2015	12	-0,82	Near normal	0,2	Near normal
2016	12	-0,82	Near normal	0,84	Near normal
2017	12	-0,82	Near normal	2,65	Extremely wet

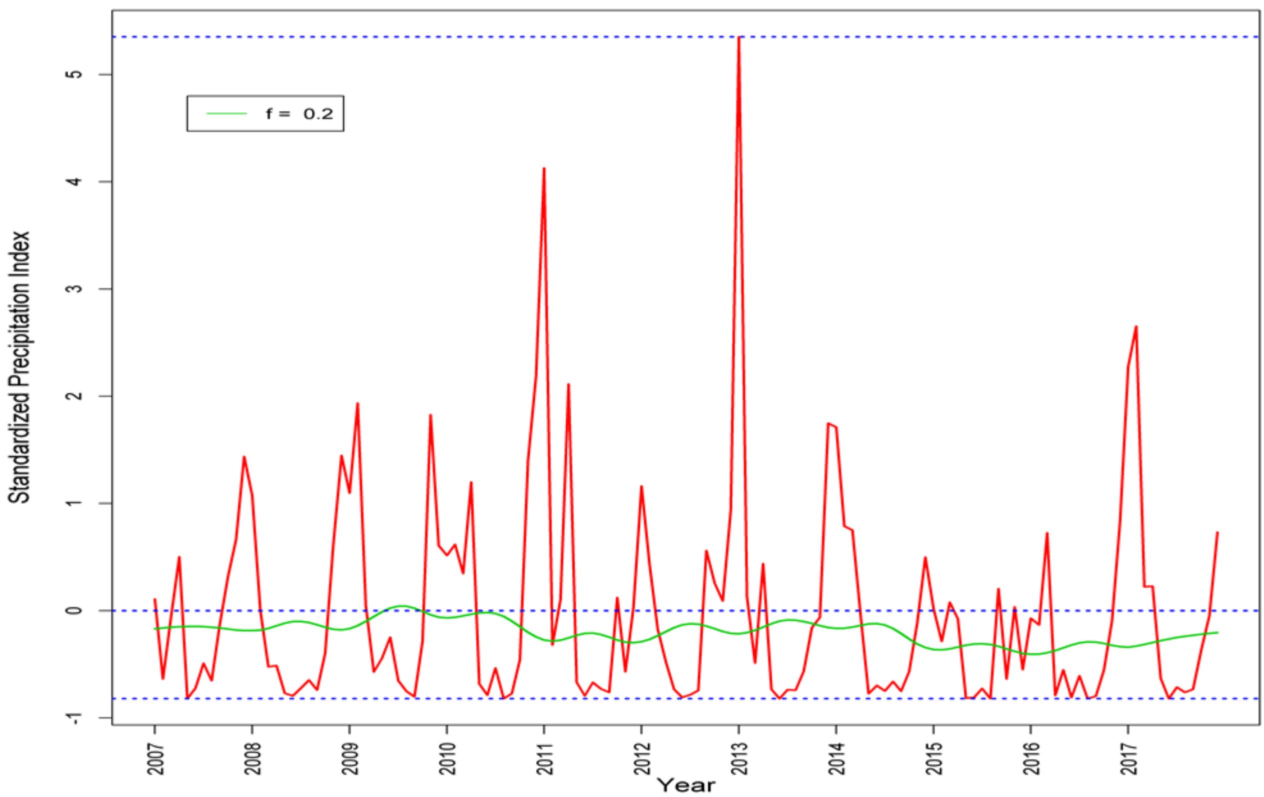


Figure 4. 3: SPI Values of 12 Months' Time Scale for Tzaneen-Westafalia Estate Weather Station

Table 4.4 and Figure 4.4 show the results of the SPI values for the 12 months' time scale in Letsitele-La Gratitude Weather Station. Near normal conditions were recorded for minimum SPI from 2011 to 2017 with values ranging from -0.99 to 0.99. The results show severely wet conditions experienced in 2012 and 2017 with SPI values from 1.50 to 1.99. Severely wet conditions indicate that excessive precipitation events were experienced for the period specified. Such weather conditions have the potential to cause damage. Near normal conditions of the maximum SPI were experienced in 2015, while extremely wet conditions were experienced in 2011, 2013, 2014 and 2016. Figure 4.5 shows the annual comparison of SPI 12 months values for all weather stations considered from 1987 to 2017.

SPI is based on a probabilistic approach and is comparable to more complex indices in terms of time and space, for example Lloyd-Hughes and Saunders (2002) showed that SPI values for 12 months is well related to Palmer Drought Severity Index (PDSI) for Europe. Guttman (1998) concluded that SPI is better able to compare drought in one location to another. Analysis of extreme drought events showed that the SPI produced better standardization than the PDSI *(*Hannaford *et al.,* 2011; Guerreiro *et al.,* 2017). Another advantage of the SPI is that drought and floods onset and termination are an implicit part of the index. Further, SPI can determine minimum precipitation amount that is needed to avoid drought formation at different severity categories and varying time periods. Nevertheless, SPI like any other precipitation only based index, assumes that droughts are solely controlled by the temporal variability of precipitation and thus insensitive to future increases in drought conditions due to rising temperatures, and consequently potential evapotranspiration (Vincente-Serrano *et al.,* 2010).

Besides the SPI advantages, practical applications of the index revealed some disadvantages (Guttman, 1999; Sen and Almazroui, 2021). It is believed that a suitable theoretical probability distribution can be developed to model the raw precipitation data prior to standardization (Hayes, 2000; Zhang and Li, 2020). Another constraint of the SPI derives from the index standardization process. Precipitation distribution estimated by the SPI can occur with the same frequency at all localities when considered over a long-term period. Another limitation is that inaccurately large negative and positive SPI values may result when the index is applied at short time periods to locations of low seasonal precipitation (Zhang and Li, 2020).

Table 4. 4: Rainfall Season Classification under SPI 12 and its Categories for Letsitele-La Gratitude Weather Station from 2011 to 2017

Year	Number of Months	Minimum SPI	Category	Maximum SPI	Category
2011	12	-0,7	Near normal	2,19	Extremely wet
2012	12	-0,71	Near normal	1,65	Severely wet
2013	12	-0,71	Near normal	4,56	Extremely wet
2014	12	-0,71	Near normal	3,34	Extremely wet
2015	12	-0,71	Near normal	0,08	Near normal
2016	12	-0,71	Near normal	2,93	Extremely wet
2017	12	-0,71	Near normal	1,85	Severely wet

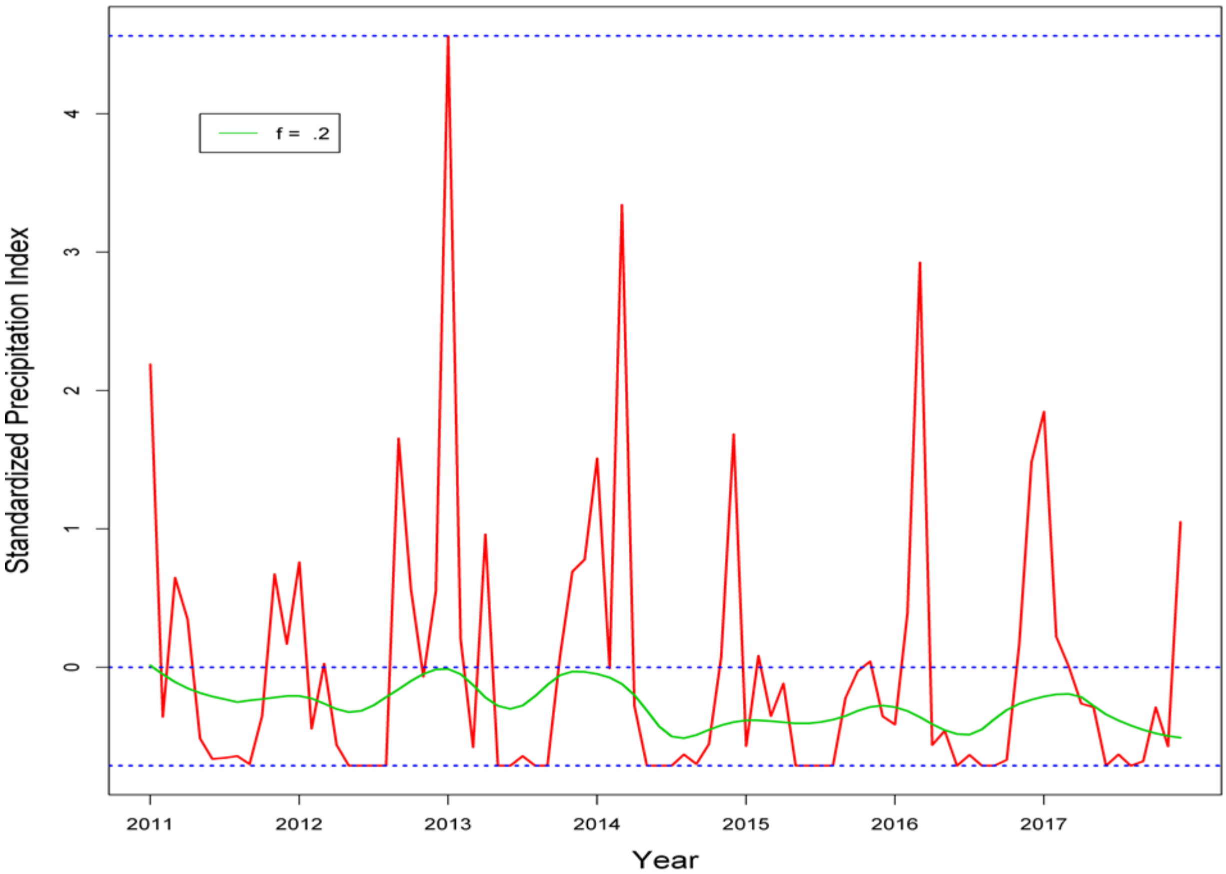


Figure 4. 4: SPI Values of 12 Months' Time Scale for Letsitele-La Gratitude Weather Station

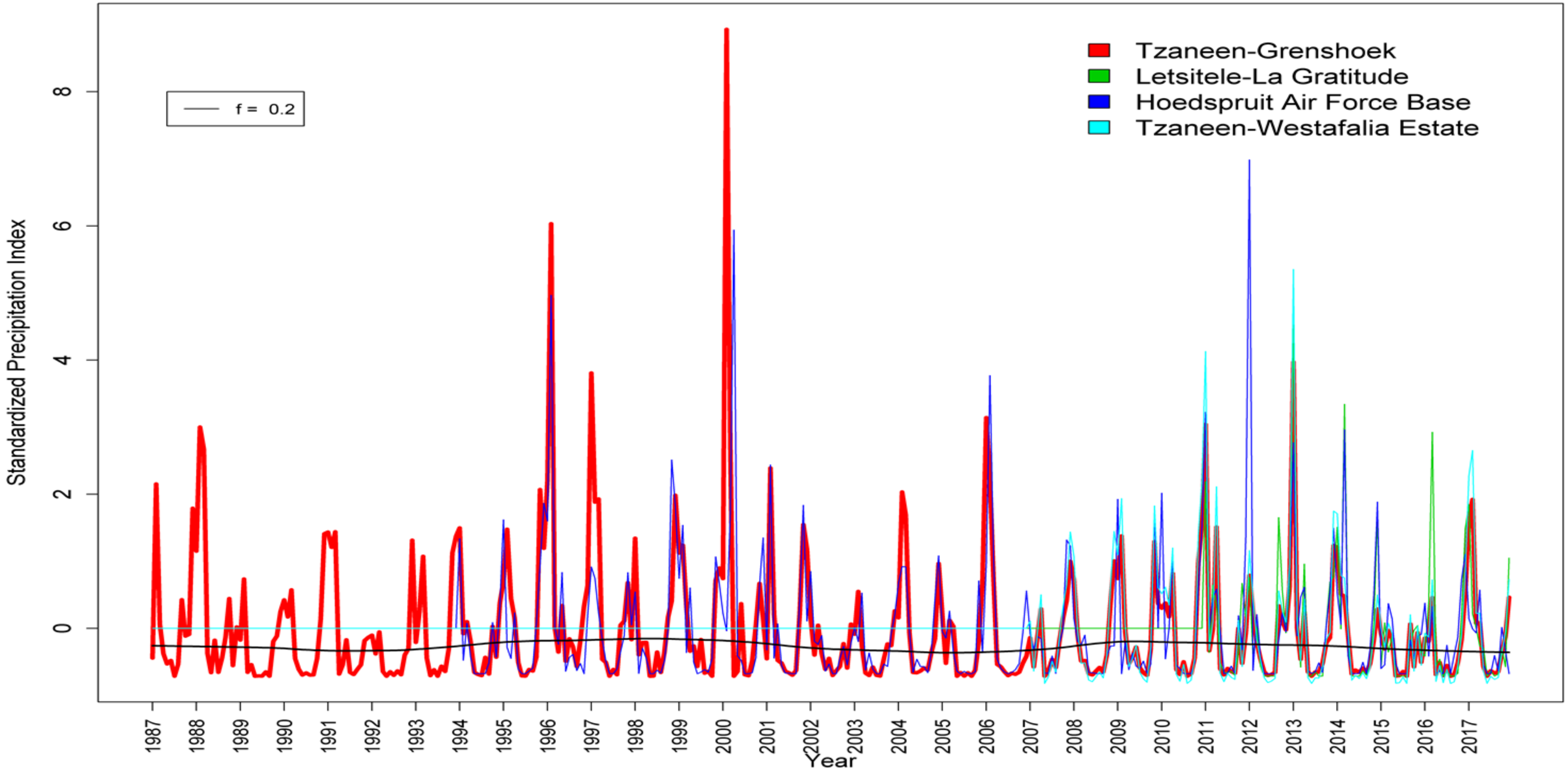


Figure 4. 5: Annual Comparison of SPI Values for All Four Weather Stations From 1987 To 2017

4.3 The Variability of Climatic Parameters in Mopani District Municipality

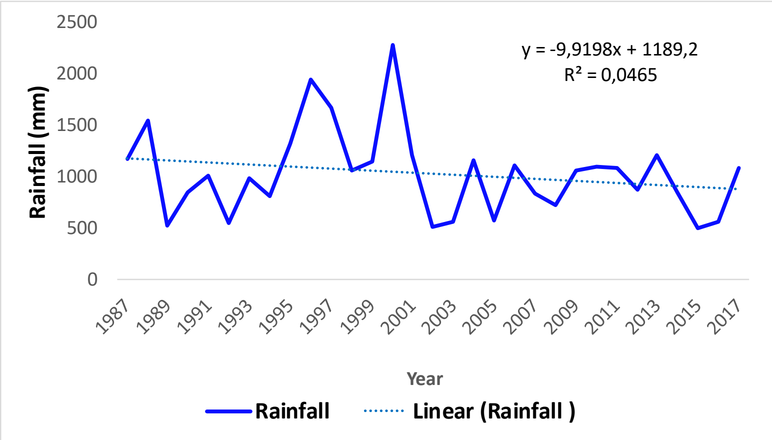
The first objective of the study was to examine the effects of climate variability on citrus production in Mopani District Municipality. In determining climatic trends, rainfall and temperature were subjected to trend analysis. The Mann-Kendall trend analysis was employed to show the climatic variables under consideration with the trendline indicating the nature and direction of the trend.

4.3.1 Seasonal Rainfall Variability and Trends

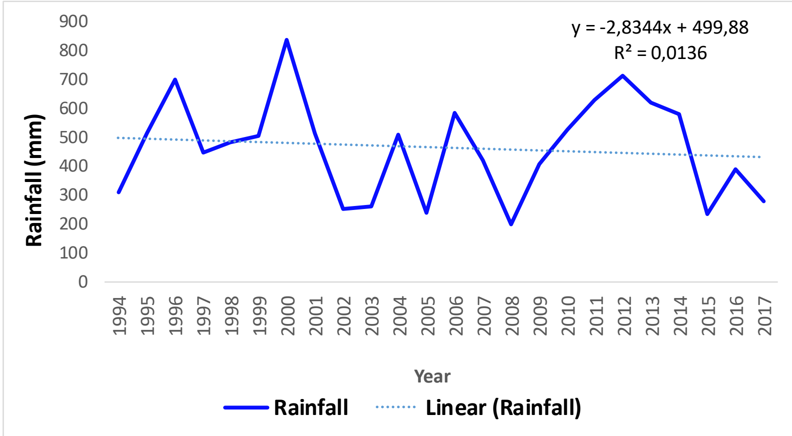
Figure 4.6 shows rainfall trends of Mopani District Municipality from 4 weather stations understudy, namely, Tzaneen-Grenshoek weather station from 1987 to 2017, Hoedspruit Air Force Base Weather Station from 1994 to 2017, Tzaneen-Westafalia Estate Weather Station from 2007 to 2017 and Letsitele La-Gratitude Weather Station from 2011 to 2017. Figure 4.6 shows a decreasing trend in rainfall from 1987 to 2017 in all weather stations. Results reveal that rainfall in the area experienced several variations over the study period. The degree of variation ($r^2 < 0.5$) in Tzaneen-Grenshoek, Hoedspruit Air Force Base, Tzaneen-Westafalia Estate and Letsitele La-Gratitude weather stations show a weak negative trend in the variability of rainfall. It can be observed from Figure 4.6 that Tzaneen-Grenshoek and Hoedspruit Air Force Base weather stations show a similar trend, as well as Tzaneen-Westafalia Estate and Letsitele La-Gratitude weather station.

Tzaneen-Grenshoek and Hoedspruit Air Force Base weather stations received excessive amounts of rainfall in 2000, with Tzaneen-Grenshoek receiving 2286 mm and Hoedspruit Air Force Base 835.8 mm. This could have caused the floods that occurred in the area in 2000. It is evident from Figure 4.6 that the area experienced adequate rainfall with annual rainfall above 499 mm in Tzaneen-Grenshoek and Tzaneen-Westafalia Estate. Furthermore, a constant trend was observed in Tzaneen-Grenshoek and Tzaneen-Westafalia Estate from 2009 to 2011 with rainfall between 1062 mm and 1102.8 mm. Irregular distribution of rainfall within the months and the patterns being variable over the years could potentially have affected most citrus farmers' in the district who depend on rainfall for production. In South Africa, drought is defined as less than 70% of normal precipitation, and such condition for two consecutive years signify prolonged drought.

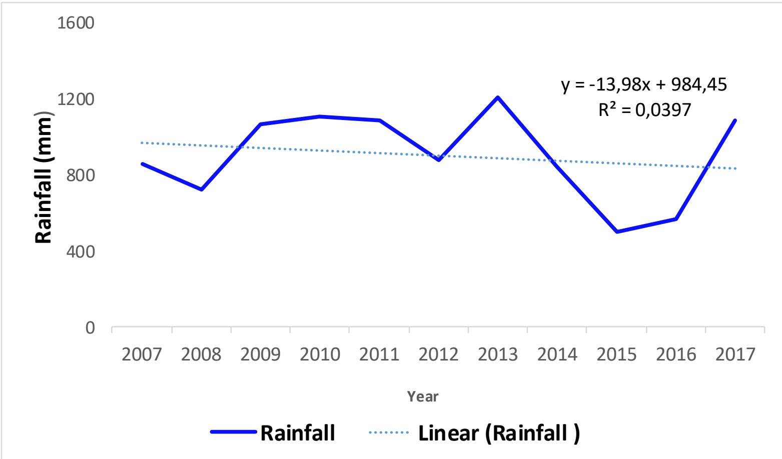
According to Gedefaw *et al.* (2018) rainfall is the key climatic variable that affect both the spatial and temporal patterns of water resources. Analysing the long-term trends and variability of rainfall is very important for sustainable water resources management (Chikoore and Jury, 2010; Wagesho *et al.,* 2012; Liao *et al.,* 2015; Yang *et al.,* 2017). Caloiero *et al.* (2011) used the Mann-Kendall test and linear regression method to analyse annual and seasonal rainfall variability in Calabria, Southern Italy and obtained a decreasing trend in annual, autumn, and winter precipitation and an increasing trend in summer.



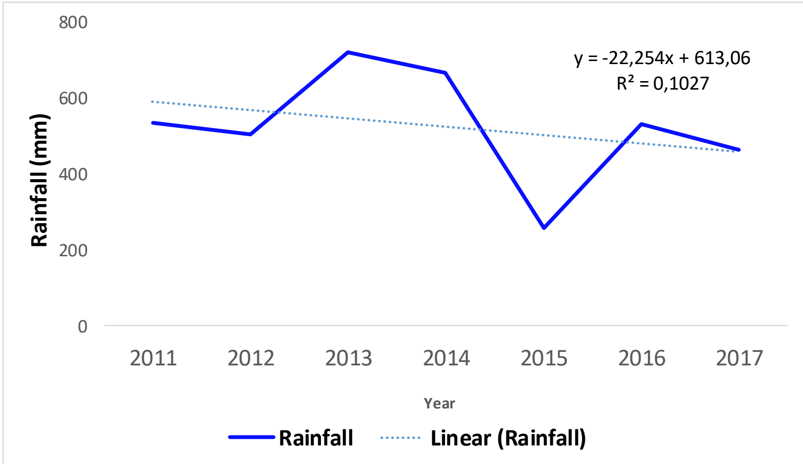
Tzaneen-Grenshoek Weather Station



Hoedspruit Air Force Base Weather Station



Tzaneen-Westafalia Estate Weather Station



Letsitele La-Gratitude Weather Station

Figure 4. 6: Rainfall Trends in Mopani District Municipality

4.3.2 Seasonal Temperature Variability and Trends

Tzaneen-Grenshoek and Hoedspruit Air Force Base weather stations were used to determine temperature trends in Mopani District Municipality. These were the only two weather stations in the area that had temperature data available or that at least had data that covered the study period without missing data. Data obtained from Tzaneen-Grenshoek weather station was from 1987 to 2017, whereas data from Hoedspruit Air Force Base weather station was from 1993 to 2017.

It is shown from Figure 4.7 that the maximum and minimum temperature has varied over the past 31 years (1987 to 2017) in Tzaneen-Grenshoek weather station. The trend equation and the trendline of the mean maximum temperature show an increasing trend (0.07x). This indicates that the average maximum temperature over the years has been increasing. The degree of variation $r^2 < 0.5$ ($r^2 = 0.4734$) shows a weak positive trend in the variability of maximum temperature in the area. The maximum temperature shows that it oscillated and increased sharply in 1993 (25.9°C), 2005 (26.9°C) and 2015 (28.1°C). However, maximum temperature shows a constant trend from 1989 (25.3°C) to 1992 (25.4°C), 2006 (25.9°C) to 2010 (26.3°C) and again from 2012 (26.5°C) to 2014 (26.1°C). Furthermore, there were exceptions in 1996 (24.1°C) and from 1999 (24.3°C) to 2001 (24.2°C) where maximum temperature fell drastically. It is observed from the time series that 2015 recorded the highest maximum temperature of 28.1°C, the lowest was 24.1°C in 1996.

The annual minimum temperature is observed to be decreasing over time (-0.0895x). The trend indicates a weak negative with $r^2 < 0.5$ ($r^2 = 0.4916$). The minimum temperature increased sharply in 1998 (15,9°C) and 2005 (16,5°C), thereafter fell in 2007 to its lowest average of 12.3°C, the highest was observed in 2005. Subsequently, minimum temperature experienced a general steady increase from 2008 to 2017. Gavrilov *et al.* (2016) used the Mann-Kendall test to analyse annual and season temperature trends in Vojvodina, Serbia for two periods: 1949 to 2013 and 1979 to 2013. The study showed that significant positive temperature trends are dominant in Vojvodina during spring and summer, and they are most frequent in the time series of monthly mean temperatures. Patle *et al.* (2016) explored changes in the seasonal and annual rainfall and temperature using time series data of 16 districts of Arunachal Pradesh, India. The trend analysis showed that the average annual minimum daily temperature increased over the study period and maximum temperature remained constant. Further, trend analysis of seasonal minimum temperature showed higher rates of warming in the post-monsoon season followed by monsoon and least in pre-monsoon season.

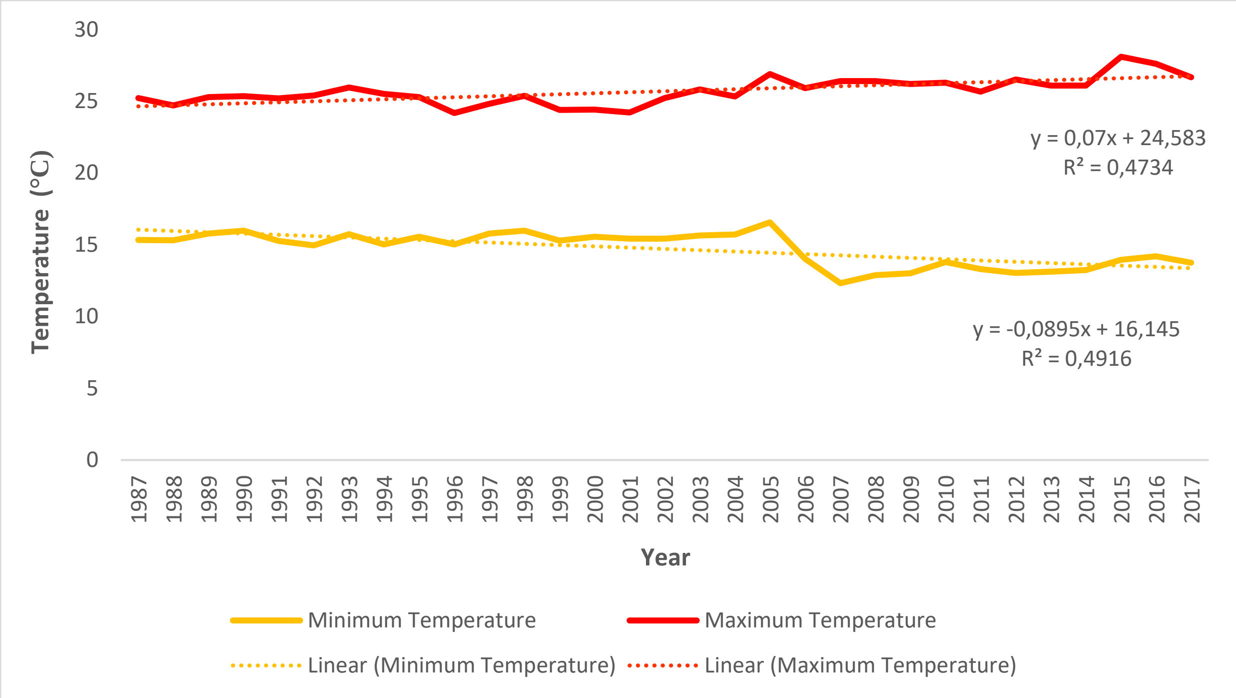


Figure 4. 7: Annual Maximum and Minimum Temperature over Tzaneen-Grenshoek Weather Station

Figure 4.8 shows the maximum and minimum temperature of Hoedspruit Air Force Base weather station from 1993 to 2017. The trend equation and the trendline of the mean maximum temperature show an increasing trend (0.0503x). This indicates that the average maximum temperature over the years has been increasing. The degree of variation $r^2 < 0.5$ ($r^2 = 0.2782$) shows a weak positive trend in the variability of maximum temperature in the area. The maximum temperature shows that it oscillated and increased sharply in 1995 (29.1°C), 2003 (29.2°C), 2005 (29.4°C), 2012 (29.5°C) and from 2015 (30.2°C) to 2016 (29.1°C). The highest maximum temperature of 30.2°C was recorded in 2015, the lowest was 27.1°C in 2000. The maximum temperature shows a constant trend from 2006 (28.1°C) to 2008 (28.6°C), 2013 (28.8°C) to 2014 (28.9°C). Moreover, there were exceptions in 1996 (27.3°C) and 2000 (27.1°C) where maximum temperature decreased drastically.

The annual minimum temperature is observed to be decreasing from 1993 to 1987 (-0.0174x). The trend indicates a very weak negative trend with $r^2 < 0.5$ ($r^2 = 0.0204$). The minimum temperature increased sharply in 2003 (17.2°C) and 2005 (17.1°C). The highest minimum temperature was recorded in 2003 (17.2°C), the lowest in 1994 (14.0°C). Furthermore, a constant trend was observed from 1999 (16.1°C) to 2000 (16.1°C), 2006 (16.4°C) to 2009 (16.2°C), 2011 (14.3°C) to 2013 (14.3°C) and 2015 (16.7°C) to 2016 (16.8°C). These results reflect those of Dawood (2017) who found positive increasing trends in mean maximum temperature detected for Chitral, Dir and Saidu Sharif met stations, whereas negative decreasing trend in mean minimum temperature has been recorded for met station Saidu Sharif and Timer Gara, in the eastern Hindu Kush, north Pakistan.

The analysis further reveals that the concern variation in temperature trend and slope magnitude is attributed to climate change phenomenon in the region.

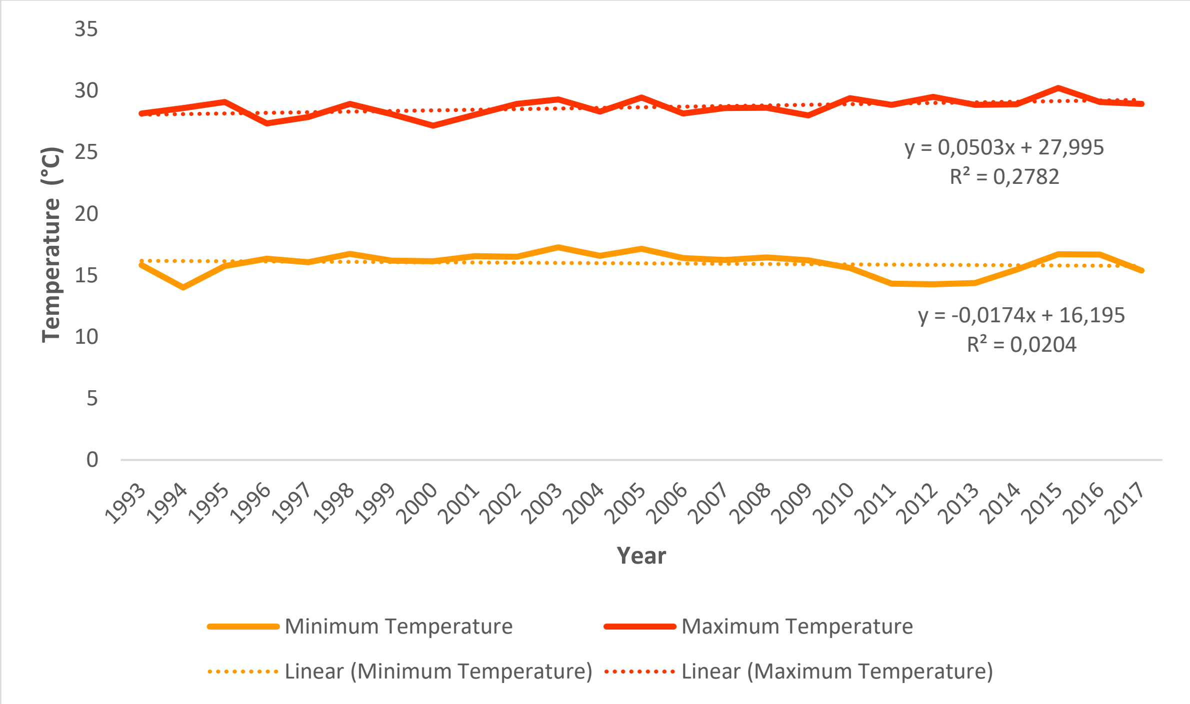


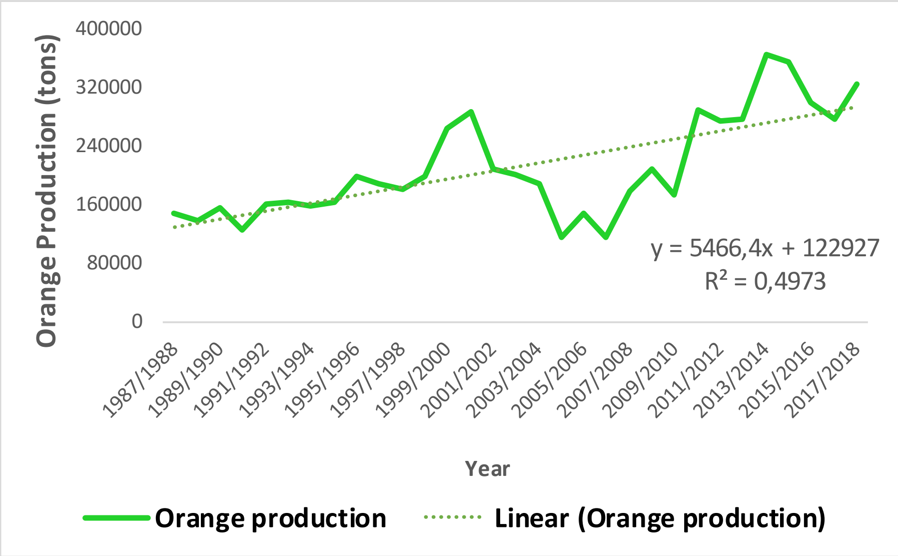
Figure 4. 8: Annual Maximum and Minimum Temperature over Hoedspruit Air Force Base Weather Station

4.4 Citrus Production Trends in Mopani District Municipality

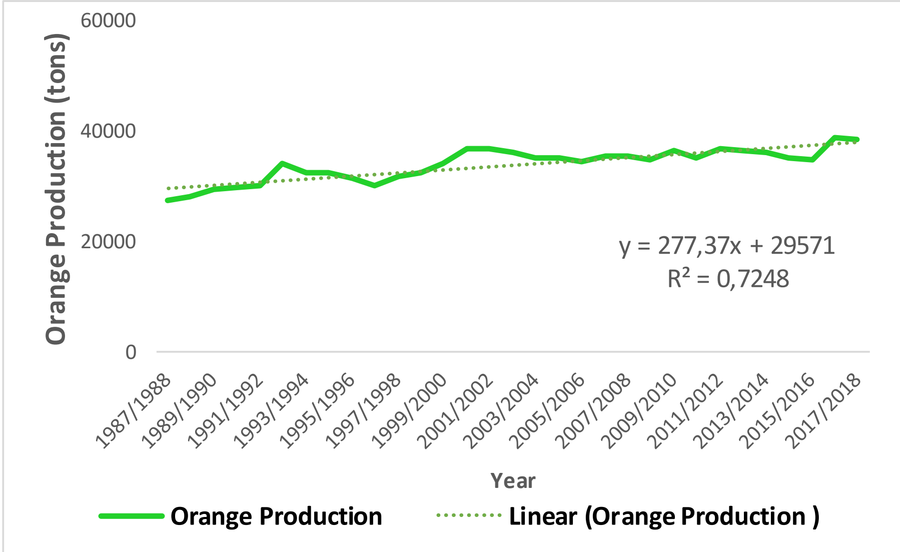
The second objective of the study was to establish the influence of citrus production on farmers' income and rural livelihoods in Mopani District Municipality. In determining citrus production trends, trend analysis was employed using the Mann-Kendall test. A total of 5 commercial citrus farms under the Mopani Department of Agriculture and Rural Development were used in this study. The farms have a high level of dependency on rainfall and irrigation for production and land size ranging from 40 to 250 hectares.

Figure 4.9 shows annual orange production of Farm 1 and Farm 2 from 1987 to 2017. Farm 1 consist of 119.5 hectares of orange production and Farm 2 consist of 40 hectares of orange production. Results show an increasing trend for both Farm 1 and Farm 2. However, the degree of variation $r^2 < 0.5$ ($r^2 = 0.4973$) of Farm 1 shows a weak positive trend in the variability of orange production. Farm 2 shows a strong positive trend in the variability of orange production with $r^2 > 0.5$ ($r^2 = 0.7248$). Farm 1's highest production was observed in 2013/2014 season with 364865 tons. The lowest was 115482 tons in the 2004/2005 season. Farm 2's highest production was observed in the 2016/2017 season with 38796 tons, the lowest was 27514 tons in the 1987/1988 season. The reason for the decline in production may be due to the droughts that occurred in the 2004/2005 and 1987/1988 seasons. Orange production for Farm 1 (287864 tons) and Farm 2 (36951 tons) for the 2000/2001 season increased to more than that of the previous and the following year. The rise in production during that period may be attributed to the adequate rainfall that occurred in the 2000/2001 season. Yadav *et al.* (2014) stated that decreases in rainfall significantly affects crop production trends. Similarly, the decrease in annual maximum temperature and an increase in minimum temperature have a positive influence on citrus production.

Figure 4.10 shows annual citrus production for Farm 3 from 1987 to 2017. Farm 3 produces oranges, tangerines, lemons and limes, and grapefruits from 250 hectares of land. Results show an increasing trend for Farm 3 for all fruits produced. Farm 3 indicates a very strong positive trend in the variation of orange, tangerines, lemons and limes, and grapefruit production with $r^2 > 0.5$. Oranges' highest production (1011256 tons) was recorded in the 2017/2018 production season, tangerines (27548 tons) in 2000/2001, lemons and limes (10387 tons) in 2017/2018 and grapefruits (8555 tons) in 2017/2018. Oranges, lemons and limes, and grapefruits had their lowest production in the 1987/1988 season. The reason for the fluctuations in production may be due to irregular weather patterns such as drought, floods, a short or a prolonged rainy season, pests, and diseases as well as the availability of farming equipment. Sarker *et al.* (2017) showed a significant increase in lemon production in terms of yield and area coverage. The results of the study indicated that from 2002 to 2013, yield and area coverage gradually increased with occasional fluctuations.

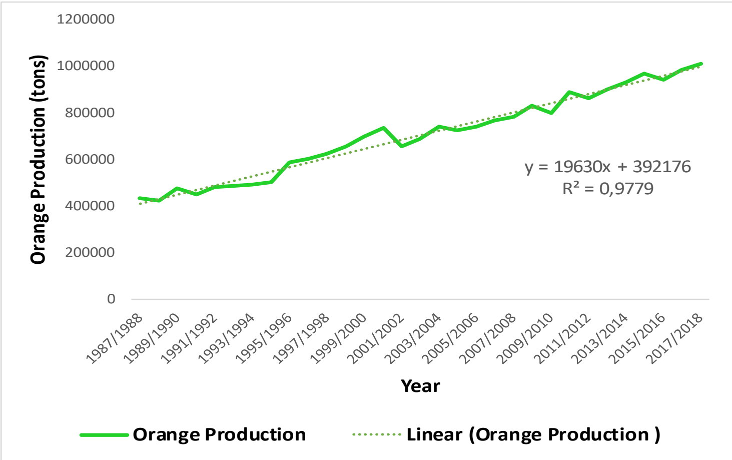


Farm 1 (Orange Production)

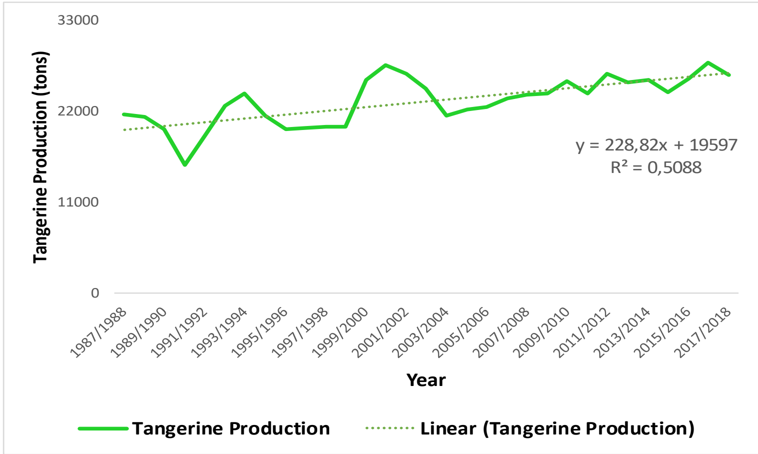


Farm 2 (Orange Production)

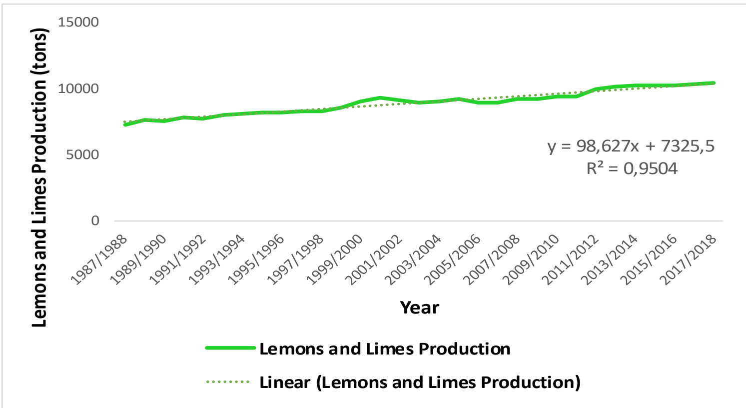
Figure 4. 9: Orange Production Trends for Farm 1 and Farm 2



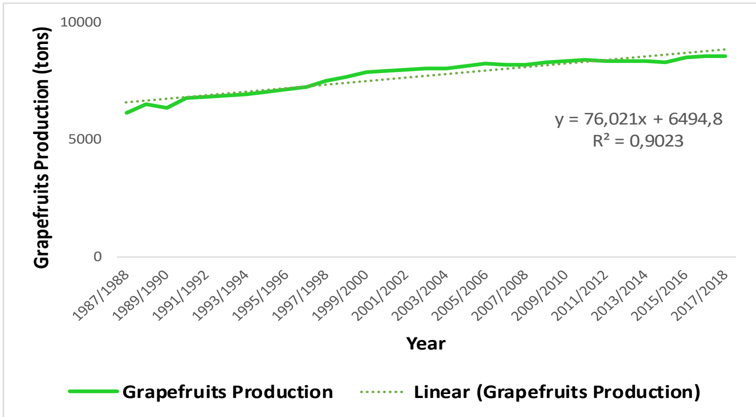
Orange Production



Tangerine Production



Lemons and Limes Production



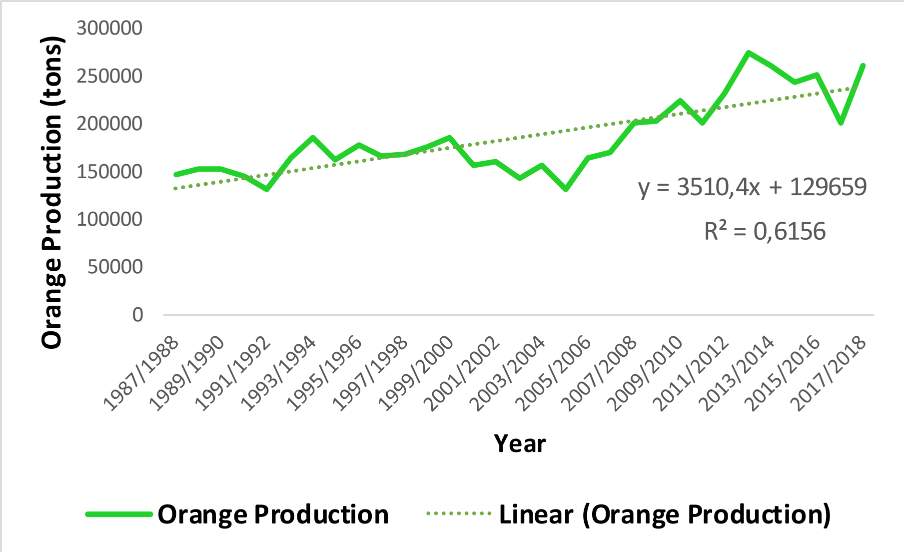
Grapefruits Production

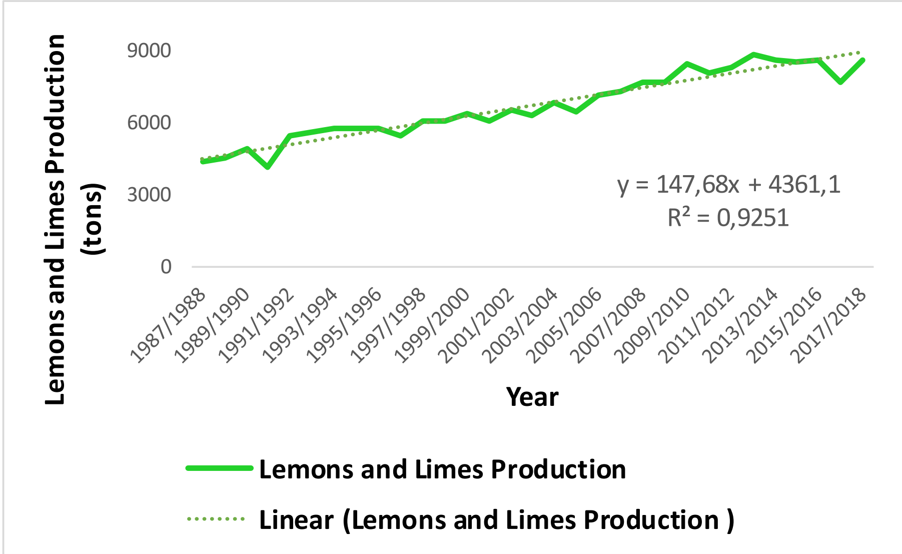
Farm 3

Figure 4. 10: Citrus Production Trends for Farm 3

Figure 4.11 shows annual citrus production of Farm 4 from 1987 to 2017. Farm 4 produces oranges, lemons, and limes from 109 hectares of land. Results show an increasing trend for Farm 4 in oranges, lemons, and limes production. Farm 4 indicates a very strong positive trend in the variation of orange $r^2 > 0.5$ ($r^2 = 0.6156$) and lemons and limes $r^2 > 0.5$ ($r^2 = 0.9251$) productivity. Oranges' highest production (275128 tons) was recorded in the 2012/2013 production season, lemons, and limes at 8878 tons in the same season. Oranges experienced their lowest production of 131456 tons in the 2004/2005 production season. Furthermore, lemons and limes had their lowest production of 4173 tons in 1990/1991 season. It is evident from Figure 4.11 that orange production experienced a period of sharp decline between the seasons 1999/2000 to 2007/2008.

Figure 4.12 shows annual citrus production of Farm 5 from 1987 to 2017. Farm 5 produces oranges and grapefruits from 114.5 hectares of land. Results show an increasing trend for Farm 5 in oranges and grapefruits production. Farm 5 indicates a very strong positive trend in the variation of orange and grapefruits productivity with $r^2 > 0.5$. Oranges' highest production (359648 tons) was observed in the 2017/2018 production season and grapefruits on 20015 tons in the same season. Oranges experienced its lowest production of 125489 tons in the 1990/1991 production season, grapefruits had their lowest production of 5051 tons in the 1987/1988 season. Figure 4.12 shows that orange production constantly increased from 1987/1988 to 1989/1990 and again between 2000/2001 to 2006/2007 production seasons with productivity ranging from 200251 tons and 210358 tons.

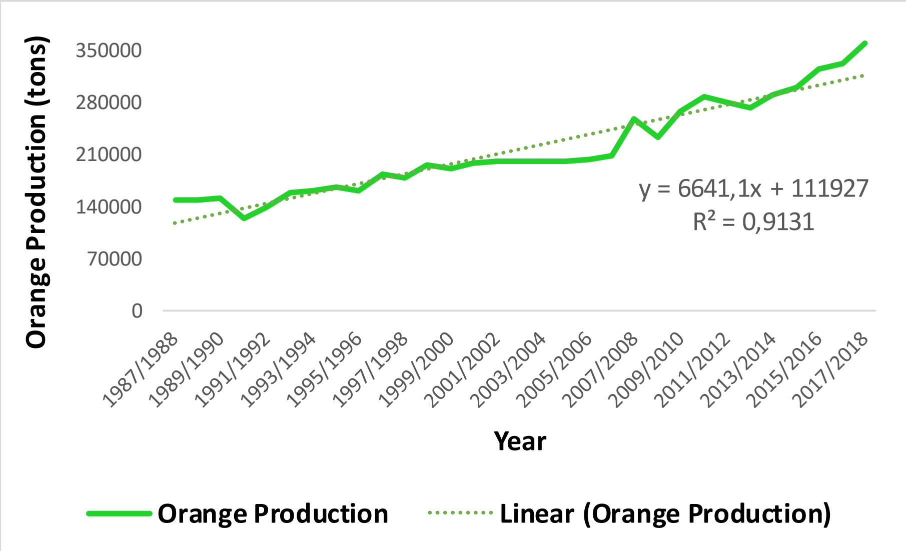




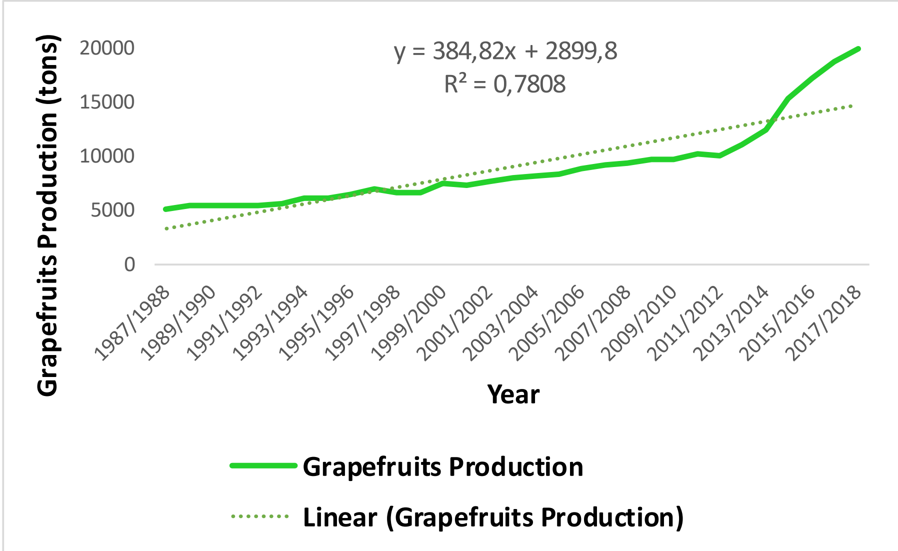
Orange Production **Lemons and Limes Production**

Farm 4

Figure 4. 11: Citrus Production Trends for Farm 4



Orange Production



Grapefruits Production

Farm 5

Figure 4.12: Citrus Production Trends for Farm 5

4.5 The Relationship Between Climate Variability and Citrus Production

The relationship between climate variability and citrus production was assessed using multiple linear regression analysis. This was done to evaluate the impact of rainfall and temperature on citrus production. The Standardized Precipitation Index (SPI) was used as an indicator of rainfall characteristics of the area. Annual citrus production was regressed against annual minimum SPI, maximum SPI, minimum temperature, and maximum temperature from 1987 to 2017.

Table 4.5 shows the relationship between climate variability and citrus production (oranges) for Farm 1. Results of the regression analysis shown in Table 4.5 provide details on the evaluation model. The adjusted r squared shows how much of the variance in the dependent variable is explained by the independent variables, this implies that SPI and temperature explain 29.92% of the variance in citrus production for Farm 1. Therefore, 70.08% of the variation is caused by factors other than SPI and temperature. The model reveals a weak negative significant relationship between climate variability and citrus production with $p< 0.05$ and adjusted $r^2< 0.5$.

The results of the evaluation of each of the independent variables show that maximum SPI coefficient is 14575.45736 and maximum temperature coefficient is 18340.30776 larger than the coefficient of the minimum SPI (-521527.4082) and minimum temperature (-27072.93656). This indicates that maximum SPI and maximum temperature make a strong individual contribution in explaining citrus production than minimum SPI and minimum temperature indicating minor contributions. This reveals that for every unit increase in maximum SPI and maximum temperature, citrus production will increase by the value of the coefficients. Likewise, a negative coefficient sign indicates that for every unit increase in minimum SPI and minimum temperature citrus production will decrease by the value of the coefficients.

Preliminary analysis was conducted to ensure no violation of the assumptions of normality, multicollinearity, and homoscedasticity. Minimum temperature indicates a significant influence on citrus production with $p< 0.05$ meanwhile minimum SPI, maximum SPI and maximum temperature have an insignificant influence recording $p> 0.05$. Pashiardis and Michaelides (2008) point out that SPI and temperature can be utilised to predict and assess the effects of drought on several sectors of the economy including crop production such as citrus. Results of the study by Pashiardis and Michaelides (2008) revealed that cereal yields are appropriate drought indicators in rainfed systems where cereal is the primary crop. Madzivhandila (2015) stated that temperature and precipitation patterns must be consistent throughout the growing and development phases of crops till harvest. Moreover, favourable temperature patterns and rainfall availability are ideal and conducive for citrus production. Therefore, the relationship between SPI, temperature and citrus production provides significant information about the effects of climate variability on agriculture.

Table 4. 5: The Relationship Between Climate Variability and Citrus Production for Farm 1

Regression Statistics						
Multiple R	0,62663193					
R Square	0,392667576					
Adjusted R Square	0,299231819					
Standard Error	58997,90602					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	58512023551	14628005888	4,202540728	0,00933699	
Residual	26	90499575778	3480752915			
Total	30	1,49012E+11				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-255587,7998	557189,5872	-0,458708859	0,650254822	-1400907,399	889731,7996
Minimum SPI	-521527,4082	441507,9351	-1,181241302	0,248199598	-1429059,966	386005,1497
Maximum SPI	14575,45736	7429,142507	1,961929973	0,06055891	-695,3637708	29846,27848
Minimum Temperature	-27072,93656	11159,69088	-2,42595757	0,022509766	-50012,00968	-4133,86344
Maximum Temperature	18340,30776	16871,89669	1,087032957	0,286997418	-16340,37258	53020,9881

Table 4.6 shows the relationship between climate variability and citrus production for Farm 2. Results indicate that 30.01% of the variation in citrus production (oranges) is explained by SPI and temperature. This reveal that 69.99% of the variation in citrus production is caused by factors other than SPI and temperature, factors such as soil moisture, socio-economic factors, and physiographic factors. The model indicates a weak positive significant relationship between climate variability and citrus production with $p< 0.05$ and adjusted $r^2< 0.5$.

The results of the evaluation of each of the independent variables show that maximum SPI coefficient is 416.7883291 and maximum temperature coefficient is 977.7318821 larger than the coefficient of the minimum SPI (-27487.21562) and minimum temperature (-980.7567081). This indicates that maximum SPI and maximum temperature makes a strong individual contribution in explaining citrus production than minimum SPI and minimum temperature indicating minor contributions. This shows that for every unit increase in minimum SPI and minimum temperature citrus production will decrease by the value of the coefficients.

Results show that minimum temperature has a statistically significant influence on citrus production with $p< 0.05$ meanwhile minimum SPI, maximum SPI and maximum temperature have an insignificant influence recording $p> 0.05$. Increasing temperatures in recent years have been linked to significant losses in citrus, maize, wheat, sorghum, and barley yields (Yang *et al.,* 2020), temperature and rainfall patterns are expected to reduce crop productivity, particularly is semi-arid areas. Citrus performance in rainfed and irrigated production is dependent on precipitation amount and distribution. A study by Yamoah *et al.* (2000) used the SPI to analyse the long-term consequences of rainfall and fertilizer nitrogen on yields and risk probabilities on maize in the semi-arid and humid climates of the Great Plains in Nebraska. The study found that regression of crop yield as the dependent variable and SPI 12 months as the independent variable explained up to 64% of yield variability in a curvilinear relationship. SPI values in the range of -1.0 to 1.0 was found to be optimal, proving the adaptability and performance of crops under modest stress as suggested by other scientists (Pramudya and Onishi, 2018). SPI and temperature can be used as a practical guide to select the choice of crops (including citrus) and management decisions to conserve water in rainfed and irrigated farming (Verner *et al.,* 2018). Subsequently, it is requiring the knowledge of rainfall and drought index to merge the process of decision making for citrus production practices to consider adaptation and mitigation of climate variability.

Table 4. 6: The Relationship Between Climate Variability and Citrus Production for Farm 2

Regression Statistics						
Multiple R	0,627269374					
R Square	0,393466868					
Adjusted R Square	0,300154078					
Standard Error	2478,05283					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	103573370,3	25893342,59	4,216644576	0,009194122	
Residual	26	159659391,5	6140745,828			
Total	30	263232761,9				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	3308,075318	23403,29219	0,141350853	0,888682304	-44798,08075	51414,23138
Minimum SPI	-27487,21562	18544,38677	-1,482239125	0,150296723	-65605,74855	10631,31731
Maximum SPI	416,7883291	312,0417122	1,335681458	0,193228861	-224,6225965	1058,199255
Minimum Temperature	-980,7567081	468,7336454	-2,092353979	0,046315347	-1944,252515	-17,26090118
Maximum Temperature	977,7318821	708,6599198	1,379691238	0,179432844	-478,939445	2434,403209

Table 4.7 shows the relationship between climate variability and citrus production for Farm 3. Results show that 57.56% of the variation in citrus production (oranges, tangerines, grapefruits, lemons, and limes) is explained by SPI and temperature. This indicates that 42.44% of the variation in citrus production is caused by factors other than SPI and temperature. The model indicates a strong negative significant relationship between climate variability and citrus production with $p< 0.05$ and adjusted $r^2> 0.5$.

The results of the evaluation of each of the independent variables show that the maximum SPI coefficient is 28787.39211 and maximum temperature coefficient is 112489.148, larger than the coefficient of the minimum SPI (-218955.0863) and minimum temperature (-67609.53559). This indicates that maximum SPI and maximum temperature make a strong individual contribution in explaining citrus production than minimum SPI and minimum temperature indicating minor contributions. This reveal that there is a large year to year variation in citrus production. Results show that minimum and maximum temperature are both statistically significant indicating $p < 0.05$ meanwhile minimum SPI and maximum SPI have an insignificant influence on citrus production recording $p > 0.05$.

The relationship between each citrus variety against SPI and temperature was analysed for Farm 3 using multiple linear regression to evaluate how each citrus variety is affected by climate variability. Table **A1** (refer to Appendix M) is the regression output of the relationship between climate variability and orange production for farm 3. Results indicate that 57.62% of the variation in orange production is explained by SPI and temperature. The model indicates a strong negative significant relationship ($p < 0.05$ and adjusted $r^2 > 0.5$). Maximum SPI and maximum temperature have shown to have a strong influence on tangerines than minimum SPI and minimum temperature. Results show that minimum temperature and maximum temperature both are statistically significant recording $p < 0.05$ and minimum SPI and maximum SPI insignificant with $p > 0.05$.

The relationship between climate variability and tangerine production for farm 3 is shown in Table **A2** (refer to Appendix N). Results indicate that 31.84% of the variation in tangerine production is explained by SPI and temperature. The model indicates a weak positive significant relationship ($p < 0.05$ and adjusted $r^2 < 0.5$). Maximum SPI and maximum temperature have shown to have a strong influence on tangerines than minimum SPI and minimum temperature. Minimum temperature indicates a statistically significant influence on tangerine production with $p < 0.05$ and minimum SPI, maximum SPI, and maximum temperature insignificant with $p > 0.05$.

The relationship between climate variability and lemons and limes production for farm 3 is shown in Table **A3** (refer to Appendix O). Results indicate that 49.97% of the variation in lemons and limes production is explained by SPI and temperature. The model indicates a weak negative significant relationship ($p < 0.05$ and adjusted $r^2 < 0.5$). Maximum SPI and maximum temperature have shown to have a strong influence on lemons and limes than minimum SPI and minimum temperature. Results show that minimum temperature and maximum temperature both are statistically significant recording $p < 0.05$, minimum SPI and maximum SPI show an insignificant influence on lemons and limes with $p > 0.05$.

The relationship between climate variability and grapefruits production for farm 3 is shown in Table **A4** (refer to Appendix P). Results indicate that 36.28% of the variation in grapefruits production is explained by SPI and temperature. The model indicates a weak positive significant relationship ($p < 0.05$ and adjusted $r^2 < 0.5$). Maximum SPI and maximum temperature have shown to have a strong influence on grapefruits than minimum SPI and minimum temperature. Minimum temperature and maximum temperature indicate a statistically significant influence on grapefruits recording $p < 0.05$, meanwhile minimum SPI and maximum SPI show an insignificant influence with $p > 0.05$.

Precipitation is not regularly distributed, absolute rainfall values are usually more poorly correlated with yields than when rainfall values are standardized (McKee *et al.,* 1993; Saada and Abu-Romman, 2017; Mlenga *et al.,* 2019). Results of the study show that Mopani District Municipality falls under the near normal SPI category which is considered as a mild stress condition for citrus production and may be favourable to crop growth and development in some years depending on other climatic factors such as temperature.

Table 4. 7: The Relationship Between Climate Variability and Citrus Production for Farm 3

Regression Statistics						
Multiple R	0,79513696					
R Square	0,632242785					
Adjusted R Square	0,575664752					
Standard Error	119957,2809					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	6,43205E+11	1,60801E+11	11,17470423	0,000020749	
Residual	26	3,74133E+11	14389749251			
Total	30	1,01734E+12				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1361011,562	1132903,731	-1,201347939	0,240445834	-3689728,533	967705,4079
Minimum SPI	-218955,0863	897694,4265	-0,243908261	0,809216258	-2064192,407	1626282,234
Maximum SPI	28787,39211	15105,27737	1,905783747	0,067791585	-2261,950206	59836,73443
Minimum Temperature	-67609,53559	22690,40147	-2,979653563	0,00618312	-114250,3238	-20968,7474
Maximum Temperature	112489,148	34304,72348	3,279115427	0,002959062	41974,77899	183003,517

Table 4.8 shows the relationship between climate variability and citrus production for Farm 4. Results show that 64.56% of the variation in citrus production (oranges, lemons, and limes) is explained by SPI and temperature. This indicates that 35.44% of the variation in citrus production is caused by factors other than SPI and temperature. The model indicates a strong positive significant relationship between climate variability and citrus production with $p< 0.05$ and adjusted $r^2> 0.5$.

The results of the evaluation of each of the independent variables show that the maximum SPI coefficient is 3781.801418 and maximum temperature coefficient is 16576.46835, larger than the coefficient of the minimum SPI (-118132.5601) and minimum temperature (-22081.57177). This indicates that maximum SPI and maximum temperature make a strong individual contribution in explaining citrus production than minimum SPI and minimum temperature indicating minor contributions. Results show that minimum and maximum temperature are both statistically significant indicating $p< 0.05$ meanwhile minimum SPI and maximum SPI have shown an insignificant influence on citrus production recording $p> 0.05$.

The relationship between each citrus variety against SPI and temperature was analysed for Farm 4 using multiple linear regression to evaluate how each citrus variety is affected by climate variability. Table **A5** (refer to Appendix Q) is the regression output of the relationship between climate variability and orange production for farm 4. Results indicate that 63.68% of the variation in orange production is explained by SPI and temperature. The model indicates a strong positive significant relationship (p<0.05 and adjusted r^2> 0.5). Maximum SPI and maximum temperature have shown to have a strong influence on oranges than minimum SPI and minimum temperature. Minimum temperature and maximum temperature both have a statistically significant influence on orange production recording p< 0.05, meanwhile minimum SPI and maximum SPI show an insignificant influence with p> 0.05.

The relationship between climate variability and lemons and limes production for farm 4 is shown in Table **A6** (refer to Appendix R). Results indicate that 66.90% of the variation in lemons and limes production is explained by SPI and temperature. The model indicates a strong positive significant relationship (p< 0.05 and adjusted r^2> 0.5). Maximum SPI and maximum temperature have shown to have a strong influence on lemons and limes than minimum SPI and minimum temperature. Minimum and maximum temperature indicate a statistically significant influence on lemons and limes recording p<0,05. Minimum SPI and maximum SPI have shown an insignificant influence with p> 0.05. Manatsa *et al.* (2010) analysed the relationship between SPI and maize yields in Zimbabwe. The results of the study showed a strong relationship between maize values and SPI 6 months (r = 0.73; p = 0.00). This suggests that the linear relationship between maize yields and SPI is more evident, and rainfall variability explains more of the yield variance when rainfall deviation from the norm is negative than when surplus. The study further noted that maize yield linear models based on the relationship between rainfall and yield have shown varying findings, particularly when considering yield projection in the context of excess rainfall.

Table 4. 8: The Relationship Between Climate Variability and Citrus Production for Farm 4

Regression Statistics						
Multiple R	0,832390107					
R Square	0,692873291					
Adjusted R Square	0,645623028					
Standard Error	24922,56062					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	36432997482	9108249371	14,66390338	0,000002165	
Residual	26	16149484725	621134027,9			
Total	30	52582482208				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1413,339072	235374,3074	0,006004645	0,995254852	-482405,4788	485232,1569
Minimum SPI	-118132,5601	186506,7596	-0,633395596	0,532007979	-501502,6951	265237,5748
Maximum SPI	3781,801418	3138,302136	1,20504695	0,239039255	-2669,07101	10232,67385
Minimum Temperature	-22081,57177	4714,202438	-4,684052511	0,000077392	-31771,75366	-12391,38988
Maximum Temperature	16576,46835	7127,21682	2,325798242	0,028096547	1926,26436	31226,67234

Table 4.9 shows the relationship between climate variability and citrus production for Farm 5. Results show that 67.58% of the variation in citrus production (oranges and grapefruits) is explained by SPI and temperature. This indicates that 32.42% of the variation in citrus production is caused by factors other than SPI and temperature. The model indicates a strong negative significant relationship between climate variability and citrus production with $p < 0.05$ and adjusted $r^2 > 0.5$.

The results of the evaluation of each of the independent variables show that the minimum SPI coefficient is 13181.07416, maximum SPI coefficient is 8634.346002 and maximum temperature coefficient is 44301.94947, larger than the coefficient of the minimum temperature (-25485.88278). This indicates that minimum SPI, maximum SPI, and maximum temperature make a strong individual contribution in explaining citrus production than minimum temperature indicating minor contributions. Results show that minimum and maximum temperature are both statistically significant indicating $p < 0.05$ meanwhile minimum SPI and maximum SPI have an insignificant influence on citrus production recording $p > 0.05$.

The relationship between each citrus variety against SPI and temperature was analysed for Farm 5 using multiple linear regression to evaluate how each citrus variety is affected by climate variability. Table **A7** (refer to Appendix S) is the regression output of the relationship between climate variability and orange production for farm 5. Results indicate that 67.81% of the variation in orange production is explained by SPI and temperature. The model reveals a strong negative significant relationship ($p < 0.05$ and adjusted $r^2 > 0.5$). Minimum SPI, maximum SPI and maximum temperature have shown to have a strong influence on oranges than minimum temperature. Minimum temperature and maximum temperature indicate a statistically significant influence on orange production recording $p < 0.05$, minimum SPI and maximum SPI indicates an insignificant influence with $p > 0.05$.

The relationship between climate variability and grapefruit production for Farm 5 is shown in Table **A8** (refer to Appendix T). Results indicate that 58.67% of the variation in grapefruits production is explained by SPI and temperature. The model indicates a strong negative significant relationship ($p < 0.05$ and adjusted $r^2 > 0.5$). Minimum SPI, maximum SPI and maximum temperature have shown to have a strong influence on grapefruits than minimum temperature. Maximum temperature indicates a statistically significant influence on grapefruits production recording $p < 0.05$. Meanwhile, minimum SPI, maximum SPI and maximum temperature reveal an insignificant influence on grapefruits production $p > 0.05$. Kom (2020) emphasised that the livelihood and crop production of farmers' have been affected by rising temperatures, decreasing rainfall and prolonged drought.

Table 4. 9: The Relationship Between Climate Variability and Citrus Production for Farm 5

Regression Statistics						
Multiple R	0,847962045					
R Square	0,719039629					
Adjusted R Square	0,675814957					
Standard Error	38099,8203					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	96588842514	24147210628	16,63493528	0,000000703	
Residual	26	37741503988	1451596307			
Total	30	1,3433E+11				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-544661,9885	359823,3324	-1,513692803	0,142166252	-1284289,441	194965,464
Minimum SPI	13181,07416	285118,136	0,04623022	0,963480021	-572887,6478	599249,7961
Maximum SPI	8634,346002	4797,610858	1,799717872	0,083521344	-1227,284352	18495,97636
Minimum Temperature	-25485,88278	7206,734031	-3,536398412	0,001546223	-40299,53674	-10672,22882
Maximum Temperature	44301,94947	10895,57707	4,066048927	0,000393459	21905,77004	66698,12889

4.6 The Relationship Between Citrus Production and Farm Net Revenue

Simple linear regression analysis was used to assess the relationship between citrus production and net farm revenue from 1987 to 2017. This was done to establish the influence of citrus production on farmers' income and rural livelihoods in Mopani District Municipality. Table 4.10 shows the relationship between citrus production (oranges) and net revenue for Farm 1. Results indicate that 97.97% of the variance in farm net revenue is explained by citrus production. This implies that 2.03% of the variation is caused by factors other than citrus production, factors such as citrus market export rates and renting of farm equipment. The model shows a very strong positive significant relationship between citrus production and net revenue with $p < 0.05$ and $r^2 > 0.5$. The results of the evaluation of the independent variable show that for every unit increase in citrus production, net revenue will increase by the value of the coefficient that is 14.36547375. Similarly, a negative coefficient sign indicates that for every unit increase in citrus production, net revenue will decrease by the value of the coefficient. Sarker *et al.* (2017) mentioned that citrus production is more profitable than other horticultural crops. Likewise, yield loss reduces the profit margin of citrus farmers'.

Table 4. 10: The Relationship Between Citrus Production and Net Revenue for Farm 1

Regression Statistics						
Multiple R	0,989812624					
R Square	0,979729031					
Adjusted R Square	0,979030032					
Standard Error	148120,5232					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	3,0751E+13	3,0751E+13	1401,617369	0,000000000	
Residual	29	6,36251E+11	21939689384			
Total	30	3,13873E+13				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-506957,4645	84999,54688	-5,964237258	0,000001757	-680801,0573	-333113,8716
Citrus Production	14,36547315	0,383711839	37,43818063	0,000000000	13,58069432	15,15025198

Table 4.11 shows the relationship between citrus production (oranges) and net revenue for Farm 2. Results indicate that 93.09% of the variance in farm net revenue is explained by citrus production. This implies that 6.91% of the variation is caused by factors other than citrus production. The model indicates a very strong positive significant relationship between citrus production and net revenue with $p < 0.05$ and $r^2 > 0.5$. Results of the evaluation of the independent variable shows that for every unit increase in citrus production, net revenue will increase by the value of the coefficient that is 24.07292403.

Mano and Nhemachena (2007) examined the economic impact of climate change on agriculture in Zimbabwe. The study showed that climatic variables have significant impact on agricultural production and farm net revenues. Mano and Nhemachena (2007) suggests that agricultural production and farm net revenue in Zimbabwe's smallholder farming system is significantly constrained by climatic factors (high temperatures and low rainfall). These findings show that the changes in farm net revenue is high for rainfed farming compared to farms with irrigation. This suggests that citrus farms with irrigation are more resistant to changes in climate, indicating that irrigation is an important adaptation option to help increase net revenue and reduce the impact of further climate changes.

Table 4. 11: The Relationship Between Citrus Production and Net Revenue for Farm 2

Regression Statistics						
Multiple R	0,964870205					
R Square	0,930974513					
Adjusted R Square	0,928594324					
Standard Error	19748,5703					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	1,52545E+11	1,52545E+11	391,1346676	0,000000000	
Residual	29	11310174835	390006028,8			
Total	30	1,63855E+11				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-315446,2072	41547,86903	-7,592355866	0,000000023	-400421,1405	-230471,2738
Citrus Production	24,07292403	1,2172105	19,77712486	0,000000000	21,58344904	26,56239903

Table 4.12 shows the relationship between citrus production (oranges, tangerines, grapefruits, lemons, and limes) and net revenue for Farm 3. Results indicate that 99.65% of the variance in farm net revenue is explained by citrus production. This implies that 0.35% of the variation is caused by factors other than citrus production. The model indicates a very strong positive significant relationship between citrus production and net revenue with $p < 0.05$ and $r^2 > 0.5$. Results of the evaluation of the independent variable shows that for every unit increase in citrus production, net revenue will increase by the value of the coefficient that is 19.11979421. According to Munro *et al.* (2016) lemons are regarded as more economically efficient in comparison to oranges (Velencias and navels) and soft citrus (tangerines), in that they provide higher net revenue. Further, Munro *et al.* (2016) revealed that in an average season, lemons generated approximately 39% more income than oranges, despite oranges being the dominant cultivar.

Table 4. 12: The Relationship Between Citrus Production and Net Revenue for Farm 3

Regression Statistics						
Multiple R	0,998296328					
R Square	0,996595558					
Adjusted R Square	0,996478164					
Standard Error	209305,3718					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	3,71905E+14	3,71905E+14	8489,283765	0,000000000	
Residual	29	1,27045E+12	43808738654			
Total	30	3,73175E+14				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2807482,923	159329,8169	-17,62057459	0,000000000	-3133348,988	-2481616,859
Citrus Production	19,11979421	0,207514137	92,1373093	0,000000000	18,69538015	19,54420828

Table 4.13 shows the relationship between citrus production (oranges, lemons, and limes) and net revenue for Farm 4. Results indicate that 97.25% of the variance in farm net revenue is explained by citrus production. This implies that 2.75% of the variation is caused by factors other than citrus production. The model indicates a very strong positive significant relationship between citrus production and net revenue with *p*< 0.05 and r^2> 0.5. Results of the evaluation of the independent variable shows that for every unit increase in citrus production, net revenue will increase by the value of the coefficient that is 16.56066249. Deressa and Hassan (2009) highlighted that increasing temperature and decreasing rainfall significantly affect crop production and farm net revenue. Fleischer *et al.* (2008) stated that farm net revenue is expected to increase with the introduction of irrigation in crop production.

Table 4. 13: The Relationship Between Citrus Production and Net Revenue for Farm 4

Regression Statistics						
Multiple R	0,986192035					
R Square	0,97257473					
Adjusted R Square	0,971629031					
Standard Error	118416,7701					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	1,4421E+13	1,4421E+13	1028,418958	0,000000000	
Residual	29	4,06653E+11	14022531439			
Total	30	1,48277E+13				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-770388,5093	101682,9503	-7,576378411	0,000000024	-978353,4933	-562423,5253
Citrus Production	16,56066249	0,516407653	32,06897188	0,000000000	15,50449025	17,61683473

Table 4.14 shows the relationship between citrus production (oranges and grapefruits) and net revenue for Farm 5. Results indicate that 99.83% of the variance in farm net revenue is explained by citrus production. This implies that 0.17% of the variation is caused by factors other than citrus production. The model indicates a very strong positive significant relationship between citrus production and net revenue with $p < 0.05$ and $r^2 > 0.5$. Results of the evaluation of the independent variable shows that for every unit increase in citrus production, net revenue will increase by the value of the coefficient that is 16.38349221.

Table 4. 14: The Relationship Between Citrus Production and Net Revenue for Farm 5

Regression Statistics						
Multiple R	0,999199193					
R Square	0,998399027					
Adjusted R Square	0,998343821					
Standard Error	44651,34066					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	3,60568E+13	3,60568E+13	18084,98225	0,000000000	
Residual	29	57818524455	1993742223			
Total	30	3,61146E+13				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-776926,8575	28822,50476	-26,9555635	0,000000000	-835875,4986	-717978,2164
Citrus Production	16,38349221	0,12182809	134,4804159	0,000000000	16,13432579	16,63265864

4.7 Chapter Summary

This chapter presented, analysed, and discussed the findings on the effects of climate variability on citrus production and the influence of citrus production on farmer's income and rural livelihood in Mopani District Municipality, South Africa. The results of the Standardized Precipitation Index revealed that Mopani District Municipality falls within the near normal category with events of extremely wet and moderately wet conditions. The results show that non-drought is a natural climatic feature of the area and occurs from time to time in defined periods. However, extremely wet, moderately wet, and severely wet conditions tend to concentrate on the maximum SPI. The Mann-Kendall test results show a weak negative decreasing trend of rainfall in the area; however, the area experienced several rainfall variations over the study period. The annual average maximum temperature shows a weak positive increasing trend. The annual minimum temperature shows a weak negative decreasing trend. The study shows very strong positive increasing trends in citrus production.

The results indicate a weak negative significant relationship between climate variability and citrus production for Farm 1. A weak positive significant relationship between climate variability and citrus production for Farm 2. A strong negative significant relationship between climate variability and citrus production for Farm 3 and 5. A strong positive significant relationship between climate variability and citrus production for Farm 4. It was noted that maximum SPI and maximum temperature makes strong individual contribution in explaining citrus production than minimum SPI and minimum temperature indicating minor contributions. The study reveals that climate variability significantly influences citrus production. However, citrus performance in different locations vary significantly, this may be attributed to uneven temperature, irregular rainfall distributions and different farming practices across the area. Citrus production depends on favourable weather conditions and the amount of rainfall received. The study shows a very strong negative significant relationship between citrus production and farm net revenue. Moreover, factors such as citrus market export rates, citrus price fluctuations and renting of farm equipment also contributes to farm net revenue.

CHAPTER 5: THE INFLUENCE OF CLIMATE VARIABILITY AND CITRUS PRODUCTION ON CITRUS WORKERS LIVELIHOODS

5.1 Introduction

The sustainable livelihood framework approach indicators, namely, financial assets, social assets, human assets, physical assets, and natural assets were used as a guide in designing questionnaires. These indicators were explored together with matters relating to climate variability, citrus production, and livelihood conditions in the study area. Themes in this chapter includes demographic and socio-economic variables, that have a reflective effect which influences citrus production, citrus workers livelihoods and their adaptive measures to climate variability. Chapter 5 and chapter 6 attempts to answer the second objective which is to establish the influence of citrus production on farmer's income and rural livelihood in Mopani District Municipality.

The survey participants were 234 citrus workers from Mopani District Municipality. Descriptive statistics such as the measures of central tendency and measures of dispersion were used to gain better understanding of gathered survey data. Tables were used to describe and summarise the results. The results are presented and discussed according to the research objectives and questions formulated. Chi-Square test, Cramer's V, *p*-value, odds ratio, and relative risk were employed to test the level of association or correlation between climate variability related variables and farm workers related variables (livelihood variables).

5.2 Socio-Economic Information

5.2.1 Employment Contract Type

Table 5.1 shows the type of employment contract for citrus workers. The study found that majority of participants (55%) were engaged on an annual basis, followed by 42.5% who were employed on a seasonal basis while only 2.5% participants were employed on an inter-annual basis. The result implies that 4 in every 10 participants were employed seasonally while 6 in every 10 were employed on annual basis. In addition, other participants were employed on permanent basis. All 234 farm workers that participated in this study indicated that they worked for 5 days per week. The participants also indicated that they worked on the farm for an average of 9 hours per day.

Table 5. 1: Employment Contract Type for Citrus Workers

Employment Contract type	Frequency	Percentage
Seasonally	99.45	42.5
Inter-annual	5.85	2.5
Annually	128.7	55.0

Total	234	100.0

5.2.2 Important Source of Income

The participants unanimously indicated that their most important source of income were wages. Table 5.2 shows a range of monthly household incomes that best describe the survey participants. Majority of participants (47.5%) earned between R3 000.00 and R4 000.00, followed by 25.0% that indicated that their monthly income ranged from R5 000.00 and above, 17.5% whose monthly income ranged between R4 000.00 and R5 000.00 while 10% had monthly income ranging from R2 000.00 and R3 000.00. Fadipe *et al.* (2014) evaluated the determinants of income among rural households in Kwara State, Nigeria. The results of the study showed that farm income is the most important source of income for rural households, making up to 57.9% of total household income.

Table 5. 2: Importance Source of Income

Monthly Household Income	**Frequency**	**Percentage**
R2000 - R3000	23.4	10.0
R3000 - R4000	111.15	47.5
R4000 - R5000	40.95	17.5
R5000 and over	58.5	25.0
Total	234	100.0

5.2.3 Remittances

Table 5.3 shows remittances for citrus workers. The study found that half (50%) of the total surveyed participants earned remittances between R0 - R1 000.00, while 37.50% participants earned between R1 000.00 - R2 000.00, 10% earned between R2 000.00 - R3 000.00 and 2.5% (n = 5.85) earned between R3 000.00- R4 000.00. Remittances significantly reduce household consumption instability. According to Combes and Ebeke (2011) remittances play an insurance role by dampening the effects of various sources of consumption instability such as agricultural shocks, economic shocks, natural disasters, systemic financial and banking crisis.

Table 5. 3: Citrus Workers Remittances

Income	Frequency	Percentage
R0 - R1 000	117	50.0
R1 000 - R2 000	87.75	37.5
R2 000 - R3 000	23.4	10.0
R3 000 - R4 000	5.85	2.5
Total	234	100.0

- **Uses of Cash Remittances**

Table 5.4 shows the uses of cash remittances by citrus workers. The study found that 60% participants did not use their cash remittances exclusively on food, while 40% participants used their cash exclusively on food. Likewise, 62.5% participants revealed that they did not exclusively use their cash remittances on food, clothes, and education while 37.5% participants reported that they used their cash remittances exclusively on food, clothes, and education. Moreover, 92.5% participants revealed that they did not solely use their cash remittances on food and clothes while 7.5% participants revealed that they exclusively use their cash remittances on food and clothes. Additionally, 87.5% participants reported that they did not exclusively use their cash remittances on food and education while 12.5% participants agreed that they exclusively use their cash on food and education. Furthermore, 65.0% participants revealed that they did not exclusively use their cash remittances on improvements to their houses while 35.0% participants agreed that they exclusively use their cash remittances on improvements to their houses.

Table 5. 4: Uses of Cash Remittances

Food, exclusively	**Frequency**	**Percentage**
No	140.4	60.0
Yes	93.6	40.0
Total	234	100.0
Food, Clothes, and Education		
No	146.25	62.5
Yes	87.75	37.5

Total	234	100.0
Food and Clothes		
No	216.45	92.5
Yes	17.55	7.5
Total	234	100.0
Food and education		
No	204.75	87.5
Yes	29.25	12.5
Total	234	100.0
Improvements to house		
No	152.1	65.0
Yes	81.9	35.0
Total	234	100.0

5.2.4 Income Comparison of the Current Year and Previous Year

Table 5.5 shows income comparison of the current year (2020) and previous year (2019). The study found that 50.0% of the participants' income for the year 2020 was better than the income of the year 2019, while 50.0% participants revealed that their income for 2020 was much the same with that of 2019.

Table 5. 5: Income Comparison of the Current Year and Previous Year

Comparison	**Frequency**	**Percentage**
Better than last year.	117	50.0
Much the same as last year.	117	50.0
Total	234	100.0

- **Citrus Workers Additional Work to Increase Income**

Table 5.6 shows that majority (87.5%) of the survey participants revealed that they did not do additional work to increase their income while the remaining 12.5% revealed that they undertook additional work to increase their income to ensure the livelihood of their families. The study found that of the 29.25 participants that did additional work, 5.85 participants revealed that the second job contributed R500.00 extra. Additionally, 5.85 participants reported that the second job contributed R1 000.00 extra while another 5.85 participants revealed that the second job contributed R1 500.00 extra income. Moreover, 11.7 participants revealed that their additional work contributed R2 000.00 extra income.

The average extra income contribution stood at R1 400.00 with a standard deviation of R651.00. The types of jobs performed ranged from anything, including running a small business at home, selling of soft drinks or containers to working on piece jobs such as washing cars and doing gardening in the neighbourhood. The participants also hinted on when they undertook these additional endeavours which ranged from every day to weekends. The participants indicated that these additional works were also done at their places of work for those that were personally involved or at home for those that were doing additional work with the help of their spouses.

An enquiry into participants level of contribution to the household income revealed that the percentage contributions ranged between 40.0% and 100.0%. The mean percentage contribution to household income is 70.55% with a standard deviation of 17.45%. The median and modal percentage contributions are 69.0% and 50.0% respectively, implying that most participants contributions to household income was 50.0% while half of the participants percentage contribution were below 69.0% or above 69.0%.

Table 5. 6: Citrus Workers Additional Work to Increase Income

Do you do additional work to increase income?	**Frequency**	**Percentage**
No	204.75	87.5
Yes	29.25	12.5
Total	234	100.0

5.2.5 Income Spent on Basic Necessities

Table 5.7 shows the amount of income spent on necessities. Results show that 97.5% participants spend less than R500.00 on transport while the remaining 2.5% revealed that they spent between R500.00 - R1 000.00 Likewise, 84.6% participants spend less than R500.00 on electricity, 15.4% participants spend between R500.00 - R1 000.00 and 2.5% participants did not say anything. Results indicate that 8.5% participants spend less than R500.00 on clothing, 33.3% participants spend between R500.00 - R1 000.00, 15.2% participants spend between R2 500.00 – R 3 000.00 and 3.0% participants did not specify the amount that they spend on clothing. Similarly, 17.5% participants reported that they spend between R500.00 - R1 000.00 on food, 35.0% participants spend between R1 000.00 - R1 500.00, 37.5% participants spend between R1 500.00 - R2 000.00 and 10.0% participants revealed that they spend R2 500.00 - R3 000.00.

Only 2.5% participants reported that they used less than R500.00 on petrol per month while 97.5% of the participants did not say anything. This might be because most participants did not own cars, hence only 2.5% owned cars. Additionally, 20.0% of the participants spend less than R500.00 on paraffin while 80.0% did not say anything. Moreover, 15.0% of the participants revealed that they spend less than R500.00 on medical per month while 85.0% did not say anything. Further, 7.5% of the participants spend less than R500.00 per months on rent while 92.5% participants did not say anything.

Likewise, 60.0% of the participants revealed that they spend less than R500.00 on loans, 5.0% spend between R500.00 - R1 000.00, 5.0% spend between R1 000.00 - R1 500.00 and 30.0% participants did not say anything. In addition, 2.5% participants reported that no money was spent on security, 12.5% spend less than R500.00 and 85.0% participants did not say anything. Similarly, 65.0% participants indicated that they spend less than R500.00 on taxes, 2.5% spend between R500.00 - R1 000.00 while 32.5% people did not say anything on taxes.

Table 5. 7: Income Spent on Basic Necessities

	Cost Range	**Frequency**	**Percentage**
Transport	Less than R500	228.15	97.5
	R500 - R1000	5.85	2.5
	Total	234	100.0
Electricity	Less than R500	193.05	82.5
	R500 - R1000	35.1	15.0
	Total	228.15	97.5

	Missing System	5.85	2.5
	Total	234	100.0
Clothing	Less than R500	93.6	40.0
	R500 - R1000	64.35	27.5
	R1000 - R1500	29.25	12.5
	R2500 - R3000	5.85	2.5
	Total	193.05	82.5
	Missing System	40.95	17.5
	Total	234	100.0
Food	R500 - R1000	40.95	17.5
	R1000 - R1500	81.9	35.0
	R1500 - R2000	87.75	37.5
	R2500 - R3000	23.4	10.0
	Total	234	100.0
Petrol	Less than R500	5.85	2.5
	Missing System	228.15	97.5
	Total	234	100.0
Paraffin	Less than R500	46.8	20.0
	Missing System	187.2	80.0
	Total	234	100.0
Medical	Less than R500	35.1	15.0
	Missing System	198.9	85.0
	Total	234	100.0
Rent	Less than R500	17.55	7.5
	Missing System	216.45	92.5
	Total	234	100.0

Loan	Less than R500	140.4	60.0
	R500 - R1000	11.7	5.0
	R1000 - R1500	11.7	5.0
	Total	163.8	70.0
	Missing System	70.2	30.0
	Total	234	100.0
Security	R0.00	5.85	2.5
	Less than R500	29.25	12.5
	Total	31.1	15.0
	Missing System	198.9	85.0
	Total	234	100.0
Taxes	Less than R500	152.1	65.0
	R500 - R1000	5.85	2.5
	Total	157.95	67.5
	Missing System	76.05	32.5
	Total	234	100.0
Other	R0.00	5.85	2.5
	Less than R 500	5.85	2.5
	Total	11.7	5.0
	Missing System	222.3	95.0
	Total	234	100.0

5.2.6 Dependence on Social Relationships in Times of Large Unforeseen Difficulties

Table 5.8 shows citrus workers dependence on social relationships in times of unforeseen difficulties. The results show that 30.0% of the participants reported that during unforeseen difficulties they do not depend on friends or family for help while 70.0% agreed that they relied on friends and family for help. Similarly, 60.0% participants indicated that they do not use lenders during unforeseen difficulties while 40.0% used any lender available. All the participants (100%) reported that they do not ask their churches for help during difficult times. All the participants (100%) reported that they do not seek help from their employer. Majority of the participants (97.5%) reported that they did not know what to do during unforeseen difficulties while the remaining 2.5% responded that they know what to do during difficult times. Only 12.5% participants responded that they asked others for help during unforeseen difficulties while 87.5% participant responded that they know what they would do during difficult times.

Table 5. 8: Dependence on Social Relationships in Times of Unforeseen Difficulties

Ask friends or family for help	**Frequency**	**Percentage**
No	70.2	30.0
Yes	163.8	70.0
Total	234	100.0
Use any lender available		
No	140.4	60.0
Yes	93.6	40.0
Total	234	100.0
Ask church for help		
No	234	100.0
Total	234	100.0
Ask employer for help		
No	234	100.0
Total	234	100.0
Do not know		
No	228.15	97.5
Yes	5.85	2.5
Total	234	100.0
Other		
No	204.75	87.5

Yes	29.25	12.5
Total	234	100.0

5.2.7 Does Your Employer Help You with The Following?

Table 5.9 shows items that citrus employers help citrus workers with. Majority of the participants (97.5%) agreed that they were helped with advanced leave days or off days whilst the remaining 2.5% participants responded that they were not helped with advance leave or off days. Additionally, 82.5% of survey participants indicated that their employer did not help them with medical insurance while the remaining 17.5% reported that their employer helped them with medical insurance. Hence, 1 in every 10 farm workers were helped by their employers with medical insurance. Majority of the participants (87.5%) reported that they were not helped with funeral cover by their employers while the remaining 12.5% agreed that they were covered with funeral cover by their employers. Similarly, 2.5% of the participants indicated that their employer was not giving them bonuses while the other 97.5% agreed that they were given bonuses.

Moreover, 75.0% of the participants did not agree that their employers helped them with their education while 25.0% agreed that their employers help them with their education. All participants reported that their employers did not help them with loans. Only 5.0% participants reported that their employers did not help them with clinic cover while 95.0% reported that their employers help them with clinic covers. Furthermore, 87.5% participants reported that they were not helped with policies by their employers while 12.5% agreed that their employers cover their policies.

Table 5. 9: Citrus Employers Assistance to Citrus Workers

Advancement leaves (Off days)	**Frequency**	**Percentage**
No	5.85	2.5
Yes	228.15	97.5
Total	234	100.0
Medical insurance		
No	193.05	82.5
Yes	40.95	17.5
Total	234	100.0

Funeral cover		
No	204.75	87.5
Yes	29.25	12.5
Total	234	100.0
Bonuses		
No	5.85	2.5
Yes	228.15	97.5
Total	234	100.0
Education		
No	175.5	75.0
Yes	58.5	25.0
Total	234	100.0
Loans		
No	234	100.0
Total	234	100.0
Clinic cover		
No	11.7	5.0
Yes	222.3	95.0
Total	234	100.0
Policies		
No	204.75	87.5
Yes	29.25	12.5
Total	234	100.0
Other		
No	234	100.0
Total	234	100.0

5.3 Climate Variability and Citrus Workers Livelihoods

5.3.1 Climate Changes Observed in The Area During the Last 10 To 20 Years

Table 5.10 shows climate changes observed in Mopani District Municipality during the last 10 to 20 years. All participants (100.0%) agreed that they observed a decrease in rainfall amount in their areas. Majority of the participants (97.5%) did not agree that there was an increase in rainfall amount while 2.5% participants agreed that there was an increase in rainfall amount. All participants agreed that they observed rising temperature in their areas. Additionally, 82.5% participants did not agree that there was a decrease in temperature in their areas while 17.5% agreed that there was a decrease in temperature in their areas. Furthermore, 57.5% of the participants did not agree that there were floods in their areas while 42.5% agreed that there were floods observed in their areas.

Moreover, 2.5% of the participants did not agree that there was drought in their areas while 97.5% agreed that there was drought in their areas. Likewise, 2.5% of the participants did not agree that there was a dry spell in their areas while 97.5% agreed that there were dry spells in their areas. Similarly, 17.5% of the participants did not agree that there was high intensity rain concentration in some days whilst 82.5% agreed that they were high intensity rain concentration in some days. Additionally, 5.0% of the participants did not agree that rain comes late and ends early while 95.0% agreed that rain comes late and ends early. Further, 77.5% of the participants did not agree that there was strong wind prevalence in their areas while 22.5% agreed.

It is evident that projected global climate changes have the potential to accelerate the global hydrological cycle (Xu *et al.,* 2005; Zhang *et al.,* 2020). Many studies found that climate change alters rainfall patterns and result in more frequent extreme weather events such as floods, droughts, increased temperature, abnormal winds, and rainstorms (Zhang *et al.,* 2009; Zhang *et al.,* 2011). These findings are unquestionably beneficial for the better understanding of the world's increasing flood and drought hazards. Likewise, public awareness of extreme climatic events has risen significantly in recent years due to the catastrophic nature of droughts, floods, winds, storms, and other climatic extremes. Hence, it is of scientific and practical merit to better understand the changing climate for enhancing integrated water resource management at farm level and citrus workers adaptation to changes in climate conditions.

Table 5. 10: Climate Changes Observed in Mopani District Municipality

A decrease in rainfall amount	**Frequency**	**Percentage**
Yes	234	100.0
An increase in rainfall amount		
No	228.15	97.5

Yes	5.85	2.5
Total	234	100.0
Rising temperature		
Yes	234	100.0
Decreasing temperature		
No	193.05	82.5
Yes	40.95	17.5
Total	234	100.0
Floods		
No	134.55	57.5
Yes	99.45	42.5
Total	234	100.0
Droughts		
No	5.85	2.5
Yes	228.15	97.5
Total	234	100.0
Increase in dry spells		
No	5.85	2.5
Yes	228.15	97.5
Total	234	100.0
Rain concentration in some days with high intensity		
No	40.95	17.5
Yes	193.05	82.5
Total	234	100.0
Rain comes late and ends early		

No	11.7	5.0
Yes	222.3	95.0
Total	234	100.0
Prevalence wind		
No	181.35	77.5
Yes	52.65	22.5
Total	234	100.0

- **Effects of Climate Change on Citrus Workers**

The survey on citrus workers indicated that it is challenging to work in extreme weather conditions due to climate change.

"Extreme weather conditions such as hotter temperatures and heavy rainfall make it difficult to work in the field." **(Participant 1)**

"It is challenging to work in extreme weather because it damages crops, machinery, fertilizers, pesticides and other working equipment's." **(Participant 4)**

"Sometimes I get sick from working in very hot weather conditions and standing too long in the field." **(Participant 7)**

Other participants showed to be concerned with their job security due to extreme weather and climate events.

"Climate change events may result in job losses and income reduction." **(Participant 10)**

"There are greater chances of job losses due to incidents of heavy rainfall and extreme heat.." **(Participant 13)**

These findings indicate that extreme weather conditions due to climate change damage citrus trees, fertilizers, machineries, and other working materials. The study found that greater incidence of extreme weather and climate events may result in the displacement of citrus workers. The study reveals that heat stress from extremely hot conditions and floods results in loss of working hours and days. The results also show that constant daily heat exposure causes health problems such as dehydration for citrus workers.

5.3.2 Effects of Climate Change on Ways of Accessing Finances for Sustaining Livelihoods

Table 5.11 shows the effects of climate change on the ways of accessing finances for sustaining livelihoods. The results show that 67.5% of farm workers revealed that climate change reduced access to finances for sustaining their livelihoods, 22.5% indicated that climate change had no effect on the ways of accessing finances for sustaining their livelihoods while 10.0% of the farm workers revealed that climate change had increased the ways in which they accessed finances for sustaining their livelihoods.

Citrus workers that indicated that there was no change in their finances pointed to the reasons that include being salaried or wage employees which made their finances constant and fixed. On the other hand, those who indicated that access to finances had been reduced pointed out to the reality that due to climate change, things had become expensive on the backdrop of wages inadequate enough to support families. Majority of the rural economies rely on agricultural livelihoods; thus, climate change can have comprehensive and disastrous effects on the activities (Von Uexkull *et al.,* 2016). Manatsa *et al.* (2010) observed that extreme climate events have dire consequences on finances, food insecurity and agriculture. Sarker *et al.* (2017) stated that climate change has the most direct and severe impact on rural livelihoods when it comes to citrus production. Hence, climate change can undermine citrus yields and reduce citrus vendors access to finances derived from farm crop sales.

Table 5. 11: Effects of Climate Change on Finances

Effects of climate change on finances	Frequency	Percentage
Increased access	23.4	10.0
No change	52.65	22.5
Reduced access	157.5	67.5
Total	234	100.0

5.4 Climate Variability Related Variables versus Socio-Economic Variables

This section presents Chi-Square test results revealing the level of association between climate variability related variables and farm workers variables (that is, livelihoods-related variables).

5.4.1 Income Comparison Versus Knowledge of Climate Variability

Table 5.12 shows a Chi-Square test that indicates a statistically significant association between “Do you know what climate variability means?” and “How does year 2020's income compare with year 2019's income?” (Chi-Square = 5.991, df = 1, $p< 0.05$, Cramer's V = 0.333, $p< 0.05$). A statistically significant relative risk value of 0.444 (95% CI: 0.308; 0.640) is reported. Hence, the likelihood of earning better than the previous year is less for farm workers that knew what climate change was than for farm workers that did not know what climate change was.

Table 5. 12: Income and Knowledge of Climate Variability Relationship

Do you know what climate variability means?	Statistic	How does this year's income compare with last year's income?		Total
		Better than last year	**Much the same as last year**	
Yes	Count	117	93.6	210.6
	Expected Count	105.3	105.3	210.6
	% Within Do you know what climate variability means?	55.6%	44.4%	100.0%
	% Within How does this year's income compare with last year's income?	100.0%	80.0%	90.0%
	Adjusted Residual	2.1	-2.1	
No	Count	0	23.4	23.4
	Expected Count	11.7	11.7	23.4
	% Within Do you know what climate variability means?	0.0%	100.0%	100.0%

	% Within How does this year's income compare with last year's income?	0.0%	20.0%	10.0%
	Adjusted Residual	-2.1	2.1	
Total	Count	117.0	117.0	234.0
	Expected Count	117.0	117.0	234.0
	% Within Do you know what climate variability means?	50.0%	50.0%	100.0%
	% Within How does this year's income compare with last year's income?	100.0%	100.0%	100.0%

5.4.2 Policies versus Climate Variability

Table 5.13 shows a statistically significant association between forms of climate variability and policies (Chi-Square = 6.632, df = 2, $p < 0.05$, Cramer's V = 0.480, $p < 0.011$). This implies that whether farm workers had policies or otherwise varied depending on what they thought climate variability was. Precisely, there is large positive residuals among farm workers with policies that described climate variability in terms of drought and floods. Similarly, there is negative positive residuals among farm workers without policies that described climate variability in terms of drought and floods. In other words, the number of farm workers that were observed under drought and floods, among those with policies, was less than what one would have expected if these two variables were truly independent.

The odds ratio of a 2X2 table for farm workers with policies and farm workers without policies identifiers provide evidence of climate variability gap and has a sample odds ratio of (3X22)/(1X12) = 5.50. Thus, of those farm workers identifying with one of the policy options, the estimated odds of identifying with the farm workers with policies rather than farm workers without policies were 5.5 times higher for workers that indicated knowing rainfall and temperature than those that indicated weather and climate.

Table 5. 13: Policies and Climate Variability

Climate Variability	Statistic	Policies		Total
		Yes	No	
Weather and climate	Count	5.85	128.7	134.55
	Expected Count	16.965	117.585	134.55
	% Within If yes, how would you describe it?	4.3%	95.7%	100.0%
	% Within Policies	20.0%	64.7%	59.0%
	Adjusted Residual	-1.9	1.9	
Temperature and rainfall	Count	17.55	70.2	87.75
	Expected Count	11.115	76.635	87.75
	% Within If yes, how would you describe it?	20.0%	80.0%	100.0%
	% Within Policies	60.0%	35.3%	38.5%
	Adjusted Residual	1.1	-1.1	
Drought and floods	Count	5.85	0	5.85
	Expected Count	0.585	5.265	5.85
	% Within If yes, how would you describe it?	100.0%	0.0%	100.0%
	% Within Policies	20.0%	0.0%	2.6%
	Adjusted Residual	2.6	-2.6	
Total	Count	29.25	198.9	228.15
	Expected Count	29.25	198.9	228.15
	% Within If yes, how would you describe it?	12.8%	87.2%	100.0%
	% Within Policies	100.0%	100.0%	100.0%

5.4.3 Medical Insurance Versus Decreasing Temperature

Table 5.14 shows a significant association between medical insurance and decreasing temperature (Chi-Square = 9.236, df = 1, $p < 0.05$, Cramer's V = 0.481, $p < 0.05$). Statistically significant odds ratio value of 13.333 (95% CI: 1.974; 90.071) and relative risk value of 6.286 (95% CI: 1.791; 22.055) are reported. The odds of receiving help with medical insurance from employers are 13.33 times higher for farm workers that observed decreasing temperature than for farm workers that did not observe decreasing temperature. In other words, the odd of observing decreasing temperature is 13.33 times higher for farm workers that received help with medical insurance from employers than for farm workers that were not helped with medical insurance by their employers. The relative risk implies that the risk of observing decreasing temperature is 6.286 higher when a farm worker received medical insurance from employers than when a farm worker did not receive medical insurance.

Table 5. 14: Medical Insurance and Decreasing Temperature

Does your employer help you with medical insurance?	**Statistic**	**Decreasing temperature**		**Total**
		Yes	**No**	
Yes	Count	23.4	17.55	40.95
	Expected Count	7.02	33.93	40.95
	% Within medical insurance	57.1%	42.9%	100.0%
	% Within decreasing temperature	57.1%	9.1%	17.5%
	Adjusted Residual	3.0	-3.0	
No	Count	17.55	175.5	193.05
	Expected Count	33.93	159.12	193.05
	% Within medical insurance	9.1%	90.9%	100.0%
	% Within decreasing temperature	42.9%	90.9%	82.5%
	Adjusted Residual	-3.0	3.0	
Total	Count	40.95	193.05	234

	Expected Count	40.95	193.05	234
	% Within medical insurance	17.5%	82.5%	100.0%
	% Within decreasing temperature	100.0%	100.0%	100.0%

5.4.4 Education Versus Decreasing Temperature

Table 5.15 shows a statistically significant association between education and decreasing temperature (Chi-Square = 4.675, df = 1, $p < 0.05$, Cramer's V = 0.342, $p < 0.05$). Odds ratio value of 6.000 (95% CI: 1.054; 34.143) and relative risk value of 4.000 (95% CI: 1.074; 14.896) are reported. The odds of receiving help with education from employers is 6.00 times higher for farm workers that observed decreasing temperature than for farm workers that did not observe decreasing temperature. In other words, the odd of observing decreasing temperature is 6.00 times higher for farm workers that received help from employers with education than for farm workers that were not helped with education by their employers. The relative risk implies that the risk of observing decreasing temperature is 4.00 higher when farm workers received education from employers than when farm workers did not receive education. Yang *et al.* (2020) suggested that investments in human capital such as education serve as an important pathway out of poverty by expanding climate change and variability knowledge. However, the lack of access to education has hindered climate change and variability knowledge in many low-income rural areas.

Table 5. 15: Education and Decreasing Temperature

Does your employer help you with education?	**Statistic**	**Decreasing temperature**		**Total**
		Yes	**No**	
Yes	Count	23.4	35.1	58.5
	Expected Count	10.53	48.555	58.5
	% Within Education	40.0%	60.0%	100.0%
	% Within Decreasing temperature	57.1%	18.2%	25.0%
	Adjusted Residual	2.2	-2.2	
No	Count	17.55	157.95	175.5

	Expected Count	31.005	145.08	175.5
	% Within Education	10.0%	90.0%	100.0%
	% Within Decreasing temperature	42.9%	81.8%	75.0%
	Adjusted Residual	-2.2	2.2	
Total	Count	40.95	193.05	234
	Expected Count	40.95	193.05	234
	% Within Education	17.5%	82.5%	100.0%
	% Within Decreasing temperature	100.0%	100.0%	100.0%

5.4.5 Type of Work Versus Floods

Table 5.16 shows a statistically significant association between type of work and floods (Chi-Square = 15.856, df = 3, $p < 0.05$, Cramer's V = 0.544, $p < 0.05$). This means that the type of work for citrus workers influence whether they experience floods. Positive residuals are reported for skilled workers and management that did not experience floods, and for crop production workers and general workers that experienced floods. This implies that more crop production workers and general workers that experienced floods were observed than what one would have expected if the hypothesis of independence were true. In addition, these results mean that more skilled workers and management workers that did not experience floods were observed than what one would have expected assuming the hypothesis of independence were true. Similarly, negative residuals are reported for skilled workers and management workers that experienced floods, and for crop production and general workers that did not experience floods. These results show that fewer crop production workers and general workers that did not experience floods were observed than what one would have expected if the hypothesis of independence were true. Likewise, fewer skilled workers and management workers that experienced floods were observed than what one would have expected assuming the hypothesis of independence were true. The odds ratio provides evidence for this gap in floods experience caused by the type of work. Consequently, a 2X2 cross-tabulation with identifiers “Yes” and “No” for management and crop production work was considered. The odd ratio of (10X5)/(2X12) = 2.08 indicates that the odds of observing floods among the crop production workers is 2.08 times higher than among the management farm workers.

Table 5. 16: Type of Work and Floods

Type of work	Statistic	Floods		Total
		Yes	No	
Skilled workers	Count	0	35.1	35.1
	Adjusted Residual	-2.3	2.3	
Management	Count	11.7	29.25	40.95
	Adjusted Residual	-0.8	0.8	
Crop production	Count	58.5	70.2	128.7
	Adjusted Residual	0.4	-0.4	
General work	Count	29.25	0	29.25
	Adjusted Residual	2.8	-2.8	
Total	Count	99.45	134.55	234

5.4.6 Improvements to House Versus Floods

Table 5.17 shows that the association between "improvements to house" and floods is statistically significant (Chi-Square = 3.913, df = 1, p< 0.05, Cramer's V = 0.313, p< 0.05) with the odds ratio value of 0.234 (95% CI: 0.053; 1.039) and a relative risk value of 0.398 (95% CI: 0.137; 1.154). The odds ratio of less than 1 implies that farm workers that observed floods are less likely to improve their houses than those that did not observe floods. Similarly, a relative risk of less than 1 implies that observing floods decreases the likelihood of farm workers to improve their houses. Alternatively, the results show that the risk of farm workers not doing improvements to their houses if they observed floods are 1.578 times higher than when floods were not observed (relative risk = 1.578; 95% CI: 1.008; 2.473). According to a study by Wilk (2018) floods are among the natural hazards that could pose a significant risk to people and the building of objects in flood prone areas. Floods can pose financial pressures to homeowners and often cause extensive damages, such as assets, folding or loose floors and roof or foundation cracks (Nicholls *et al.,* 2019). This may be the reason farm workers that observed floods are less likely to improve their houses than those that did not observe floods. In addition, the study suggests that houses along the floodplain have lost value following repeated severe floods. Thus, results indicate that floods affect property values across all of kinds communities.

Table 5. 17: Improvements to House and Floods

Floods	Statistic	Improvements to house		Total
		Yes	No	
Yes	Count	17.55	81.9	99.45
	Expected Count	35.1	64.35	99.45
	% Within Floods	17.6%	82.4%	100.0%
	% Within Improvements to house	21.4%	53.8%	42.5%
	Adjusted Residual	-2.0	2.0	
No	Count	64.35	70.2	134.55
	Expected Count	46.8	87.75	134.55
	% Within Floods	47.8%	52.2%	100.0%
	% Within Improvements to house	78.6%	46.2%	57.5%
	Adjusted Residual	2.0	-2.0	
Total	Count	81.9	152.1	234
	Expected Count	81.9	152.1	234
	% Within Floods	35.0%	65.0%	100.0%
	% Within Improvements to house	100.0%	100.0%	100.0%

5.4.7 Clothing Versus Floods

Table 5.18 shows a statistically significant association between clothing and floods (Chi-Square = 10.654, df = 3, $p< 0.05$, Cramer's V = 0.502, $p< 0.05$). This implies that the expenditure on clothing by farm workers depends on whether farm workers observed floods. There is evidence of the gap in spending that is caused by observation or non-observation of floods by farm workers. The odds ratio for a 2X2 table of “Less than R500.00” and “R500.00 - R 1 000.00” identifiers have a sample odds ratio of (8X9)/(3X7) = 3.43. Therefore, of those farm workers identifying with one of the clothing expenditures options, the estimated odds of identifying with the "R500.00 - R1 000.00" rather than "Less than R500.00" are 3.43 times higher for farm workers that observed floods than in those that did not observe floods. A relative risk of 2.13 (>1) indicates that observing floods increases the likelihood of farm workers to spend R500.00 to R1 000.00 on clothing on monthly basis. Alternatively, observing floods decreases the probability of spending less than R500.00 on clothing per month. Some of the major impacts of floods is loss of employment and access to basic needs such as clothing. Most of the losses to these assets were attributed to households' proximity to flood prone areas.

Table 5. 18: Clothing and Floods

		Clothing				
Floods	**Statistic**	**Less than R500**	**R500 - R1000**	**R1000 - R1500**	**R2500 - R3000**	**Total**
Yes	Count	40.95	46.8	0	0	87.75
	Expected Count	42.705	29.25	13.455	2.925	87.75
	% Within Floods	46.7%	53.3%	0.0%	0.0%	100.0%
	% Within Clothing	43.8%	72.7%	0.0%	0.0%	45.5%
	Adjusted Residual	-0.2	2.2	-2.2	-0.9	
No	Count	52.65	17.55	29.25	5.85	105.3
	Expected Count	50.895	35.1	15.795	2.925	105.3
	% Within Floods	50.0%	16.7%	27.8%	5.6%	100.0%
	% Within Clothing	56.3%	27.3%	100.0%	100.0%	54.5%
	Adjusted Residual	0.2	-2.2	2.2	0.9	
Total	Count	93.6	64.35	29.25	5.85	193.05
	Expected Count	93.6	64.35	29.25	5.85	193.05
	% Within Floods	48.5%	33.3%	15.2%	3.0%	100.0%

	% Within Clothing	100.0%	100.0%	100.0%	100.0%	100.0%

5.4.8 Medical Insurance Versus Floods

Table 5.19 shows a statistically significant association between medical insurance and floods (Chi-Square = 8.831, df = 1, $p < 0.05$, Cramer's V = 0.396, $p < 0.05$). A statistically significant relative risk value of 1.438 (95% CI: 1.097; 1.884) indicates that the risk of farm workers not having medical insurance when floods are observed is 1.278 times higher than when floods are not observed. Moreover, observing floods increases the risk of not having medical insurance. Tesselaar *et al.* (2020) stated that medical insurance could enhance the financial stability of individuals to the changing likelihood of floods triggered by climate change and variability. Consequently, income inequalities suggest that not all citrus workers can afford medical insurance. Floods risks can cause greater risk-based insurance premiums, minimise interest in purchasing insurances and exacerbate problems with the overpriced coverage for low-income households. The study by Tesselaar *et al.* (2020) indicates that vast differences exist in the use of floods and medical insurance as an instrument to cope with the increasing floods risk. The results from the study revealed that there is a rising unaffordability and declining demand for floods and medical insurance across scenarios towards 2080.

Table 5. 19: Medical Insurance Versus Floods

Floods	Statistic	Medical Insurance		Total
		Yes	No	
Yes	Count	0	99.45	99.45
	Expected Count	17.55	81.9	99.45
	% Within Floods	0.0%	100.0%	100.0%
	% Within Medical insurance	0.0%	51.5%	42.5%
	Adjusted Residual	-2.5	2.5	
No	Count	40.95	93.6	134.55
	Expected Count	23.4	111.15	134.55
	% Within Floods	30.4%	69.6%	100.0%

	% Within Medical insurance	100.0%	48.5%	57.5%
	Adjusted Residual	2.5	-2.5	
Total	Count	40.95	193.05	234
	Expected Count	40.95	193.05	234
	% Within Floods	17.5%	82.5%	100.0%
	% Within Medical insurance	100.0%	100.0%	100.0%

5.4.9 Funeral cover Versus Floods

Table 5.20 shows a statistically significant association between funeral cover and floods (Chi-Square = 6.057, df =1, $p< 0.05$, Cramer's V = 0.325, $p< 0.05$). This means that the extent to which farm workers possess funeral cover depends on whether they have observed floods before. A statistically significant relative risk value of 1.944 (95% CI: 1.409; 2.683) is reported, this indicates that the likelihood of non-observing floods when farm workers have funeral cover is 1.944 times higher than when workers are without funeral cover. In other words, the result reveals that the risk of a farm worker not having funeral cover when floods are observed is 1.278 times higher than when floods are not observed.

Table 5. 20: Funeral Cover and Floods

Funeral Cover	Statistic	Floods		Total
		Yes	No	
Yes	Count	0	29.25	29.25
	Expected Count	12.285	16.965	29.25
	% Within Funeral Cover	0.0%	100.0%	100.0%
	% Within Floods	0.0%	21.7%	12.5%
	Adjusted Residual	-2.1	2.1	
No	Count	99.45	105.3	204.75
	Expected Count	87.165	117.585	204.75
	% Within Funeral Cover	48.6%	51.4%	100.0%

	% Within Floods	100.0%	78.3%	87.5%
	Adjusted Residual	2.1	-2.1	
Total	Count	99.45	134.55	234
	Expected Count	99.45	134.55	234
	% Within Funeral Cover	42.5%	57.5%	100.0%
	% Within Floods	100.0%	100.0%	100.0%

5.4.10 Policies Versus Floods

Table 5.21 shows that the association between policies and floods is statistically significant (Chi-Square = 6.057, df = 1, $p < 0.05$, Cramer's V = 0.325, $p < 0.05$). A statistically significant relative risk value of 1.278 (95% CI: 1.030; 1.585) for farm workers without policies is reported and indicates that the risk of a farm worker not having policies when floods are observed is 1.278 times higher than when farm workers did not observe floods. In other words, not observing floods increases the risk of farm workers not having policies. Flood insurance policies in South Africa cover the value loss of the physical structure (Douglas *et al.,* 2010; Garvin *et al.,* 2016). Vulnerability to flood risks arises from the lack of mitigation strategies such as flood policies (Abbas *et al.,* 2015). For instance, flood victims have no access to compensation or reimbursement beyond emergency relief provided by aid organisations (Linnerooth-Bayer *et al.,* 2019). These and other significant risks are common in rural areas.

According to Harrington and Niehaus (2001) coverage of personal possessions is based on the policy that one has chosen. Therefore, it is necessary to ensure that all personal belongings are protected by the policy before deciding on what policy to purchase. The results indicate that farm workers receive low incomes and would not purchase policies even if it were fairly priced. However, farm workers would receive disaster relief after a flood and, as a result, would ultimately be able to obtain flood insurance policies at no cost.

Table 5. 21: Policies and Floods

Floods	Statistic	Policies		Total
		Yes	No	
Yes	Count	0	99.45	99.45
	Expected Count	12.285	87.165	99.45
	% Within Floods	0.0%	100.0%	100.0%
	% Within Policies	0.0%	48.6%	42.5%
	Adjusted Residual	-2.1	2.1	
No	Count	29.25	105.3	134.55
	Expected Count	16.965	117.585	134.55
	% Within Floods	21.7%	78.3%	100.0%
	% Within Policies	100.0 %	51.4%	57.5%
	Adjusted Residual	2.1	-2.1	
Total	Count	29.25	204.75	234
	Expected Count	29.25	204.75	234
	% Within Floods	12.5%	87.5%	100.0%
	% Within Policies	100.0 %	100.0%	100.0%

5.4.11 Droughts Versus Food and Education Expenses

Table 5.22 shows that the association between “food and education” and droughts is statistically significant (Chi-Square = 4.349, df = 1, $p < 0.05$, Cramer's V = 0.424, $p < 0.05$). Therefore, observation or non-observation of droughts by farm workers influences the extent to which they use their cash remittances on food and education. A statistically significant relative risk of 0.103 (95% CI: 0.041; 0.260) for workers that use their cash remittances on food and education is reported and shows that observing droughts decrease the likelihood of spending cash remittances on food and education. Madzivhandila (2015) observed that drought effects are intensifying daily, leaving most of the rural poor without food security, proper education, and adequate housing.

Table 5. 22: Droughts versus Food and Education

Droughts	Statistic	Food and education		Total
		Yes	No	
Yes	Count	23.4	204.75	228.15
	Expected Count	28.665	199.485	228.15
	% Within Droughts	10.3%	89.7%	100.0%
	% Within food and education	80.0%	100.0%	97.5%
	Adjusted Residual	-2.7	2.7	
No	Count	5.85	0	5.85
	Expected Count	0.585	5.265	5.85
	% Within Droughts	100.0%	0.0%	100.0%
	% Within food and education	20.0%	0.0%	2.5%
	Adjusted Residual	2.7	-2.7	
Total	Count	29.25	204.75	234
	Expected Count	29.25	204.75	234
	% Within Droughts	12.5%	87.5%	100.0%
	% Within food and education	100.0%	100.0%	100.0%

5.4.12 High intensity Rain Concentration in Some Days Versus Food and Clothes

Table 5.23 shows a statistically significant association between “rain concentration” and food and clothes (Chi-Square = 3.973, df = 1, $p < 0.05$, Cramer's V = 0.368, $p < 0.05$). Therefore, observation or non-observation of high intensity rain concentration in some days by farm workers during the last 10 to 30 years influences the extent to which farm workers use their cash remittances on food and clothes. A statistically insignificant odds ratio of 0.078 (95% CI: 0.006; 1.030) and relative risk of 0.106 (95% CI: 0.011; 1.014) are reported. The results indicate that observing high intensity rain concentration in some days decreases the likelihood of spending cash remittances on food and clothes. However, the statistical insignificance of the odds ratio leads to the conclusion that the results could be due to chance. Gitz *et al.* (2016) and Kogo *et al.* (2021) stated that climatic conditions such as rainfall would have a significant impact on the food security of natural resource-based livelihoods including skilled and unskilled workers. In contrast, the study reveals that rain concentration affects food and clothes access for citrus farm workers. Such observations raise the need to make clothes and food security interventions in citrus production 'all inclusive' by considering all livelihoods groups. Similarly, Islam and Al Mamun (2020) found that individuals that were less reliant on natural resources for their livelihoods such as unskilled workers were slightly more likely to encounter intolerable level of food access due to floods and natural hazards.

Table 5. 23: Rain concentration versus Food and Clothes

Rain concentration in some days with high intensity	**Statistic**	**Food and Clothes**		**Total**
		Yes	**No**	
Yes	Count	5.85	187.2	193.05
	Expected Count	14.625	178.425	193.05
	% Within Rain concentration in some days with high intensity	3.0%	97.0%	100.0%
	% Within Food and Clothes	33.3%	86.5%	82.5%
	Adjusted Residual	-2.3	2.3	
No	Count	11.7	29.25	40.95
	Expected Count	2.925	38.025	40.95
	% Within Rain concentration in some days with high intensity	28.6%	71.4%	100.0%
	% Within Food and Clothes	66.7%	13.5%	17.5%
	Adjusted Residual	2.3	-2.3	
Total	Count	17.55	216.45	234
	Expected Count	17.55	216.45	234
	% Within Rain concentration in some days with high intensity	7.5%	92.5%	100.0%

	% Within Food and Clothes	100.0%	100.0%	100.0%

5.4.13 High intensity Rain Concentration in Some Days Versus Food and Education

Table 5.24 shows a statistically significant association between “rain concentration” and food and education (Chi-Square = 5.491, df = 1, $p < 0.05$, Cramer's V = 0.423, $p < 0.05$). Therefore, observation or non-observation of high intensity rain concentration in some days by farm workers during the last 10 to 30 years influences the extent to which farm workers use their cash remittances on food and education. A statistically insignificant odds ratio of 0.086 (95% CI: 0.011; 0.682) and relative risk of 0.141 (95% CI: 0.029; 0.695) are reported. The results reveal that observing high intensity rain concentration in some days decreases the likelihood of spending cash remittances on food and education. Changes in rainfall intensity predicted due to climate variability is likely to have an influence on food security and education. According to Nciizah and Wakindiki (2014) variations in rainfall intensity will negatively influence crop production, including citrus production. This indicates that rain concentration directly and indirectly affects food security and education of citrus farm workers. It is therefore crucial to assess the interaction between predicted high intensity rainfall concentration with food and education.

Table 5. 24: Rain Concentration versus Food and Education

Rain concentration in some days with high intensity	**Statistic**	**Food and education**		**Total**
		Yes	**No**	
Yes	Count	11.7	181.35	193.05
	Expected Count	23.985	169.065	193.05
	% Within Rain concentration in some days with high intensity	6.1%	93.9%	100.0%
	% Within Food and education	40.0%	88.6%	82.5%
	Adjusted Residual	-2.7	2.7	
No	Count	17.55	23.4	40.95
	Expected Count	5.265	35.685	40.95
	% Within Rain concentration in some days with high intensity	42.9%	57.1%	100.0%

	% Within Food and education	60.0%	11.4%	17.5%
	Adjusted Residual	2.7	-2.7	
Total	Count	29.25	204.75	234
	Expected Count	29.25	204.75	234
	% Within Rain concentration in some days with high intensity	12.5%	87.5%	100.0%
	% Within Food and education	100.0%	100.0%	100.0%

5.4.14 High Intensity Rain Concentration in Some Days Versus Year Income Comparison

Table 5.25 shows a statistically significant association between rain concentration and year 2020's income comparison with year 2019's income (Chi-Square = 4.723, df = 1, $p< 0.05$, Cramer's V = 0.329, $p< 0.05$). Therefore, observation or non-observation of high intensity rain concentration in some days by farm workers during the last 10 to 30 years influences the extent to which farm workers income in 2019 compared with their income in 2020. Statistically insignificant odds ratio of 8.143 (95% CI: 0.878; 75.479) and relative risk value of 4.030 (95% CI: 0.641; 25.328) are reported. This indicates that observing high intensity rain concentration in some days during the last 10 to 30 years increases the likelihood of getting an income that is better than the income of the previous years. Therefore, the statistical insignificance of the odds ratio leads to the conclusion that the result could be due to chance.

A study by Torres *et al.* (2019) emphasised that rainfall is a vital input to agricultural production, hence fluctuations in water availability can affect crop productivity and farm revenue. The findings of the study indicated that shifts in rainfall patterns is a significant economic variable on farm revenue. Similarly, dry and wet rainfall extremes of the previous years may decrease or improve the well-being of citrus farm workers. The study reveals that citrus farm workers' income is driven by citrus productions dependency on rainfall patterns that could have a direct impact on improved food security and poverty reduction.

Table 5. 25: Rain Concentration Versus 2020 and 2019's Income

Rain concentration in some days with high intensity	Statistic	How does this year's income compare with last year's income?		Total
		Better than last year.	Much the same as last year.	

Yes	Count	111.15	81.9	193.05
	Expected Count	96.525	96.525	193.05
	% Within Rain concentration in some days with high intensity	57.6%	42.4%	100.0%
	% Within How does this year's income compare with last year's income?	95.0%	70.0%	82.5%
	Adjusted Residual	2.1	-2.1	
No	Count	5.85	35.1	40.95
	Expected Count	20.475	20.475	40.95
	% Within Rain concentration in some days with high intensity	14.3%	85.7%	100.0%
	% Within How does this year's income compare with last year's income?	5.0%	30.0%	17.5%
	Adjusted Residual	-2.1	2.1	
Total	Count	117	117	234
	Expected Count	117	117	234
	% Within Rain concentration in some days with high intensity	50.0%	50.0%	100.0%
	% Within How does this year's income compare with last year's income?	100.0%	100.0%	100.0%

5.5 Chapter Summary

This chapter presented, analysed, and discussed the findings on the influence of climate variability and citrus production on citrus workers livelihoods. The results show that there are significant relationships between livelihood variables (financial assets, social assets, human assets, physical assets, and natural assets) and climate variability variables (temperature and rainfall) with $p < 0.05$. However, some of the relationships show a statistically insignificant relative risk value implying that the established relationships could be due to chance.

The study revealed that citrus workers’ most important source of income were wages. Majority of participants (47.5%) earned between R3 000.00 and R4 000.00. The results indicate a statistically significant association between income comparison of the years 2019 and 2020, and knowledge of climate variability (Chi-Square = 5.991, df = 1, $p < 0.05$, Cramer's V = 0.333, $p < 0.05$). Citrus workers earned cash remittances that were used exclusively on food, clothes, education, and improvements to households. Remittances significantly reduce household consumption instability. The results indicate that citrus workers mean percentage contribution to household income is 70.55%. Citrus workers (67.5%) indicated that climate change and variability reduced access to finances for sustaining their livelihoods. Majority of rural economies rely on agricultural livelihoods; thus, climate variability can have comprehensive and disastrous effects on the activities.

The involvement of citrus workers in citrus production has improved their access to necessities such as food, transport, electricity, clothing, medical and security. Majority of rural economies rely on agricultural livelihoods such as citrus production. Thus, climate change and variability can have comprehensive and disastrous effects on the livelihood activities.

CHAPTER 6: THE INFLUENCE OF CLIMATE VARIABILITY AND CITRUS PRODUCTION ON CITRUS VENDORS LIVELIHOODS

6.1 Introduction

This chapter presents, interprets, and discusses the descriptive statistics and Chi-Square test results revealing the level of association between climate variability related variables and citrus vendors related variables (livelihood variables). Themes in this chapter include socio-economic variables, livelihood variables and climate variability awareness and perceptions variables that have a reflective effect which influences citrus production and citrus vendor's livelihoods. This chapter is a response to the second objective which is to establish the influence of citrus production on farmer's income and rural livelihood in Mopani District Municipality. The survey participants were 25 citrus vendors from Mopani District Municipality. The data is presented using tables.

6.2 Socio-Economic Variables

6.2.1 Numbers of Years in Citrus Vending

Table 6.1 shows the distribution of survey participants by their level of experience in citrus vending. Of all the participants, 36.0% had less than or equal to 5 years in citrus vending, 36.0% had 6 to 10 years in citrus vending, 24.0% had 11 to 15 years of experience in citrus vending while only one person had between 16 to 20 years in citrus vending. Therefore, 4 in every 10 citrus vendors have 5 years or less experience in citrus vending. Similarly, 4 in every 10 citrus vendors have 5 to 10 years of experience in citrus vending while 2 in every 10 citrus vendors have 11 to 15 years of experience in citrus vending. Sarker *et al.* (2017) states that people who engaged in citrus vending were landless, unemployed and day workers. Citrus vendors revealed that participating in citrus vending was more profitable than other horticultural crops such as bananas, mangos, and pawpaw's, in that citrus fruits have a long shelf life.

Table 6. 1: Number of years in Citrus Vending

Experience	Frequency	Percentage
16 to 20 years	1	4.0
11 to 15 years	6	24.0
6 to 10 years	9	36.0
Less or equal to 5 years	9	36.0
Total	25	100.0

6.2.2 Citrus Production and Development in Mopani District Municipality

Table 6.2 summarises the participants' responses to the question "Do you think citrus production contributes to the development of the Mopani District Municipality?". The results show that majority (80.0%) of the participants agreed that citrus production contributed to the development of Mopani District Municipality while the remaining 20.0% of the participants disagreed that citrus production contributed to the development of Mopani District Municipality. The results agree with the report by (MDM, 2020) which states that agriculture including citrus production plays an important role in the economic growth and development of Mopani district municipality. The study reveals that citrus production provides a unique opportunity for vendors to the realisation of transformative agricultural development and rural economic transformation in Mopani district municipality.

Table 6. 2: Citrus Production and Development in Mopani District Municipality

Citrus production	Frequency	Percentage
No	5	20.0
Yes	20	80.0
Total	25	100.0

- **Explanation by participants who said yes**

"Citrus production makes a significant contribution to reducing poverty in Mopani District Municipality." **(Participant 4)**

"Citrus production encourages unemployed people to consider vending because the profits are good." **(Participant 9)**

"There is a lot of unemployment in the area and selling citrus is my source of income." **(Participant 14)**

"It creates jobs for people who can't work in the formal sector and supports the economic growth of the area by producing a wide range of citrus." **(Participant 19)**

These findings indicate that citrus production plays a strategic role in the process of economic development in the area. Citrus production promotes job opportunities and ensures safe and reliable food supply. The vendors also stated that citrus contributes to the economy of Mopani by providing food and raw materials to non-agricultural sectors such as machinery manufacturers and food processing companies. The rising demand of citrus fruits and food products adversely affects the growth rate of the economy in Mopani. The study shows that citrus production increases vending opportunities and decreases poverty rates. Furthermore, citrus production increases self-employment amongst people who do not have university and college qualifications in the area.

- **Explanations by participants who said No**

“Citrus farmers’ do not do anything to help the communities. They are just farming to get their profits.” **(Participant 1)**

“Even after years of citrus production in the area there is still high unemployment rate, poverty and poor roads and infrastructure.” **(Participant 7)**

The results show that there is high unemployment in Mopani. One vendor revealed that citrus farmers’ do not participate in uplifting the communities.

6.2.3 Average Seasonal Income from Selling Citrus Produce

Table 6.3 presents the frequency distribution by their average seasonal incomes. One (4.0%) participant reported earning a mean seasonal income ranging between R2 000.00 to R3 000.00 from selling citrus produce, 16.0% reported earning an average income of R3 000.00 to R4 000.00 and 12% reported that earning an average seasonal income ranging between R4 000.00 to R5 000.00 from selling citrus produces. Majority (68.0%) reported that they earned an average seasonal income ranging from R5 000.00 and above. Hence, 7 in every 10 citrus vendors earned a mean seasonal income ranging from R5 000.00 and above. In addition, all participants reported that their seasonal income was not regular. The occupation of the household head is a key socio-economic indicator for determining livelihood status. Citrus production, both commercial and homestead have the potential to be a source of livelihood for rural impoverished people. Previous studies show that agriculture has a positive influence on rural livelihood (Sarker *et al.,* 2017).

Table 6. 3: Average Seasonal Income

Average seasonal income	**Frequency**	**Percentage**
R2000 to R3000	1	4.0
R3000 to R4000	4	16.0
R4000 to R5000	3	12.0
R5000 and over	17	68.0
Total	25	100.0

- **Comparison Between Present Income and Income for The Past 10 Years**

Table 6.4 presents frequency distributions following a comparison of citrus vendors present incomes versus the income levels 10 years back. Of all the participants, 48.0% reported that their present incomes had remained constant compared to their incomes for the past 10 years, 40.0% reported that their income had increased in comparison with the income for the past 10 years, 4.0% reported that the income had decreased while 8.0% had different views. Citrus vendors indicated that their income from selling citrus was enough to support their families. The study reveals that citrus production can create more sustainable jobs such as citrus vending, absorbing even the semi-skilled and unskilled individuals and, as such improve the vendors livelihoods and bring about sustainable rural development.

Table 6. 4: Current Income versus Income for the past 10 years

Current versus income for the past 10 years	Frequency	Percentage
Increasing	10	40.0
Decreasing	1	4.0
Constant	12	48.0
Other	2	8.0
Total	25	100.0

6.2.4 Other Means to Increase Citrus Vendors Income

Table 6.5 illustrates the frequency distribution summarising other means of earning income. Citrus vendors (4.0%) revealed that they received other incomes from gambling, side business such as owning a tuck-shop at home or selling fruits and vegetables that are in season besides citrus fruits (16.0%), loaning people money (4.0%), monthly stokvel (4.0%), renting a spare room at home and social grant (8.0%). The study revealed that citrus vendors have other means to increase their income and do not entirely depend on citrus vending as their only livelihood activity.

Table 6. 5: Other Means to Increase Income

Other means to increase income	Frequency	Percentage
Gambling	1	4.0
Side business e.g., tuck-shop at home or selling fruits and vegetables that are in season besides citrus fruits.	4	16.0

Loaning people money	1	4.0
Monthly Stokvel	1	4.0
Renting a spare room at home	1	4.0
Social grant	2	8.0
None	14	56.0
Total	25	100.0

6.2.5 To What Extent Has Your Standard of Living Changed Since You Started Selling Citrus?

Table 6.6 shows that 100.0% of the participants reported that they can afford decent food since they started selling citrus fruits. All the participants (100.0%) reported that selling citrus fruits had led to the increase in their clothing. Majority of the participants (92.0%) noted that most of their children attained education following their participation in selling citrus fruits whilst 8.0% reported that their children had dropped out or struggled to make ends meet. This shows that many citrus vendors could afford to pay all the requirements needed at school for their children's education.

All participants (100.0%) reported that through selling citrus fruits they could afford better health care services and their access to electricity and clean water increased. 88.0% of the participants stated that their social security increased ever since they started selling citrus fruits whilst the remaining 12.0% noted that their social security had decreased. The study reveals that participants who reported to have increased social security may have savings, received social grants and some sort of assistance that secures their social security. Those that reported to have a decreased social security could be due to not having pension funds and monetary assistance from government for people with inadequate income. All participants (100.0%) reported that they had access to transport ever since they started selling citrus fruits. The participants further hinted that they use transport to and from their vending locations and that stocking fruits from the farms required transportation. Randell and Gray (2016) state that climate variability has an influence in crop production, which has an impact on households' ability to invest in human capital, financial capital, natural capital, social capital, and improved living standards.

Table 6. 6: Standard of Living Since Started Selling Citrus Fruits

Food	Frequency	Percentage
Increase	25	100.0
Total	25	100.0

Clothes		
Increase	25	100.0
Total	25	100.0
Education of children		
Increase	23	92.0
Decrease	2	8.0
Total	25	100.0
Health care		
Increase	25	100.0
Total	25	100.0
Electricity/water		
Increase	25	100.0
Total	25	100.0
Social security		
Increase	22	88.0
Decrease	3	12.0
Total	25	100.0
Transportation		
Increase	25	100.0
Total	25	100.0

6.2.6 Accessible Community Infrastructure

Table 6.7 shows that 88.0% of the participants reported to have high access to transport whilst 12.0% reported to just having access to transport. Participants that reported to having access to transportation indicated that they practice citrus vending in the townships, towns, and main roads where there is high accessibility of transportation. Likewise, those that reported to have accessible transport practice citrus vending in the rural areas and just outside the citrus farms where there is few and just accessible transportation.

Nearly half (48.0%) of the participants reported to having high access to health facilities whilst 52.0% of the participants reported that the health facilities were just accessible. The results show that participants that reported to having high access to health facilities live closer to health facilities and receive free health care services. Similarly, those that reported to just having accessible health facilities live a bit far from health facilities. That may be accompanied by factors such as poor health care services from clinics, hospitals, pharmacies, the availability of medication, treatments and that other participants must pay for such services. A study by Sarker *et al.* (2017) showed that people in Kathalia Bangladesh especially those involved in citrus production were unable to access health facilities. In the livelihood pattern, food and shelter are the most essential needs. Small and marginalised people constantly put health facilities at risk since they cannot afford food and shelter. The study highlights that citrus production gradually increases household income. As a result, citrus workers are in a much better condition to have access to health facilities.

Majority (70.8%) of the participants reported that they had access to storage facilities, 24.0% had high access to storage facilities whilst the remaining 4.2% participants had “low access” to storage facilities. Participants that indicated to have accessible storage facilities revealed that they had enough room in their households and vending spaces to store citrus fruits. Likewise, 64.0% of the participants reported that market facilities were accessible to them whilst the remaining 32.0% had high access to market facilities. The results show that some vending areas have accessible market facilities while others have very high to low access. This may be due to the demand and supply of the citrus fruits.

In relation to water supply, 76.0% of the participants reported that they had high access, 20.0% had accessible water supply whilst the remaining 4.0% had low access to water supply. The study shows that there is no water scarcity in the area, but often experience events of drought and low rainfall that may result in the municipalities limiting water usage for the communities. Participants that indicated to have high access and accessible water supply revealed that water is available in the area and that they could afford to settle their water bills. Participants who reported to have low access to water supply indicated that they lived in an area where there was no running tap water. They either bought water, used borehole water, used water from the river or use water supplied by the municipalities with water tank trucks. Similarly, 52.0% of the participants reported that they had access to groundwater, 40.0% had low access to groundwater whilst the remaining 8% had high access to groundwater. Participants that indicated to have high access and accessible groundwater stated that they had community boreholes available to them for usage.

On waste disposal, 76.0% of the participants reported that waste disposal was accessible to them, 12.0% had low access to waste disposal while the remainder, 8.0% reported to having high access to waste disposal services. Participants that have high access and accessible waste disposal revealed that they had access to waste disposal facilities in their communities such as landfills, and that the municipalities waste collection services operate in their area. Participants that reported to having low access to waste disposal indicated that they did not get the municipalities waste collection services. Therefore, they dug holes in their yards to dispose waste.

In addition, 60.0% of the participants reported that they had high access to credit facilities, 36.0% reported that credit facilities were accessible and 4% had low access to credit facilities. Participants that reported to having high access and accessible credit indicated that they had unlimited access to credit and could obtain goods and services before payment based on the trust that payment will be made in the future.

Table 6. 7: Access to Community Infrastructure

Transport	**Frequency**	**Percentage**
High access	22	88.0
Accessible	3	12.0
Total	25	100.0
Health facilities		
High access	12	48.0
Accessible	13	52.0
Total	25	100.0
Education facilities		
High access	12	48.0
Accessible	13	52.0
Total	25	100.0
Tel-communications		
High access	8	32.0
Accessible	17	68.0
Total	25	100.0
Storage facilities		
High access	6	24.0
Accessible	17	68.0

Low access	1	4.0
Total	24	96.0
Missing System	1	4.0
Total	25	100.0
Market facilities		
High access	9	36.0
Accessible	16	64.0
Total	25	100.0
Water supply		
High access	19	76.0
Accessible	5	20.0
Low access	1	4.0
Total	25	100.0
Groundwater		
High access	2	8.0
Accessible	13	52.0
Low access	10	40.0
Total	25	100.0
Electricity		
High access	22	88.0
Accessible	3	12.0
Total	25	100.0
Waste disposal		
High access	3	12.0
Accessible	19	76.0
Low access	3	12.0

Total	25	100.0
Credit		
High access	15	60.0
Accessible	9	36.0
Low access	1	4.0
Total	25	100.0

6.3 Awareness and Perception of Climate Variability Trends and Related Variables

6.3.1 Impacts of Climate Variability on Livelihoods

Table 6.8 shows that 100.0% of the participants reported that climate variability had increased socio-economic problems. The participants indicated that climate variability increased income inequality between and within vendors. Similarly, Smith *et al.* (2019) pointed out that climate variability impacts can be measured as economic costs, particularly well-suited to market impacts that are linked directly to market transactions and directly affect GDP. The results indicate that climate variability disproportionally affect poor and low-income communities. According to Rayner and Malone (2001), those in poverty have a higher chance of experiencing the ill-effects climate variability and change due to increased exposure and vulnerability.

Ninety percent of the participants reported that climate variability contributed to reduced income whilst 4.0% reported that climate variability had not contributed to reduced income. The results agree with Smith *et al.* (2019) who emphasised that a slight increase in the global mean temperatures could result in net negative market sector in many developing countries and net positive in many developed countries. Seventy-six percent of the participants noted that climate variability had not contributed to decreased unemployment while the remaining 24.0% reported that climate variability contributed to decreased unemployment. Similarly, 72.0% of the participants reported that climate variability had increased unemployment whereas 28.0% participants reported that climate variability had not increased unemployment. The participants indicated that climate variability may render an area unproductive and make workplaces impossible for work.

Table 6. 8: Impacts of Climate Variability on Citrus Vendors Livelihoods

Increased socio-economic problems	**Frequency**	**Percentage**
Yes	25	100.0

Reduced Income		
No	1	4.0
Yes	24	96.0
Total	25	100.0
Decrease Unemployment		
No	19	76.0
Yes	6	24.0
Total	25	100.0
Increase Unemployment		
No	7	28.0
Yes	18	72.0
Total	25	100.0

6.3.2 Impacts of Climate Variability on Food Security

Table 6.9 illustrates that 96.0% of the participants reported that climate variability had no impact on loss of employment while only 4.0% did not agree that climate variability had an impact on loss of employment. Additionally, 96.0% of the participants disagreed that climate variability had an impact on increased employment whilst only 4.0% agreed that climate variability had an impact on increased employment. The study reveals that climate variability may not be the only reason there is reduced employment in the area and that there are other factors at play. Similarly, 96.0% of the participants reported that climate variability had an impact on reducing income whereas 4.0% disagreed that climate variability had an impact on reducing income. The participants hinted that some of the reasons that negatively influence their financial capital was citrus price fluctuations and market demand.

Furthermore, 80.0% of the participants reported that climate variability had an impact on food scarcity whilst 20.0% participants disagreed that climate variability had an impact on food scarcity. The study reveals that food scarcity is one of the main problems caused by climate variability and change. Climate variability can disrupt food availability and reduce access to food quality. Projected increases in temperature and changes in rainfall patterns, changes in extreme weather events and reductions in water availability may all result in reduced agricultural productivity (Adhikari *et al.,* 2015).

Nearly all participants (96.0%) disagreed that climate variability had an impact on reducing food prices whilst 4.0% of the participants agreed that climate variability had an impact on reducing food prices. Likewise, 100.0% of the participants reported that climate variability had an impact on increasing food prices. Moreover, 68.0% of the participants reported that climate variability had an impact on reducing local market while the remaining 32.0% agreed that climate variability had an impact on reducing local markets. Madzivhandila (2015) argues that given the extent and severity of rural poverty in South Africa, the prevalent climate variability is likely to have a negative impact on impoverished households' food systems. Therefore, climate variability undermines the efforts to reduce poverty and provide for food security.

Table 6. 9: Impacts of Climate Variability on Food Security

Loss of Employment	**Frequency**	**Percentage**
No	1	4.0
Yes	24	96.0
Total	25	100.0
Increased Employment		
No	24	96.0
Yes	1	4.0
Total	25	100.0
Reduced Income		
No	1	4.0
Yes	24	96.0
Total	25	100.0
Food scarcity		
No	5	20.0
Yes	20	80.0
Total	25	100.0
Reduced food prices		
No	24	96.0

Yes	1	4.0
Total	25	100.0
Increased food prices		
Yes	25	100.0
Total	25	100.0
Lack of local markets		
No	17	68.0
Yes	8	32.0
Total	25	100.0

6.3.3 Factors That Influences Climate Adaptation Strategies

Table 6.10 shows that 100.0% of the participants agreed that the lack of alternatives influenced climate adaptation strategies. More than half (52.0%) of the participants agreed that lack of education influenced climate adaptation strategies while the remaining 48.0% disagreed that lack of education influence climate adaptation strategies. The participants (56.0%) disagreed that lack of skills influenced climate adaptation strategies while 44% agreed that lack of skills influenced climate adaptation strategies.

In addition, 52.0% of the participants disagreed that lack of climate information influenced climate adaptation strategies while the remaining 48.0% agreed that lack of climate information had an influence on climate adaptation strategies. Moreover, 84.0% of the participants agreed that lack of money or funds influenced climate adaptation strategies while 16.0% disagreed that lack of money or funds had an influence on climate adaptation strategies. Less than half (44.0%) of the participants disagreed that shortage of labour had an influence on climate adaptation strategies while the remaining 56.0% agreed that labour shortages influenced climate adaptation strategies.

Table 6. 10: Factors Influencing Climate Adaptation Strategies

Lack of alternatives	**Frequency**	**Percentage**
Yes	25	100.0
Total	25	100.0
Lack of education		

No	12	48.0
Yes	13	52.0
Total	25	100.0
Lack of skills		
No	14	56.0
Yes	11	44.0
Total	25	100.0
Lack of climate information		
No	13	52.0
Yes	12	48.0
Total	25	100.0
Lack of money/funds		
No	4	16.0
Yes	21	84.0
Total	25	100.0
Shortage of labour		
No	11	44.0
Yes	14	56.0
Total	25	100.0

6.4 Citrus Vendors Livelihoods Versus Climate Related Variables

This section presents Chi-Square test results revealing the level of association between citrus vendors livelihood and climate related variables.

6.4.1 Do You Think Citrus Production Contributes to The Development of Mopani District Municipality Versus Unusual Hotness?

Table 6.11 shows a Chi-Square test that reveals a statistically significant association between "the month citrus vendors experience unusual hotness" and "whether or not citrus vendors think citrus production contributes to the development of Mopani District Municipality (Chi-Square = 8.199, df = 2. $p< 0.05$, Cramer's V = 0.699, $p< 0.05$). This means that the month that citrus vendors experience unusual hotness determines whether they view citrus production as a vehicle for development or otherwise. The odds ratio provide evidence for this gap that is created by unusual hotness. For example, consider a 2X2 table with identifiers "citrus production contributes to development" and "citrus production does not contribute to development" and has sample odds of (12X1)/(2X1) = 6. Hence, the odds of identifying with "citrus production contributes to development" rather than "citrus production that does not contribute to development" is 6 times higher in citrus vendors who felt unusual hotness in spring than in citrus vendors who felt unusual hotness in winter.

Table 6. 11: Citrus Production's Contribution to the Development of Mopani District Municipality and Unusual Hotness

Unusual Hotness - Indicate which month	Do you think citrus production contributes to the development of the Mopani District Municipality?		Total
	Yes	No	
Winter	2	1	3
Summer	0	2	2
Spring	12	1	13
Total	14	4	18

6.4.2 Average Seasonal Income from Selling Citrus Produce Versus Increased Rainfall

Table 6.12 shows a Chi-Square test that indicates a statistically significant association between average seasonal income from selling citrus produce and increased rainfall (Chi-Square = 8.397, df = 3, $p< 0.05$, Cramer's V = 1.000, $p< 0.05$). This means that the observation or non-observation of increased rainfall in the area has an influence on average seasonal income realised by citrus vendors. For instance, citrus vendors that reported an income ranging from R2 000.00 to R3 000.00 had observed increased rainfall while those that reported an average income of at least R3 000.00 had not observed an increased rainfall in their area. Similar conclusions were also reached for the statistically significant association between average seasonal income from selling citrus produce and decreased rainfall (Chi-Square = 8.397, df = 3, $p< 0.05$, Cramer's V = 1.000, $p< 0.05$). That is, citrus vendors that reported an income ranging from R2 000.00 to R3 000.00 had observed a decrease in rainfall while those that reported an average income of at least R3 000.00 had not observed decreased rainfall in their area.

Table 6. 12: Average Seasonal Income and Increased Rainfall

	Increased rainfall		
Average seasonal income from selling citrus produce?	**Yes**	**No**	**Total**
R2 000.00 to R3 000.00	1	0	1
R3 000.00 to R4 000.00	0	4	4
R4 000.00 to R5 000.00	0	2	2
R5 000.00 and over	0	17	17
Total	1	23	24

6.4.3 Income for The Past 10 Years Versus Loss of Employment as An Impact of Climate Variability and Food Security

Table 6.13 shows a statistically significant association between “income for the past 10 years” and “loss of employment as an impact of climate variability on food security” (Chi-Square = 8.397, df = 3, $p< 0.05$, Cramer's V = 1.000, $p< 0.05$). Therefore, the extent to which citrus vendors’ income increased, decreased, or remained constant for the last 10 years depends on whether they viewed loss of employment as an impact of climate variability or not. In particular, the study demonstrates that citrus vendors that viewed loss of employment as an impact of food security caused by climate variability had income from the past 10 years that was either increasing or constant. On the other hand, citrus vendors that did not view loss of employment as an impact that climate variability had on food security had their previous 10-year income decreasing. Similar conclusions were reached for income for the past 10 years versus increased employment (Chi-Square = 8.397, df = 3, $p< 0.05$, Cramer's V = 1.000, $p< 0.05$). This means that, citrus vendors who viewed increased employment as an impact that climate variability had on food security reported income from the previous 10 years that was either increasing or constant. Wheeler and Von-Braun (2013) assert that climate change and variability impacts on income from crop productivity has shown a robust and coherent global pattern which could have implications on food security and employment. Therefore, the stability of income, employment and food security may be at risk under climate variability.

Table 6. 13: Income and Loss of Employment as an Impact of Climate Variability on Food Security

What would you describe your income for the past 10 years?	What impacts has climate variability had on food security? Loss of employment.		Total
	Yes	No	
Increasing	10	0	10
Decreasing	0	1	1
Constant	12	0	12
Other	2	0	2
Total	24	1	25

6.4.4 Household Income Contribution from Selling Citrus Versus Lack of Education

Table 6.14 shows a statistically significant association between household income contribution from selling citrus and lack of education (Chi-Square = 20.754, df = 2, $p < 0.05$, Cramer's V = 0.774, $p < 0.05$). This implies that the extent to which citrus vendors view lack of education as a factor that influences climate adaptation strategies depends on their household income contribution from selling citrus produce. The evidence of this gap is shown by considering a 2X2 with identifiers “Yes - Lack of education” and “No - Lack of education”. The relative risk is (8X10)/(8X5) = 2. This means that the risk of identifying with “yes for lack of education” is 2 times higher in citrus vendors whose household income contribution from selling citrus ranged between 51% to 75% than in citrus vendors whose household income contribution ranged between 76% to 100%.

Table 6. 14: Household Income Contribution and Lack of Education

Household income contribution from selling citrus	Lack of education		Total
	Yes	No	
25-50%	0	7	7
51-75%	8	0	8

76-100%	5	5	10
Total	13	12	25

6.4.5 Education of Children Versus Food Scarcity

Table 6.15 shows a statistically significant association between food scarcity and education (Chi-Square = 7.208, df = 1, $p < 0.05$, Cramer's V = 0.590, $p < 0.05$). The extent to which the education of children has increased or decreased ever since citrus vendors started selling citrus produce depends on whether they viewed food scarcity as an impact that climate variability had on food security. A statistically significant relative risk value of 0.130 (95% CI: 0.045; 0.375) is reported. The relative risk of less than 1 means that the risk of food scarcity is less among citrus vendors whose children's education increased ever since they started selling citrus than in citrus vendors whose children's education decreased ever since they started selling citrus produces. According to Davis and Vincent (2017), approximately 35% of the South African population is subjected to food insecurity and this trend has shown to be a long-term threat to communities especially in rural areas. A study by Randell and Gray (2016) indicates that childhood climatic conditions such as milder temperatures and greater rainfall during the summer crop production season are linked with an increased likelihood of a child having completed any education. These findings suggests that projected climate variability in rural areas may limit children's participation in education impeding progress towards human development goals, poverty alleviation and food security.

Table 6. 15: Education of Children and Food Scarcity

	Food scarcity		
Education of children	**Yes**	**No**	**Total**
Increase	3	20	23
Decrease	2	0	2
Total	5	20	25

6.4.6 Electricity/Water Versus Floods

Table 6.16 shows a Chi-Square test that indicates a statistically significant association between electricity/water and floods (Chi-Square = 8.397, df = 1, $p < 0.05$, Cramer's V = 1.000, $p < 0.05$). This implies that the extent to which electricity/water situation improved or worsened after citrus vendors engaged into citrus selling depends on whether citrus vendors had observed floods. The study reveals that citrus vendors that observed floods had their electricity/water increased while citrus vendors that had not observed floods had their electricity/water decreased. Similar conclusions have also been reached in terms of the statistically significant association between electricity/water and strong wind (Chi-Square = 8.397, df = 1, $p < 0.05$, Cramer's V = 1.000, $p < 0.05$).

Table 6. 16: Relationship Between Electricity/Water and Food

Electricity/water	Floods		Total
	Yes	No	
Increase	24	0	24
Decrease	0	1	1
Total	24	1	25

6.4.7 Social Security Versus Floods

Table 6.17 illustrates a statistically significant association between social security and floods (Chi-Square = 4.578, df = 1, $p < 0.05$, Cramer's V = 0.553, $p < 0.05$). Therefore, the degree to which social security situation improved or worsened after citrus vendors had engaged into citrus selling business depends on whether citrus vendors had observed floods. Specifically, the study shows that majority of citrus vendors that observed floods had their social security increased while citrus vendors that had not observed floods had decreased social security. However, a statistically insignificant relative risk value (relative risk = 1.500, 95% CI: 0.674; 3.339) means that the risk of observing floods between “citrus vendors whose social security increased ever since they started selling citrus produces” and “citrus vendors whose social security decreased ever since they started selling citrus produces” are equal.

Table 6. 17: The Relationship Between Social Security and Floods

Social security	Floods		Total
	Yes	No	
Increase	22	0	22
Decrease	2	1	3
Total	24	1	25

6.4.8 Social Security Versus Reduced Income

Table 6.18 shows a statistically significant association between social security and reduced income (Chi-Square = 4.578, df = 1, $p< 0.05$, Cramer's V = 0.553, $p< 0.05$). Hence, the degree to which social security situation improved or worsened after engaging into citrus selling business depends on whether citrus vendors saw reduced income as an impact that climate variability had on food security. Specifically, the study reveals that majority of citrus vendors that viewed reduced income as an impact of climate variability on food security had increased social security while citrus vendors that did not view reduced income as an impact of climate variability on food security had decreased social security. However, the reported statistically non-significant relative risk value (relative risk = 1.500, 95% CI: 0.674; 3.339) means that the risk of reduced income being an impact of climate variability on food security between “citrus vendors whose social security reportedly increased ever since they started selling citrus produces” and “citrus vendors whose social security reportedly decreased ever since they started selling citrus produces” are equal. In other words, the relative risk ratio is statistically indifferent from 1. Similar conclusions were also reached in terms of the statistically significant association between social security and reduced food prices (Chi-Square = 4.578, df = 1, $p< 0.05$, Cramer's V = 0.553, $p< 0.05$).

Table 6. 18: The Relationship Between Social Security and Reduced Income

	Reduced Income		
Social security	**Yes**	**No**	**Total**
Increase	22	0	22
Decrease	2	1	3
Total	24	1	25

6.4.9 Transport Versus Loss of Employment

Table 6.19 shows a statistically significant association between “access to transport” and “whether or not climate variability causes loss of employment” (Chi-Square = 4.578, df = 1, $p< 0.05$, Cramer's V = 0.553, $p< 0.05$). This suggests that the degree to which climate variability contributes to loss of employment depends on citrus vendors’ level of access to transport infrastructure at the community level. However, the relative risk of the 2X2 cross-tabulation is statistically insignificant (relative risk = 1.500; 95% CI: 0.674; 3.339) implying that the established relationship could be due to chance.

Table 6. 19: Access to Transport and Loss of Employment

What infrastructure in the community do you have access to? Transport	What impacts has climate variability had on Loss of employment		Total
	No	Yes	
High access	0	22	22
Accessible	1	2	3
Total	1	24	25

6.4.10 Transport Versus Increased Employment

Table 6.20 shows a statistically significant association between “access to transport” and “whether or not climate variability increased employment” (Chi-Square =7.639, df = 1, $p< 0.05$, Cramer's V = 0.553, $p< 0.05$). This demonstrates that the degree to which climate variability impact increased employment depends on citrus vendors’ level of access to transport infrastructure at the level of the community. However, the relative risk of the 2X2 cross-tabulation is statistically insignificant (relative risk = 1.500; 95% CI: 0.674; 3.339) implying that the established relationship between the two variables could be due to chance. Similar conclusions were also reached for the established statistically significant relationship between “access to transport” and “whether or not lack of alternatives influence climate adaptation strategies” (Chi-Square =7.639, df = 1, $p< 0.05$, Cramer's V = 0.553, $p< 0.05$).

Table 6. 20: Access to Transport and Increased Employment

What infrastructure in the community do you have access to? Transport	Increased employment		Total
	Yes	No	
High access	0	22	22
Accessible	1	2	3
Total	1	24	25

6.4.11 Credit Versus Decreased Unemployment

Table 6.21 reveals that the association between “access to credit infrastructure” and “whether or not climate variability decreases unemployment” is statistically significant (Chi-Square = 6.725, df = 2, $p< 0.05$, Cramer's V = 0.519, $p< 0.05$). This means that the extent to which climate variability impacts unemployment depends on the level of access available on credit facilities for citrus vendors. In other words, there is a gap in terms of how climate variability impacts unemployment caused by “access to credit.” A 2X2 table with identifiers “Yes - Decrease unemployment” and “No - Decrease employment” provides evidence to the gap and the sample table has a relative risk of 1.5. This suggests that the potential impact of climate variability to decrease unemployment is 1.5 times higher in citrus vendors with “access” to credit facilities than in citrus vendors that have “high access” to credit facilities.

Table 6. 21: Credit and Decreased Employment

Access to Credit	**Decrease unemployment**		**Total**
	Yes	**No**	
High access	5	10	15
Accessible	0	9	9
Low access	1	0	1
Total	6	19	25

6.4.12 Credit Versus Increased Unemployment

Table 6.22 shows a statistically significant association between “access to credit facilities” and “whether or not climate variability increases unemployment” (Chi-Square = 7.143, df = 2, $p< 0.05$, Cramer's V = 0.535, $p< 0.05$). Therefore, the extent to which climate variability impacts unemployment depends on the level of access available on credit facilities for citrus vendors. Consequently, there is a gap in terms of how climate variability impacts unemployment which is caused by accessibility to credit facilities. A 2X2 table with identifiers “Yes – Increase Unemployment” and “No – Increase Unemployment” is used to provide evidence to this access-to-credit gap. The sample table has a relative risk value of 1.67. This suggests that the potential of climate variability to cause increased unemployment is 1.67 times higher among citrus vendors with ‘access” to credit facilities than among citrus vendors with “high access” to credit facilities.

Table 6. 22: Access to Credit and Increased Unemployment

Access to Credit	**Increase Unemployment**		**Total**
	Yes	**No**	
High access	9	6	15

Accessible	9	0	9
Low access	0	1	1
Total	18	7	25

6.5 Chapter Summary

This chapter presented, analysed, and discussed the findings on the influence of climate variability and citrus production on citrus vendors livelihoods. The results show that there are significant relationships between livelihood variables (financial assets, social assets, human assets, physical assets, and natural assets) and climate variability variables (temperature and rainfall). However, some of the relationships demonstrates a statistically insignificant relative risk value implying that the established relationships could be due to chance. The results show that citrus vendors participating in citrus vending, have better access to community infrastructures (such as health facilities, education facilities, market facilities, access to credits, access to water, access to electricity and transport) and increased standard of living (social security). The results revealed that 7 in every 10 citrus vendors earned a mean seasonal income ranging from R5 000.00 and above. However, their seasonal income was not regular. The results indicated that citrus vendors have other means to increase their income and do not entirely depend on citrus vending as their only livelihood activity.

The chapter revealed that socio-economic and environmental conditions of citrus vendors in Mopani District Municipality play a substantial role in terms of their ability to respond positively to the effects of climate change and variability. The devastating impacts of floods, droughts and heatwaves have exposed most citrus vendors whose livelihoods depend on selling citrus fruits. Citrus vendors have diversified to other income earning opportunities such as selling other fruit and vegetables produce and starting side businesses such as tuckshops, as a coping measures to climate variability. However, lack of economic opportunities has rendered majority of citrus vendors to be food insecure.

CHAPTER 7: ADAPTIVE MEASURES TO CLIMATE VARIABILITY ON CITRUS PRODUCTION FARM INCOME AND LIVELIHOODS

7.1 Introduction

This chapter presents, interprets, and discusses the descriptive statistics of findings on farmer's adaptive measures to climate variability on citrus production farm income and livelihood in Mopani District Municipality. The survey participants were 5 citrus farmers' from Mopani District Municipality. The study was limited to 5 citrus farms that were linked to Mopani Department of Agriculture and Rural Development. Themes in this chapter include land characteristics, climate variability variables, livelihood variables, citrus production factors, economic viability and marketing information of citrus farmers' that have a reflective effect which influences citrus production and citrus farmers' livelihoods. The data is presented using tables.

7.2 Land Characteristics and Climate Variability Issues

7.2.1 Citrus Land Size

The minimum and maximum citrus land size of 40 and 250 hectares were reported by farmers' as shown in Table 7.1. On average, citrus fruits were produced on land size of 126.6020 hectares (standard deviation = 69.93765 hectares).

Table 7. 1: Land Size

Statistics			
N	Valid	5	
	Missing	0	
Mean		126.6020	
Median		114.5000	
Std. Deviation		69.93765	
Range		210.00	
Minimum		40.00	
Maximum		250.00	
Land Size		**Frequency**	**Percentage**
40.00		1	20.0
109.00		1	20.0

114.50	1	20.0
119.51	1	20.0
250.00	1	20.0
Total	5	100.0

7.2.2 Ownership Structure of The Farm

Table 7.2 illustrates the ownership structure of the surveyed citrus farms. Majority of the participants (60.0%) reported that their farms were joint enterprises whilst the remaining 40.0% were equally owned by corporations or companies and communities.

Table 7. 2: Farm Ownership

Ownership	Frequency	Percentage
Corporation or company	1	20.0
Community	1	20.0
Collective or communal (joint enterprise)	3	60.0
Total	5	100.0

7.2.3 Long-term Observations on Selected Climate Variables

Table 7.3 presents a summary of the long-term observations by citrus farmers' on certain selected climate variables. The tabulated results show how farmers' believed that temperature (100.0%), frequency of droughts (100.0%), heat waves (100.0%) and floods (60.0%) were increasing on long-term basis, while rainfall (100.0%) and reliable seasons (100.0%) were shown to be decreasing. Similarly, farmers' reported that no long-term changes had been observed on abnormal wind (100.0%) and frost (100.0%). Kom (2020) states that farmers' observations on climate variability corresponds well with climatic trends that indicated flood and drought cycles. The results suggest that citrus farmers' are aware of climate variability and its consequences over the past decades.

Table 7. 3: Long-term Observations on Selected Climate Variables

Climate variable	Increasing	Decreasing	No Change
Temperature	100.0%	0.0%	0.0%
Droughts	100.0%	0.0%	0.0%
Heat waves	100.0%	0.0%	0.0%
Floods	60.0%	0.0%	40.0%
Rainfall	0.0%	100.0%	0.0%
Reliable seasons (shift)	0.0%	100.0%	0.0%
Abnormal wind	0.0%	0.0%	100.0%
Frost	0.0%	0.0%	100.0%
Other (specify)	0.0%	0.0%	0.0%

7.2.4 Impacts of Drought on Citrus Production

All participants (100.0%) indicated that drought episodes had negative impacts on citrus productivity (Table 7.4). Citrus farmers' reported that yield (100.0%), quality (100.0%), quantity (100.0%), and income (80.0%) had decreased while production costs (100.0%) were reported to have increased due to the negative impacts of drought. About 25.0% of citrus farmers' revealed that drought episodes increased pests and diseases (100.0%) while majority (75.0%) reported that drought episodes caused no change on pests and diseases. According to Jayanthi *et al.* (2013), drought is a severe natural disaster that has a significant impact on food production and thus the economy. Donkor and Anane (2016) posit that several factors have been attributed to low citrus fruit crops performance. They include insufficient financial resources and supporting facilities such as lack of ready market, disease, and pest infestation, among others. Although the citrus industry is a capital-intensive enterprise, it receives very little investments.

Table 7. 4: Magnitude of Drought on Citrus Production

Magnitude	Increasing	Decreasing	No Change
Yield	0.0%	100.0%	0.0%
Quality	0.0%	100.0%	0.0%
Quantity	0.0%	100.0%	0.0%

Income	0.0%	80.0%	20.0%
Production cost	100.0%	0.0%	0.0%
Pests and diseases	25.0%	0.0%	75.0%

7.2.5 Climate Variability Impacts on Household Food Security

Table 7.5 reveals that 100.0% of citrus farmers' indicated that climate variability had an impact on food security in their households. The farmers' revealed that climate variability had an impact on their household's food security by increasing food prices (100.0%), causing price instability (100.0%), increasing seasonal food scarcity (60.0%), and reducing household income levels (40.0%).

Table 7. 5: Areas of Climate Variability Impacts on Household Food Security

Areas of Impact	**No**	**Yes**
Increased food prices	0.0%	100.0%
Price instability	0.0%	100.0%
Seasonal food scarcity increases	40.0%	60.0%
Reduced income	60.0%	40.0%
Pest and diseases	100.0%	0.0%
Other	100.0%	0.0%

7.3 Production Factors

7.3.1 Factors Influencing Citrus Farming

Table 7.6 presents the factors that influence citrus farming. Growing demand/market (100.0%), rainfall (80.0%), soil type (80.0%) and access to irrigation (80.0%) are some of the main factors that influences the farming of citrus fruits. Donkor and Anane (2016) argued that the availability and accessibility of microcredit from financial institutions is a concern for most citrus farmers' in rural areas. This is due to a lack of collateral security which includes savings. Farmers' personal savings become an essential source of capital for expanding their farm when other financial sources are limited. This implies that savings need careful management of expenditure. The farmers' further indicated that they are more interested in cultivating citrus due to its maximum and quick returns. Sarker *et al.* (2017) emphasises that the market demand of citrus fruits is higher than other fruit crops and essential like vegetables.

Table 7. 6: Factors Influencing Citrus Farming

Factor	No	Yes
Growing demand/market	0.0%	100.0%
Rainfall	20.0%	80.0%
Soil type	20.0%	80.0%
Access to irrigation	20.0%	80.0%
Capital access	100.0%	0.0%
Access to credit	100.0%	0.0%

7.3.2 Sources of Water for Farming

Table 7.7 shows the results describing the main sources of water in citrus farming which include river (100.0%), rainfall (100.0%), borehole (80.0%), and reservoir (80.0%).

Table 7. 7: Sources of Water for Farming

Sources of water	No	Yes
River	0.0%	100.0%
Rainfall	0.0%	100.0%
Borehole	20.0%	80.0%
Reservoir	20.0%	80.0%
Dam	100.0%	0.0%
Other	100.0%	0.0%

7.3.3 Assessing Water Quality

All farmers (100%) revealed that they assessed the quality of water they used on the farms. Some of the water quality issues assessed relates to the following:

"Annual water analysis for chemistry and microbial components are taken to the lab." **(Participant 1)**

"Excessive nutrients in the water reduce yield and quality." **(Participant 2)**

“The pH and alkalinity are two crucial factors in determining the suitability of water for irrigating citrus trees.” **(Participant 3)**

“Poor water quality is responsible for slow citrus growth, poor aesthetic quality of the trees and in some cases result in the gradual death of the citrus trees.” **(Participant 4)**

“Salinity solicit and ion toxicity are major problems in irrigation waters. Thus, periodic testing of water is required to monitor any change in salt content.” **(Participant 5)**

These findings show that the health and well-being of citrus trees can be pro-actively managed by monitoring water quality on the farm. This suggests that water quality has a direct and indirect influence on citrus production. Water with high alkalinity and salinity can adversely affect the pH of the growing medium, interfering with nutrient uptake and causing nutrient deficiencies that compromise citrus tree health. Furthermore, the concentration of salts dissolved in water has a direct effect on the water available for the citrus tree. The higher the salt content, the more energy is required by the tree to utilise the water. The indirect effects of water quality include factors that have a detrimental effect on soil properties.

7.3.4 Soil Tests and Analysis

All farmers (100.0%) agreed to taking soils from their farms for laboratory tests and analysis. Some of the reasons for soil testing and analysis relates to the following:

“Good soil quality promotes the growth of citrus trees and protect watersheds by regulating the infiltration and partitioning of precipitation.” **(Participant 1)**

“High soluble salts can directly injure citrus tree roots, interfering with water and nutrient uptake.” **(Participant 2)**

“Micro-organisms in soils transform nutrients into forms that can be used by growing citrus trees. Soils are storehouses for water and nutrients.” **(Participant 3)**

“Some soils are inherently more productive because they can store and make available larger amounts of water and nutrients to citrus trees.” **(Participant 4)**

“To monitor the levels of nutrients in the soil.” **(Participant 5)**

The results indicate that soil quality is the foundation of productive and sustainable farming practices. Fertile soil provides essential nutrients to citrus trees. This reveals that citrus farmers can determine if a set of management practices is sustainable by assessing soil quality. Managing soil health allows citrus farmers to improve nutrient cycling, maximise water infiltration, control water runoff, reduce soil erosion, and save money on inputs. This eventually improve the resilience of their farming land.

7.3.5 Farm Irrigation Systems

Table 7.8 presents the main irrigation systems used by citrus farmers. Micro-jet sprinkler/spray (now), natural rainfall/ rain-fed (now), natural rainfall/ rain-fed (before), drip irrigation (now) and surface irrigation (before) were the main irrigation systems reported by citrus farmers. All farmers (100.0%) further indicated that that they experienced water shortages during the maturity stage (May to August) of the citrus calendar. The results reveal that there is less need of water for citrus trees during flowering (September to December) and Growth and Development (January to April) period. Manatsa *et al.* (2010) state that crop production is influenced by rainfall with minimal or no irrigation, making the production mainly a response to rainfall amounts received. Citrus is a perennial fruit crop that requires constant supply of water to maximise yields and returns (Nelson *et al.,* 2011). Therefore, it is important to gain a better understanding of citrus water use for the summer and winter seasons.

Table 7. 8: Types of Irrigation Systems Used by Citrus Farmers

Type of irrigation system	No	Yes
Micro jet sprinkler/spray (Now)	0.0%	100.0%
Micro jet sprinkler/spray (Before)	100.0%	0.0%
Natural rainfall/ rain fed (Now)	0.0%	100.0%
Natural rainfall/ rain fed (Before)	20.0%	80.0%
Drip irrigation (Now)	40.0%	60.0%
Drip irrigation (Before)	100.0%	0.0%
Surface irrigation (Now)	100.0%	0.0%
Surface irrigation (Before)	80.0%	20.0%

- Factors that influence the choices of irrigation systems were also reported and include the following:

“Existing infrastructure on the farm, the amount of available water, the quality of water and the cost of water influence the choice of irrigation system.” **(Participant 2)**

“The availability of water and low rainfall in the area due to ridiculously hot climate conditions. **(Participant 4)**

“The availability of water and the cost of water is expensive; the choices influence sustainable use

*of water." * **(Participant 5)**

Frequent events of drought and unpredictable rainfall patterns necessitate the sustainable use of limited water resources. The choice of an irrigation system depends on numerous factors such as soil type, terrain, type of crops planted, water availability, limited water supply, policies that aim to reduce farming water usage, and socio-economic variables (Pokhrel *et al.,* 2018). The study shows that citrus farmers can increase their yields and net revenues by adopting an irrigation system. The adoption of drip irrigation and micro jet sprinkler/spray helps increase water use efficiency. The high cost of water encourages citrus farmers to adopt more efficient irrigation technologies.

7.3.6 Frequency of Irrigation and Water Quantity Used per Irrigation Cycle

About 60.0% of survey farmers reported that they irrigated their farm for a frequency of 3 times per week whilst the remaining 40.0% revealed that they irrigated their farms twice per week (Table 7.9). The quantity of water (litres used by citrus farmers per irrigation cycle per tree) was gathered from the farmers. Sixty percent of the farmers indicated that they used 20 litres per irrigation cycle per tree whilst the remaining 40.0% revealed using 30 litres per irrigation cycle per tree. The mean water quantity used per irrigation cycle per tree and its standard deviation were 24.00 litres and 5.026 litres, respectively.

Table 7. 9: Frequency of Irrigation and Water Quality Used per Irrigation Cycle

	Response	**Frequency**	**Percentage**
Frequency of farm irrigation	Twice a week	2	40.0
	Thrice a week	3	60.0
	Total	5	100.0
Water used per irrigation cycle per tree	**Litres of water**		
	20.00	3	60.0
	30.00	2	40.0
	Total	5	100.0

7.3.6 Quality of Citrus Harvest from 1987 to 2017

Table 7.10 presents quality rating results of citrus harvest at the end of each citrus season for a period ranging from 1987 to 2017. The results show that during normal seasons, the quality and storage life of produce is excellent (100.0%), there are more jobs and new marketing opportunities (100.0%). However, the converse was also reported for abnormal seasons. The results show that there is acute infestation of pests and diseases in citrus harvest in both normal and abnormal seasons (80.0%). Pests and diseases create a high production loss for citrus farmers (Ndou, 2012; Sarker *et al.,* 2017). Kom (2020) observes that farmers struggle from the negative consequences of climate variability and change on their crop productivity, for example reduced crop yields, frequent pests, and diseases outbreaks. Farmers employ a variety of pesticides and insecticides to control pests and diseases to reduce yield loss. Moreover, yield loss during normal and abnormal seasons reduces the profit margin for citrus farmers.

Table 7. 10: Quality of Citrus Harvest from 1987 to 2017

Quality rating	**No**	**Yes**
Excellent storage life (Normal season)	0.0%	100.0%
Poor storage life (abnormal season)	0.0%	100.0%
Excellent quality (Normal season)	0.0%	100.0%
Poor quality (Abnormal season)	0.0%	100.0%
More job opportunities (Normal season)	0.0%	100.0%
Less job opportunities (Abnormal season)	0.0%	100.0%
New marketing opportunities (Normal season)	0.0%	100.0%
Less marketing opportunities (Abnormal season)	0.0%	100.0%
Pests and diseases (Normal season)	20.0%	80.0%
Pests and diseases (Abnormal season)	20.0%	80.0%
More harvest losses (Abnormal season)	20.0%	80.0%
Less harvest loses (Normal season)	20.0%	80.0%
No pests and diseases (Abnormal season)	60.0%	40.0%
No pests and diseases (Normal season)	80.0%	20.0%
More harvest losses (Normal season)	80.0%	20.0%

Less harvest loses (Abnormal season)	80.0%	20.0%
Excellent storage life (abnormal season)	100.0%	0.0%
Poor storage life (Normal season)	100.0%	0.0%
Excellent quality (Abnormal season)	100.0%	0.0%
Poor quality (Normal season)	100.0%	0.0%
More job opportunities (Abnormal season)	100.0%	0.0%
Less job opportunities (Normal season)	100.0%	0.0%
New marketing opportunities (abnormal season)	100.0%	0.0%
Less marketing opportunities (Normal season)	100.0%	0.0%
Other (Normal season)	100.0%	0.0%
Other (Abnormal season)	100.0%	0.0%

7.3.7 Insurance Against Drought and Floods

Farmers were asked if they had insurance against drought and floods. Eighty percent of the farmers reported that they were not insured against drought while the remaining 20.0% revealed that they were insured (Table 7.11). Farmers were also asked if they had insurance against floods. Eighty percent of the farmers reported that they were not insured against floods while the remaining 20.0% revealed that they were insured. Farmers that reported not insured against drought and floods pointed the lack of awareness as their reasons for lack of drought and floods insurance.

The study reveals that currently there are no drought and floods insurance available for citrus farmers. Farmers indicated that they were not aware of any climate change and variability insurance available. They further revealed that the government and private companies do not offer such insurance. This suggests that farmers rely on their own capital when it comes to issues relating to drought, floods, and climate change insurance. Farmers further noted that it is only a few farmers that can save money for circumstances such as droughts and floods to be able to pay wages/salaries to their employees and to maintain the farm. Olson and DeFrain (2000) indicate that people save to ensure that they are adequately prepared for unanticipated circumstances such as financial hardships, job losses, disasters, and a variety of other calamities. Furthermore, farmers with positive attitudes towards saving are likely to succeed in commercial citrus farming with or without drought and floods insurance.

Table 7. 11: Insurance Against Drought and Floods

	Response	Frequency	Percentage
Drought	No	4	80.0
	Yes	1	20.0
	Total	5	100.0
Floods	**Response**	**Frequency**	**Percentage**
	No	4	80.0
	Yes	1	20.0
	Total	5	100.0

7.3.8 Recommendations for Reducing the Effects of Climate Variability

Farmers were asked the question “What do you believe can be done by each of the following (farmers, government, and private sector) to reduce the effects of climate variability to safeguard livelihoods?.” Farmers expressed the following sentiments:

Farmers should:

“Adapt to farming practices that promotes good agricultural practice and nature conservation.” **(Participant 1)**

“Change farming practices to conserve soil moisture, organic matter and nutrients, and crop diversification.” **(Participant 2)**

“Have a sound management plan that is better equipped to increase production output, that is more efficient and saves production costs.” **(Participant 3)**

“Practice climate-smart agriculture, by treating the soil and water quality. Reduce distribution loses of irrigation water, improving infrastructure and farming methods.” **(Participant 4)**

The results show that citrus production is amongst the most vulnerable industry to greater climate extremes and rising temperatures. Farmers are taking the lead to combat climate variability by adapting to sustainable farming practices and advocating for policy change (Mburu, 2013). These techniques build resilience on the farms and livelihoods as they face climate variability and its challenges. Further, climate-smart agriculture promotes soil and water conservation and increases resilience against droughts, floods, and changing growing seasons.

Government should:

“Develop innovative risk financing instruments and insurance schemes to reduce climate change related risks.” **(Participant 1)**

"Implement strict standard regulations against environmental violations." **(Participant 2)**

"Improve demand management and water allocation to encourage efficiency of use." **(Participant 3)**

"Promote farm-based risk management measures to face crop failures and soaring production costs." **(Participant 4)**

"Make concerted efforts to increase the development and investments in agriculture." **(Participant 5)**

Citrus farmers face systematic economic pressures, such as the complexity of accessing sustainable farm inputs at a decent cost. The higher operational costs intensify the need for access to external capital. Similarly, capital is most accessible to farmers with the most conventional low-return systems of production. The results show that it is important that the government learns of the actual challenges posed by farmers in coping with farm-level risk management prior to developing adaptation strategies. Farmers indicated that government should guide policy makers in fostering an environment wherein farmers adaptation strategies can be implemented. Kom (2020) posits that the government appears not to be doing enough to help farmers adapt to climate variability, as 95% of the farmers stated that they need support and protection against adverse climate conditions. The results of a study by Salinger *et al.* (2005) state that governments should develop strategies that effectively target specific policy matters to achieve sustainable development. Therefore, there is a significant need for integrating the readiness for climate variability. Similarly, capacity building must be incorporated with adaptation strategies for improved agricultural development strategies.

Private sector should:

"Invest more in agricultural projects that seeks to promote nature conservation." **(Participant 1)**

"Develop climate forecast early warning systems that are more effective." **(Participant 2)**

"Enhance investments in soil and water management practices to improve productivity and to increase the competitiveness of agricultural enterprises." **(Participant 3)**

"Policies such as insurance may need to be adapted in the context of climate variability because existing insurance do not cover circumstances made more common by climate change." **(Participant 4)**

"Support and facilitate research on crop production and climate change and establish new farming technologies." **(Participant 5)**

The results show that monitoring weather and farm data will help farmers predict climate patterns and project more effectively. Farmer's ability to adapt to climate variability is not only a good policy mostly for farming, but also for the economy, insurance companies and financial institutions (Yaro, 2013). Reducing the likelihood of adverse weather and climate extremes is important for financial institutions working with agribusiness credit and insurance companies, decreasing risk losses, and improving the repayment of loans. Kom (2020) notes that farmers who receive adequate support and guidance will adapt sufficiently to keep their farming activities going while safeguarding their livelihoods.

7.3.9 Quantity and Amount of Farm Inputs for Citrus Production

Table 7.12 presents descriptive statistics summarising the quantities and amounts of farm inputs seasonally spent by farmers for citrus production. Consequently, the minimum and maximum quantities, mean and standard deviations for quantities and amounts are shown. Citrus production requires less agricultural practices which results in lower labour costs than other horticultural crops such as banana, pineapple, mango, and other fruits (Misbahuzzaman, 2016; Sarker *et al.,* 2017). Therefore, citrus production is more profitable than other horticultural crops.

Table 7. 12: Quantities and Amounts of Farm Inputs Used in Citrus Production

Input	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
Fertilizer quantity in kg	5	2000.00	12500.00	6300.0000	3500.52628	3500.52628
Fertilizers- Amount spent in rands	5	11480.00	71750.00	36182.0000	20090.05545	20090.05545
Pesticides- quantity in litres	5	160.00	1000.00	504.0000	280.04210	280.04210
Pesticides- Amount spent in rands	5	20736.00	129600.00	65318.2000	36293.49913	36293.49913
Herbicides and insecticides- quantity in Kg	5	200.00	1250.00	630.0000	350.05263	350.05263
Herbicides and insecticides- amount spent in rands	5	34300.00	214375.00	108044.8000	60034.06774	60034.06774
Water quantity in litres	5	4000.00	25000.00	12600.0000	1565.48294	7001.05255

Water amount in rands	5	178000.00	1112500.00	560700.0000	69663.99092	311546.83858
Packaging Quantity in Kg/ litres	5	5258.00	13500.00	7575.2000	686.89433	3071.88483
Package- Amount in Rands	5	39540.00	101520.00	56964.7200	5165.52493	23100.92975

7.3.10 Estimated Annual Costs on Basic Necessities

Table 7.13 presents a summary of descriptive statistics describing costs incurred annually by citrus farmers on necessities such as transport, electricity, petrol, paraffin, medical, insurance, security, and others. The minimum, maximum, mean, and standard deviations incurred per each item are shown.

Table 7. 13: Estimated Annual Costs on Basic Necessities

Item	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
Transport	4	120000.00	200000.00	160000.00	7527.72	30110.90
Electricity	5	80000.00	132000.00	101400.00	3892.23	17406.59
Petrol	3	50000.00	80000.00	63333.33	3760.50	13026.77
Paraffin	0					
Medical	5	20000.00	50000.00	40000.00	2901.90	12977.71
Insurance	4	20000.00	30000.00	22500.00	1118.03	4472.13
Security	5	70000.00	100000.00	91000.00	2554.66	11424.81
Other	1	200000.00	200000.00	200000.00	0.000	0.00

7.3.11 Adjustments to Farming Due to Long-Term Effects of Climate Change

All participants (100.0%) reported to have adjusted their farming practices due to long-term changes in climate. The adjustments made by citrus farmers relate to the following:

"Improving irrigation efficiency, as water becomes a limiting factor and adapting soil conservation measures that conserve soil moisture." **(Participant 1)**

While participant 3 stated that:

"Increasing the resilience of the soil, improve soil quality and planting drought resistant varieties of citrus fruit trees." **(Participant 3)**

Participant 5 added that:

"Using drip irrigation and sprinkler irrigation systems to increase citrus productivity up to 50% and crop diversification." **(Participant 5)**

The results show that adjustments to long-term climate change and variability involves changes in agricultural management practices in response to changes in climate conditions. Drought tolerant citrus varieties allow the trees to maintain yields in drought years and at higher temperatures. This helps in reducing citrus vulnerability to climate variability and change. Diversification towards drought resistant crop varieties and high value crops is feasible in the long-term (Mekonnen *et al.,* 2021; Shabani and Pauline, 2022). The study pointed out that improving existing rain fed farming systems and altering irrigation scheduling is some of the smart water management alterations to long-term climate changes used by citrus farmers in Mopani District Municipality. The study further indicates that citrus farmers alter fertiliser's rates to maintain fruit quality consistent with climate, minimises farm flow of nutrients and pesticides. It is evident that incidences of climate change such as changes in soil moisture and soil quality adversely affect citrus production. The situation can be improved by frequent analysis of soil moisture and soil quality.

7.3.12 Farmers Adaptation to Climate Changes

Table 7.14 presents a summary of adaptation strategies adopted by citrus farmers in their efforts to counter the changing climate. The results show that increased irrigation, increased use of fertilizers, pesticides, and manure were, and equally used strategies followed by planting of different crop varieties, change amount of land under citrus production, increased water conservation, soil conservation and insurance. Water harvesting was reported by 40.0% of survey farmers and crop diversification reported by 20.0%. Farmers that stated to be adapting to crop diversification revealed that they are venturing into other subtropical fruit varieties that perform well in hot climate conditions. Kori *et al.* (2021) stated that farmers are encouraged to adapt to climate variability by practicing conservation farming and crop diversification among other measures. Adaptation is an effective approach to increase resilience against climate variability (Biagini *et al.,* 2014; Constinot *et al.,* 2016;

Menike and Arachchi, 2016). It is envisaged that adaptation measures will improve citrus farmers resilience and ability to safeguard food security and livelihoods.

Table 7. 14: Strategies for Adapting to Climate Change and Variability

Ways of adapting to climate change and variability	No	Yes
Increase irrigation	0.0%	100.0%
Increased use of fertilizers, pesticides, and manure	0.0%	100.0%
Different crop varieties	20.0%	80.0%
Change amount of land under citrus production	20.0%	80.0%
Increased water conservation	20.0%	80.0%
Soil conservation	20.0%	80.0%
Insurance	20.0%	80.0%
Water harvesting	60.0%	40.0%
Crop diversification	80.0%	20.0%

- **Constraints Experienced when Adjusting to Weather and Climate Changes**

The participants unanimously agreed that the main constraints experienced by citrus farmers when adjusting to climate changes were lack of capital and access to water. Poor health and unidentified constraints were some of the minor limitations which were reported to be experienced when adapting to climate changes as reported by 20.0% of surveyed citrus farmers (Table 7.15).

Table 7. 15: Constraints of Adapting to Weather and Climate Changes

Constraints	No	Yes
Lack of capital	0.0%	100.0%
Lack of access to water	0.0%	100.0%
Poor health	80.0%	20.0%
Lack of information	100.0%	0.0%
Shortage of labor	100.0%	0.0%
Other	80.0%	20.0%

7.4 Economic Viability and Marketing Information

7.4.1 Number of Citrus Workers Hired by Farmers

Table 7.16 presents summary statistics for the number of seasonal, inter-annual and annual workers normally hired by citrus farmers. Farmers normally hire between 40 and 100 seasonal workers with an average of 66 seasonal workers (SD = 22.10). A minimum and maximum of 15 and 50 inter-annual workers were hired by citrus farmers with an average of 33 inter-annual workers (SD = 11.85) being reported. In addition, annual workers were also reported by citrus farmers with a minimum and maximum value of 15 and 30 having been reported whilst on average, citrus famers revealed that they hired 21 workers (SD = 5.17). Sarker (2017) found that agriculture employs 47.71% of the population, whereas 22.76% people depend on citrus production labourer and 2.82% on wage labourer. Kabir *et al.* (2012) found a positive significant relationship between crop production enterprises and improved livelihood. Thus, the employment in citrus production is a significant socio-economic indicator for determining one's livelihood status.

Table 7. 16: Number of Citrus Workers Hired by Farmers

	N	Minimum	Maximum	Mean		Std. Deviation
Type of Workers	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Seasonal	5	40.00	100.00	66.0000	4.94177	22.10025
Inter- annual	5	15.00	50.00	32.8000	2.64933	11.84816
Annual	5	15.00	30.00	20.6000	1.15713	5.17484

- **Labour Composition**

Citrus farmers noted that their labour was composed of permanent workers, skilled workers, semi-skilled workers, unskilled workers, temporary workers, and learner students as shown in Table 7.17.

Table 7. 17: Farm Workers Composition

Labour Composition	No	Yes
Permanent workers	0.0%	100.0%
Skilled workers	0.0%	100.0%
Unskilled workers	0.0%	100.0%

Semi-skilled workers	0.0%	100.0%
Temporary workers	20.0%	80.0%
Learner students	40.0%	60.0%
Other	100.0%	0.0%

7.4.2 Workers Monthly Income

Forty percent of the surveyed citrus farmers reported that the salaries of their employees ranged between R2 000.00 and R3 000.00 (Table 7.18). All participants also reported that they had farm workers who earned salaries ranging between R3 000.00 - R4 000.00, R4 000.00 - R5 000.00 and R5 000.00 and above. Farmers further indicated that their skilled workers do not earn salaries below the minimum wage of R3 500.00. Sarker *et al.* (2017) states that adoption of modern agricultural technologies has resulted in significant increases of income, households' assets, and other aspects of livelihood. Furthermore, Sarker *et al.* (2017) revealed that citrus workers in Kathalia Bangladesh earned an annual income of USD610 to USD730 from one lemon field acre which is approximately R9 263.67 to R11 086.04 in South African rand.

Table 7. 18: Citrus Workers Monthly Income

Salary category	**No**	**Yes**
R5 000.00 and above	0.0%	100.0%
R4 000.00 - R5 000.00	0.0%	100.0%
R3 000.00 - R4 000.00	0.0%	100.0%
R2 000.00 - R3 000.00	60.0%	40.0%
R1 000.00 - R2 000.00	100.0%	0.0%
R0.00 - R1 000.00	100.0%	0.0%

7.4.3 Effects of Climate Variability and Change on Citrus Price and Harvest

All farmers (100.0%) reported that the prices of citrus fruits changed depending on whether a season was a flood or drought year (Table 7.19). Farmers highlighted that during the dry seasons, market supply was less which led to increased citrus prices while more supplies experienced during favourable farming seasons led to a drop in prices. South Africa's citrus industry shows increasing trends in production, citrus producer price, and trade performance (Dlikilili, 2018). Farmers participate in citrus production to sell their produce into three arenas, being the local fresh fruit market, the regional fresh fruit market, and the export (International) fresh fruit market (Chisoro-Dube, 2019). This contributes to poverty reduction through income realised from sales, improved food security, and reduced unemployment as farmers employ community' members.

Table 7. 19: Citrus Market

	N	Minimum	Maximum	Mean		Std. Deviation
Citrus market (%)	**Statistic**	**Statistic**	**Statistic**	**Statistic**	**Std. Error**	**Statistic**
Local (%)	5	5.00	15.00	9.0000	0.85840	3.83886
Regional (%)	5	15.00	40.00	27.0000	2.47088	11.05013
International (%)	5	50.00	80.00	64.0000	2.44949	10.95445

7.4.4 Main Citrus Market Outlets

Table 7.20 shows the main citrus market outlets where citrus fruits are sold locally by citrus farmers. The results show that hawkers, shops/commercial market, local people, consumers and other formed some of the main local markets for citrus farmers. Farmers further revealed that the citrus demand levels they achieved ranged between 80.0% (minimum) and 98.0% (maximum). The mean demand and a standard deviation of 92.2% and 6.9% were reported, respectively. Moreover, a median demand value of 95.0%. Citrus farmers further indicated that they introduced different types of modern citrus varieties to better meet the demand and supply chain. Sarker *et al.* (2017) noted that citrus production has increased substantially and getting better market price.

Table 7. 20: Citrus Market Outlets

Citrus market outlets	No	Yes
Hawkers	0.0%	100.0%
Shops/Commercial market	0.0%	100.0%
Local people	20.0%	80.0%
Consumers	40.0%	60.0%
Contractors	100.0%	0.0%
Other	0.0%	100.0%

7.4.5 Sources of Farm Income

Table 7.21 presents descriptive statistics describing two major sources of farm income: crop sales and renting out equipment. Crop sales contribute between 95.0% and 100.0% to farm income whilst leasing of equipment contributes between 5.0% and 6.0%. On average, crop sales contribute 97.0% (SD = 2.513%) to total farm income whereas equipment leasing contributes an average of 5.25% (SD = 0.447%).

Table 7. 21: Sources of Farm Income Contribution

	N	Minimum	Maximum	Mean		Std. Deviation
Income source	**Statistic**	**Statistic**	**Statistic**	**Statistic**	**Std. Error**	**Statistic**
Crop sales	5	95.00	100.00	97.0000	0.56195	2.51312
Renting out equipment	4	5.00	6.00	5.2500	0.11180	0.44721

7.5 Chapter Summary

This chapter presented, analysed, and discussed the findings on farmer's adaptive measures to climate variability on citrus production farm income and livelihood in Mopani District Municipality. The results showed that citrus farmers are aware of climate variability and have adjusted their farming practices due to long-term changes in climate. The results indicated that drought and flood episodes have negative impacts on citrus productivity. Furthermore, citrus yields, quality, quantity, and income have decreased due to the negative impacts of drought while production costs have increased. Farmers noted that climate variability had an impact on household's food security by increasing food prices, causing price instability, increasing seasonal food scarcity, and reducing household income levels. The results show that 80% of citrus farmers are not insured against climate variability. The study revealed that increased irrigation, increased use of fertilizers, pesticides, and manure were, and equally used as adaptation strategies adopted by citrus farmers in their efforts to counter the changing climate; followed by planting of different crop varieties, change amount of land under citrus production, increased water conservation, soil conservation, water harvesting, crop diversification and insurance.

CHAPTER 8: SUMMARY, CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

This chapter presents a summary of the research findings based on the specific objectives, conclusions from the findings and recommendations drawn from the conclusions. The study analysed the influence of climate variability on citrus production and rural livelihoods in Mopani District Municipality.

8.2 Summary of Findings

The study set out to achieve the following objectives. The first objective was to examine the effects of climate variability on citrus production in Mopani District Municipality for the period 1987 to 2017, the second objective was to establish the influence of citrus production on farmer’s income and rural livelihood and the third objective was to evaluate farmer's adaptive measures to climate variability on citrus production farm income and livelihood in Mopani District Municipality.

- **The effects of climate variability on citrus production in Mopani District Municipality**

The first objective was achieved using the Standardized Precipitation Index (SPI), Mann-Kendall trend analysis and multiple linear regression analysis. The SPI revealed that annual precipitation anomalies in Mopani fall within the near normal category. However, the area occasionally experiences events of extremely wet conditions. The results show that the area tends to be drier in winter seasons and wetter in summer seasons. Different locations in Mopani District Municipality show similar patterns of dry and wet conditions. This leads to the conclusion that the study area receives moderate climate conditions.

The Mann-Kendall trend analysis shows that climatic trends have varied over the years in Mopani District Municipality. The results indicate a weak negative decreasing trend in rainfall ($r^2 < 0.5$). The annual average maximum temperature shows a weak positive increasing trend ($r^2 < 0.5$). The annual minimum temperature reveals a weak negative decreasing trend ($r^2 < 0.5$). The results are reflective of a very strong positive increasing trends in citrus production for all the 5 farms ($r^2 > 0.5$).

Multiple linear regression analysis shows that climate variability significantly influences citrus production with $p < 0.05$. The results indicate a weak negative significant relationship between climate variability and citrus production for Farm 1 ($p < 0.05$ and adjusted $r^2 < 0.5$). A weak positive significant relationship between climate variability and citrus production for Farm 2 ($p < 0.05$ and adjusted $r^2 < 0.5$). A strong negative significant relationship between climate variability and citrus production for Farm 3 and 5 ($p < 0.05$ and adjusted $r^2 > 0.5$). A strong positive significant relationship between climate variability and citrus production for Farm 4 ($p < 0.05$ and adjusted $r^2 > 0.5$). It was noted that maximum SPI and maximum temperature make a strong individual contribution in explaining citrus production than minimum SPI and minimum temperature indicating minor contributions. This leads to the conclusion that citrus performance in different locations vary significantly, this may be attributed to temperature variability, rainfall variability and different farming practices across the area. Citrus production depends on favourable weather conditions and the amount of rainfall received.

- **The influence of citrus production on farmer's income and rural livelihood**

The second objective was achieved using simple linear regression analysis, descriptive statistics, and Chi-Square test. The results of the regression show that there is a very strong positive significant relationship between citrus production and farm net revenue ($p< 0.05$ and $r^2> 0.5$). Moreover, factors such as citrus market export rates, citrus price fluctuations and renting of farm equipment's also contributes to farm net revenue.

Descriptive statistics and Chi-Square test results show that climate variability and citrus production does have an influence on rural livelihoods (citrus workers and citrus vendors). The results show that there are significant relationships between livelihood variables (financial assets, social assets, human assets, physical assets, and natural assets) and climate variability variables (temperature and rainfall) with $p< 0.05$. However, some of the relationships show a statistically insignificant relative risk value implying that the established relationships could be due to chance.

The results reveal that citrus workers most important source of income were wages, with the majority (47.5%) earning monthly household incomes of between R3 000.00 and R4 000.00. It was noted that citrus workers earned cash remittances that were used exclusively on food, clothes, education, and improvements to households. The results indicate that citrus workers mean percentage contribution to household income is 70.55%. Citrus workers indicated that climate variability reduced access to finances for sustaining their livelihoods. However, their involvement in citrus production has improved their access to necessities such as food, transport, electricity, clothing, medical and security. The results show that there are statistically significant relationships between the socio-economic variables of citrus workers and climate variability variables with $p< 0.05$. Majority of rural economies rely on agricultural livelihoods such as citrus production. Thus, climate change and variability can have comprehensive and disastrous effects on the livelihood activities.

The results show that citrus vendors participation in selling citrus fruits have increased their access to community infrastructures such as health facilities, education facilities, market facilities, credits, water, electricity, transport, and increased standard of living (social security). The results reveal that 7 in every 10 citrus vendors earned a mean seasonal income ranging between R5 000.00 and above. However, the seasonal income ranges were not regular. The results show that citrus vendors have other means to increase their income and do not entirely depend on citrus vending as their only livelihood activity. The results show that factors such as the lack of alternatives, education, skills, climatic information, money/funds, and shortage of employment influenced citrus vendors adaptation strategies to climate variability. The study reveals that there are statistically significant relationships between citrus vendors livelihood variables and climate variability related variables with $p < 0.05$. These findings suggest that citrus production in Mopani District Municipality has a positive impact on poverty alleviation to the rural people in terms of job creation and access to goods and services.

- **Farmer's adaptive measures to climate variability on citrus production farm income and livelihood**

The third objective was achieved using descriptive statistics. The results revealed that citrus farmers are aware of climate variability and have adjusted their farming practices due to long-term changes in climate. The results indicate that drought and flood (100.0%) episodes have adverse impacts on citrus productivity. Moreover, citrus yields, quality, quantity, and income have decreased due to the negative impacts of drought while production costs have increased. Citrus farmers (100.0%) indicated that citrus fruit prices varied depending on whether a season was a flood or drought year. This suggests that during the dry seasons, the market supply was less which led to increased citrus prices while more supplies were experienced during favourable farming seasons which led to a drop in citrus prices.

Citrus farmers (100.0%) revealed that climate variability had an impact on household's food security by increasing food prices, causing price instability, increasing seasonal food scarcity, and reducing household income levels. The results show that 80.0% of citrus farmers were not insured against climate variability. The study shows that increased irrigation, increased use of fertilizers, pesticides, and manure were, and equally used as adaptation strategies adopted by citrus farmers in their efforts to counter the changing climate; followed by planting of different crop varieties, change amount of land under citrus production, increased water conservation, soil conservation, water harvesting, crop diversification and insurance.

8.3 Conclusion

The main objective of the study was to analyse the influence of climate variability on citrus production and rural livelihoods in Mopani District Municipality. The study found that annual precipitation anomalies in Mopani District Municipality ranged within the near normal category with irregular events of extremely wet conditions between 1987 to 2017. The study concludes that Mopani District Municipality receives moderate climate conditions. The study shows that there is a weak negative decreasing trend in rainfall ($r^2 < 0.5$), a weak positive increasing trend in annual average maximum temperature ($r^2 < 0.5$) and a weak negative decreasing trend in annual minimum temperature ($r^2 < 0.5$). The study indicates very strong positive increasing trends in citrus production ($r^2 > 0.5$).

The study found that there is a significant relationship between climate variability and citrus production ($p < 0.05$). The study revealed that maximum SPI and maximum temperature make a strong individual influence in explaining citrus production than minimum SPI and minimum temperature indicating minor contributions. Climate variability leads to the variation of citrus fruit productivity. The study concludes that citrus production performance in different locations vary significantly. The study found that there is a very strong positive significant relationship between citrus production and farm net revenue ($p < 0.05$ and $r^2 > 0.5$).

The study highlights that climate variability and citrus production have an influence on rural livelihoods. It revealed that there are significant relationships between livelihood variables (financial assets, social assets, human assets, physical assets, and natural assets) and climate variability variables (temperature and rainfall) with $p < 0.05$. In addition, the study found that citrus farmers have adjusted their farming practices due to long-term changes in climate. The study indicated that drought and flood episodes have negative impacts on citrus productivity and farm income. Furthermore, the study found that 80.0% of citrus farmers were not insured against climate variability. To add on, the study revealed that increased irrigation, increased use of fertilizers, pesticides, and manure were, and equally used as adaptation strategies adopted by citrus farmers in their efforts to counter the changing climate; followed by planting of different crop varieties, change amount of land under citrus production, increased water conservation, soil conservation, water harvesting, crop diversification and insurance. Citrus farmers intend to make adaptation to climate variability their priority.

8.4 Recommendations

Based on the findings of this study, the following recommendations were made.

It is evident from the SPI estimation on 12 months' time scale that the frequency of near normal rainfall conditions is the same order of magnitude over Mopani District Municipality. The SPI versality allows it to monitor short term water supplies such as soil moisture, which is critical for citrus production and long-term water resources such as streamflow, reservoirs, and groundwater. The SPI should gain more visibility in the future as water resource management and policy makers become aware of its existence. Since climate variability is overly critical in low rainfall areas, SPI values should have a wider range to represent the degree of wetness or dryness to result in a more accurate assessment of drought and flood conditions. The SPI should be studied further to discern whether the index can be improved or its interpretation. An improvement could be by calculating it on a weekly or biweekly basis rather than monthly, as it is currently done.

Rainfall and temperature are major drivers of climate variability. Changes in the frequency and intensity of rainfall have significant implications on citrus production, livelihoods, food security and economic stability. Understanding the changes in climate and weather extremes is crucial in terms of its influence on floods and droughts, which have major repercussions particularly for agriculture. Therefore, to ensure that moisture stress does not supress citrus growth and development, soil and water management practices should be improved to reduce loss of moisture from the soil and increase water holding capacity during the dry period. There is a need to dig trenches to prevent water logging during heavy rainfall seasons and the water should be drained into dams and reservoirs for storage and irrigation use during low rainfall seasons. Farmers should not only focus on climate variability as a primary influence on citrus production, but they also need to consider other factors such as low relative humidity, high winds, and citrus export market rates.

Citrus yield and production can be improved with the availability of modern citrus varieties and technologies which may increase farm income. Farmers require a reasonable price of fertilisers, pesticides, herbicides, water quantity for irrigation and citrus protection utilities. Farmers should seek to get citrus varieties that are pests and disease tolerant for a better return on citrus productivity. Farm extension facilities and assets should be ensured against climate change and variability. Farmers should establish financial institutions, marketing centres and develop functional relationships with high value commercial entities to ensure fair prices of their produce.

Citrus production plays a dominant role in its economy in terms of sustainable land management, employment, value addition, food security and export earnings. It is recommended that government and private sectors should take initiative to provide training for farmers on modern agricultural technologies and to supply agricultural inputs on time to assure increased citrus production and sustainable livelihood. The study revealed that the main source of income for citrus vendors was selling citrus fruits. Therefore, it is recommended that citrus vendors diversify their source of income by selling different fruit types and vegetables.

Farmers, government, and private sectors need to empower the rural poor involved in citrus production through education, advocacy, awareness, and capacity building to enhance their climate adaptation strategies. The government and private sectors should provide skills development workshops and seminars in diverse skills that will increase citrus workers and citrus vendors choices so that they can engage in a variety of activities and earn income from multiple sources such as carpentry, carving, metalwork, and masonry. As a result, it is necessary to support the rural people to advance their already existing skills to allow them to be more productive.

The availability of a robust and well-designed intuitive planning characterised by a combination of stakeholders should be a major factor in the success of climate variability adaptation strategies. These stakeholders need to play a critical role in determining the extent to which farmers, citrus workers and citrus vendors are vulnerable to various climatic hazards. As an outcome, tactical and strategic planning at the national level should be developed from the grass root (farm-level) to the national level. The designed strategy will then have specific instructions, accountability, and the provision of sufficient financial capital.

The departments at the district and national level should increase water supply to farmers so that they may invest in rain-fed and irrigation systems, and better farming technologies. There is a significant degree of rainfall variability in the study area and various forms of dry spells posing serious hazards to citrus production and harvest. However, lack of adequate storage structures for rainwater harvesting often results in rainwater wastage. Farmers at national and local levels should employ rainwater harvesting equipment's to manage seasonal drought through supplementary irrigation, therefore rainwater harvesting, and conservation should be regarded as the key adaptation approach.

Integrating indigenous knowledge systems with western climate change and variability policies would increase the legitimacy of farmers decision making processes. This may demand that adaptation intervention designers search for solutions together with farmers rather than prescribing solutions that farmers may not view as feasible or appealing. The department of agriculture in Mopani District needs to play a significant role in ensuring that citrus farmers record their annual production. A good farm record system would provide accurate and updated information that will be sufficient to provide data in a variety of ways needed for further research.

The findings of the study showed that citrus farmers are engaged in various diversification and adaptation strategies, but their efforts to adapt are constrained by the lack of access to credit and capital assets. The availability of credit and capital would enable farmers to employ more rural individuals (human labour) and tangible goods to improve their livelihoods. Farmers indicated that the lack of assets is the most significant barrier for not increasing their capital resource generating activities, as a result it is critical to expand local micro-credit facilities and make them accessible to farmers throughout the planting seasons.

8.5 Recommendation for Further Research

The study focused on the effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality. The empirical evidence suggests that climate variability has a negative impact on citrus production, farmers income and rural livelihoods among the rural communities. Due to the limitations of the study, further studies are recommended to expand from this study to a larger scale such as provincial, national, and include both commercial and small-scale citrus farmers to address related challenges. The researcher recommends that further studies should use a larger sample size of citrus farms. There is a need for government, municipalities, and private sectors to invest in citrus production. More research is needed to investigate the impacts of climate variability on other sectors of the economy that affect local communities, farmers livelihoods and inequality at a macro-level. Further research is required on weather and climate elements such as wind, humidity, atmospheric pressure, and soil moisture among others which affect citrus production. In addition, further research is also required on the selection of citrus varieties that will do well in hostile climate conditions.

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APPENDICES

APPENDIX A: Questionnaire for Citrus Farmers

My name is Tanganedzani Tshitavhe, a postgraduate student at the University of Venda. This questionnaire is designed to assist gather data for academic purposes in writing my dissertation entitled **"Effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality, South Africa."** Your farm has been chosen to participate in this study and your contribution is very important. The information collected will be treated with uttermost confidence, used only for the purpose of the intended evaluation, and will not be provided to unauthorized parties. Names of the farms and respondents will be strictly kept confidential and protected. The respondents are kindly requested to give the requested information as truthful as possible.

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District Municipality	
Local Municipality	
Number of years farming in the area	

SECTION A: LAND CHARACTERISTICS AND CLIMATE VARIABILITY ISSUES

1. How many hectares of land do you have? (Write the number only)

…………………………………………………………………………………………..

2. Do you receive information on climate change and variability?

Yes	
No	

3. If yes, what is your source of information? (Select as many as possible)

Source of information		**What type of information?**	
Newspaper		Rainfall	
Radio		Temperature	
Television		Wind	
Internet		Fog	
Magazine		Humidity	
Other		Other	

4. Kindly indicate your long-term observations of the following climate variables.

Dimension	**Increasing**	**Decreasing**	**No Changes**
Temperature			
Rainfall			
Floods			
Droughts			
Reliable season (shift)			
Heat waves			
Abnormal wind			
Frost			
Other (specify)			

5. (a) Have you made any adjustments in your farming due to the long-term changes in climate?

Yes	
No	

(b) If yes, name the alternatives
…………………………………………………………………………………………………
…………………………………………………………………………………………………

6. (a) Have drought episodes negatively impacted on your citrus production?

Yes	
No	

(b) If yes, to what magnitude?

Dimension	Increasing	Decreasing	No Change
Yield			
Quality			
Quantity			
Income			
Production cost			
Pests and diseases			

(c) If no, why has it not affected you?

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

……………………………………………………………………………………………….....

7. (a) Has climate variability impacted food security in your household?

Yes	
No	

(b) If yes, how?

Reduced income	
Seasonal food scarcity increases	
Increased food prices	
Price instability	
Pest and diseases	
Other (specify)	

(b) If no, why were you not affected?

……

SECTION B: PRODUCTION FACTORS

8. What is your current influence of growing citrus on your farm? (Select as many as possible)

Rainfall	

Type of soil	
Capital access	
Access to irrigation	
Access to credit	
Other (specify)	

9. What is your source of water for farming?

Borehole	
Dam	
River	
Reservoir	
Rainfall	
Other (specify)	

10. Do you assess the quality of water you use on the farm? (Laboratory tests and analysis).

……….....

11. Do you take the soils on your farm for laboratory tests and analysis?

....

12. At which period of the citrus calendar do you experience water shortages?

Flowering (September to December)	
Growth and Development (January to April)	
Maturity (May to August)	

13. (a) What irrigation system do you use?

Dimension	**Now**	**Before**
Drip irrigation		
Surface irrigation		
Micro jet sprinkler/spray		
Natural rainfall/rain fed		

Other (specify)		

(b) What influences your choice in 13 (a) above?

………

14. How often do you irrigate?

Once a week	
Twice a week	
Thrice a week	
Other (specify)	

15. How many litres of water do you use per irrigation cycle per tree?

……......

16. How many tons per hectare do you produce at the end of the citrus season?

Tons per hectare	**Normal Season (Wet)**	**Abnormal Season (Dry)**
Below 5 tons		
Between 5 to 10 tons		
Above 10 tons		

17. What can you say about the quality of your harvest at the end of each citrus season from 1987 to 2017?

Dimensions	**Normal Season**	**Abnormal Season**
Excellent storage life		
Poor storage life		
Excellent quality		
Poor quality		
More job opportunities		
Less job opportunities		
Pests and diseases		
No pests and diseases		
New marketing opportunities		

Less marketing opportunities		
More harvest losses		
Less harvest loses		
Other		

18. (a) How would you describe citrus production in your farm per year for the last 30 years?

Increasing	
Decreasing	
Constant	
Other (specify)	

(b) What could be the reason for the trend?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

19. Do you have any insurance protection against?

(a) Drought

Yes	
No	

(b) If no, why?

Cost	
No awareness	
Not necessary	
Other	

(c) Floods

Yes	
No	

(d) If no, why?

Cost	
No awareness	
Not necessary	
Other	

20. What do you believe can be done by each of the following to reduce the effects of climate variability to safeguard livelihoods?

a) Farmers:

……

……

b) Government:

……

……

c) Private sector:

……

……

21. Which assets other than land and citrus crop/trees do you also own?

Motor vehicle/bakkie	
Tractor/cart	
Shop/workshop	
Plough	
Harrower	
Generator	
Appliances	
Other	

22. What is the average amount spent and the quantity used for the following farm inputs in citrus production at the end of each season?

Farm Input	**Quantity in Kg or Litres**	**Amount spent in Rands**

Fertilizers (Kg)		
Pesticides (Liters)		
Herbicides and insecticides (Liters)		
Manure		
Water		
Packaging		
Other (specify)		
Total		

23. How much do you spend per year on the following necessities? (Estimate the amount)

Item	**Estimated amount**
Transport costs	
Electricity	
Petrol	
Paraffin	
Medical	
Insurance	
Security	
Other	

SECTION C: FARMERS' ADAPTATION MEASURES

24. How have you adopted to the changing climate? (More than one answer allowed)

Different crop plantation	
Different crop varieties	
Crop diversification	
Change amount of land under citrus production	
Change from crops to livestock	
Change from farming to non-farming activities	
Increase irrigation	
Increased use of fertilizers, pesticides, and manure	
Increased water conservation	

Soil conservation	
Water harvesting	
Insurance	
Cultural adaptation/Prayer	
No action	
Other (specify)	

25. What are the main constraints experienced in adjusting to the weather changes?

Lack of capital	
Lack of information	
Shortage of labor	
Lack of access to water	
Poor health	
Other (specify)	

SECTION D: ECONOMIC VIABILITY AND MARKETING INFORMATION

26. How many labourers do you normally hire? (Write the number only)

Seasonal	
Inter-annual	
Annual	

27. What do your labourers comprise of?

Permanent workers	
Temporary workers	
Learner students	
Skilled workers	
Semi-skilled workers	
Unskilled workers	
Other	

28. Please indicate the salary categories that best describes your labourer's monthly income.

<R1000	
R1000 - R2000	
R2000 - R3000	
R3000 - R4000	
R4000 - R5000	
R5000 and over	

29. Does the price of citrus fruits in Rands/tons change depending on whether a season was a flood or drought year? Explain your answer.

Yes	
No	

30. What percentage is your citrus market? (Local, regional, and international)

……..

31. What is the percentage of the demand you meet?

……..

32. What are your main citrus market outlets (to whom do you sell) locally? (More than one answer allowed)

Contractors	**Local people**	**Consumers**	**Hawkers**	**Shops/Commercial market**	**Other**

33. What % of your farm income comes from

Crop sales	
Renting out equipment	
Other	

34. What is the ownership structure of the farm?

Individual owned	
Family owned	
Corporation or company	
Government owned	

Community	
Collective or communal (joint enterprise)	
Other	

35. Any further comments?

……

…….

DATA REQUEST

1. Citrus production data in tons from 1987 to 2017.
2. Citrus fruits in Rands/tons from 1987 to 2017.
3. Citrus chain statistics of the farm from 1987 to 2017.

THANK YOU FOR ANSWERING THIS QUESTIONNAIRE

Compiled by: Tanganedzani Tshitavhe, University of Venda, Thohoyandou, South Africa

APPENDIX B: Questionnaire for Citrus Farm Workers

My name is Tanganedzani Tshitavhe, a postgraduate student at the University of Venda. This questionnaire is designed to assist gather data for academic purposes in writing my dissertation entitled **“Effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality, Limpopo Province, South Africa.”** You have been chosen to participate in this study and your contribution is particularly important. The information collected will be treated with uttermost confidence, used only for the purpose of the intended evaluation, and will not be provided to unauthorized parties. The names of respondents will be strictly kept confidential and protected. The respondents are kindly requested to give the requested information as truthful as possible.

ADMINISTRATION

Enumerator’s name :……………………………………………………………………………

Questionnaire number :…………………………………………………………………………

Date :…………………………………………………………………………....

SECTION A: SOCIO-ECONOMIC INFORMATION OF RESPONDENT (tick appropriate box).

1. Gender

Male	
Female	

Age

<20	21 to 30	31 to 40	41 to 50	51 to 60	60>

2. What type of work do you do?

…………………………………………………………………………………………………

3. Are you employed seasonally, inter-annual or annually, etc.? Please specify

…………………………………………………………………………………………………

4. How many days do you work per week?

…………………………………………………………………………………………………

5. How many hours per day do you work on the farm?

8 hours in shift groups	
8 hours per day	
Other (specify)	

6. What is your most important source of income?

Wages	
Pension	
Remittances	
Farming	
Other	

7. (a) Please indicate the range that best describes your monthly household income.

<R1000	
R1000 - R2000	
R2000 - R3000	
R3000 - R4000	
R4000 - R5000	
R5000 and over	

(b) Remittances:

<R1000	
R1000 - R2000	
R2000 - R3000	
R3000 - R4000	
R4000 - R5000	
R5000 and over	

8. What is your use of cash remittances, if any?

Food, exclusively	
Food, clothes, and education	
Food and clothes	

Food and education	
Improvements to house	

9. How does this year's income compare with last year's income?

Better than last year	
Much the same as last year	
Worse than last year	

10. (a) Do you do additional work to increase income (second job)?

Yes	
No	

(b) If yes, what type of job?
……………………………………………………………………………………………………….....

(c) When is the job done?
………………………………………………………………………………………………….........

(d) How much does it bring?
……....

(e) What percentage do you contribute to the household income?
……....

11. What other sources of finances are available to you in sustaining your livelihood?
……………………………………………………………………………………………………….

12. How much per month do you spend on the following basic necessities?

Item	**<R500**	**R500 – R1000**	**R1000 – R1500**	**R1500 – R2000**	**R2500 – R3000**	**R3500 – R4000**	**R4500 – R5000**	**R5000 and over**
Transport								
Electricity								
Clothing								
Food								
Petrol								
Paraffin								
Medical								

Rent								
Loan								
Security								
Taxes								
Other								

13. What is your dependence on social relationships in times of large unforeseen difficulties?

Strategy	**Option**
Ask friends or family for help	
Use any lender available	
Ask church for help	
Ask the employer for help	
Do not know	
Other	

14. Does your employer help you with the following?

Item	**Option**
Advancement leaves (off days)	
Medical insurance	
Funeral cover	
Bonuses	
Education	
Loans	
Clinic cover	
Policies	
Other	

SECTION B: CLIMATE VARIABILITY, CITRUS PRODUCTION, AND RURAL LIVELIHOODS.

15. Do you know what climate variability means?

Yes	
No	

16. If yes, how would you describe it?

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

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

17. Which of the following climate changes have you observed in your area in the last 10 to 30 years?

A decrease in rainfall amount	
An increase in rainfall amount	
Rising temperature	
Decreasing temperature	
Floods	
Droughts	
Increase in dry spells	
Rain concentration in some days with high intensity	
Rain comes late and ends early	
Prevalence of wind	

18. How do these changes affect you as a worker at a citrus farm?

……

……

19. What influence has the change in climate had on the way you access finances that you use in sustaining your livelihood?

…….....

THANK YOU FOR ANSWERING THIS QUESTIONNAIRE

Compiled by: Tanganedzani Tshitavhe, University of Venda, Thohoyandou, South Africa

APPENDIX C: Questionnaire for Citrus Vendors

My name is Tanganedzani Tshitavhe, a postgraduate student at the University of Venda. This questionnaire is designed to assist gather data for academic purposes in writing my dissertation entitled **"Effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality, Limpopo Province, South Africa."** You have been chosen to participate in this study and your contribution is particularly important. The information collected will be treated with uttermost confidence, used only for the purpose of the intended evaluation, and will not be provided to unauthorized parties. The names of respondents will be strictly kept confidential and protected. The respondents are kindly requested to give the requested information as truthful as possible.

ADMINISTRATION

Enumerator's name :………………………………………………………………………………….

Questionnaire number :………………………………………………………………………………….

Date :…………………………………………………………………………………....

SECTION A: SOCIO-DEMOGRAPHIC CHARACTERISTICS OF CITRUS VENDORS

1. Gender

Male	
Female	

2. Age

<20	21 to 30	31 to 40	41 to 50	51 to 60	60>

3. What is your education level?

Primary school (Grade R to Grade 7)	
Lower secondary school (Grade 8 to Grade 10)	

Upper secondary school (Grade 11 to Grade 12).	
College or Technikon	
University	
Unschooled	
Other	

4. Number of years into citrus vending

< 5 years	
6 to 10 years	
11 to 15 years	
16 to 20 years	
>21	

5. (a) Do you think citrus production contributes to the development of the Mopani District Municipality?

Yes	
No	

(b) Explain your answer

…………………………………………………………………………………………………

…………………………………………………………………………………………………

6. What is your average seasonal income from selling citrus produce?

< R1000	
R1000 - R2000	
R2000 - R3000	
R3000 - R4000	
R4000 - R5000	
R5000 and over	

7. How do you describe your seasonal income?

Regular	
Not regular	

Neither	

8. What would you describe your income for the past 10 years?

Increasing	
Decreasing	
Constant	
Other (specify)	

9. What other means do you have to increase your income?

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

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

10. Is your income for selling citrus fruits enough to support your family?

Yes	
No	

11. If no, how do you compensate?

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

12. How much do you contribute to household income from selling citrus? Estimate percent.

……………………………………………………………………………………………..............

13. How many years since you started selling citrus?

…………………………………………………………………………………………………..

14. To what extent has your standard of living changed since you started selling citrus fruits?

Living standard indicator	**Increase**	**Decrease**	**Explanation** (what exactly happened)
Food			
Clothes			
Education of children			
Health care			
Electricity/water			

Social security			
Transportation			
Other (specify)			

15. What infrastructure in the community do you have access to? Rank according to majority access. Use a scale of 1 – 4. 1- Indicate high access, 2 – accessible, 3 – low access, 4 – not accessible.

Item	**High access**	**Accessible**	**Low access**	**Not accessible**
Transport				
Health facilities				
Education facilities				
Tel-communications				
Storage facilities				
Marketing facilities				
Water supply				
Groundwater				
Electricity				
Waste disposal				
Credit				
Other				

16. What type of skills, training, experience, and knowledge do you have?

……………………………………………………………………………………………….......

17. (a) Do you use the skills, training, experience, and knowledge to make a living/ to sustain your livelihood?

Yes	
No	

(b) If yes, how?

…………………………………………………………………………………………………

(c) If no, why?

…………………………………………………………………………………………………

18. How have you used the skills in formulating different kinds of livelihood?

……………………………………………………………………………………………......

SECTION B: AWARENESS AND PERCEPTION OF CLIMATE VARIABILITY TRENDS RELATED ISSUES

19. Have you experienced the following in your area? (If yes, indicate the month and year if possible, more than one answer allowed)

Dimensions	**X**	**Month**	**Year**
Droughts			
Floods			
Unusual coldness			
Unusual hotness			
Increased rainfall			
Decreased rainfall			
Heat waves			
Strong wind			
Other			

20. What impacts has climate variability had on your livelihood?

Decreased socio-economic problems	
Increased socio-economic problems	
Reduced income	
Increased income	
Decreased unemployment	
Increased unemployment	
Other (specify)	

21. What impacts has climate variability had on food security?

Loss of employment	

Increased employment	
Reduced income	
Decreased income	
Food scarcity	
Reduced food prices	
Increased food prices	
Lack of local markets	
Other (specify)	

22. What may be other reasons which can negatively influence your financial, human, social, physical, and natural capitals apart from climate variability?

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

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

23. What are the factors that you consider influencing your climate adaptation strategies?

Lack of alternatives	
Lack of education	
Lack of education	
Lack of skills	
Lack of climate information	
Lack of money/funds	
Shortage of labor	
Other (specify)	

THANK YOU FOR ANSWERING THIS QUESTIONNAIRE

Compiled by: Tanganedzani Tshitavhe, University of Venda, Thohoyandou, South Africa

APPENDIX D: Participant Information Letter

Dear Participant

I am Tanganedzani Tshitavhe, Environmental Sciences masters' student at the University of Venda with student number 14014023, under the School of Environmental Sciences, Department of Geography and Geo-Information Sciences. I am conducting research entitles *"Effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality, Limpopo Province, South Africa,"* supervised by Prof. H. Chikoore (Ph.D.) and Mr. E. Kori.

Climate variability acutely affects rural livelihoods and citrus productivity, yet it is just one of many stresses that vulnerable rural farmers must cope with Climate variability has a negative impact on citrus production yields and it is important to assess and understand them to provide the best adaptive measures and strategies. The purpose of the study is to analyse the influence of climate variability on citrus production and rural livelihoods in Mopani District Municipality.

Semi-structured questionnaires (open-ended and close-ended questions) will be utilized to gather data from the respondents. A participant will spend approximately 30 minutes to complete the questionnaire and a respondent is expected to give honest information required.

Risks and benefits for participation: No harm or injury will be intended on any participant. The researcher will ensure that there is no emotional and physical harm to the participants. There are no complicated questions in this survey and no right or wrong answers.

Benefits from the study: The researcher will publish research manuscripts in academic journals in the future. The participant will gain more information or a better understanding of climate variability and its influence on citrus production and rural livelihoods.

Consent: Be knowledgeable that participation in this study is voluntary, you are free to withdraw at any time without penalty and you are under no obligation to take part in this study. If you decide to continue with the participation, you will be treated fairly.

The reason participants may withdraw from participating: There is no reason the participant may want to withdraw, but if they chose to withdraw there will be no adverse consequences.

Remuneration of participants: The participant should not expect to receive any monetary or other types of remuneration, but your participation will be highly appreciated.

Costs of the study to the participant: The participant will not be expected to cover any costs towards the study.

Confidentiality: All participants are entitled to privacy about their opinions and beliefs. No personal details will be revealed in public. Information collected from this study will be kept confidential and will not be disseminated to other parties without your permission. A participant should not expect any remuneration any monetary, but your participation will be appreciated.

For any enquiries, please feel free to contact the researcher, Tshitavhe T (0720647803) or the supervisors, Prof. H. Chikoore (0159628586) or Mr. E. Kori (0159628565) or the University of Venda Research Ethics Committee Secretariat on 0159629058. Complaints can be reported to the Director: Research and Innovation, Senior Prof. G.E Ekosse on 0159628313.

Yours sincerely,

Tanganedzani Tshitavhe

APPENDIX E: Participant Consent Form

I hereby confirm that I have been informed by Tanganedzani Tshitavhe (14014023), about the nature of the study. I have received, read, and understood the participant information letter regarding the study.

I am aware that there are no risks or discomfort involved should I participate in the study. I am aware that the researcher and I will benefit from the study. I know that I should not expect monetary or any type of remuneration. I am aware that I am not expected to cover any costs for the study. I am aware that the results of the study including personal details regarding my gender, age, 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 am aware that participation is voluntary and that 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 that may relate to my participation will be made available to me.

Participant's Signature: ……………………...........Date: …………………… Time…………………….

I, Tanganedzani Tshitavhe herewith confirm that the above participant has been fully informed about the nature, conduct, and risks of the above study.

Researcher's Signature: ……………………...........Date: …………………. Time……………………

APPENDIX F: Research Ethics Certificate

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Ms T Tshitavhe

Student No:
14014023

PROJECT TITLE: **Effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality.**

PROJECT NO: SES/19/GGIS/10/2011

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Dr H Chikoore	University of Venda	Supervisor
Mr E kori	University of Venda	Co-Supervisor
Ms T Tshitavhe	University of Venda	Investigator – Student

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: November 2019
Decision by Ethical Clearance Committee Granted
Signature of Chairperson of the Committee: ....
Name of the Chairperson of the Committee: Senior Prof. G.E. Ekosse

UNIVERSITY OF VENDA
DIRECTOR
RESEARCH AND INNOVATION
2019 -11- 20
Private Bag X5050
Thohoyandou 0950

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

APPENDIX G: Request for Permission to Conduct Research

DEPARTMENT OF GEOGRAPHY & GEO-INFORMATION SCIENCES

SCHOOL OF ENVIRONMENTAL SCIENCES

25 November 2019

TO WHOM IT MAY CONCERN

REQUEST FOR THE PERMISSIONS TO CONDUCT A RESEARCH

This serves to confirm that Tanganedzani Tshitavhe (14014023) is a Master's student in the Department of Geography and Geo-Information Sciences. Ms Tshitavhe presented a research proposal entitled "Effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality, South Africa". The proposal was defended and approved by the University Higher Degree Committee.

Ms Tshitavhe has made outstanding progress in her work and is busy collecting data to achieve the study objectives. In my capacity as her supervisor, I am happy with her excellent progress and have every confidence that she will complete the dissertation and submit for examination by the first quarter of the 2020 academic year.

Kind Regards,

Mr. E. Kori

Supervisor

University of Venda

SCHOOL OF ENVIRONMENTAL SCIENCES DEAN 2019 -11- 28 OFFICE OF THE DEAN UNIVERSITY OF VENDA

Private Bag X5050
Thohoyandou 0950 South Africa
TEL:+27159628565
E-mail: edmore.kori@univen.ac.za

DEPARTMENT OF GEOGRAPHY & GEO-INFORMATION SCIENCES

SCHOOL OF ENVIRONMENTAL SCIENCES

Tshitavhe Tanganedzani
University of Venda
Private bag X5050
Thohoyandou
0950

Dear Sir/ Madam

REQUEST FOR THE PERMISSIONS TO CONDUCT A RESEARCH

I am Tshitavhe Tanganedzani, an Environmental Sciences Masters' student, under Department of Geography and Geo-Information Sciences, School of Environmental Sciences, at the University of Venda. I am conducting research entitled "Effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality, South Africa". The research proposal has been presented, defended and approved by the University Higher Degree committee, under the supervision of Dr. H. Chikoore and Mr.E. Kori. I humbly request your permission to conduct my research that will involve data collection in the form of secondary citrus production data in tons, citrus fruits in Rands/tons and citrus chain statistics from 1987 to 2017. As well as primary data in the form of questionnaires distributed to the farm owner and farm labourers.

Any assistance given to my research work will be highly appreciated.

Regards,

T.T ....

Student | Supervisor

Tshitavhe T
tshitavhetangie@gmail.com
0720647803

Mr.E. Kori
edmore.kori@univen.ac.za
0159628565/0710767607

University of Venda

SCHOOL OF ENVIRONMENTAL SCIENCES
DEAN
2019 -11- 28
OFFICE OF THE DEAN
UNIVERSITY OF VENDA

Private Bag X5050
Thohoyandou 0950 South Africa
TEL:+27159628565
E-mail: edmore.kori@univen.ac.za

DEPARTMENT OF GEOGRAPHY & GEO-INFORMATION SCIENCES

SCHOOL OF ENVIRONMENTAL SCIENCES

Tshitavhe Tanganedzani
University of Venda
Private bag X5050
Thohoyandou
0950
25 November 2019

The Head of Department
Limpopo Department of Agriculture
Private bag X9487
Polokwane
0700

Dear Sir/ Madam

REQUEST FOR THE PERMISSIONS TO CONDUCT A RESEARCH

I am Tshitavhe Tanganedzani, an Environmental Sciences Masters' student, under Department of Geography and Geo-Information Sciences, School of Environmental Sciences, at the University of Venda. I am conducting research entitled "Effects of climate variability on citrus production and rural livelihoods in Mopani District Municipality, South Africa". The research proposal has been presented, defended and approved by the University Higher Degree committee, under the supervision of Dr. H. Chikoore and Mr.E. Kori. I humbly request your permission to conduct my research that will involve data collection in the form of secondary citrus production data in tons, citrus fruits in Rands/tons, citrus chain statistics from 1987 to 2017 and the number of commercial citrus farms in greater Tzaneen and Greater Maruleng local municipalities.

Any assistance given to my research work will be highly appreciated.

Regards,

....

Student   Supervisor

Tshitavhe T   Mr.E. Kori

University of Venda

SCHOOL OF ENVIRONMENTAL SCIENCES
DEAN
2019 -11- 28
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UNIVERSITY OF VENDA

Private Bag X5050
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E-mail: edmore.kori@univen.ac.za

APPENDIX H: Permission Letter from The Provincial Department of Agriculture and Rural Development

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
AGRICULTURE AND RURAL DEVELOPMENT

Ref: 12R
Enquiries: Dr Thomas Raphulu

08 January 2020

Ms Tshitavhe Tanganedzani
Department of Geography and Geo-Information Sciences
University of Venda
Thohoyandou

RE: APPLICATION TO CARRY OUT RESEARCH UNDER THE DEPARTMENT OF AGRICULTURE & RURAL DEVELOPMENT IN MOPANI DISTRICT.

1. The research proposal "Effects of climate variability on citrus production and rural livelihoods in Mopani District municipality, Limpopo Province, South Africa" was presented to the Research Committee, held on the 10th December 2019, Polokwane, Limpopo Province.
2. Kindly take note that your request to conduct Research in Mopani District has been granted.
3. You are required to visit the office of the Director: Mopani District to brief them on the study, to request citrus farmers database and the assistance from the officials.
4. The Department is prepared to embark on any activity which could assist our citrus farmers to improve their farming systems and production at large.
5. Kindly take note that you will be expected to hand over a copy of your final report to the Department for record purposes as well as for reporting. You may also be invited to share your findings in the Departmental Research Forum.
6. Hoping that you will find this in order.

Kind regards

08 | 01 | 2020

Dr T. Raphulu
Chairperson: Research Committee

Date

67/69 Biccard Street, POLOKWANE, 0700, Private Bag X9487, Polokwane, 0700

Tel: (015) 294 3135 Fax: (015) 294 4512 Website: http://www.lda.gov.za

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APPENDIX I: Average Monthly Rainfall Data for Four Weather Stations

Tzaneen-Grenshoek

Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
1987	32,7	345,5	93,8	40,2	22	28,2	0	21,6	137,5	72	75,3	302
1988	224,8	447,8	407,9	41,2	6,5	64,7	7	32,4	70,8	139,7	19,1	88,5
1989	65	174,8	7	20,9	0	0,5	0,2	7,8	0	62,5	72,5	116,3
1990	137,3	106,6	155,1	32,1	12,6	2	6	2	2,4	31,8	103,5	256
1991	259	231,7	259,5	4	20,5	65,5	7	3	12	20,5	63,9	69,5
1992	73,7	40	79,5	8,5	0	8	1,5	9,5	2,5	38	50	244,5
1993	60,8	115,6	215,5	33	1	11,5	0	18	8,5	48,7	221,5	251,4
1994	266,5	76,5	98	62,5	7	3	1	34	4	89,5	34,2	131,3
1995	170	264,2	140	104,5	25	0,5	0,3	12	9,4	34,5	335,5	229,9
1996	352,7	813,5	88,3	43,4	127	27	67,2	53	17,5	64,4	125,5	163,8
1997	545	313	318,5	30,5	24,6	0	12,2	2,7	91,9	99,3	168,2	65,8
1998	248,2	38,6	60,6	60,8	0	0,4	43,4	6,8	43,2	105,6	135,2	325,2
1999	221,2	235,4	125	45	54,4	17,6	66	5,4	9	0	172,2	194,4
2000	175,4	1162,8	417,8	0	8,4	130,4	2,6	0,8	28	91,2	166,8	101,8
2001	31,4	374,2	111,6	28,4	23,6	9	6,2	1,8	10,6	112,4	272,6	228
2002	104,6	38	91,6	40,6	12,4	32	1,2	9,8	17,4	58,4	14,6	93,6
2003	75,4	152,4	53,8	5,6	1,4	16,4	1,6	0,4	31,6	58	55	117,6
2004	105	331,2	289,6	79	6,8	6,2	9,4	14,8	11,2	42,4	67,4	202,8
2005	110,8	23	100,6	89,4	0	6,4	0,4	6,2	0	11,2	62,4	167
2006	464,8	355	173,4	21,4	17	8	1	5,4	3,5	7,2	23,5	36,2
2007	69,4	16,8	69,6	121	0	9	30,2	15,4	63	104,2	135,8	206,6
2008	173,2	75,4	27,2	28,2	4,6	2,4	9	15,8	7,4	38,6	130,6	207,4
2009	175,4	252,2	79,8	22,8	34,4	52,4	15,4	6,4	1,6	48,8	242,2	130,6
2010	122,2	131,6	106,8	184,8	12,6	3	26	0	4,4	33,2	202,8	275,4
2011	452,8	45,8	84,6	268,4	14	2,4	13,8	8,4	5,4	86,2	23	77,8
2012	181,4	114,2	59,6	31,2	8	1,2	3,2	7	126,4	98,6	83,4	161,3
2013	564,8	87	30,4	115,2	8	0	7,6	7,2	23,4	60,4	69,4	235
2014	231,6	147,2	143,8	72	4,2	11,2	6,6	14,6	6,4	23,2	64,8	120,8
2015	76,4	48,8	82,2	68	0,4	1	8,6	0	93,8	16,8	78,2	24,8
2016	68,6	63	141,4	2,8	24,6	1	19,4	0	2,2	24,4	66,4	151,8
2017	283,2	317,8	95,4	96	17,4	0	9,8	5,4	8	41,8	70,8	142

Hoedspruit Air Force Base

Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
1994	115,5	11,4	43,2	14,6	0	0	0	0	9,4	43,8	14,2	57,2
1995	131,6	22,4	13	52	4	0	0	2,4	4,8	43,5	92,3	145,8
1996	130,4	323,6	39,9	25,1	86,6	2	13,9	16,6	2,6	8,8	0	50,6
1997	91,4	81,4	52	29,4	10,6	0	0	4	19	32,6	86,4	41,6
1998	70	0,2	21,8	13,2	0	0	3	0,4	10,8	38	182,8	143,6
1999	81,4	127	18	73,4	10	0	1,4	3,6	1,2	13	100	76,6
2000	51,6	36,6	136	379,4	15,2	11,4	0	0	0,8	13,6	75	116,2
2001	20,2	178,6	13,2	42,6	7,2	0,4	0,4	0	0	63,6	144	45
2002	87,4	27,8	25	32,6	2,2	8,4	0	0	13	23,4	7,4	26,2
2003	39,8	27,4	69	3	17,8	4	0	0	8,2	6,2	34,4	50,6
2004	77,2	91,6	91,4	36,8	1,2	12,4	6	6,2	0,8	18,2	64	100,8
2005	36	30,4	53,6	18,2	2	0	2	0	0	1.6	79,4	17,8
2006	94,2	255	98,6	12,6	4,6	1,3	0	1,2	3,4	8,8	34,8	70,8
2007	34,4	20,8	31,8	30	0,6	0,2	15,2	0,2	26	37,8	114,4	109,2
2008	47,2	27,6	24,6	33	1	0,8	0,2	0	0	14,8	23,6	23,6
2009	149,2	0	26,8	3,4	17,6	6,4	4,4	10,8	0,4	8	138,2	39,2
2010	154,4	12,6	38,8	101	7,4	4,4	0,2	0	0	9,6	73,4	125,4
2011	223,6	38,4	64,6	72,4	38	0	0,4	6,6	0	49,6	20,4	116,4
2012	439,4	2,8	50,6	13,8	0	0	0	0	28,4	52,4	35,8	87,2
2013	197,6	32,4	65,4	74	2,4	0,2	1,6	9,4	1	41,6	71	124,4
2014	69,4	42	208,6	15	0,2	0	0,2	9,8	0	21,6	66,2	146,8
2015	4,4	7,6	60	46,8	8,6	0	0	0	28,8	13	32,4	33,6
2016	60,4	15	57,6	0,2	2,2	0	24,4	0	15,8	31,2	80,6	102,2
2017	47	38,4	34,8	71,6	7,6	0	0	15,6	2,4	39,6	19,8	0

Tzaneen-Westafalia Estate												
Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
2007	85	16,8	69,6	121	0	9	30,2	15,4	63	104,2	135,8	206,6
2008	173,2	75,4	27,2	28,2	4,6	2,4	9	15,8	7,4	38,6	130,6	207,4
2009	175,4	252,2	79,8	22,8	34,4	52,4	15,4	6,4	1,6	48,8	242,2	130,6
2010	122,2	131,6	106,8	184,8	12,6	3	26	0	4,4	33,2	202,8	275,4
2011	452,8	45,8	84,6	268,4	14	2,4	13,8	8,4	5,4	86,2	23	77,8
2012	181,4	114,2	59,6	31,2	8	1,2	3,2	7	126,4	98,6	83,4	161,3
2013	564,8	87	30,4	115,2	8	0	7,6	7,2	23,4	60,4	69,4	235
2014	231,6	147,2	143,8	72	4,2	11,2	6,6	14,6	6,4	23,2	64,8	120,8
2015	76,4	48,8	82,2	68	0,4	1	8,6	0	93,8	16,8	78,2	24,8
2016	68,6	63	141,4	2,8	24,6	1	19,4	0	2,2	24,4	66,4	151,8
2017	283,2	317,8	95,4	96	17,4	0	9,8	5,4	8	41,8	70,8	142
Letsitele-La Gratitude												
Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
2011	178	21,7	83,4	65	12,1	3	3,5	4,3	0,7	22,1	85	54
2012	90,3	16,4	45,3	9,2	0	0	0	0	145,2	78,5	39,5	77,5
2013	323,7	56,2	8,2	102,6	0	0	4,3	0	0	48,2	86,1	91,5
2014	136,3	43,2	248,8	26,6	0	0	0	5	0,8	9,6	48,2	147
2015	8,7	48,8	22	36,5	0	0	0	0	30	41,9	46,3	21,9
2016	18,3	67,7	223,2	9,2	15,5	0	4,8	0	0	2,6	53,8	134,7
2017	157	57,2	44	27,6	26	0	5	0	2	25,9	8,6	108,1

APPENDIX J: Average Monthly Maximum Temperature Data for Two Weather Stations

Tzaneen-Grenshoek

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	26,7	29,5	27,9	26,6	25,5	21,1	22,2	22,3	23,7	23,6	26,6	26,9
1988	28,6	26,4	26,5	26,4	23,7	21,7	22,4	22,9	24,8	24	24,2	25,1
1989	24,8	26,3	27,7	23,5	24,2	21,2	21	25,2	26,9	27,1	27,3	28,4
1990	29,2	29,3	27,6	24,4	22,3	22,7	22,3	22,1	24,1	26,3	27,1	26,9
1991	28,3	27,6	25	25,1	23,8	20,1	22,2	23,8	25,1	27,1	27,6	26,8
1992	30,1	28,1	27,1	23,7	20,5	21,9	23,4	22	25,7	26,8	27,1	28,4
1993	28,9	28	26,3	26,5	26,2	22,6	22,3	22,2	28,2	26,9	25,1	28,4
1994	26,4	25,6	27,1	25,8	25,1	22,2	21,3	23,4	26,6	24,8	29	28,8
1995	30,9	27,1	26,1	24,7	21,5	21,4	22,4	24	26,7	26,7	26	26
1996	25,6	25,3	25,5	22,8	22,2	21,4	19,3	21,4	26,3	26,2	27,4	26,8
1997	27,3	26,7	25,8	24,5	21,5	23,6	20,3	24,2	24	24,8	27,6	27,7
1998	26,7	27,7	28,7	26,8	25,5	24	22	23	25,1	24	24,8	26,2
1999	28	25,1	24,9	24,9	22,8	21,6	20,7	22,9	23,4	26,1	25,3	27
2000	25,7	24,6	26,1	23,7	22,6	21,3	21,3	23,2	24,7	25,9	26	28
2001	27,2	24,5	25,3	24,5	22,7	21,8	20,3	23,9	24,1	25,6	24,5	26,4
2002	28,4	27	27,3	25,6	24,3	20,6	22,5	22,9	24,5	25,6	26,2	27,9
2003	29,5	29	27,8	26,3	23,6	20,3	22	23,5	25,2	26,6	26,8	29,3
2004	27,7	26,7	24,2	24,5	23,1	20,5	20,7	24,9	25,4	27,1	30,3	29
2005	29	30,1	27,6	25,4	25,4	24	22,9	25,7	28,7	28,7	28,6	26,7
2006	27,7	27,8	24,8	25,1	22,5	24,5	25,3	24,5	22,7	27,8	28,4	29,9
2007	29.9	31,2	29,9	26,9	24,8	23	22,6	25,3	27,8	25	27,7	26,3
2008	26,8	29,1	27	25,7	24,6	23,1	23,1	25,4	28,2	28,4	27,4	28,1
2009	28,8	27,7	26,4	25,8	24,9	23	20,7	24,4	28,5	27,7	27,2	29,5
2010	28,4	28,8	28,6	24,8	24,4	22,1	21,2	24,2	28,2	28,5	27,6	28,9
2011	27,6	27,7	29,7	24,8	25,8	23,4	20,5	22,7	27,8	27,1	23,9	27,2
2012	28,6	30,1	29,6	25,5	25,6	23,1	23,1	26,5	24,7	25,8	27,6	28
2013	27,9	28,8	27,2	25,1	24,5	24,3	22,3	24,4	27,9	26,2	29,2	25,4
2014	27,8	27,4	27,2	25,3	25,1	24,1	22,7	25,2	27,4	26,6	26,6	27,8
2015	29,2	29,9	29,4	26,3	27,9	23,6	24,7	27	26	30,1	30,7	32,5
2016	30,6	30,8	30	28	23,5	23,6	22,5	26,6	28,4	29,9	28,6	29
2017	27,8	27,8	28,1	25,6	24,9	23,9	24,2	24,6	28	27,9	28,3	29

Hoedspruit Air Force Base

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	27,6	30,1	28,9	30	26,2	23,9	26,2	24,6	29,7	29,6	29,3	31,6
1994	29,8	30,7	31,8	29,1	27,5	25,3	23,9	25,2	28,7	27,5	32,2	31,2
1995	31,6	32,3	30,9	29,4	25,4	24,9	25,5	26,9	30,6	31,4	29,7	30,2
1996	30,5	30,2	27,5	26,2	25,9	24,2	21,7	23,4	28,3	28,8	30	31,5
1997	31,4	25,9	29,6	27,8	25,2	26,7	23,6	27,2	27,5	28	30,5	31
1998	32,1	32,1	33,2	30,6	28,4	26,6	24,7	25,9	28,1	28	28,9	28,6
1999	30,3	28,6	29,3	28,5	26,4	25,5	24,7	26,5	27,1	30,1	29,2	30,9
2000	28,6	31.7	28,7	26,1	24,8	24	23,7	25,8	27,6	29,2	29,1	31,1
2001	31	29,1	28,9	28,2	26,5	25,5	24,3	27,2	28,4	29,6	28,4	29,5
2002	32,7	30,7	31,5	29,6	27,9	24,1	25,9	26,4	27,7	29,5	29,3	31,8
2003	33,3	33,6	31,7	29,5	26,4	23,2	24,4	26,6	28,3	30,4	30,6	33,3
2004	31,6	30,5	27,6	27,3	26	23,8	23,9	27,3	27,7	29,5	32,4	32,1
2005	32,5	33,1	30,9	28,2	27,7	26,6	25,1	27,6	30	30,9	30,7	30
2006	30,6	30,4	26,9	26,9	25,4	23,8	25,8	25,3	28,2	31,2	30,2	32,9
2007	31,2	33,2	32,3	28,6	27,4	25	24,4	26,8	29,8	26,9	29,3	28,1
2008	29,5	32	30,4	27,8	27,4	25,1	25,1	27	29,3	30,1	29,3	30,2
2009	29,8	29,6	28,4	27,9	26,8	25,7	23,3	25,9	28,9	29,4	29,3	30,7
2010	30,8	31,9	32,7	28,1	27,6	25,6	25,2	27,3	30,5	31,1	30,8	31,2
2011	30,2	30,6	33	27,9	27,8	25,8	23,3	25,4	30,4	29,8	30,8	31,2
2012	30,8	34,1	33,3	28,6	29,3	26	25,4	28,5	27,3	28,5	30,6	31,6
2013	30,2	31,4	30,1	27,9	27,2	27,1	25,3	27,1	30,1	29,6	31,3	28,9
2014	31,4	31,4	31	28,7	28,2	25,8	25,6	27,5	29,5	28,3	29,4	30,1
2015	31,4	33,6	32,5	30,1	31,4	26	25,9	27,8	26,6	31,5	31,7	34,1
2016	32,6	33	31,6	30,6	25,6	25,3	24,1	26,9	28,9	29,8	29,8	30,8
2017	29,9	31,6	31,5	28,1	27,4	26,1	25,7	26	27,2	27,7	31,3	34,7

APPENDIX K: Average Monthly Minimum Temperature Data for Two Weather Stations

Tzaneen-Grenshoek

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	17,5	19,5	18,4	16,8	15	9,9	10,3	11,7	14	14,1	17,4	19,6
1988	18,8	19,3	18,9	16,8	13,7	11,3	11,6	11,9	13,9	15,3	15	17,3
1989	15,7	19	18,2	14,8	14,7	12,3	10,4	14,4	14,7	16,2	18,4	20,5
1990	21,2	21,5	19,8	16,5	13,4	12,7	12,3	11,8	13	15,4	16,2	18
1991	19,1	18,5	17,5	14,9	13,8	11,1	11	12,6	14,9	15,9	16,9	17,2
1992	19,6	17,6	16,9	13,6	14,7	10,8	9,4	11,5	14,6	15,6	17,6	17,5
1993	18,7	17,5	17,7	16,8	15	11,9	12,7	12	15,5	16,8	15,9	18,3
1994	17,7	17,1	17,4	15,9	13,9	11,8	10,4	12	14,8	13,4	18,1	17,8
1995	18,8	18,6	17,6	16,2	13,6	11	11,8	13,3	15,2	16,4	17	17,2
1996	18,6	18,6	17	14,6	14,3	9,9	9,1	11,4	14,8	16	17,4	18,5
1997	19,2	18,3	18	15,3	13	13,2	11,5	13,7	15,3	15,6	17,7	18,6
1998	19,3	19	18,8	17,7	14,3	13,1	12,2	12,5	14,3	15,5	17,3	17,9
1999	18,8	17,4	18,3	16,6	13,8	11,8	11,5	12,2	13,5	15	16,8	17,9
2000	17,8	18,8	19,1	15,2	12,1	12,8	11,5	12,6	15,1	16,5	16,9	18,4
2001	17,7	18,1	17,6	16,6	13,7	12,1	10,5	13,5	13,8	16	17,2	18,3
2002	18,7	18,3	17,8	16,3	14,1	11,5	12,1	13,9	13,6	15,5	15,6	17,8
2003	18,9	19,3	18,1	16,6	14,1	12,2	11,6	11,8	14,3	15,9	17	18
2004	18,6	18,4	17,3	16,2	13,1	11,1	10,3	14,6	13,8	16,5	19	19,6
2005	20	19,7	18,2	16,8	14,9	14,1	12,2	14,7	15,9	16,7	18,1	17,5
2006	19,3	19,5	16,8	16	12,3	7,9	9,2	8,9	10,7	14,9	15,6	17,2
2007	18.6	18,3	15,7	14,5	7,9	7,1	5,7	7,7	12	14,1	15,6	17
2008	17,6	16,6	16,1	11,6	10,4	8	7,2	8,8	10,8	13,6	16,3	17,7
2009	19,5	18	16	12,4	10,3	8	5,8	7,5	11,4	14,6	15	17,6
2010	18	18,2	17,6	15,7	12,3	7,1	7,8	8,3	11,7	14,4	16,3	18,2
2011	19,3	17,8	17,8	15,1	11,4	7,1	6,4	7,5	10,8	13,8	15,8	17
2012	18,4	18,4	16	12,2	10,2	7,3	7,2	8,3	12,1	14,4	14,9	17,2
2013	18,2	17,5	16,5	12,4	9,8	7,9	8,5	9,2	11,9	13	15,9	16,7
2014	18,4	17,9	17,2	13,6	10,7	7,6	7,1	9	11,4	12,9	15,7	17,5
2015	18	17,7	16,4	14,6	11,8	8,1	8,6	10,1	12,8	15,1	15,1	19,2
2016	18,4	19,1	17,9	15,1	10,5	9,5	7,6	8,7	12,8	14,9	17,5	18,3
2017	18,2	18,7	16,7	14,7	11,1	8,9	9,5	9,4	12,2	13,9	14,7	17

Hoedspruit Air Force Base

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	19,6	20,2	19,8	17,1	13,9	10,5	10,7	9,3	14	17,4	17,5	19,8
1994	19,5	19,1	18,6	15,5	10,8	6,5	5,2	7,8	12,5	14,4	18,8	19,4
1995	20,4	20,6	20,1	16,2	13,3	7,2	8,9	10,9	14,3	19	18,8	19,3
1996	21,1	21,2	17,9	16,5	15,1	13,6	10,7	10,9	14,8	16,2	18,2	20
1997	21	18,9	19,6	15,7	12,5	10,5	10,8	13,1	16,4	16,1	18,6	19,6
1998	21,1	20,6	20,4	17,8	14,6	12	11,9	13,1	15,3	16,9	17,7	19,4
1999	20,4	19,7	19,4	17	14,1	10,6	11,6	12,7	14,8	15,2	18,8	20
2000	19,4	21,4	20,2	16,1	12,4	12,4	10,4	11,8	15,1	17,1	18	19,4
2001	19,2	20	19,4	18,1	14,1	11,5	10,8	13,5	15	17,7	19,2	20,1
2002	20,7	19,5	19,5	17,5	14	11,7	10,8	14,6	15,1	17,2	17,2	20,4
2003	21,1	21,6	20,4	18,1	14,8	13,2	11,3	12,9	15,7	18,1	19,8	20,3
2004	20,7	20,9	19,5	17,7	13,2	10,7	10,4	13,9	14,4	17,4	19,7	20,4
2005	21,3	20,7	19,1	17,5	14,8	13,4	11,6	15	16,2	17,6	19,6	18,9
2006	21,3	21,2	18,2	16,6	12,2	11,1	11,3	12,3	14,1	18,7	18,8	21,1
2007	19,8	20,6	19,9	17,1	12,4	11,8	10,2	12,3	16,5	16,9	18,3	19
2008	20	19,5	19,2	15,5	14,5	12,4	11,5	13,5	14,4	17,1	19,2	20,5
2009	21,5	20,3	18,2	15,7	13,6	12,2	9,8	12	16	17,5	17,7	20,1
2010	20,4	20,8	19,7	17,5	13,9	7,7	9,3	10	13,8	16,9	18,2	19
2011	20	18,7	19	15,8	11,3	6,5	7,1	8,5	13	15,8	17,8	18,5
2012	19,1	19,8	17,9	12,8	10,9	7,8	7,7	9,8	13,9	16,3	16,4	18,8
2013	19,1	18,9	17,6	13,4	10,1	8,1	9,5	10,7	14,5	14,8	17,6	18,2
2014	20,1	19,3	18,7	14,1	13,2	9,4	10,5	12,6	15,1	15,1	18	19,5
2015	20,2	20,4	19,1	16,3	14,1	11,1	12,3	14	16,2	17,9	17,7	21,1
2016	20,2	20,7	20	17,8	13,5	12,4	10,9	12	16,4	17,1	19,2	20
2017	19,5	20,2	18,6	17,1	13	11,3	12,1	12,9	15,2	14,1	14,6	16,1

APPENDIX L: Annual Citrus Production Data and Farm Net Revenue

Citrus Production Data and Farm Net Revenue 1 Carton = 16 kg							
Farm 1				Farm 2			
Year	Ha	Total (Oranges)	Net Revenue	Year	Ha	Total (Oranges)	Net Revenure
1987/1988	119,51	148358	1498415,8	1987/1988	40	27514	360433,4
1988/1989	119,51	137896	1406539,2	1988/1989	40	28350	374220
1989/1990	119,51	156112	1607953,6	1989/1990	40	29405	391086,5
1990/1991	119,51	124558	1295403,2	1990/1991	40	29728	398355,2
1991/1992	119,51	160798	1688379	1991/1992	40	30112	406512
1992/1993	119,51	162146	1718747,6	1992/1993	40	34245	465732
1993/1994	119,51	157486	1685100,2	1993/1994	40	32518	445496,6
1994/1995	119,51	162487	1754859,6	1994/1995	40	32546	449134,8
1995/1996	119,51	198244	2160859,6	1995/1996	40	31581	438975,9
1996/1997	119,51	187554	2081849,4	1996/1997	40	30158	425227,8
1997/1998	119,51	179854	2014364,8	1997/1998	40	31845	452199
1998/1999	119,51	198547	2243581,1	1998/1999	40	32515	464964,5
1999/2000	119,51	262889	2996934,6	1999/2000	40	34157	491860,8
2000/2001	119,51	287864	3310436	2000/2001	40	36951	535789,5
2001/2002	119,51	208457	2418101,2	2001/2002	40	36827	537674,2
2002/2003	119,51	201257	2354706,9	2002/2003	40	36112	530846,4
2003/2004	119,51	187925	2217515	2003/2004	40	35152	520249,6
2004/2005	119,51	115482	1374235,8	2004/2005	40	35244	525135,6
2005/2006	119,51	148124	1792300,4	2005/2006	40	34527	521357,7
2006/2007	119,51	116050	1415810	2006/2007	40	35565	540588
2007/2008	119,51	179302	2205414,6	2007/2008	40	35648	545414,4
2008/2009	119,51	207845	2577278	2008/2009	40	34992	538876,8
2009/2010	119,51	174053	2175662,5	2009/2010	40	36548	566494
2010/2011	119,51	289228	3644272,8	2010/2011	40	35148	548308,8
2011/2012	119,51	273749	3476612,3	2011/2012	40	36895	579251,5
2012/2013	119,51	276104	3534131,2	2012/2013	40	36451	575925,8
2013/2014	119,51	364865	4706758,5	2013/2014	40	36124	574371,6
2014/2015	119,51	355319	4654678,9	2014/2015	40	35248	567492,8
2015/2016	119,51	299087	3947948,4	2015/2016	40	34858	564699,6
2016/2017	119,51	276538	3677955,4	2016/2017	40	38796	632374,8
2017/2018	119,51	323911	4340407,4	2017/2018	40	38521	631744,4

Farm 3						
Year	Ha	Total (Oranges)	Total (Tangerines)	Total (Lemons and Limes)	Total (Grapefruits)	Net Revenue
1987/1988	250	435848	21663	7258	6145	6351597,78
1988/1989	250	425864	21426	7585	6472	6268931,56
1989/1990	250	475127	19875	7548	6318	6969656,29
1990/1991	250	452561	15478	7785	6758	6667873,24
1991/1992	250	482153	18974	7699	6784	7161649,1
1992/1993	250	485215	22658	8011	6875	7350631,98
1993/1994	250	490859	24158	8032	6928	7497768,22
1994/1995	250	502458	21475	8145	7001	7688119,18
1995/1996	250	586478	19875	8124	7145	8932980,1
1996/1997	250	602546	19984	8217	7251	9230630,35
1997/1998	250	622589	20148	8254	7475	9590367,11
1998/1999	250	654812	20157	8499	7627	10135102,25
1999/2000	250	697593	25786	8980	7847	10910570,25
2000/2001	250	735679	27548	9245	7915	11575568,8
2001/2002	250	658572	26541	9147	7985	10546980,01
2002/2003	250	689478	24832	8954	8001	11060527,3
2003/2004	250	742579	21478	9015	8015	11907982,19
2004/2005	250	725248	22313	9154	8142	11751086,59
2005/2006	250	742478	22548	8925	8214	12090649,12
2006/2007	250	768915	23574	8951	8145	12590738,97
2007/2008	250	785492	23978	9151	8157	12939116,46
2008/2009	250	833145	24251	9228	8257	13778130,66
2009/2010	250	802379	25684	9425	8324	13396408,8
2010/2011	250	889520	24158	9351	8376	14941546,06
2011/2012	250	862012	26578	9920	8345	14629404,04
2012/2013	250	901526	25489	10124	8311	15352857,78
2013/2014	250	932548	25789	10187	8347	15982216,55
2014/2015	250	968512	24289	10201	8299	16651713,99
2015/2016	250	945218	25974	10242	8478	16385618,78
2016/2017	250	985164	27846	10265	8554	17173293,26
2017/2018	250	1011256	26477	10387	8555	17696915,75

Farm 4				
Year	**Ha**	**Total (Oranges)**	**Total (Lemons and Limes)**	**Net Revenue**
1987/1988	109	146233	4368	1607100,7
1988/1989	109	152497	4512	1690647,2
1989/1990	109	152147	4896	1711620,3
1990/1991	109	145864	4173	1643806,6
1991/1992	109	131458	5495	1535733,1
1992/1993	109	164852	5610	1912797,6
1993/1994	109	185682	5767	2160611,7
1994/1995	109	163148	5788	1948697,2
1995/1996	109	178953	5801	2142917,5
1996/1997	109	167548	5449	2024613,3
1997/1998	109	167895	6078	2061090,6
1998/1999	109	175895	6114	2171362,7
1999/2000	109	185265	6372	2304550,8
2000/2001	109	156847	6098	1984510,9
2001/2002	109	161021	6527	2060612
2002/2003	109	143420	6329	1863024,3
2003/2004	109	157654	6837	2077171
2004/2005	109	131456	6481	1765140,1
2005/2006	109	164665	7195	2205974
2006/2007	109	169564	7288	2286251,2
2007/2008	109	201132	7692	2708757,6
2008/2009	109	202548	7723	2748269
2009/2010	109	225598	8439	3080289,1
2010/2011	109	202154	8103	2795008
2011/2012	109	232154	8298	3207215,4
2012/2013	109	275128	8878	3832341,4
2013/2014	109	262157	8656	3683797,2
2014/2015	109	243218	8572	3456814,2
2015/2016	109	251248	8604	3591287,6
2016/2017	109	202154	7703	2930897,6
2017/2018	109	261025	8595	3775988,5

Farm 5

Year	Ha	Total (Oranges)	Total (Grapefruits)	Net Revenue
1987/1988	114,46	150157	5051	1717757,8
1988/1989	114,46	150895	5378	1744879,6
1989/1990	114,46	151273	5399	1764994,6
1990/1991	114,46	125489	5543	1488221,8
1991/1992	114,46	139854	5428	1665315
1992/1993	114,46	160254	5687	1919228,6
1993/1994	114,46	161487	6178	1955502,5
1994/1995	114,46	166875	6102	2035026,6
1995/1996	114,46	161785	6485	1995928
1996/1997	114,46	185256	6954	2319482,4
1997/1998	114,46	179862	6657	2269540,5
1998/1999	114,46	197895	6609	2509451,1
1999/2000	114,46	193024	7439	2479046,1
2000/2001	114,46	200251	7325	2588107,5
2001/2002	114,46	200896	7658	2620888,2
2002/2003	114,46	201235	8001	2650096,3
2003/2004	114,46	201784	8265	2681188,7
2004/2005	114,46	202135	8394	2709108,9
2005/2006	114,46	205325	8795	2797056,5
2006/2007	114,46	210358	9215	2890070,1
2007/2008	114,46	258413	9425	3553762,9
2008/2009	114,46	234771	9751	3267818,9
2009/2010	114,46	267854	9698	3738223,8
2010/2011	114,46	289512	10253	4067576,3
2011/2012	114,46	280231	10121	3968713,5
2012/2013	114,46	274132	11112	3926366,4
2013/2014	114,46	292031	12395	4221605,4
2014/2015	114,46	301251	15412	4451077,5
2015/2016	114,46	325621	17258	4853349,6
2016/2017	114,46	334152	18762	5029784,4
2017/2018	114,46	359648	20015	5449133,7

APPENDIX M: The Relationship Between Climate Variability and Orange Production for Farm 3.

Table A 1: The Relationship Between Climate Variability and Orange Production for Farm 3

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0,795481098					
R Square	0,632790178					
Adjusted R Square	0,576296359					
Standard Error	117479,213					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	6,18359E+11	1,5459E+11	11,20105157	0,000020366	
Residual	26	3,58836E+11	13801365490			
Total	30	9,77195E+11				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1363367,986	1109500,296	-1,228812639	0,230148478	-3643978,508	917242,5347
Minimum SPI	-186522,0193	879149,9268	-0,212161787	0,833635301	-1993640,575	1620596,536
Maximum SPI	28023,70275	14793,23376	1,894359489	0,069352094	-2384,224737	58431,63023
Minimum Temperature	-65875,2392	22221,66497	-2,964460101	0,006414691	-111552,5257	-20197,95267
Maximum Temperature	110976,2193	33596,05924	3,30325109	0,002785842	41918,53052	180033,9081

APPENDIX N: The Relationship Between Climate Variability and Tangerine Production for Farm 3.

Table A 2: The Relationship Between Climate Variability and Tangerine Production for Farm 3

Regression Statistics						
Multiple R	0,639812812					
R Square	0,409360434					
Adjusted R Square	0,318492809					
Standard Error	2407,769362					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	104468761	26117190,26	4,505019602	0,006730167	
Residual	26	150731185,8	5797353,301			
Total	30	255199946,8				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	2209,283291	22739,5192	0,097156113	0,923347498	-44532,46785	48951,03444
Minimum SPI	-29677,10699	18018,42389	-1,647042337	0,111584507	-66714,50773	7360,293756
Maximum SPI	533,0688948	303,1914676	1,75819227	0,090482969	-90,15009248	1156,287882
Minimum Temperature	-1169,402753	455,4392451	-2,567637211	0,016338533	-2105,571529	-233,2339774
Maximum Temperature	641,6871504	688,5606402	0,9319254	0,359948736	-773,6695158	2057,043817

APPENDIX O: The Relationship Between Climate Variability and Lemons and Limes Production for Farm 3.

Table A 3: The Relationship Between Climate Variability and Lemons and Limes for Farm 3

Regression Statistics						
Multiple R	0,752656729					
R Square	0,566492152					
Adjusted R Square	0,499798637					
Standard Error	650,5400538					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	14378658,34	3594665	8,493961546	0,000159733	
Residual	26	11003261,4	423202,4			
Total	30	25381919,74				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-386,4472749	6143,847612	-0,0629	0,950327307	-13015,30691	12242,41236
Minimum SPI	-1729,485044	4868,284575	-0,35526	0,725264023	-11736,3873	8277,417216
Maximum SPI	136,2929356	81,9173949	1,663785	0,108164024	-32,09068115	304,6765524
Minimum Temperature	-340,5997328	123,0522639	-2,76793	0,010257828	-593,5372838	-87,66218176
Maximum Temperature	498,8248609	186,0378668	2,681308	0,01256674	116,418549	881,2311729

APPENDIX P: The Relationship Between Climate Variability and Grapefruits Production for Farm 3.

Table A 4: The Relationship Between Climate Variability and Grapefruit Production for Farm 3

Regression Statistics						
Multiple R	0,669186136					
R Square	0,447810084					
Adjusted R Square	0,36285779					
Standard Error	580,806929					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	7112828,284	1778207,071	5,271312401	0,003027136	
Residual	26	8770753,909	337336,6888			
Total	30	15883582,19				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	533,5880485	5485,272188	0,097276494	0,923252832	-10741,55041	11808,72651
Minimum SPI	-1026,474894	4346,440158	-0,236164506	0,815155587	-9960,710591	7907,760803
Maximum SPI	94,32753338	73,1364507	1,289747212	0,208493357	-56,00659407	244,6616608
Minimum Temperature	-224,2939097	109,8619633	-2,0415975	0,051460463	-450,1184095	1,530590102
Maximum Temperature	372,4166576	166,0959713	2,242177547	0,033699722	31,00149889	713,8318162

APPENDIX Q: The Relationship Between Climate Variability and Orange Production for Farm 4.

Table A 5: The Relationship Between Climate Variability and Orange Production for Farm 4

Regression Statistics						
Multiple R	0,827820356					
R Square	0,685286542					
Adjusted R Square	0,636869087					
Standard Error	24512,98348					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	34019081320	8504770330	14,15370844	0,000002944	
Residual	26	15623045331	600886358,9			
Total	30	49642126650				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4649,295169	231506,168	0,020082813	0,98413064	-471218,4484	480517,0388
Minimum SPI	-114292,4473	183441,7092	-0,623045042	0,538682202	-491362,2808	262777,3862
Maximum SPI	3669,513344	3086,727306	1,188803863	0,245261768	-2675,345502	10014,37219
Minimum Temperature	-21405,36917	4636,729276	-4,61648026	0,000092509	-30936,3027	-11874,43565
Maximum Temperature	15914,83026	7010,088201	2,270275323	0,031712991	1505,387591	30324,27292

APPENDIX R: The Relationship Between Climate Variability and Lemons and Limes Production for Farm 4.

Table A 6: The Relationship Between Climate Variability and Lemons and Limes Production for Farm 4

Regression Statistics						
Multiple R	0,844477813					
R Square	0,713142777					
Adjusted R Square	0,669010897					
Standard Error	803,1240006					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	41691666,54	10422916,63	16,15935623	0,000000915	
Residual	26	16770212,17	645008,1604			
Total	30	58461878,71				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-3235,956097	7584,884966	-0,426632192	0,673159117	-18826,91043	12354,99824
Minimum SPI	-3840,112822	6010,139055	-0,638939097	0,528451743	-16194,13058	8513,904937
Maximum SPI	112,2880738	101,1310918	1,110321977	0,277023848	-95,58986258	320,1660103
Minimum Temperature	-676,202592	151,9141303	-4,451215898	0,00014307	-988,4665589	-363,938625
Maximum Temperature	661,6380945	229,6729848	2,88078328	0,00784516	189,538513	1133,737676

APPENDIX S: The Relationship Between Climate Variability and Orange Production for Farm 5.

Table A 7: The Relationship Between Climate Variability and Orange Production for Farm 5

Regression Statistics						
Multiple R	0,849164333					
R Square	0,721080065					
Adjusted R Square	0,678169305					
Standard Error	35847,56332					
Observations	31					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	4	86376690957	21594172739	16,80417865	0,000000641	
Residual	26	33411242705	1285047796			
Total	30	1,19788E+11				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-487317,8106	338552,5074	-1,439415748	0,161964711	-1183222,456	208586,8348
Minimum SPI	2353,111213	268263,4814	0,008771642	0,993068291	-549070,372	553776,5945
Maximum SPI	8181,610829	4514,001842	1,812496121	0,081473606	-1097,052844	17460,2745
Minimum Temperature	-24730,98512	6780,710577	-3,647255673	0,001164723	-38668,93533	-10793,03491
Maximum Temperature	41028,1958	10251,48901	4,002169418	0,000464868	19955,95835	62100,43325

APPENDIX T: The Relationship Between Climate Variability and Grapefruits Production for Farm 5.

Table A 8: The Relationship Between Climate Variability and Grapefruit for Farm 5

Regression Statistics	
Multiple R	0,801136319
R Square	0,641819402
Adjusted R Square	0,586714695
Standard Error	2545,546981
Observations	31

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	301888358,6	75472089,64	11,64726994	0,000014923
Residual	26	168475045,3	6479809,434		
Total	30	470363403,9			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-57344,1779	24040,72225	-2,385293474	0,024642075	-106760,5902	-7927,76559
Minimum SPI	10827,96294	19049,47594	0,568412642	0,574631879	-28328,79565	49984,72154
Maximum SPI	452,7351731	320,5407201	1,412410794	0,169687528	-206,1457134	1111,61606
Minimum Temperature	-754,8976604	481,5004352	-1,567802654	0,129018669	-1744,63598	234,8406588
Maximum Temperature	3273,753667	727,961526	4,497152047	0,000126749	1777,40732	4770,100014