Assessing the impacts of climate change on agricultural productivity and income stability in Marange rural area, Mutare district in Zimbabwe

Bindura University of Science Education

Faculty of Agriculture and Environmental Science

Department of Agricultural Economics, Education and Extension

Ngundu Ahashveroshi

B211417B

This Research Thesis is Submitted in Partial Fulfilment of the Requirements for the Bachelor of Agricultural Science Honours Degree in Agricultural Economics and Management

Submission Date: 23/06/2025

RELEASE FORM

AUTHOR'S NAME:	AHASHVEROSHI NGUNDU
STUDENT NUMBER:	B211417B
PROJECT TITLE:	Assessing the impacts of climate change on agricultural Productivity and Income stability for smallholder farmers in Zimbabwe.
DEGREE TITLE:	BACHELOR OF SCIENCE HONOURS DEGREE IN AGRICULTURAL ECONOMICS AND MANAGEMENT
YEAR GRANTED:	2025

SIGNED ………………………. DATE: ………………………

PERMANENT ADDRESS: Vumba Court Flat Number 3, 3rd Street
Mutare

APPROVAL FORM

The undersigned certify that they have supervised, read and recommend to the Bindura University of Science Education for acceptance of the research project titled '**ASSESSING THE IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTIVITY AND INCOME STABILITY FOR SMALLHOLDER FARMERS IN ZIMBABWE**, submitted by Ahashveroshi Ngundu (B211417B), in partial fulfilment of the requirements for the Bachelor of Science Honours degree in agricultural economics and management.

Supervisor: *Dr A.C Mujeyi*

Signature: .... Date: 25 May 2025

Signature: .... Date: ....

Chairperson

Signature: .... Date: ....

Examiner

DEDICATION

This study is dedicated to Shamiso Mupara, my sister, who instilled in me a deep passion for education and made sacrifices to ensure that I have access to it. More so, I dedicate this work to my family and friends whose unwavering support played a pivotal role in my academic

ABSTRACT

The economy and food security of Zimbabwe, a low-income nation, are largely dependent on agriculture. The effects of climate change on agricultural productivity and income stability for smallholder farmers, whose contribution to Zimbabwe's agricultural sector is not insignificant, were thus evaluated in this research thesis. Smallholder farmers, who make up the majority of the agricultural workforce, face a number of difficulties as climate variability increases, such as changed rainfall patterns, rising temperatures, and an increase in the frequency of extreme weather events. In order to document the complex impacts of climate change, this thesis used a combination of qualitative structured interviews with farmers and quantitative data from agricultural yield statistics. The results of the analysis show that crop yields have declined as a result of changing climatic conditions, especially for staple crops like maize, which are vital for both income generation and sustenance. The study also emphasises how smallholder farmers are more susceptible to climate-related shocks like floods and droughts, which can lead to unstable incomes and heightened food insecurity. The study also looks at the difficulties smallholder farmers have adjusting to the negative consequences of changing climate conditions, such as a lack of funding and the high upfront costs of implementing climate-smart technologies. The study also examines the adaptive tactics used by farmers, including crop diversification, conservation agriculture, and the use of climate-resilient farming methods, demonstrating that their efficacy varies depending on the local context. The findings of this thesis highlight the pressing need for focused legislative initiatives that strengthen smallholder farmers' resilience. Based on the analytical study conducted for this project, the researcher suggests that policy makers and practitioners create inclusive and adaptable agricultural policies. Examples include the creation of climate-smart agriculture programs, the opening of doors for smallholder farmers to obtain financial services, and policies that prioritise better extension services to give farmers the tools and information they need to adjust to changing climate conditions. Finally, by highlighting the significance of assisting Zimbabwe's smallholder farmers in securing their livelihoods and maintaining agricultural productivity and income stability in the face of persistent environmental challenges, this research adds to the larger conversation on climate change and agriculture.

ACKNOWLEDGEMENTS

First and foremost, I want to express my gratitude to the Almighty Lord for providing me with the strength, health, and wisdom I needed to pursue my academic goals as well as for allowing me to achieve this ultimate life goal.

Secondly, I am deeply grateful and thankful to my family, but particularly my sister Shamiso, who supported me financially, morally and mentally from the beginning up to the end of my academic journey here at Bindura University. I sincerely appreciate your love and support; may the Lord grant you success in all that you do in life.
Additionally, I would like to thank the Agricultural Economics Department at Bindura University of Science Education for giving me the chance to continue my education. I would especially like to thank Dr. A. C. Mujeyi, my thesis supervisor, for her invaluable advice and vast knowledge, which were crucial in making this research a reality. I pray that the Lord will bless you and give you more wisdom because you are an excellent mentor. I also want to express my gratitude to all of my friends, whose support is invaluable. Finally, I want to express my sincere gratitude to my classmates for their contributions to this journey

I would like to give my special mention to the “dream chasers” group, which includes Mazivisa and Gumbo. I recall the sleepless nights we spent together and all the fun we have had over the past four years. I give a big shoutout to you guys; thank you.

LIST OF ACRONYMS

NDS	National Development Strategies
UN	United Nations
IPCC	International Panel on Climate Change
IFAD	International Fund for Agricultural Development
FAO	Food and Agriculture Organisation
WB	World Bank
C-CIARN	Canadian Climate Impacts and Adaptation Research Networks
CSA	Climate Smart Agriculture
MLRA	Multivariate Linear Regression Analysis
ANOVA	Analysis of Variance
SPSS	Statistical Package for the Social Sciences
ICT	Information and Communication Technology
SS	Sum of Squares
MS	Mean Square
UNFCCC	United Nations Framework Convention on Climate Change
NGOs	Non-Governmental Organisations
WHO	World Health Organisation

TABLE OF CONTENTS

Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

1.0: Introduction

Climate change, defined as the long-term shift in average weather patterns that shape the Earth's climates, is one of the major challenges of the 21st century. It has significant effects on agricultural productivity, food security, and rural livelihoods. In Zimbabwe, the agricultural sector is the backbone of the economy. As of 2022, it accounted for 27.01% of the nation's Gross Domestic Product (World Bank report, 2022). This sector is also the largest employer, providing jobs for about 52.5% of the total population (World Bank, 2023). It is the second largest source of export earnings and foreign exchange. Tobacco, horticultural products, tea, coffee, and beef are Zimbabwe's main agricultural exports. These contribute significantly to foreign exchange earnings, improve the country's trade balance, and increase fiscal revenues. Agriculture remains the primary source of income for many rural communities, with around 70-80% of the Zimbabwean population relying on this sector (Abalu and Hassan, 1998). Agriculture supports rural development and helps reduce poverty. Improving agricultural productivity raises rural incomes and lessens poverty. However, despite these benefits, most agriculture in Zimbabwe relies on rainfall (approximately 80%), making the sector vulnerable to climate change, which is now a major global challenge. The Zimbabwean agricultural sector faces intense climate-related shocks, such as rising temperatures, changing rainfall patterns, and more extreme weather events. These factors are key contributors to declining agricultural productivity in the country. They diminish both crop and animal productivity. Drought reduces water availability from surface and ground sources, leading to lower crop yields and increased crop failures, which worsen food security. Climate change also raises the incidence of crop pests and diseases. Warmer temperatures allow pests, like armyworms, and diseases to spread more widely, affecting crop and animal health and reducing overall productivity and yields in the agricultural sector. Lastly, extreme weather events, such as floods and cyclones, destroy crops, erode topsoil, and damage infrastructure like roads and irrigation systems. These events also contribute to post-harvest losses due to inadequate storage and transport in flooded areas. This cycle can severely impact overall agricultural productivity and income stability, especially for smallholder farmers.

1.1 Background

Zimbabwe's climate has historically followed seasonal patterns with wet and dry seasons that have supported its agricultural industry. In the southern African region, Zimbabwe has been recognized for its vibrant agricultural sector, often referred to as the breadbasket of Africa. This important agricultural sector has been the backbone of its economy. During the late 1980s and 1990s, Zimbabwe was notably the breadbasket of Africa (Nyakwawa, 2017, p. 117). Agriculture plays a crucial role in ensuring food security, improving economic stability and growth, and providing jobs for a significant part of the population.

However, despite the efforts of Zimbabwean farmers to enhance agricultural resilience and income stability, the sector faces serious challenges from climate change. Rising temperatures are causing severe droughts, changes in rainfall patterns, and other extreme weather conditions. Climate change involves long-term shifts in temperature, rainfall, and other weather conditions (United Nations, 2019). While some of these changes may occur naturally, human activity has been the main cause of climate change since the 1800s. The burning of fossil fuels, such as coal, oil, and gas, releases gases that trap heat. Over the past few decades, Zimbabwe's climate has been changing, shown by a steady rise in temperatures, changes in rainfall patterns, and more frequent extreme weather events.

1.2 Problem statement

Despite the growing research on how climate change affects agriculture, there is still a significant gap in understanding its specific impacts on agricultural productivity and income stability in Zimbabwe. Some studies have examined the experiences of smallholder farmers in Zimbabwe, who are especially vulnerable to climate-related shocks. However, earlier research has mainly focused on the general effects of climate change on agriculture. Additionally, most studies have concentrated on the physical effects of climate change, paying less attention to the social and economic impacts.

As a result, there is a need for deeper and more specific research that can guide policy and practices to improve the productivity and income stability of smallholder farming systems in Zimbabwe.

1.3 Objectives of the study

1.3.1 Main Objective

To assess the impacts of climate change on agricultural productivity and income stability for stallholder farmers in Zimbabwe.

1.3.2 Specific Objectives

1.To quantify the impacts of Sustainable Agricultural Technologies and Farming factors on agricultural productivity of staple maize for farming households.

2.To analyse the economic impacts of climate change on farmer’s income stability.

3. To identify the adopted sustainable agricultural practices that can mitigate the adverse effects of climate change.

4. To investigate the challenges smallholder farmers, encounter in adjusting to the negative effects of climate change on agricultural productivity and income stability.

1.4 Research Questions

1. How much does climate change impact smallholder farmers' income stability and agricultural productivity?

2. How do changes in climate patterns affect farmer’s productivity and income stability?

3. What are the strategies can farmers adopt to mitigate the impacts of climate change on agricultural productivity and income stability?

1.5 Significance of the study

There are several reasons why it is important to evaluate the effects of climate change on agricultural productivity and income stability in Zimbabwe. This research thesis will explore its significance in the following way.

1.5.1: To the farmers

The results of this study could greatly impact decision-making for farmers in Zimbabwe and in other countries. Farmers in Zimbabwe can use the findings from this study to make informed choices and develop strategic plans to address the effects of climate change on agricultural productivity and income stability.

1.5.2: To the agricultural sector

The research can provide important information about how climate change affects agricultural productivity and the income stability of the agricultural sector. This information can help agricultural stakeholders make informed decisions and develop effective strategies to reduce the impacts of climate change on agricultural productivity and income stability for smallholder farmers in Zimbabwe.

1.5.3: To the academic literature

This research could significantly contribute to the current academic literature on the link between climate change and agricultural productivity. It can also provide a useful case study for future investigations on this topic.

1.6 Delimitations and Limitations of the study

1.6.1 Delimitations of the study

1) The research data focused only on Zimbabwe and did not include other countries.

2) The data sources came from trusted organizations and individuals, which limited the range of data used.

3) The research data collection methods were qualitative, making the results more subjective.

4) The research relied solely on information and literature available in English, so it may have missed important information published in other languages.

1.6.2 Limitations of the study

1) The researcher faced time constraints while working on the research project. To address this challenge, he put in extra effort to conduct the research even during the off semester.

2) The researcher also faced financial constraints, particularly during the data collection process. To reduce this challenge, he chose online data collection methods to lower costs, such as transport expenses.

3) Another challenge the researcher dealt with during the project was potential biases in self-reported data from surveys.

1.7: Conclusion

As climate change continues to threaten agricultural productivity and income stability, Zimbabwe is working on climate-smart agriculture to boost productivity, improve food security, reduce poverty, and achieve a middle-class economy by 2030. Policymakers in Zimbabwe are creating policies like the ZNDS1 irrigation policy to raise agricultural output by using water resources efficiently and sustainably, and by expanding land for farming. Findings from this research project will greatly benefit farmers, policymakers, and other stakeholders by revealing the real effects of climate change on productivity and income stability. The results will also help in developing policies and strategies to improve productivity and income stability against climate change impacts by 2050. This chapter will cover the following topics: introduction, study background, problem statement, objectives, research questions, significance of the study, assumptions, study delimitations, and limitations.

CHAPTER 2

LITERATURE REVIEW

2.0: Introduction

Climate change affects many industries, especially agriculture. It is one of the most urgent issues today, including in Zimbabwe. Understanding how climate change impacts agricultural productivity and income stability is crucial in Zimbabwe, where many people rely on agriculture for their livelihoods. This research thesis focuses on temperature changes, precipitation patterns, and extreme weather events to assess the impacts of climate change on Zimbabwe's agricultural systems.

This thesis is important because it can shape decisions and policies that improve Zimbabwe's agricultural output, food security, and income stability. Policymakers, farmers, and agricultural extension services will find value in the study's examination of how climate change affects crop yields and farmer incomes. The findings will be vital for developing practical plans that mitigate agricultural risks, promote sustainable farming practices, and ensure the stability of rural economies amid climate change.

Climate change refers to significant long-term changes in global temperatures, precipitation, and other climate factors. It is primarily driven by human activities, such as burning fossil fuels, deforestation, and industrial processes, which increase greenhouse gas levels in the atmosphere. Climate change includes global warming, characterized by a notable rise in average global temperatures, and is linked to extreme weather events, altered precipitation patterns, and rising sea levels. Greenhouse gas emissions, like carbon dioxide, methane, and nitrous oxide, also relate to climate change.

These factors affect agricultural productivity by altering crop growth, soil health, precipitation patterns, water availability, and pest and disease dynamics. Unusual temperature increases can lead to heat stress in plants, reducing photosynthesis and causing premature crop death, which ultimately decreases productivity. Changes in precipitation patterns can create both droughts and floods. Heavy rainfall can lead to flooding, resulting in soil erosion, nutrient loss, and crop damage. Similarly, droughts can increase water scarcity, affecting irrigation and crop survival.

Additionally, climate change increases the spread of pests and diseases. Warmer temperatures can expand the range and life cycles of these threats, leading to greater crop damage.

Climate change context in Zimbabwe

Zimbabwe's agricultural productivity is significantly affected by climate change. The biophysical conditions that support farming are shifting due to rising temperatures, changing rainfall patterns, and more extreme weather. The average annual temperature is rising by about 0.03°C each year, while average annual rainfall is decreasing. As a result, Zimbabwe's climate is changing. Droughts have become more severe, particularly from January to March.

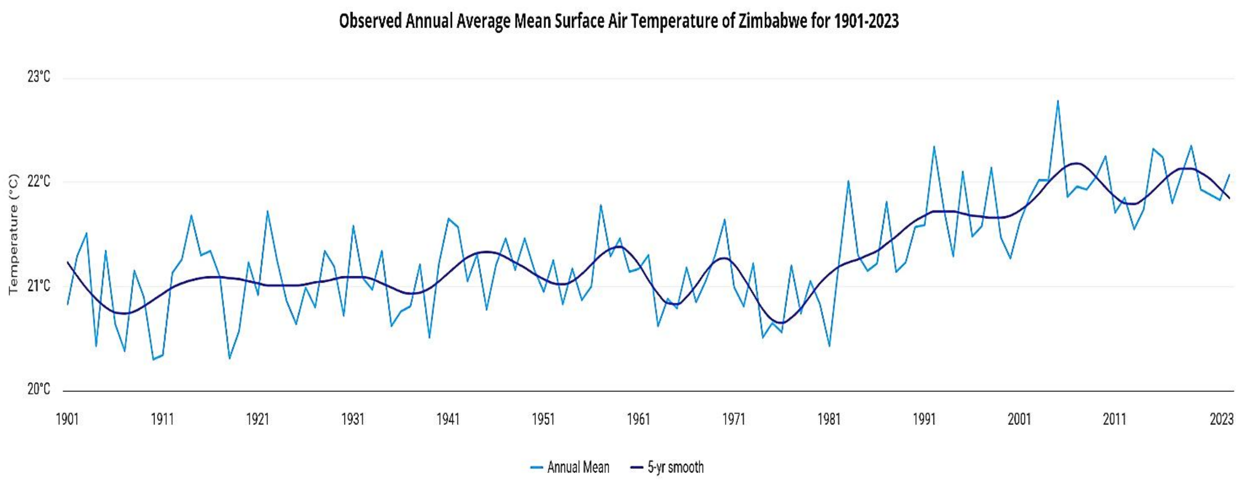

Fig 1: The graph below shows temperature changes in Zimbabwe from 1901-2023

Source: Zimbabwe Meteorological Service Department, (2017).

2.1: Climate Change on Agricultural Productivity

2.1.1: Climate Change Impacts on Global Agriculture Productivity

Agricultural production is crucial for human survival and development, and it is heavily affected by rapid global climate change. One of the largest threats to agricultural productivity worldwide is climate change. Since 1961, the combined temperature of the land and ocean has risen by

0.06°C on average each decade. This rise has led to a 34% drop in agricultural productivity in Africa, increasing the risk of severe food insecurity and malnutrition (IPCC, 2022). Major causes of global warming, which significantly affect agricultural productivity globally, include high greenhouse gas emissions, rapid population growth, and the burning of fossil fuels over the last century. Besides causing more extreme weather events like droughts, floods, and uneven rainfall that reduce crop yields, global warming also disrupts ecological balance and affects the prevention and control of crop pests and diseases. Climate change has harmed the sustainable growth of agricultural production, leading to soil degradation and a shortage of land resources.

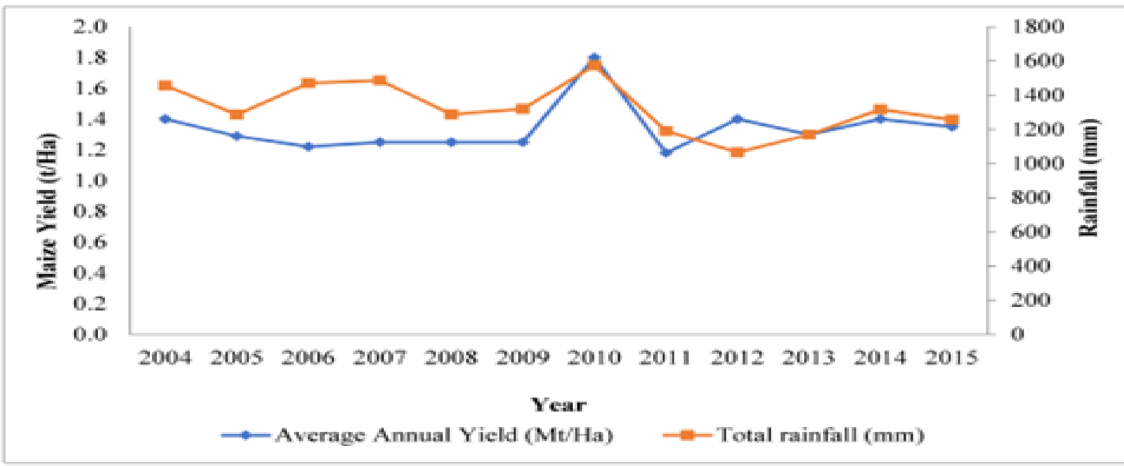

Fig 2: The relationship between maize yield/ha and total annual rainfall

Source: MDPI

2.1.2: Specific impacts of climate change on agricultural productivity in Zimbabwe

The biophysical impacts of climate change on global agricultural productivity are complicated and diverse. They present challenges to crop yields, livestock production, and overall food security. The effects of climate change on agriculture vary by region, with some improvements in agricultural output due to longer growing seasons, the benefits of carbon fertilization, and the movement of viable cropland toward the poles (Kucharik & Serbin, 2008, p. 109). However, many studies show that climate change negatively affects global crop yields. For instance, in 1999, the maize yield in Zimbabwe was 1.09 tonnes per hectare, but by 2008, it had dropped to 0.27 tonnes per hectare (Schlenker & Roberts, 2009).

Rising temperatures, shifting precipitation patterns, and increased extreme weather events are changing the conditions that affect agricultural productivity. These climatic changes have several consequences: Increased heat stress leads to lower yields and productivity in crops and animals. Changes in growing seasons also emerge from warmer temperatures, causing plants to bloom earlier. This makes them more vulnerable to frost damage, ultimately reducing crop yields and productivity. Additionally, soil degradation, water scarcity, and altered precipitation are significant consequences of climate change (Hatfield et al. 2011, Betzelberger et al. 2012). Droughts and floods result from the changing frequency, intensity, and duration of precipitation events caused by climate change. Water scarcity can harm crop growth and livestock productivity due to altered precipitation patterns and increased evaporation from warmer temperatures.

In Zimbabwe, extreme weather events greatly contribute to declining agricultural productivity and the stability of farmers' income. Extreme conditions such as heat waves, droughts, and floods are becoming more frequent and severe due to climate change. These events lead to crop damage and loss, as well as livestock mortality, which lowers productivity and financial returns. Climate change broadly affects agricultural productivity. A decrease in rainfall in the Bulawayo region had the expected negative effects on grain yields, particularly for maize. Drought and water stress from climate change have become critical issues impacting crop productivity. For example, the El Niño event in 2015-2016 brought extreme drought conditions that resulted in significant crop failures and food shortages. Poor management and overuse of water resources exacerbate water scarcity, limiting farmers' irrigation options and ultimately reducing overall crop yields and productivity. As climate change accelerates, extreme weather events like cyclones and severe storms have increased in frequency. Cyclone Idai in 2019 exemplifies how climate change significantly affected crop production in Chimanimani due to the devastating cyclone that hit the area.

Livestock productivity thrives in specific environmental conditions. When temperatures fall below or exceed optimal levels, efficiency declines because nutrients shift toward maintaining body temperature instead of supporting processes like milk, meat, and foetus production (Lance H, Robert P, 2015). Heat stress negatively influences various factors, including milk yield, growth, reproduction, and carcass traits. Moreover, increased heat loads raise healthcare costs, and animals can suffer from severe thermal stress, especially lactating cows and sows (Pollmann, 2010).

The availability of crops for animal feed directly affects farm animal productivity. Populations reliant on livestock may face food insecurity due to climate change's impact on crop yields, such as droughts harming grain production. Changes in precipitation patterns may affect animals' access to freshwater. Reduced water supplies can lead to dehydration and malnutrition in livestock, lowering productivity in drought-affected areas like Marange in Mutare.

2.2: Climate Change Impacts on Income Stability

2.2.1: Climate change impacts on global income stability

One of the biggest problems we face today is climate change. It affects many industries, including agriculture and the global economy. Income stability is one of the main issues tied to climate change, especially for smallholder farmers who depend on farming for their livelihoods. Climate change impacts agricultural productivity, which in turn affects income stability. Events like droughts, floods, and heat waves can significantly reduce crop yields and livestock productivity, leading to financial losses for farmers and agricultural workers. By 2050, climate change could cause agricultural productivity to drop by 10 to 20%, particularly in Africa, according to IFAD. This would result in substantial income losses for smallholder farmers.

Climate change also threatens global income stability due to its effect on labour productivity. Climate-related events can lead to higher rates of illness and death, lowering labour productivity. The World Health Organization (WHO) states that between 2030 and 2050, climate change might cause an additional 250,000 deaths each year, mainly from heat stress and malnutrition. These issues seriously affect income stability, particularly for households that rely on labour income. Additionally, climate change impacts economic growth and development, further influencing income stability.

Climate-related events can lead to significant financial losses. Damage to roads and other agricultural infrastructure raises production costs for smallholder farmers and may hurt their earnings from crop sales. For example, the World Bank estimates that by 2050, climate change could result in a 2 to 5% decline in the global economy, mainly due to damage and losses in agricultural productivity.2.2.2: Particular effects of climate change on Zimbabwe's income stability

Globally, with the exception of Zimbabwe, climate change is significantly affecting agricultural productivity. The biophysical conditions that support agricultural productivity are changing as a result of rising temperatures, shifting precipitation patterns, and an increase in the frequency of extreme weather events.

2.2.3: Specific Effects on Crops

Crop yields are expected to drop due to climate change, particularly in tropical and subtropical countries with lower economic development. Heat stress, caused by rising temperatures, makes plants lose water faster, slowing down their growth and productivity. For instance, crops such as maize and wheat are sensitive to temperature increases. A 1°C rise in average temperature can lead to a 5 to 10% drop in crop productivity. Changes in rainfall patterns can also affect yields. Droughts and floods can damage crops, reducing their growth and productivity. Droughts caused by shifts in rainfall can strain water supplies, especially in dry regions. This shortens the growing season and limits water availability for crops, negatively affecting overall yields and productivity. Extreme weather events, like storms and frost, also significantly impact crop production. Unexpected frosts and more frequent, severe storms can destroy crops that are vulnerable to temperature changes. These effects of climate change led to a general decline in crop productivity and total yields.

2.2.4: Specific impacts on livestock

Livestock production is negatively affected by climate change. Rising temperatures can cause heat stress. This leads to lower growth rates and milk production in dairy farming. Productivity also declines because higher temperatures influence fertility and reproductive outcomes in livestock. For example, Wako (2017) reported that many Sub-Saharan countries, including Zimbabwe, experienced a significant increase in cattle and sheep deaths during droughts. He found an average 9.7% drop in beef production across sub-Saharan Africa with a 1.9% decrease in Zimbabwe when temperatures rise by 1°C. The warmer temperatures contributed to this decline in livestock productivity by promoting the spread of parasites and diseases, which reduced body weight and overall mass. High temperatures also affect the effectiveness of vaccines and drugs used for treating livestock diseases, lowering productivity. Barati (2008) showed that heat stress hinders the growth of animal oocytes, their pregnancy rates, and the development of embryos. It also decreases the concentration of sperm and motile cells per ejaculation in bulls, leading to a 20-27% drop-in conception rates in cows. This negatively impacts livestock performance and overall productivity in sub-Saharan Africa. The United Nations found that climate change could lead to a 10-12% reduction in livestock productivity in Africa by 2050. Changes in rainfall patterns cause water shortages, affecting animal hydration and health. Droughts and floods can also reduce livestock productivity by decreasing the availability and quality of feed (Food and Agriculture Organisation (FAO), 2022).

2.3: Vulnerability of Zimbabwe's Agricultural Sector to Climate Change

2.3.1: Economic and social implications of climate change impacts on agriculture

For centuries, thinkers have debated how climate factors like temperature, rainfall, and severe storms affect societies and economies. A new wave of research combining different fields has started to shed light on the connections between these complex natural and human systems. This research reveals significant impacts of climate on health, agriculture, economics, conflict, migration, and demographics (D. B. Lobell & W. Schenker, 2011). Therefore, this work must show that various factors greatly influence societies and economies, both in the past and today, with important consequences for the future.

2.3.2: Social implications of climate change impacts on agriculture

Temperature has a strong effect on human systems across various social levels. Heat can lead to deaths, have long-lasting effects on foetuses and infants, and even cause violence while reducing productivity. This impacts people's ability to engage in agriculture, where many earn their income. As a result, food security and overall livelihoods suffer, especially in rural areas. Additionally, climate conditions can break connections between individuals in societal groups, leading to violence or migration (Tamma, A., Carleton and Solomon, M. Hsiang, 2016). High temperatures also harm crops, resulting in food insecurity and poverty. This can push people into harmful practices like prostitution as they struggle to survive. Destructive tropical cyclones increase electricity demand and may cause people to move both within and across borders. This significantly reduces the labour supply needed for agricultural production, exacerbating food insecurity, poverty, and economic instability. Tropical cyclones can also lead to deaths and damage assets and economic output for long periods. Extreme precipitation negatively impacts economies and populations, particularly in regions that rely heavily on agriculture.

2.3.4: Economic implications of climate change impacts on agriculture

The study of how climate directly impacts economic outcomes started in agriculture, where the impact of climate is most evident. Crops are especially sensitive to high temperatures during certain growth stages, affecting overall crop yields. Research in dairy science indicates that both temperature and humidity impact milk production and yields, which then reduces profitability in milk production. Climate change is believed to influence labour supply and productivity. N. Charles, (2014). Heat stress is reported to decrease work intensity, hurt cognitive performance, and lead to shorter working hours in sectors like agriculture and construction that are most affected by outdoor temperatures; this slowdown also impacts production downstream.

The connection between energy and climate is distinct. Climate change directly impacts energy systems. High temperatures can lead to increased demand while putting pressure on supply and transmission. Droughts may cause a shift from hydropower to more carbon-intensive fuel sources. World Bank, (2023). Climate change also affects trade decisions. For example, global wind patterns and ocean currents have historically influenced trade patterns due to their role in shipping costs along various routes. High temperatures that reduce productivity led to a lower volume of goods exported, both in agriculture and manufacturing; cyclones that decrease national income tend to reduce imports. R. Mano, C. Nhemachena, (2007). In large integrated trade networks, the spatial distribution of climate can influence market prices, likely through its impacts on both supply and demand.

2.3.5: Climate change role in exacerbating poverty and inequality in Zimbabwe

According to Brock et al. (2003), poverty is a complex issue that people view differently based on their position in local policy-making. In much of Zimbabwe, poverty remains primarily a rural problem, largely worsened by climate change. Fluctuations in climate force people to lose their livelihoods, push families to alter their lifestyles, and plunge people deeper into poverty. In areas with few economic opportunities, the options for new sources of income to adapt to climate change are often limited (Skoufias et al., 2011). The poor frequently depend heavily on industries affected by climate change, such as agriculture and livestock. However, they lack the financial, institutional, and human resources needed to prepare for and respond to the direct and indirect effects of climate change. As a result, climate change significantly impacts the livelihoods of impoverished communities (Mashizha, 2019). It also degrades the natural resources that people rely on, making it harder for them to escape poverty. Smallholder farmers face increased vulnerability to poverty and inequality due to declining agricultural productivity. Climate change alters crop-growing conditions, leading to reduced yields and lower-quality produce. Consequently, smallholder farmers who struggle to make ends meet are experiencing a drop in their income. With falling incomes, the gap in wealth and financial status between these farmers and successful commercial farmers widens, trapping the poor in poverty. Furthermore, climate change exacerbates poverty and inequality by limiting smallholder farmers' access to markets and financial services. They often struggle to sell their produce and obtain credit because they lack access to formal markets and financial services. Many formal markets and financial institutions hesitate to engage with smallholder farmers due to the perceived risks of climate-related shocks.

2.4: Income stability Challenges faced by smallholder farmers

Smallholder farmers in Zimbabwe face major challenges related to income stability, especially due to climate change. Climate variability and change significantly affect these farmers, who grow most of the country’s staple crops, including maize, sorghum, and millet. Rising temperatures, changing rainfall patterns, and more frequent extreme weather events like floods and droughts alter the conditions that support farming. This shift impacts smallholder farmers' income stability.

Moreover, these farmers have limited access to climate information and advisory services. Without timely and accurate climate data, they struggle to make informed decisions about their farming practices. This decreases overall farm productivity and lowers income stability. Smallholder farmers are particularly vulnerable to the effects of climate change on their revenue stability because they lack the skills and knowledge needed to adapt to the changing environment.

2.5: Sustainable Agricultural Practices and Adaptation Strategies

For millions of people across the country, especially in rural areas, smallholder farming systems provide the basis for their livelihoods and food security. Water shortages, soil erosion, and climate change are some of the challenges these systems face. To make smallholder farming systems in Zimbabwe more sustainable and productive, we need to use sustainable farming practices and smart adaptation strategies. Agroforestry, climate-smart farming, integrated pest management, conservation agriculture, and sustainable water management are some of these methods.

2.5.1: Pfumvudza, or Conservation Agriculture

This method involves encouraging crop rotations, maintaining soil cover, and reducing soil disturbance. Many farmers noted that conservation practices have several benefits for lowering drought risks (C-CIARN Agriculture, 2003). These benefits include reducing soil compaction, improving soil moisture retention, and decreasing soil erosion. Conservation agriculture is also said to promote biodiversity by increasing biomass and lowering greenhouse gas emissions. Additionally, conservation tillage is recognized for its role in reducing soil erosion caused by runoff and washouts during floods.

The Masvingo province conducted a case study on pfumvudza, a form of conservation agriculture. The results showed impressive crop yields. Maize yields increased from 1.16 t/h under the conventional farming system in the 2019–2020 season to 5.2 t/h under pfumvudza in the 2020–2021 season (Vhera, 2022). The Pfumvudza program, which incorporates sustainable agricultural practices to boost crop productivity and resilience, has significantly improved food security in Zimbabwe, according to this study. Pfumvudza has helped lessen the effects of climate change, unpredictable rainfall, and soil degradation by promoting conservation agriculture (Penot et al., 2015). All these factors greatly influence agricultural productivity in the country. This program has been shown to increase water retention and enhance soil fertility. It has benefited over 100,000 smallholder farmers, proving to be effective in boosting agricultural productivity and income stability in Zimbabwe.

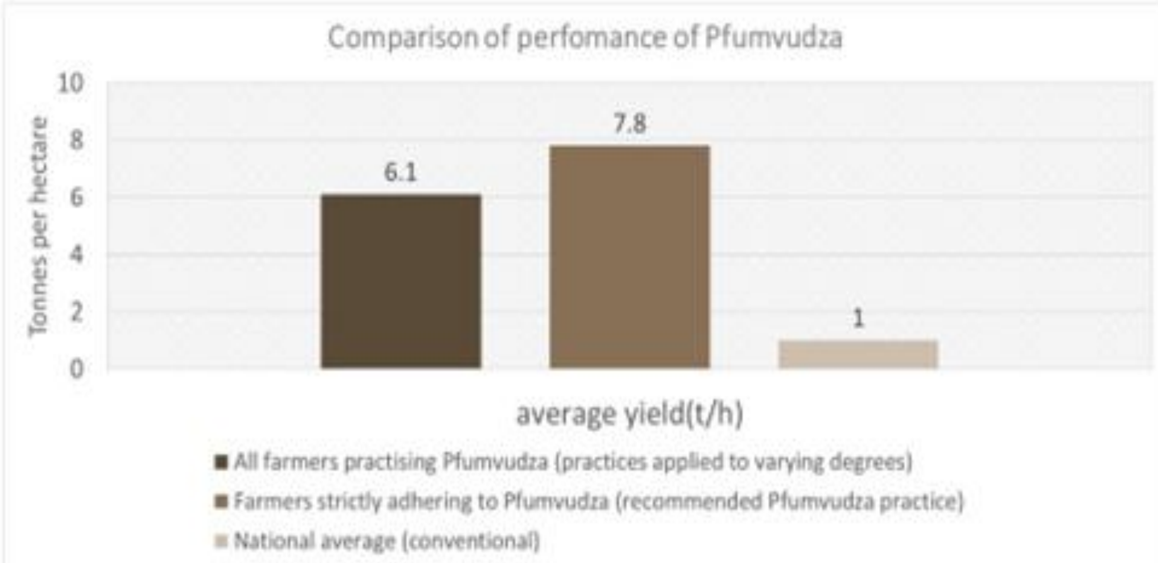

Fig 3: Performance comparison between pfumvudza and conventional farming

Source: AGRITEX

2.5.2: Climate Smart Agriculture

The term "climate-smart agriculture" refers to methods or technologies that reduce greenhouse gas emissions, improve resilience to climate change, and sustainably increase agricultural productivity. By promoting techniques that raise crop yields, climate-smart agriculture enhances productivity and ensures food security as the climate changes. This involves using climate-resilient plant varieties, better soil management, and water conservation. It also greatly improves the resilience of smallholder farmers. With climate-smart agriculture, farmers can better cope with climate-related challenges like droughts and floods. Farming systems become stronger when practices like agroforestry, crop rotation, and intercropping support soil health and biodiversity.

Techniques in climate-smart agriculture also aim to cut greenhouse gas emissions from farming. For instance, using conservation tillage and boosting nitrogen efficiency can lower greenhouse gas emissions while maintaining productivity and overall food security. By managing landscapes, crops, livestock, forests, and fisheries, this method addresses the linked issues of climate change and food security. Leslie Lipper et al. (2014) describe climate-smart agriculture as a way to change agricultural systems to support food security in light of new climate realities.

This strategy includes farming practices like agroforestry, conservation agriculture, drought-tolerant breeds, water harvesting, biogas, and integrated soil management. It also involves technologies like the Internet of Things, which employs drones and sensors to manage farm resources and help farmers adapt to climate change. Additionally, it leverages sustainable irrigation methods, such as drip irrigation, and drought-resistant crop varieties. Climate-smart agriculture also uses climate data and advisory services to help farmers make informed decisions about their practices.

2.5.3: Sustainable Water Management

The rise in drought conditions due to climate changes is creating more interest in irrigation. Some farmers are adopting newer, more efficient systems and timing for applications to avoid waste. This significantly reduces the amount of water farmers need to use during droughts caused by climate change (C-CIARN Agriculture, 2004). This approach includes conservation tillage, mulching, and drip irrigation. It also involves promoting both in-situ and ex-situ water harvesting and storage.

In-situ water harvesting uses techniques like contour farming, check dams, rain gardens, and swales to capture rainwater where it falls, whether on the ground, rooftops, or other collection areas. On the other hand, ex-situ water harvesting involves gathering and storing water outside its natural location, often in central water storage facilities. Water is moved to storage tanks or reservoirs through a network of pipes, gutters, downspouts, and other systems.

Another part of sustainable water management involves different infield water harvesting methods like potholing, tied ridges, and infiltration pits. Infiltration pits are deeper excavations filled with permeable materials, such as gravel. They help surface water soak into the soil, reducing runoff and promoting groundwater recharge. This technique significantly improves soil fertility and structure while lowering the risk of flooding.

Tied ridges are created by forming soil mounds into ridges connected by ties, such as plants or stones. This method helps retain water in the field by minimizing runoff. These water harvesting technologies are believed to be more effective in boosting agricultural productivity. They also decrease soil erosion, enhance soil health, and increase water availability, all of which contribute to greater agricultural output.

A case study conducted at Mount Zonwe in Zimbabwe's Marange smallholder farming area during the 2025–2026 season showed that plots using infield water harvesting technologies produced higher yields, especially for maize. The average yield for tied ridges was 2210 kg/ha, and for infiltration pits, it was 1792 kg/ha. Both were 88% and 52% higher than the standard contours' yield of 1176 kg/ha. These results suggest that, if implemented and managed correctly by farmers, infield water harvesting techniques can significantly boost productivity.

2.6: Adaptation strategies versus productivity and income enhancement

Zimbabwe is an Agro-based country where the economy relies heavily on agriculture. However, this sector faces many challenges due to climate change, such as water scarcity and soil degradation. Several adaptation strategies and sustainable farming practices have been implemented to tackle these problems. As a result, these efforts have improved smallholder farmers' ability to cope with the impacts of climate change on their income stability and productivity.

2.6.1: Agroforestry

Agroforestry is a term for land use systems and practices where woody perennial plants are intentionally grown alongside agricultural crops and animals. This can happen in a spatial mix or in a sequence over time. It has been recognized in global sustainable development models due to the benefits it provides to ecosystems, economies, and societies. A case study in Goromonzi District established trial and demonstration farms that showed agroforestry is vital and effective in boosting productivity and income stability for smallholder farmers.

Farmers who adopted this method saw increases in both crop and animal production. Income and maize output were higher for those using agroforestry compared to those who did not. In Goromonzi, agroforestry also improved crop and animal yields by enhancing soil fertility. This program helped around a certain number of smallholder farmers, and its positive effects on productivity and income stability are significant. The crop productivity, especially maize yield, increased by roughly 50% among the 50,000 households that adopted agroforestry compared to those using traditional farming methods. Additionally, smallholder farmers who switched to agroforestry saw about a 30% rise in income levels.

By boosting farm production such as food, fodder, timber, fuelwood, and manure and supporting ecosystem services like soil improvement, climate mitigation, windbreaks, erosion control, and pest management, this study showed how agroforestry can make smallholder farmers more resilient to climate change.

2.6.2: Crop diversification

The practice of growing different crop varieties from the same or different species in a specific area through intercropping or rotations is called crop diversification. This method is considered one of the most cost-effective, practical, and environmentally friendly ways to reduce agricultural uncertainty, especially for smallholder farmers (Joshi 2005). Crop diversification also increases resilience and boosts the farm's biodiversity in both time and space (Holling 1973; Joshi 2005). Lin (2011) states that crop diversification helps maintain yield stability, improves nutrition variety, and supports health while also increasing soil fertility and reducing the impact of pests and diseases. It can also be a better choice than using chemicals for soil fertility and pest management. Truscott et al. (2009) suggest that crop diversification is an eco-friendly alternative for pest control and maintaining soil fertility in agriculture. Overall, diversified cropping systems tend to be more resilient and stable agronomically. This resilience mainly comes from lower pressures from weeds and insects, a reduced need for nitrogen fertilizers especially if the crop mix includes leguminous plants less erosion from cover crops, better soil fertility, and higher yields per area (Lin, 2011).

Additionally, these systems can provide habitats for beneficial insects, which can help lower pest numbers by making crops less appealing for pests to colonize. Shoffner and Tooker (2012) note that crop diversification is increasingly popular because it favours mixing species instead of relying solely on monoculture. This practice can help manage pests and diseases effectively. By mixing crops, farmers can create a dilution effect that lowers resource concentration, alters the microenvironment within the crop canopy, increases natural enemies of insect pests, disrupts disease cycles, suppresses weeds and volunteer plants, and makes it harder for pests and disease pathogens to thrive. Moreover, when farmers grow native varieties, crop diversification can support local biodiversity. One notable benefit of crop diversification is the improvement of soil fertility, which is essential for productive and sustainable farming systems (Lin 2011).

In Zimbabwe, farmers plan crop production around both summer and winter growing seasons. They use both crop rotations like planting maize in summer and sowing beans soon after harvesting and intercropping, such as maize-legume combinations, as part of their practices. Well managed soils can reduce pest pressure, optimize water usage, and enhance overall crop yields. There is also a belief that crop diversification can positively affect climate change since native plants can store carbon, leading to lower carbon dioxide emissions.

2.6.3: Integrated Pest Management

This approach combines various techniques to manage pests and diseases. It includes crop rotation, biological control, cultural methods, and push-pull technology. Push-pull technology is an intercropping strategy for controlling agricultural pests. It uses repellent plants, called push plants, like Desmodium uncinatum (silverleaf) and attractive trap plants, known as pull plants, like Napier grass to control the parasitic plant striga. The push element in this scheme comes from plants that release volatile chemicals, known as kairomones. These chemicals repel pests like stemborer moths and drive them away from main crops, such as maize or sorghum. The most common push plants are legumes from the genus Desmodium, such as silverleaf Desmodium (D. uncinatum) and Greenleaf Desmodium (D. intortum). Desmodium is planted between the rows of main crops, like maize, where it releases volatile chemicals, such as (E)-4.8-dimethyl, that repel pests like stemborer moths. Other grasses, like molasses grass, also have good repellent properties for pest control and management.

In contrast, the pull approach relies on planting companion crops around and among the main crop. Both domestic and wild grasses can attract and trap insects, helping to protect crops. Effective trap crops include well-known grasses such as Napier grass, signal grass, and Sudan grass. This pest management technology became important in East African countries over the past decades. Its effectiveness in improving crop productivity amid climate change has driven its relevance. For example, using Desmodium improves soil quality by increasing soil organic nitrogen content and biodiversity. It also conserves moisture, moderates soil temperature, and prevents soil erosion. These benefits ultimately lead to increased productivity and more stable incomes for smallholder farmers.

2.7: Challenges and Opportunities for scaling up climate adaptation strategies

2.7.1: Challenges

Economic constraints are one of the main challenges smallholder farmers faces when trying to adopt climate adaptation strategies. Zimbabwe's economy has struggled with hyperinflation, high unemployment, and a lack of agricultural investment. Farmers often find it hard to access credit and financial services needed to support sustainable practices. Limited market access further complicates their situation, making it difficult to sell their produce or invest in better technologies.

Land tenure issues also play a role in preventing smallholder farmers in Zimbabwe from effectively scaling up their climate adaptation efforts. The complex land tenure system established by Zimbabwe's land reform policies can discourage investment in sustainable practices. When many farmers cannot secure land tenure, they feel less motivated to invest in sustainable farming methods. This uncertainty about land ownership often leads them to focus on short-term gains instead of long-term sustainability.

Furthermore, farmers' limited access to information and technology is a significant barrier to adapting to climate change. To adopt sustainable practices, farmers need access to modern agricultural technologies and information. However, many Zimbabwean farmers lack access to extension services that provide training in climate-smart agriculture and modern farming techniques. This challenge is worsened by the digital divide, as many farmers, especially in rural areas, do not have access to mobile devices or the internet, which could provide valuable information.

2.7.2: Opportunities

Improving communal farmers' ability to respond to climate change requires strategies that focus on the community. Community-run initiatives offer a great chance to expand adaptation techniques. By using local knowledge and traditions, communities can create tailored solutions that improve their resilience to climate change. Participatory methods that involve nearby farmers in decision-making lead to more effective and lasting results.

Support from NGOs and the government is essential in helping farmers adopt their preferred climate adaptation methods. The need for sustainable farming practices in Zimbabwe has gained more attention in recent years. With backing from NGOs, government policies and programs are beginning to promote sustainable agriculture and climate adaptation. This support makes it easier for farmers to access technology, training, and resources.

Rural farmers also benefit significantly from access to financial services, which allows them to invest in technologies that strengthen their climate adaptation strategies. Microfinance and insurance are financial models that provide farmers with the funds they need to adopt sustainable practices. These services help farmers manage the risks from market fluctuations and climate change, enabling them to implement resilient long-term plans.

2.8: Theoretical framework

The connection between climate change and agriculture in Zimbabwe is explored from a theoretical viewpoint. This analysis uses different schools of thought, including the Capital Approach Framework.

2.8.1: Framework for the Capital Approach

An economic and environmental model called the Capital Approach Framework is used to analyse how agriculture and climate change interact. It highlights how different types of capital, financial, social, human, and natural, support agricultural systems. This support is especially important when facing environmental challenges like climate change.

2.8.2: Capital Approach Framework Elements

Capital of Nature

The soil, water, biodiversity, and climate are vital natural resources and ecosystem services that support agricultural production. Climate change directly affects natural resources by altering weather patterns, increasing the frequency of extreme weather events like storms, floods, and droughts, and influencing water availability. These disturbances weaken agricultural systems' reliance on natural resources for productivity. The availability and quality of resources such as fertile land, water, and a stable climate are essential for agricultural success. Climate change may make it harder for farmers to sustain their livelihoods and produce food due to the potential worsening of resource degradation.

Human Resources

This element includes the labour, health, knowledge, and skills of people involved in agricultural production. Climate change may affect farmers' ability to use their human resources to adapt to changing conditions. For example, the education, skills, and health of the farming community influence their ability to use climate information, like weather forecasts, apply new farming methods, and manage agricultural systems effectively. As climate conditions change, farmers face a greater need to learn new skills, adopt climate-resilient farming practices, and manage risks related to climate variability. By enhancing adaptation strategies and investing in human resources through education and training, farmers can better cope with the impacts of climate change.

Social Capital

Within communities, it refers to the networks, connections, and group efforts that promote collaboration, support, and information exchange. Fostering group responses to climate change requires social capital. Strong social networks in agricultural communities can facilitate community-based disaster risk management, increase access to resources for climate adaptation, and encourage the sharing of knowledge about climate-resilient practices. Collaboration and group efforts at the community level are frequently necessary for effective climate adaptation. By empowering communities to pool resources, exchange knowledge, and work together to advocate for or change policies that address the effects of climate change on agriculture, strong social capital can improve resilience.

Financial Capital

This component refers to the resources available for investing in agricultural activities, such as access to credit, savings, subsidies, or financial support. Climate change raises the financial risks to agriculture due to unpredictable weather events, crop failures, and higher costs for inputs like irrigation systems or drought-resistant seeds. The reduced predictability of agricultural yields and the increased cost of adaptation can strain farmers' finances. Financial capital is essential for farmers to invest in climate adaptation strategies, like buying climate-resilient seeds, building irrigation infrastructure, or diversifying income sources. However, many smallholder farmers struggle to obtain enough financial resources, making it harder for them to adapt to climate change.

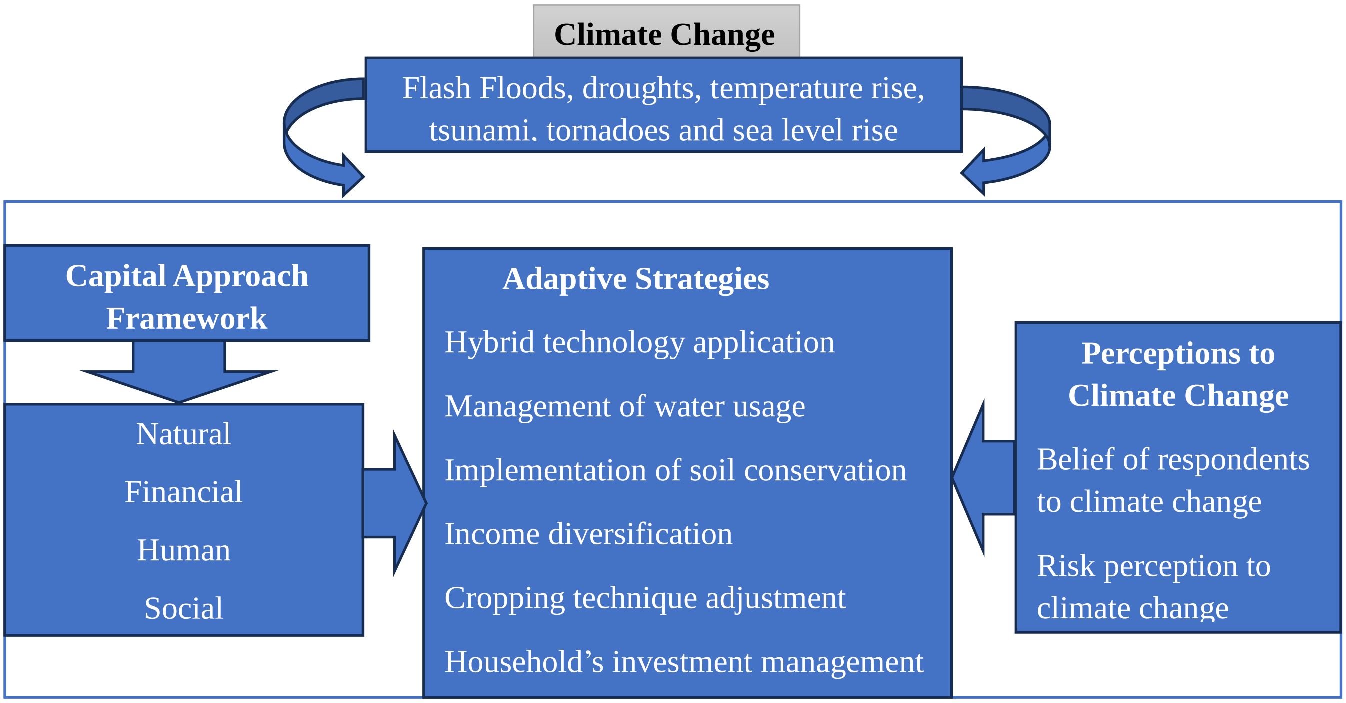

Fig 4: Relationship between Climate Change and Agriculture

Source: Developed by the author

2.9: Conclusion

This chapter looked at the work of other scholars and researchers. It reviewed different views and opinions from various authors on how climate change affects agricultural productivity and income stability in Zimbabwe. The literature highlights a mix of environmental, economic, and social factors in the relationship between climate change and agriculture. Evidence shows that the agricultural sector, which is essential to Zimbabwe's economy and the main source of income for many people, faces serious threats from rising temperatures, changing rainfall patterns, and more frequent extreme weather events. The findings also reveal that smallholder farmers struggle with limited access to resources, technology, and information, making them more vulnerable to climate variability. This situation negatively impacts agricultural productivity, resulting in lower crop yields and reduced income stability. To address the socioeconomic effects of climate change in smallholder farming, appropriate policies and adaptation measures need to be put in place.

Based on the findings from this chapter, I recommend that future researchers continue to explore the effectiveness of different adaptation strategies and their socioeconomic impacts on agricultural productivity and income stability. It's important to ensure that the voices of marginalized farmers are heard by including them in the discussion.

CHAPTER 3

RESEARCH METHODOLOGY

3.0: Introduction

The purpose of this chapter is to explain the methods and theoretical model used to examine the relationship between climate change impacts and agricultural productivity, along with farm income stability in Zimbabwe. This chapter will also discuss the research design, sample population, and data collection and analysis tools. Additionally, it will include the model specification, reasons for choosing specific variables, and the econometric tests used in the analysis. Lastly, this section will outline the expected results of the research.

3.1: Conceptional framework

A conceptual framework is a research tool that helps guide the investigation of relationships between different variables. It shows how various elements interact and influence the research topic. In this study, the conceptual framework focuses on how climate change affects the income stability and agricultural productivity of smallholder farmers in Zimbabwe. The diagram below visualizes the direct and indirect factors that contribute to these impacts.

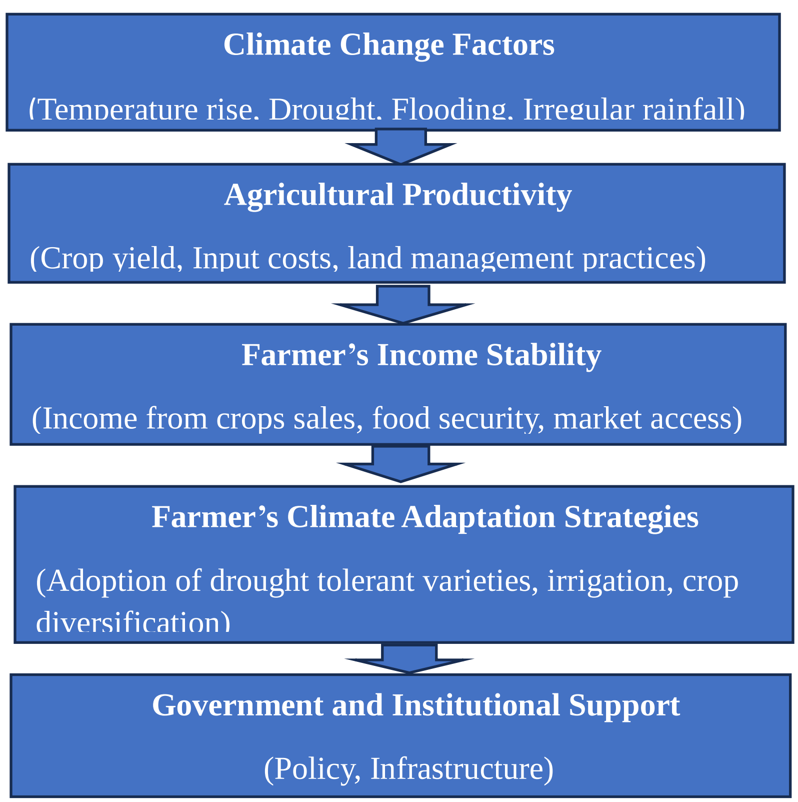

Fig 5: Diagram shows linkages between climate change and agriculture sector

Source: Developed by the author

3.2: Components of the Conceptual Framework

3.2.1: Climate Change Factors

The set of climate change factors affecting the agricultural environment is the framework's first and most important element. These factors include droughts, floods, erratic rainfall, and rising temperatures. These changes disrupt Zimbabwe's traditional farming cycles. They significantly impact agricultural output and make crop production less predictable. For example, prolonged droughts can lead to crop failure, while floods can erode land and destroy crops. These factors directly threaten smallholder farmers' ability to make a living and ensure food security.

3.2.2: Agricultural Productivity

Agricultural productivity refers to how well farmers grow crops and manage their land. Water availability and temperature changes are two climate factors that influence this productivity. Excessive heat can stress crops and reduce their yields. Similarly, less rainfall or long droughts can lead to low crop production. Other factors, such as the costs of inputs like fertilizers, seeds, and labour, land management, and water availability, also significantly impact agricultural productivity. Farmers' incomes and overall food security depend directly on the productivity of key crops like maize, which is Zimbabwe's staple food.

3.2.3: Income Stability

Income stability means a steady and dependable flow of income from farming. Climate change causes crop yields to vary, which creates income instability for smallholder farmers. When yields drop, farmers struggle to pay for household bills, invest in future production, or save for emergencies because their income from selling crops decreases. Market access also plays a crucial role in income stability. Climate-related changes in supply and demand can lead to price swings, affecting revenue from crop sales. Income insecurity worsens for Zimbabwean farmers, who often face challenges in securing credit or financial services needed for their farming activities.

3.2.4: Adaptation Strategies

Adaptation strategies are the methods smallholder farmers use to deal with climate change. These tactics help farmers become more resilient to changing weather patterns and reduce their vulnerability. Common tactics include the following:

Using drought-tolerant cultivars

This allows farmers to grow crops like drought-tolerant millet or maize, which are better suited for dry conditions.

Watering

Irrigation systems provide crops with a steady supply of water. This support is especially important during dry spells, as it helps reduce the impact of unpredictable rainfall.

Crop diversification

This practice involves planting a range of crops. It allows farmers to still earn income even if one crop fails due to bad weather.

Conservation Agriculture

Techniques like minimum tillage and soil conservation improve soil health and water retention, making farms more resilient to floods and droughts. These adaptation methods can directly affect agricultural productivity, but their success depends on the resources, knowledge, and support available to farmers.

3.2.5: Government and Institutional Support

Government policies and institutional support are crucial for adopting climate adaptation strategies. Examples of effective policies include subsidies for climate-resilient technology, training in sustainable farming methods, improving access to credit and insurance, and funding for rural infrastructure. Through a mix of funding and education, government programs like Zimbabwe's Climate Smart Agriculture Programme aim to boost resilience to climate change. However, the effectiveness of these programs is often limited by challenges in implementing policies, unstable political situations, and inadequate infrastructure.

3.3: Framework Relationships Specification

The framework shows how climate change affects agricultural productivity, which then impacts income stability. Changes in weather patterns can lead to lower yields, reducing the income of smallholder farmers. Limited access to adaptation methods, such as crop diversification, irrigation, and climate-resistant crop varieties, worsens these effects. Income stability and agricultural productivity are linked in both directions. While productivity determines income levels, farmers' ability to invest in technologies that boost productivity can also be influenced by their income stability. This creates a cycle of vulnerability.

Farmers' ability to access resources, including financial, technical, and informational support, impacts the adaptation strategies they choose. To help smallholder farmers adapt to climate change, they need support from institutions and the government. If smallholders cannot afford or implement effective adaptation measures without proper assistance, their vulnerability may increase.

3.4: Description of the study area

Marange is a rural communal area in the Mutare district of Manicaland. It lies in Agro-ecological Region 3. This region is known for its high temperatures and low annual rainfall, which ranges from 600 to 750 mm. Most of the soils here are sandy, making them poor for growing crops. Because of severe deforestation, farmers in this area face greater risks from climate change, especially droughts.

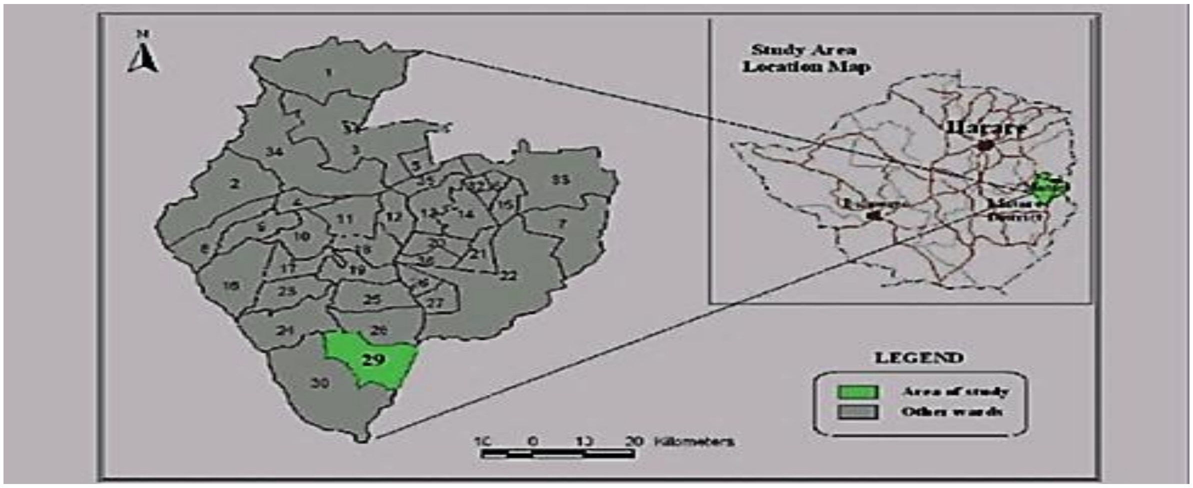

Fig 6: Study Area Location Map

Source: Developed by the author

3.5: Research Design

This research used a mixed methods approach, specifically a correlational research design. This method was chosen because it is more affordable than other types of research, such as experimental studies. The study combined both quantitative and qualitative techniques common in statistics to gather data. A quantitative correlational design was adopted to examine the effects of climate change on agricultural productivity and income stability due to its cost-effective and time-saving nature compared to longitudinal studies. The researcher conducted surveys by distributing structured questionnaires to farmers to gather information on the strategies they used to achieve agricultural productivity and income stability in response to climate change, along with economic factors like income and expenses. Interviews were also carried out with key informants, including local leaders and agricultural extension officers. Focus group discussions with farmers were held to collect insights on resilience strategies and economic challenges.

3.6: Sampling Procedure

The study gathered relevant data from local leaders, agricultural extension officers, and other civil society organizations. We used a simple random sampling method to obtain a representative sample that reflects the entire farmer population across various farming systems and community areas. A sample size of 52 farming households was used to collect data from the areas being studied. This sample size was calculated as follows:

3.5.1: Sample size calculations

Formula for calculating sample size: $$n = \frac{N.\ Z^2.p(1-p)}{(E^2\,(N-1) + Z^2\,p(1-p)}$$

Where:

n= required sample size

N= population size

Z= z-score (1.04 for 70% confidence interval)

P= estimated proportion of the population (if unknown, 0.5 is used for the maximum sample size)

E= margin of error (0.05)

Therefore, to determine an appropriate sample size from the population size of 100 households (N=100), the above formular was used based on a confidence level of 70% (Z-score=1.04) a margin of error of 5% (E=0.05)

Sample size calculation:

$$n = \frac{\mathbf{100 \times 1.0816 \times 0.25}}{\mathbf{0.05^2(100-1) + 1.04^2 \times 0.5(1-0.5)}}$$

$$= \frac{\mathbf{27.04}}{\mathbf{0.2475+0.2704}}$$

$$\mathbf{=} \frac{\mathbf{27.04}}{\mathbf{0.5179}}$$

Sample size (n) = 52.2 0r 52 if rounded off to the nearest tenth

Therefore, a sample size used to gather data for the study is 52 households

3.6: Data collection methods

The research gathered data using a mix of qualitative and quantitative methods. Combining these approaches allows for a better understanding of how climate change affects agriculture in Zimbabwe. The data came directly from the farmers, and we used random sampling to get a representative population sample for the study. This method was chosen to minimize bias, giving every individual an equal chance of being selected. This approach also helped identify effective adaptation strategies and guide policy decisions to improve agricultural productivity and income stability for smallholder farmers in Zimbabwe.

3.6.1: Qualitative Methods

Key Informant Interviews

The researcher carried out structured interviews with farmers, agricultural experts (extension officers), the meteorological department, and NGOs to gain detailed insights into personal experiences and views on how climate change affects agricultural productivity and income stability. There was a total of 8 interview sessions with all the key participants. This qualitative method was chosen for data collection because it allowed the researcher to gather historical perspectives on weather patterns and farming practices.

Table 1: Shows number of interviews done with each key informant

Key Informants	Number of key informant interviews done
AGRITEX	3
Village Heads	3
Meteorological department	1
NGOs	1

Focus Group Discussions

The researcher organized focus groups with farmers from various communities. Participants were split into groups of 10 farmers each, with 5 males and 5 females in every group. Two discussions took place for each of the five focus groups. Overall, there were 10 focus group discussions held in each village, totalling 30 discussions across the three villages involved. The researcher led the discussions and used a checklist to detail the steps for conducting the discussions for each of the five groups. This method of data collection allowed for exploring shared experiences and challenges related to the effects of climate change on farming productivity. It also enabled the researcher to guide discussions on strategies for adapting and building community resilience against climate change.

Table 2: Shows number of focus group discussions done per each group

Villages	Number of groups participated per village	Number of focus group discussions done
Chigonda	1	2
Chikuku	2	4
Manzwi	2	4

3.6.2: Quantitative Methods

Household Survey Questionnaires

The researcher also used structured survey questionnaires as an additional method for collecting data alongside the qualitative methods mentioned earlier. The structured questionnaires were given to a larger group of farmers to gather quantitative data on agricultural practices, crop yields, and economic conditions. The surveys included questions about how often extreme weather events occur, changes in crop types, and the climate-smart practices and strategies farmers are using to maintain agricultural productivity and income stability. In this instance, the questionnaires were also randomly distributed to the farmers, who first received an overview of the study's purpose before the data collection began.

Table 3: Shows summarised data on type of data collected, data collection methods and respondents for each research objective.

Specific Research Objectives	Data concepts and variables/ indicators	Data collection methods/tools	Respondents/ subjects
1.To quantify the impacts of climate change on agricultural productivity of staple maize for farming household	- maize crop yield/ha) -adaptation strategies (farming practices e.g. conservation tillage)	Household survey	Data collected per/ha

2.To analyse the economic impacts of climate change on farmer's income stability.	-Farmer's income levels and sources of income e.g. crop sales, livestock)	-Interviews -Structured survey questionnaires	Data collected per household head
3: To identify adopted sustainable agricultural practices that can mitigate the adverse effects of climate change.	-Agricultural practices data (types of sustainable practices e.g. agroforestry, conservation tillage) -adoption rates and methods of implementation	-Focus group discussions -Survey and questionnaires	Data collected per household
4. To examine the barriers faced by smallholder farmers in adapting to the impacts of climate change on agricultural productivity and income stability	-Specific climate related challenges faced by farmers (e.g., financial constraints, high upfront cost of implementing climate smart technologies). -Mitigation strategies by farmers	Survey Questionnaires	Data collected per household head

3.7: Data analysis methods

When the data was collected, the researcher used a mixed approach that included both quantitative and qualitative methods to evaluate the impacts of climate change on agricultural productivity and income stability in Zimbabwe. The researcher analysed the quantitative data using SPSS for statistical analysis, which included descriptive statistics, correlation, and regression techniques. The qualitative data were categorized through thematic analysis. Below are some data analysis methods organized as qualitative and quantitative.

3.7.1: Quantitative Methods

The analysis used multiple linear regression to look at the collected data. This method examined the relationships between sustainable agricultural practices, including conservation agriculture, agroforestry, and the productivity of staple maize. The researcher chose this statistical technique to assess how several independent sustainable agricultural practices, such as conservation agriculture, agroforestry, and soil conservation, influence the productivity of staple maize, which served as the dependent variable. To test for significance and determine whether the implemented sustainable agricultural practices significantly improved maize productivity for smallholder farmers, the researcher also used multiple linear regression.

Multiple Linear Regression Model:

$$\mathbf{Y = \beta_0+\beta_1X1+\beta_2X_2+\beta_3X_3+\beta_4X_4,\ \beta_5X_5+\beta_6X_6+\beta_7X_7+\beta_8X_8+\beta_9X_9+\beta_{10}X_{10}+e}$$

Where:

Y (Independent variable) = Agricultural productivity of maize yield (measured in kgs/ha)

$\beta 0$ = Intercept of the regression model (the expected productivity when all independent variables are zero, i.e., no adoption of the technologies)

β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9, and β_{10} are regression coefficients that represent the change in productivity associated with the adoption of each technology (measured in terms of kg/ha of maize yield).

X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, and X_{10} = Parameters that represent the independent variables (household and farming factors and adopted sustainable agricultural technologies, e.g., household head's age, education level, farming experience, farmer's management practices, fertiliser application rate, crop diversification, drought-tolerant crops, irrigation or other water management practices and conservation agricultural practices)

e = Error term (captures the unobservable factors affecting maize productivity that are not included in the model).

Additionally, the researcher analysed the gathered data using descriptive statistics. This method described the main features of the dataset, such as central tendency, variability, and distribution, without making predictions or generalizations about the population from which the data came. This analysis looked at frequencies, average mean, medians, mode, and standard deviations. The researcher chose this method to analyse data for some research questions because it provided a clear picture of the dataset. This technique was also chosen for its ability to effectively communicate findings through tables, graphs, and summary measures like mean and standard deviation.

Panel data analysis was also used to examine the effects of climate change on agricultural productivity and income stability for smallholder farmers across the studied areas. Lastly, econometric modelling was another method used for data analysis in this research project. Models such as Ricardian, Hedonic, and Dynamic models were used to estimate climate change impacts on agricultural productivity and income stability for smallholder farmers in Zimbabwe.

3.7.2: Qualitative Methods

Qualitative methods like content analysis were used to examine policy documents, reports, and stakeholder interviews to understand climate change adaptation strategies. Case study research looks at specific farms, communities, and regions to gain deeper insights into how climate change negatively affects farmers' productivity and income stability.

Table 4: Shows data collected and analysis methods used per each objective

Specific Research Objectives	Variables/ Concepts	Data analysis methods/tools
1.To quantify the impacts of climate change on agricultural productivity of staple maize for farming household	- maize crop yield/ha) -adaptation strategies (farming practices e.g. conservation tillage)	-Multivariate Linear Regression Analysis (MLRA) -ANOVA

2.To analyse the economic impacts of climate change on farmer's income stability.	-Farmer's income levels and sources of income e.g. crop sales, livestock)	-Descriptive statistics Analysis, (frequencies, mean, mode, median, standard deviation)
3: To identify adopted sustainable agricultural practices that can mitigate the adverse effects of climate change.	-Agricultural practices data (types of sustainable practices e.g. agroforestry, conservation tillage) -adoption rates and methods of implementation	Descriptive Statistics (frequencies and percentages)
4. To examine the barriers faced by smallholder farmers in adapting to the impacts of climate change on agricultural productivity and income stability	-Specific climate related challenges faced by farmers (e.g., financial constraints, Limited knowledge & skills). -Mitigation strategies by farmers	Descriptive Statistics (frequencies and percentages)

Table 5: Shows tools used to carry out the research thesis and their functions

Tools	Function
1.SPSS Software	-Statistical analysis of quantitative data
2.ODK (Data collection toolkit)	-Collect primary data from farmers
3.Laptop	- Typing, processing and storing the research document
4.Cell phone	

	-Facilitates communication with the supervisor

3.8: Validity and Reliability of the Methodological process

The research's reliability and credibility were ensured by using consistent procedures for data collection and analysis, as well as testing the survey questions. For example, the questionnaire was pre-tested with a small focus group to check the clarity and dependability of the responses. A random sampling technique was also used to avoid bias in selecting the population sample for this study.

3.9: Conclusion

This chapter gave an overview of the research method. It covered the research design, sample population, data source, collection tool, econometric model setup, and the reasons for choosing the variables in the model. The goal of this chapter was to explain the approach used to conduct the study.

CHAPTER 4

RESULTS AND DISCUSSION

4.0: Introduction

This chapter focuses on presenting the findings of this research thesis regarding the impacts of climate change on agricultural productivity and income stability for smallholder farmers in the Marange rural area of Mutare district. It will also discuss the study's results. The discussion below will highlight how and to what extent agricultural productivity and income stability for smallholder farmers are affected by changes in climatic conditions. Additionally, this chapter will interpret the findings and suggest solutions to address the impacts of climate change on agricultural productivity and income stability in Marange, Mutare.

4.1: Results on demographic information for sampled households

4.1.1: Household heads age.

Table 6: Shows summarised data on household head's age

Frequence (N)	Missing	Mean	Mode	Median	Standard Dev
52	0	46.67	45	49	10.67

The table above shows the mean age, median, and mode, along with the total number of smallholder farmers surveyed during the data collection. The frequency indicates that there are 52 data points in the dataset, representing the total number of households surveyed. There are no missing values, which is beneficial for conducting some statistical analysis on the data. The average age of the heads of households is about 45.67 years. This means most household heads are in their middle to late 40s. The median age of household heads is exactly 45 years. Since the median is close to the mean, it suggests the data is relatively evenly distributed. The mode, which is the most common value in the dataset, is 49 years. This means more household heads are 49 years old than any other age. The data shows that the ages of the household heads are quite varied, with a standard deviation of 10.62. This indicates that the ages differ significantly, which may impact their ability to adjust to climate change.

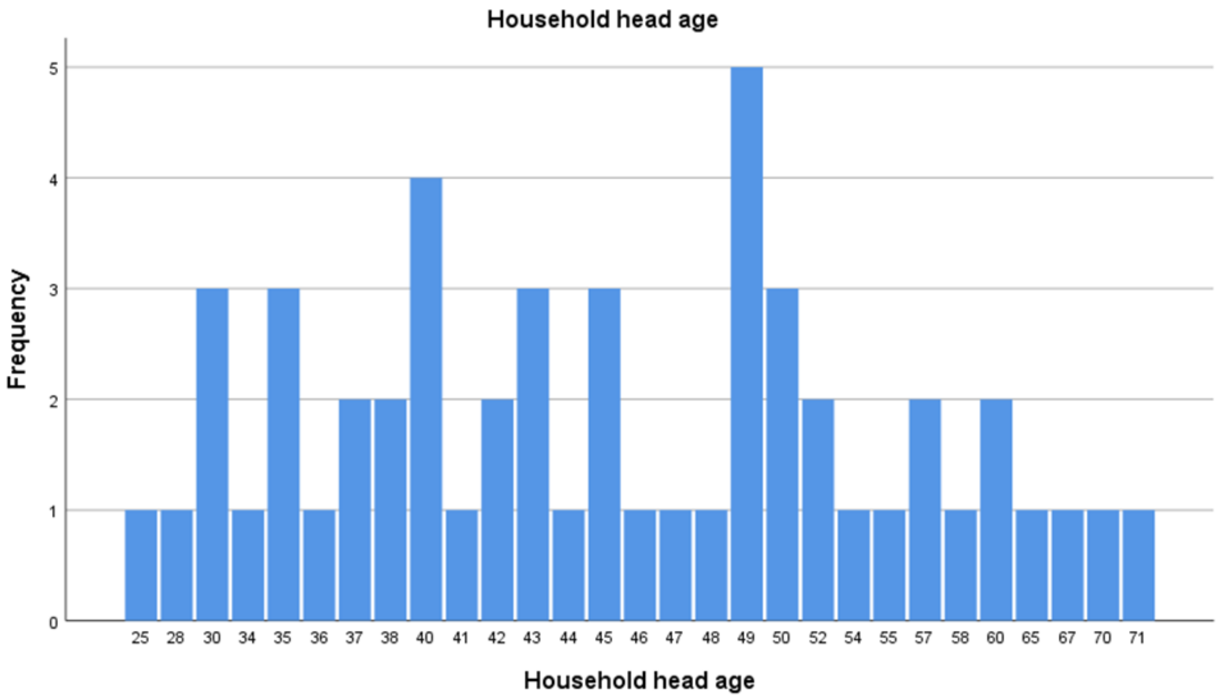

Fig. 7: The bar chart below shows the data on household heads' ages for 52 households in graphical form.

According to the bar chart, many farmers who still engage in farming despite the negative impact of climate change on their productivity and financial security are aged 40 to 49. Following them are younger people aged 25 to 38, who are less engaged in farming, and older individuals between 65 and 71, who also participate in farming less. The data suggests that young people may avoid agriculture for various reasons, some linked to climate issues. Sumberg and Okali (2013) found that many young people in developing countries view agriculture as a low-status job. Morton (2017) notes that the physical demands of farming, combined with the uncertainty caused by climate-related events such as droughts, floods, and heatwaves, may discourage young individuals from pursuing careers in agriculture. Additionally, young people might leave rural areas for cities in search of better economic opportunities. This migration, driven by their creativity and adaptability when facing climate challenges, could make smallholder farmers in rural communities even more vulnerable to climate change. Older adults may also engage less in farming due to health issues and physical limitations. As people age, they often experience declines in physical strength, mobility, and cognitive abilities, making farming increasingly difficult (FAO, 2017). The movement of young people to urban areas seeking better job prospects can lead to a brain drain from rural regions. This may also worsen the vulnerabilities of smallholder farmers in these areas against climate change, as young people tend to be more innovative when tackling climate-related difficulties that negatively influence agricultural productivity and income stability.

4.1.2: Household head's gender

Table 7: Shows statistical data on gender dynamics in agriculture

Variables	Frequence	Percentage	Valid Percentage	Cumulative Percentage
Male	38	73.1	73.1	73.1
Female	14	29.9	29.9	100.0
Total	52	100.0	100.0	

The dataset provides valuable information about the gender dynamics of household heads regarding agricultural productivity and income stability in the context of climate change. The data shows that 38 of the 52 household heads are men, which is 73.1% of the total. In contrast, 14 are women, representing 26.9%. Additionally, the valid percentage and cumulative percentage columns indicate that there are no missing data points.

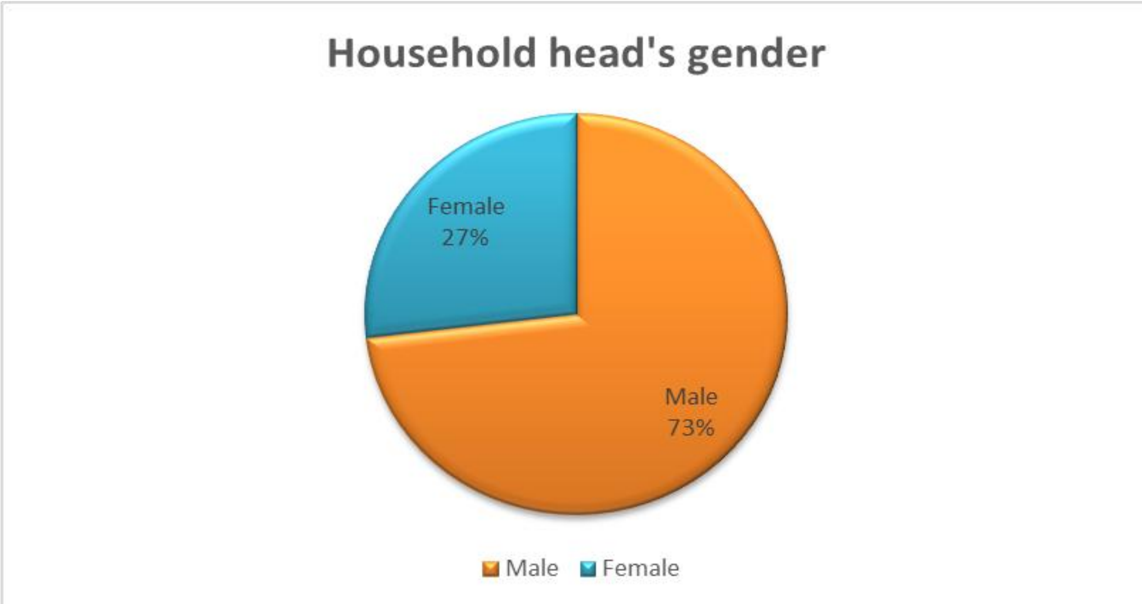

Fig. 8: The gender of the household head is displayed in the pie chart below.

As shown in the figure above, there are gender gaps. Men make up 73% of smallholder farmers, while women account for only 27%. This indicates that very few women participate in agriculture. This gap has important effects on understanding social and economic dynamics within households, especially considering climate change. Climate change negatively affects the productivity and income stability of smallholder farmers, and the male dominance in farming has implications for their resilience and ability to adapt.

Based on this information, I believe that men may have more power in making agricultural decisions, accessing resources, and finding opportunities to adapt to climate change. This could stem from several factors, including persistent patriarchal cultural and social norms, access to education and training, and control over financial resources. However, women face greater challenges due to climate change, which worsens existing inequalities in farming. It can be difficult for women to establish themselves as independent farmers because they often face barriers to land ownership and securing credit. Consequently, men dominate the agricultural sector, as women's roles are often informal and unpaid, making it tough for them to obtain resources and support for adapting to climate change.

4.1.3: Results on household head's educational level

Table 8: Shows household head's educational level

Educational level	Frequence	Percentage	Valid Percentage	Cumulative Percentage
Secondary	38	75.0	75.0	75.0
Tertiary (diploma, degree)	8	15.4	15.6	90.4
Vocational	5	9.6	9.6	100.0
Total	52	100.0	100.0	

The table above shows data on the education levels of 52 household heads who took part in the data collection. The data is divided into three education levels: secondary, tertiary, and vocational. According to the figure, 38 respondents, or 75% of the total, have completed secondary education. This suggests that most farmers have finished high school but may not have continued their studies. The information also reveals that only a small percentage of farmers involved in my data collection earned certificates for higher education.

Based on the data in the table above, only 8 people, or 15.4% of the total, reached the tertiary education level. This indicates that a relatively small number of surveyed farmers pursued higher education. Lastly, the least common education level is vocational, with only 5 farmers, or 9.6%, having pursued this type of education.

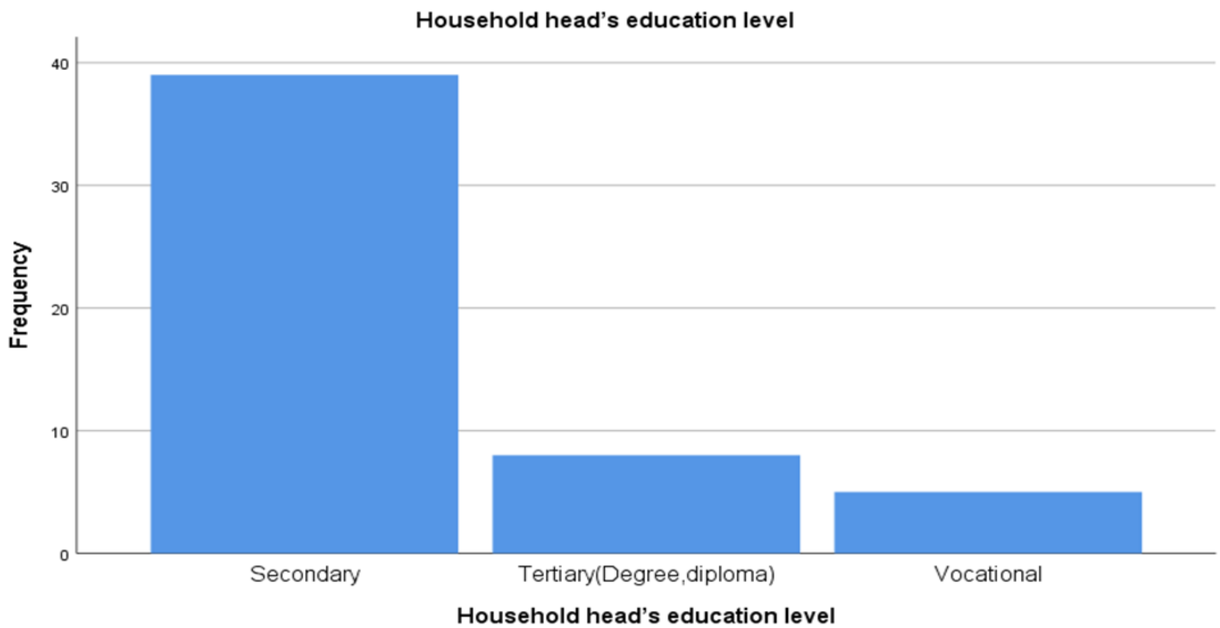

Fig. 9: The percentages of household heads' educational attainment are displayed in the bar graph that follows.

Education plays a key role in how smallholder farmers respond to climate change. It significantly affects their ability to manage and adjust to the impacts of climate change on their crops and income. The longest bar in the graph shows that many farmers only have a secondary education. This may make it harder for them to cope with climate change effects, and they often have limited access to relevant information.

As climate change continues to pose risks, the productivity and income of smallholder farmers could decline. This situation may lead to a lack of understanding about the causes and effects of climate change. New agricultural practices aimed at resilience, such as conservation agriculture and agroforestry, can help farmers adapt. However, these methods might be challenging for them to adopt. Consequently, farmers' productivity and income are more vulnerable to climate-related events like droughts and floods, which can seriously threaten their livelihoods.

Unfortunately, the shorter bars in the graph indicate that many smallholder farmers may struggle to reach higher education levels. Achieving tertiary and vocational education is essential for stabilizing their output and income against climate change. Such education equips farmers with the knowledge and skills necessary to handle climate change effects. Stern (2007) notes that educated smallholder farmers are more capable of making informed farming decisions. This includes choosing climate-resilient crop and animal varieties and implementing conservation agriculture techniques.

Finally, smallholder farmers with higher education levels are more likely to access information and communication technologies (ICTs), such as computers and smartphones. These tools provide them with important information on market prices, weather forecasts, and climate change (FOA, 2017). By leveraging this knowledge, farmers can make better decisions and improve their productivity and income stability.

4.2: Average maize yield among surveyed farming households

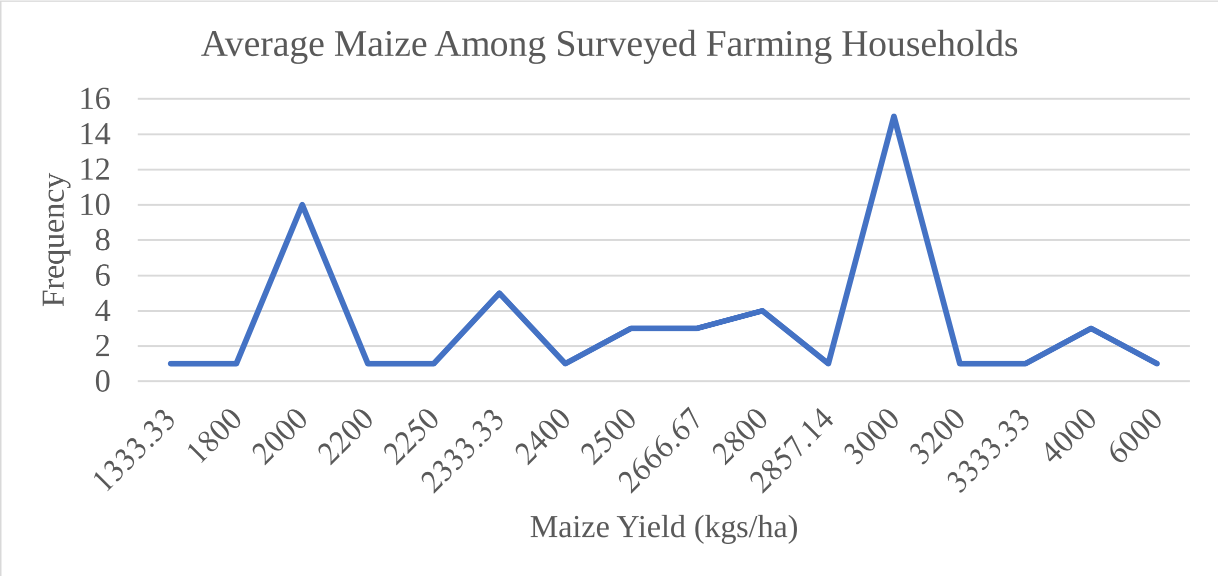

Fig. 10: The line graph below shows the distribution of maize yield (kg) for the sample studied.

Maize productivity is a key issue in the context of climate change because higher temperatures and changing weather patterns can greatly affect crop yields. The line graph above shows a wide range of maize yields, from 1333.33 kg to 6000 kg. According to the data in the figure, a significant number of farmers appear to have yields between 2000 kg and 3000 kg, making up 29% of the total sample. This suggests that these are not major failures, but rather suboptimal yields caused by factors such as water stress and extreme temperatures. The data also shows that a few cases in the lower yield categories, like 1333.33 kg and 1800 kg, indicate that some farmers are achieving less than ideal yields. These issues might reflect the impacts of climate change, such as droughts, unpredictable rainfall, poor soil quality, or increased pest and disease problems.

4.2.1: Adaptation Strategies used to compart climate change impacts on maize productivity.

Table 9: Shows average maize yield (kgs/ha) for each adopted sustainable agricultural technology

Sustainable Agricultural Technologies adopted	Average maize yield (kgs)/ha per each technology adopted
Crop Diversification	2666.67
Drought Tolerant Varieties	3200.00
Irrigation or other water management practices	4000.00
Conservation agricultural practices	3000.00

The data in the table above show various sustainable agricultural technologies and their average maize yield (kgs/ha) for each method. Reports indicate that crop diversification, which involves growing different types of crops to reduce risk, minimize reliance on one crop, and enhance farm resilience, can yield 2666.67 kg per hectare. This amount suggests that while crop diversification may not maximize maize productivity, it still delivers a decent yield compared to other methods. The findings indicate an average yield of 3200.00 kg/ha, which is relatively high. This suggests that this technology helps farmers maintain reasonable productivity even amid water stress. Drought-tolerant varieties are crucial in regions with irregular rainfall and frequent droughts. Many farmers prefer this technology because it strikes a good balance between improving productivity and climate resilience. The higher yield from drought-tolerant varieties compared to crop diversification also shows their effectiveness in stabilizing productivity under climate stress. Water management and irrigation systems appear to have the greatest impact on increasing maize yield. The highest average maize yield of 4000.00 kg/ha among the methods studied indicates that these approaches significantly boost maize productivity, even though they are not widely adopted, possibly due to infrastructure or financial challenges. However, these strategies could gain wider use and potentially further enhance agricultural productivity if access to affordable irrigation technologies improves. With a maize yield of 3000.00 kg/ha, conservation agriculture (CA) methods, which often involve crop rotation, minimal tillage, and soil health management, perform better than crop diversification but not as well as drought-tolerant varieties and irrigation systems. This yield suggests that conservation agriculture offers moderate benefits to productivity. These practices are noted for supporting long-term soil health and preventing erosion. While yields may not match those achieved through irrigation, they are still significant regarding sustainability.

4.3: Data presentation and analysis for objective 1

Objective 1: To quantify the impacts of Sustainable Agricultural Technologie and Farming factors on agricultural productivity of staple maize for farming households

Table 10: Shows Multiple linear regression analysis data

Model	B	Regression Coefficient (Beta)	Standard Error	t-value	p-value
Constant	2040.87		858.43	2.38	0.02
Household head age	24.63	0.36	18.65	1.32	0.19
Household head’s education level	-71.29	-0.06	180.62	-0.40	0.70
Household farming experience	-39.76	-0.35	30.55	-1.30	0.20
Crop diversification	113.74	0.08	234.93	0.48	0.63
Drought tolerant varieties	73.94	0.03	403.23	0.18	0.86
Irrigation or other water management strategies	249.40	-0.17	240.27	-1.04	0.31
Conservation agricultural practices	-340.75	-0.19	313.80	-1.09	0.28
basal fertilizer application rate	0.64	0.21	1.02	0.62	0.54

Top dressing fertilizer application rate	0.28	0.07	1.29	0.22	0.83
Farmer's management practices	224.86	0.12	272.95	0.82	0.42

Multiple Linear Regression Model description

Multiple Linear Regression Model:

$$\mathbf{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + e}$$

Where:

Y (Independent variable) = Agricultural productivity of maize (measured in kgs/ha)

β0 = Intercept of the regression model (the expected productivity when all independent variables are zero, i.e., no adoption of the technologies)

β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9, and β_{10} are regression coefficients that represent the change in productivity associated with the adoption of each technology (measured in terms of kg/ha of maize yield).

X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, and βX_{10} are parameters that represent the independent variables (adopted sustainable agricultural technologies, e.g., crop diversification, drought-tolerant crops, irrigation or other water management practices, conservation agricultural practices, fertiliser application rate, and the farmer’s management practices).

e = Error term (captures the unobservable factors affecting maize productivity that are not included in the model).

Therefore, the econometric model can be mathematically represented as shown below:

$$\mathbf{Y = 2040.87 + 24.63X_1 - 71.29X_2 - 39.29X_3 + 111.74X_4 + 73.94X_5 + 249.40X_6 - 345.75X_7 + 0.64X_8 + 0.28X_9 + 224.86X_{10} + e}$$

The regression results above examine how various demographic and farming factors relate to climate adaptation strategies. These factors include the household head's age, education level, farming experience, fertilizer application rates, crop diversification, drought-tolerant varieties, irrigation or other water management strategies, and conservation agricultural practices. This regression analysis aims to determine whether changes in these demographic and farming practices, along with the adoption of climate adaptation strategies, significantly impact maize yields, especially in the context of climate change.

The regression coefficients represent the change in the dependent variable for a one-unit change in each independent variable while keeping other factors constant. The findings indicate a baseline maize yield of about 2040.87 kg/ha with a p-value of 0.02 when no adaptation strategies or other farming and demographic factors are used. This value is statistically significant at the 5% level.

The age of the household head has a p-value of 0.19 and a positive coefficient of 24.63, indicating that maize productivity tends to increase with the household head's age, likely due to accumulated experience. However, since the relationship is not statistically significant, age may not be a reliable indicator of productivity on its own.

The education level of the household head shows a p-value of 0.70 and a coefficient of -71.29. The negative coefficient is surprising, as a higher education level is usually linked with better farming practices. Most studies, including one by Ogundari, K. and Bolarinwa, O. D. (2018), find that education is positively associated with productivity and technology adoption. The lack of statistical significance here suggests that education level does not measurably impact maize productivity.

Household farming experience has a p-value of 0.20 and a coefficient of -39.76, indicating that more farming experience correlates with lower productivity. This may stem from relying on conventional practices instead of newer technologies. Other studies, such as one by Shehu, J. F. and others (2010), indicate that experience is often linked to productivity but note that the effect can be minor. However, this result is also not statistically significant.

Crop diversification shows a positive coefficient of 113.74 and a p-value of 0.63, suggesting that diversifying crops may lead to increased maize productivity, perhaps through improved soil health and better risk management. Yet, the high p-value indicates this effect is not statistically significant in this model. This finding aligns with research by Kansiime, M. K. and others (2018), which suggests crop diversification typically leads to higher income and lower risk.

According to Fisher, M. and others (2015), adopting improved or drought-tolerant varieties generally leads to higher yields and income, supporting these results. The results for drought-tolerant varieties show a positive coefficient of 73.94 and a p-value of 0.86. This suggests that using drought-tolerant maize varieties may enhance productivity, especially under water stress. However, the small coefficient and high p-value indicate that this strategy does not have strong statistical support here, possibly due to limited adoption or other influencing factors.

Irrigation shows practical benefits with a positive coefficient of 249.40, but a p-value of 0.31 does not indicate a statistically significant relationship with maize productivity. The coefficient suggests a potential yield increase of over 1000 kg/ha for farmers using irrigation or other water management techniques.

For conservation agricultural practices, there is a p-value of 0.28 and a negative coefficient of -340.75. Generally, conservation agriculture improves soil health and productivity with methods like cover crops and minimal tillage. The negative coefficient here may indicate challenges in implementation or short-term yield drops during the transition to fully adopting conservation agriculture principles. This practice does not show a statistically significant impact on maize productivity.

The basal fertilizer application rate has a coefficient of 0.64 and a p-value of 0.54. While the positive coefficient aligns with expectations that basal fertilizer supports early growth, the small size and non-significant p-value suggest a limited effect in this context. The top-dressing fertilizer application rate has a coefficient of 0.28 and a p-value of 0.83. This indicates that top dressing may provide nutrients during critical growth periods. The small coefficient and high p-value imply that its effect on maize productivity is minimal in this study.

Finally, the farmer's management practices show a coefficient of 224.86 and a p-value of 0.42. Effective management is important for optimizing inputs and responding to environmental conditions. The positive coefficient suggests potential benefits, but the lack of statistical significance points to the need for more detailed data on specific management strategies.

The coefficients indicate that drought-tolerant varieties, irrigation, crop diversification, fertilizer application rates, farming management practices, and age generally have positive effects on productivity. In contrast, conservation agriculture and farming experience seem to have neutral to slightly negative effects on yield. None of the adaptation strategies included in the model are statistically significant at the 5% level. These results differ from existing literature, which may stem from the small sample size.

Table 11: Multiple Regression Model Summery

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.46[a]	0.21	0.01	728.88

Predictors: Constant, farmer's management practices, household head's age, farming experience, drought-tolerant varieties, fertiliser application rate (basal and top dressing), irrigation or other water management practices, crop diversification, conservation agricultural practices.

The regression model summary table above shows key statistics that help evaluate the strength and quality of the model. It explains the relationship between household and farming factors, climate adaptation strategies, and maize productivity. The data indicates a correlation coefficient (R) of 0.46, suggesting a moderate positive relationship between the observed and predicted maize productivity values. This means that as the predicted values go up, the observed values generally increase as well, though not perfectly. The R^2 value of 0.21 suggests that about 20.9% of the variability in maize productivity can be explained by the independent variables in the model. While this shows some explanatory power, a significant 79.1% of the variability remains unexplained, indicating that other factors may also influence maize productivity. The model only accounts for around 1.1% of the variability when looking at the number of predictors. The adjusted R^2 of 0.01 is much lower than the R^2, indicating that some variables might not be effectively contributing to the model and could be adding noise instead. Finally, a standard error of 728.88 shows that actual maize productivity values differ from the predicted values by an average of about 729 units. This level of error can be significant, depending on the context of maize productivity, suggesting that the model's predictions might not be very precise.

Table 12: Shows the analysis of variables used in the multiple linear regression model

Source	DF	SS	MS	F	Sig (p-value)
Regression	10	5601083.52	560108.35	1.05	0.42[b]
Residual	40	21250522.68	531263.07	-	-
Total	50	26851606.20	-	-	-

The ANOVA (Analysis of Variance) table above breaks down the climate adaptation strategies as explained by the independent variables. The sum of squares (SS) shows the variation in the data and the regression. SS (5601083.52) indicates the variation explained by the independent variables, while the residual SS (21250522.68) reveals the variation that the model cannot explain. The MS helps us understand the average variation each source contributes, including regression and residual.

To determine if the independent variables collectively explain the variation in maize productivity, the F-value (1.05) compares the explained variance (regression) to the unexplained variance (residual). The p-value is 0.50, significantly higher than the usual significance level of 0.05, and the F-statistic is 1.05, which is low based on the data. These results suggest that adopting these strategies (crop diversification, drought-tolerant varieties, irrigation, and other water management strategies, along with factors like age and farming experience) might not be the main reasons for variations in maize productivity. However, other research suggests that factors such as soil fertility, pest management, and environmental conditions could play a significant role that is not accounted for here.

4.4: Data presentation and Analysis for Objective 2

Objective 2: To analyse the economic impacts of climate change on farmers' income stability

To examine the economic effects of climate change on smallholder farmers' income stability in Marange, Mutare, we did a descriptive statistical analysis. This analysis looked at frequencies, means, medians, modes, standard deviations, and percentages for the following climate factors: droughts, floods, and heatwaves.

Table 13: Shows climate change impacts on agricultural productivity

Climate change impacts (Factors)	Frequency	Percentage
Droughts	36	69.20
Floods	8	15.40
Heatwaves	8	15.40
Total	52	100.00

The data above shows how often smallholders reported income instability from climate-related shocks. Droughts have a frequency of 36 and a percentage of 69.2%. Smallholder farmers most often mention droughts as a climate shock. In fact, 69.2% of respondents say that droughts have impacted their ability to make a living.

Floods are the second most common climate-related event mentioned by farmers, with 15.4% of respondents noting their effects on income. Floods can lead to significant losses for smallholder farmers by destroying livestock, infrastructure, and crops. According to the data, around 15.4% of all respondents indicated that heatwaves affect their crop and livestock production. These heatwaves threaten their ability to maintain a stable income and are impacting the financial stability of smallholder farmers.

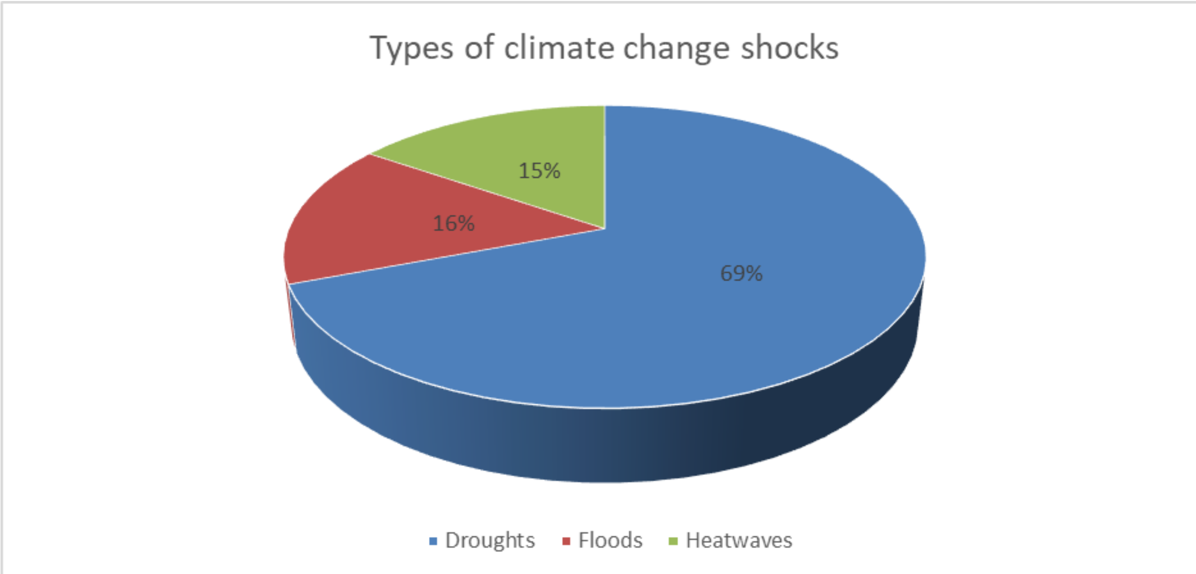

Fig 11: The pie chart below shows climate-related shocks that are impacting income stability for smallholder farmers.

The data presented in the pie chart above shows that climate change impacts, including droughts, floods, and heatwaves, are causing income instability for smallholder farmers in Marange, Mutare. Droughts are the biggest threat to farmers' income stability. Water scarcity is a major issue for many smallholder farmers, as 69% of respondents reported droughts as the most significant impact. Due to the drop in agricultural productivity caused by climate change, many smallholder farmers are likely already experiencing long-term declines in income stability. These farmers often lack access to resources like irrigation, drought-resistant crops, and financial support to mitigate the effects of droughts. This vulnerability is especially pronounced in developing countries like Zimbabwe.

These findings align with existing research, which indicates that droughts are the leading climate-related challenge for smallholder farmers, especially in Sub-Saharan Africa, South Asia, and other semi-arid regions. The FAO (2016) states that drought is the most common cause of food shortages in developing nations. Speranza et al. (2010) report that smallholder farmers in Kenya view droughts as the most frequent and serious threat. Heat waves and floods also pose growing risks to the livelihoods of smallholder farmers. While farmers report these events less frequently, with each accounting for only 15.4%, this suggests that they may occur less often in the surveyed areas. However, recent studies indicate that these events are becoming more common and impactful, particularly regarding crop yields and livestock health.

Research supports this; for example, Thornton et al. (2014) highlight the rising importance of heat stress in African agriculture. As climate change worsens, these occurrences may become more frequent, increasing the vulnerability of smallholder farmers in the future. The data clearly shows that droughts are the primary climate shock affecting income stability for smallholder farmers, and literature throughout the globe, especially in Africa and dryland regions, reinforces these results. Heat waves and floods follow in significance. Even though these factors are often underreported, their impact is rising as the climate continues to change. To help smallholder farmers cope with the challenges of a changing climate, we urgently need targeted strategies for adaptation, financial support, and capacity-building initiatives. These climate change impacts pose a serious threat to income stability.

Table 14: Shows impacts of climate change on income stability.

Climate Change impacts on farmer's income stability	Frequence	Percentage
Reduced income from crop sales	19	38.50
Increased costs for inputs (e.g., fertilisers and seeds)	4	7.70
Reduced income from crop sales and increased input costs	15	28.80
Reduced income from crop sales, increased input costs and labour	6	11.50
Total	52	100

From the table above, the data shows that the largest group of respondents, 38.5%, reported lower income from crop sales due to climate. This suggests that climate-related events like droughts, floods, or unpredictable rainfall patterns are directly decreasing crop yields. As a result, farmers can sell less produce, which ultimately lowers their income. According to the data, 7.7% of farmers face higher input costs because of climate change, including costs for seeds and fertilizers. Additionally, 28.8% of farmers reported both lower crop sales revenue and higher input costs. This indicates that changes in climate have combined effects on farmers' income stability, reducing income from crop sales while also increasing their costs. Climate change is also raising labour costs for farmers. According to the statistics mentioned, 15.5% of farmers reported reduced income because of increased labour costs. This further undermines farmers' income stability due to the rise in total farm production costs.

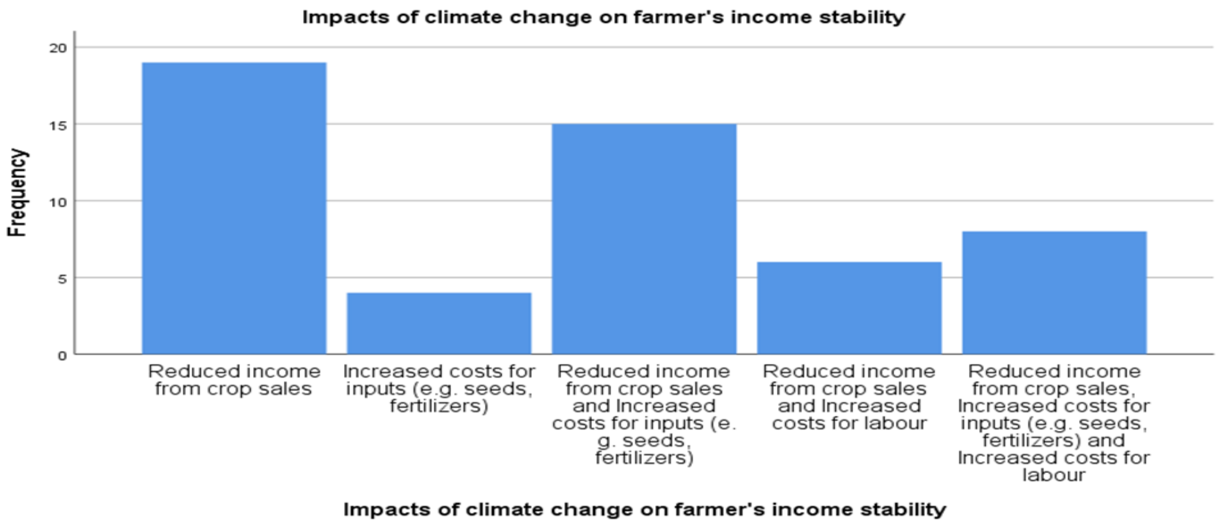

Fig. 12: The bar chart below shows the impacts of climate change on smallholder farmer's income stability.

From the data shown in the bar chart above, it is clear that climate change contributes significantly to income instability for smallholder farmers. This finding agrees with existing research, as many studies indicate that increased climate variability, including droughts, floods, heatwaves, and other unpredictable weather patterns, likely leads to crop failures and lower yields. This situation creates a greater need for adaptation strategies, which ultimately reduce the overall income from crop sales. According to FAO (2016), "Climate change is causing declining yields and crop failures, reducing incomes for smallholder farmers."

Wheeler and von Braun (2013) stated, "Reduced and unstable crop yields due to climate change are a major driver of smallholder income instability," and this aligns well with my findings for this research objective. Climate change also lowers productivity and raises input costs and labour needs. All these factors decrease the profitability and sustainability of farming. Olayide et al. (2016) noted, "Farmers are compelled to use more inputs to cope with climate variability, increasing production costs." This view is also reflected in the work of Khatri-Chhetri et al. (2017), who mentioned that "Labour requirements for adaptation to climate change can increase, adding to the financial burden on smallholders."

Smallholder farmers face rising operational costs, such as labour expenses for managing crops affected by changing climate conditions and higher costs for inputs like fertilizers, seeds, and pesticides. They also experience direct losses from lower crop sales. These increasing costs can further strain farmers' livelihoods, especially if their incomes are already dropping. This financial pressure may force farmers to cut back on investments aimed at boosting farm productivity, worsening their income instability and trapping them in a cycle of declining productivity.

Moreover, the data highlights the interconnected impacts of climate change on farmers' income stability. As indicated by the figure above, it's not just about lower yields; there are cascading effects on input costs and labour requirements that make it even harder for farmers to recover financially from climate change. The combined effects are most severe for those respondents who report three issues: reduced income, higher input costs, and increased labour costs. These farmers are likely experiencing the greatest income instability.

Thus, my findings are well supported by the broader literature. Most studies agree that reduced income from crop sales is the main impact, followed by increased input costs and, to a lesser but growing degree, higher labour costs from adaptation efforts. The presence of these combined impacts in my data is also well documented. However, addressing this issue calls for focused climate adaptation strategies, financial support, and policy changes to help smallholder farmers cope with evolving conditions and secure their income stability.

4.5: Data presentation analysis for objective 3

Objective 3: To identify adopted sustainable agricultural practices that can mitigate the adverse impacts of climate change.

To study the sustainable farming practices used by smallholder farmers to reduce the negative effects of climate on crop yields and income stability in Marange, descriptive statistics were carried out. The analysis included statistical elements like frequencies, means, medians, and percentages for different sustainable agricultural practices such as agroforestry, conservation agriculture, soil conservation, and infield water harvesting.

Table 15: Shows sustainable agriculture practices adopted by smallholder farmers in Marange

Climate adaptation strategies	Households number	Frequence (N)	Percentage (%)
Soil conservation	52	8	15.40
Conservation agriculture	52	43	83.70
Agro-forestry	52	2	3.80
Infield water harvesting (e.g. tied ridges, potholing)	52	11	21.20

The data provided above shows how smallholder farmers in Marange, Mutare, are adopting climate adaptation strategies. The table indicates that the most common strategy is conservation agriculture (CA), used by 83.7% of respondents, or 43 out of 52 farmers. Infield water harvesting techniques, such as tied ridges and potholing, follow next, used by 21.2%, which is 11 out of 52 respondents. Soil conservation practices are reported by 15.4% of farmers, or 8 out of 52. Additionally, agroforestry, which includes integrating trees into farming systems, is the least adopted strategy, with only 3.8% of respondents, or 2 out of 52, practicing it.

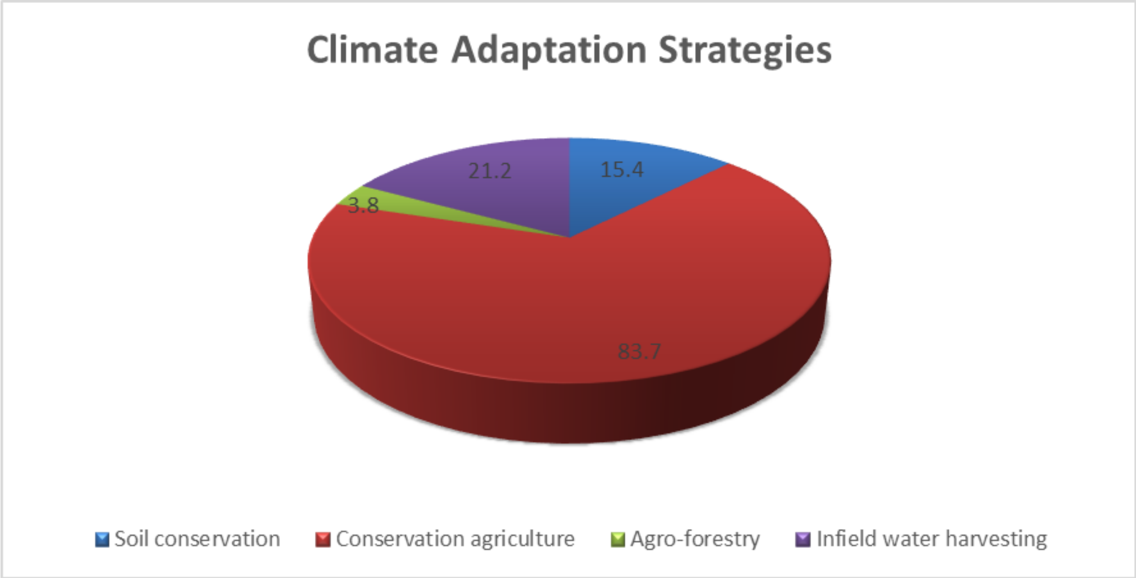

Fig. 13: The pie chart below shows climate adaptation strategies (sustainable agricultural practices) adopted by smallholder farmers in Marange.

The information above highlights how important sustainable farming methods are for adapting to climate change. The popularity of conservation agriculture (CA) as a climate-resilient farming method shows in its high adoption rate. Research in various areas supports this, as conservation agriculture is promoted as a key tactic due to its benefits for soil health and moisture retention. Mango, N., Siziba, S., and Makate, C. (2017) found that conservation agriculture was widely adopted in areas where extension services and NGOs encouraged the practice, with adoption rates between 60% and 85% in targeted districts. This strongly supports my findings on the widespread adoption of conservation agriculture in the Marange rural area, where 83.7% of the population reported using conservation agriculture, mostly pfumvudza. As climate change increasingly affects agricultural productivity, practices like minimal tillage, cover cropping, and crop rotation can reduce soil erosion, increase moisture retention, and improve soil health. The fact that 83.7% of respondents practice CA suggests this strategy is not only effective for adapting to climate change but also practical for most farmers, especially in areas where soil degradation is a major concern.

Additionally, even though only 21.2% of farmers use infield water strategies, these methods are still vital in areas with unpredictable rainfall or during droughts. They help farmers capture and store water on-site, boosting crop resilience during dry spells. However, the relatively low adoption rate may point to challenges related to costs or the technical support needed to implement these practices widely. Despite the recognition that soil conservation is critical for sustainable agriculture, its low adoption rate of 15.4% indicates that farmers might see it as more expensive or labour-intensive compared to other methods. To adopt longer-term soil conservation techniques, farmers may face obstacles like limited access to training, financial constraints, or insecurity of land tenure.

Nonetheless, results for soil and water conservation align with existing literature, including findings from Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., and Herrero, M. (2013). They reported that 22% and 18% of households in Kenya adopted soil and water conservation methods, respectively, which is similar to my results. Furthermore, the very low adoption of agroforestry (3.8%) may stem from barriers like space constraints, lack of technical knowledge, or high initial costs. These results align with findings by Muthee, K., Muriuki, J., and Muthini, D. (2017), who noted low adoption rates (5-12%), similar to my observations.

Agroforestry offers long-term benefits like increased biodiversity, carbon sequestration, and better soil health. However, because it may not provide immediate financial returns, it is less appealing to farmers seeking short-term profits. Mbow, C., Smith, P., Skole, D., Duguma, L., and Bustamante, M. (2014) stated, "Despite the recognised potential of agroforestry, actual adoption rates among smallholders are often below 10%, mainly due to lack of awareness and long-term returns."

Thus, my results for this objective closely align with findings from other research in sub-Saharan Africa and similar Agro-ecological zones, reflecting both the successes of promoted practices and the challenges faced by less-adopted strategies. This suggests my research is consistent with broader regional trends.

4.6: Data presentation and Analysis for objective 4

Objective 4: To examine the barriers faced by smallholder farmers in adapting to the impacts of climate change on agricultural productivity and income stability.

To look at the challenges smallholder farmers face in the Marange area of Mutare, we conducted a descriptive statistical analysis. We included statistical data like frequencies, means, medians, and standard deviations to study the data.

Table 16: Shows descriptive data on barriers faced by smallholder farmers on climate change adaptation in Marange.

Barriers to climate change adaptation	Number of surveyed farming households	Frequence	Percentage
Lack of financial Resources	52	50	96.20
Limited access to information and training	52	24	46.20
High upfront costs of climate smart technologies	52	47	90.40
Limited labour and skills to operate climate smart technologies	52	2	3.80

The data above highlights the challenges smallholder farmers face in dealing with climate change. The table shows that 96.2% of smallholder farmers in Marange see a lack of financial resources as the biggest barrier to adapting to climate change. For these farmers, this is the main obstacle. The data reveals that the high upfront costs of climate-smart technologies are a significant hurdle, which follows closely after the issue of financial resources. The initial investment for new technologies, such as irrigation systems and sustainable farming equipment, is often too high, even if farmers have some access to funds.

According to the data, 46.2% of smallholder farmers surveyed reported that another major challenge to adapting to climate change is the lack of information and training. This suggests that farmers struggle to find high-quality and useful information about climate-smart technologies and best practices, even if they have some access to information about climate change adaptation. Lastly, only 3.8% of farmers mentioned a lack of labour and skills as a barrier, showing that most farmers believe they can use climate-smart technologies once they are accessible.

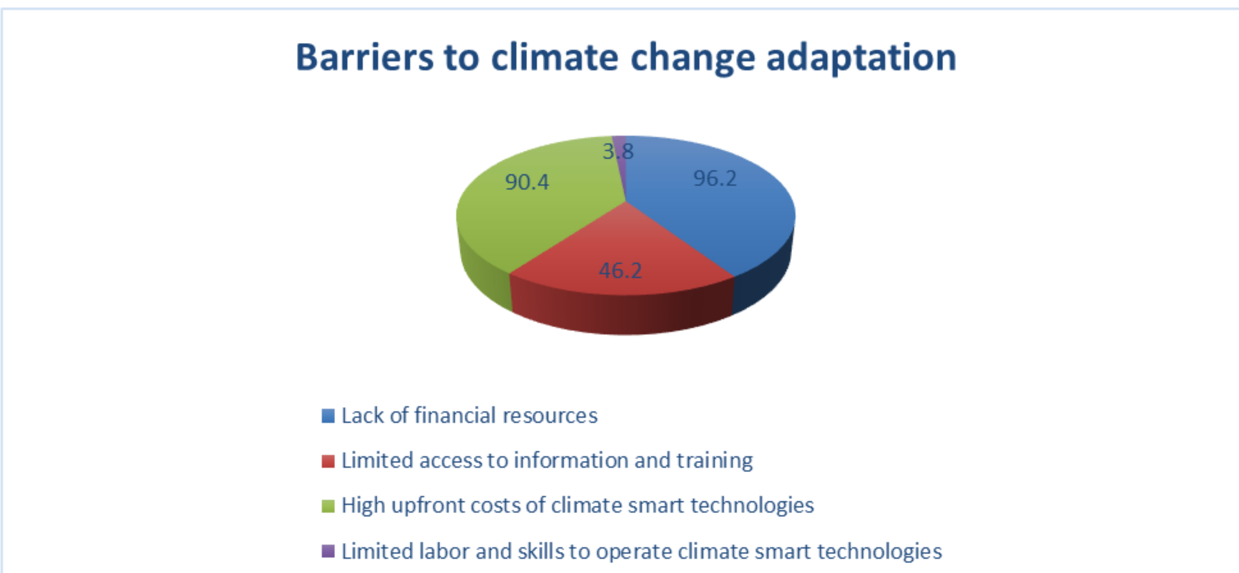

Fig. 14: The percentages of obstacles smallholder farmers in Marange face in adapting to climate change are displayed in the pie chart below.

The data presented highlights the major challenges smallholder farmers face in adjusting to climate change in Marange. The pie chart shows that the two main obstacles are the lack of financial resources (96.2%) and the high upfront costs of climate-smart technologies (90.4%).

These findings match existing research, which indicates that limited access to finance is the leading barrier for smallholder farmers in Africa, Asia, and Latin America. In Kenya and Ethiopia, lack of credit was often mentioned as the main hurdle to adaptation (Bryan et al., 2009). These two issues are interconnected. Even if farmers recognize the benefits of investing in climate-smart technologies, they might not have the funds for the initial investment. Due to their limited access to credit, loans, and investment options—often due to insufficient collateral—smallholder farmers struggle to adopt practices or buy technologies that could reduce the impacts of climate change. Without proper funding, farmers cannot purchase climate-smart seeds, enhance their infrastructure (like irrigation systems), or afford the initial costs of sustainable farming methods. My results align with existing literature, which commonly addresses the high costs of improved seeds, irrigation, and conservation agriculture. For example, Mertz et al. (2009) found significant cost barriers among West African farmers. To tackle this issue, we need financial support systems, such as microfinance and subsidies, that allow farmers to access the resources required for adapting to climate change.

Knowledge gaps and training also pose major problems for farmers as they cope with climate change. Limited access to training and information (46.2%) is an issue, but it is not as critical as financial obstacles. Many farmers, especially those in rural areas like Marange, may not be aware of climate-smart practices or may lack the skills to implement them. Research indicates that labour skills and availability can be more pressing challenges in some regions, particularly where migration or demographic changes lead to a decline in farm labour (below et al., 2012). This highlights the need for training programs and extension services that are more accessible and tailored to smallholders' needs. Lastly, a small percentage of farmers (3.8%) mentioned a lack of labour and skills as a barrier. This suggests that once resources are available, farmers generally feel capable of adopting climate-smart technologies, though this may vary by region and specific technologies.

Overall, these findings align with the literature, indicating that smallholder farmers in developing countries face numerous challenges in adapting to climate change. These challenges include insufficient funding, limited access to training and information, and high initial costs of climate-smart technologies (IPCC, 2014; UNFCCC, 2015). To support smallholder farmers in their efforts to adapt to climate change, it is vital to address these issues, particularly the funding gap and limited access to information and training.

4.7: CONCLUSION

In the Marange area of Mutare, Manicaland, Zimbabwe, smallholder farmers struggle to deal with climate change. This chapter explores how climate change impacts the agricultural productivity of staple maize, examines how it affects farmers' income stability, and identifies sustainable farming practices that can help reduce the negative effects of climate change. The findings discussed in this chapter show that climate change greatly impacts maize productivity, leading to lower crop yields and less stable incomes for farmers.

The study revealed that climate change has led to higher production costs, decreased income from crop sales, and increased vulnerability to climate-related shocks. Despite these challenges, the study identified several sustainable farming methods, such as infield water harvesting, agroforestry, and conservation agriculture, that can mitigate the adverse effects of climate change. However, several barriers hinder the widespread use of these practices, including a lack of funding, limited access to training and information, high initial costs of climate-smart technologies, and a shortage of labour and expertise to implement these technologies. Based on the analysis, I recommend that farmers invest more in climate-resilient agriculture. This includes promoting sustainable farming practices and providing access to climate data and early warning systems. I also suggest that lawmakers create policies and programs that address the challenges smallholder farmers face, such as funding gaps and limited access to information and training.

CHAPTER 5

CONCLUSIONS AND RECCOMMENTATIONS

5.0: Introduction

The main objective of this research was to examine the effects of climate change on agricultural productivity and income stability for smallholder farmers in Zimbabwe. It also looked at other factors that make it difficult for farmers to cope with climate-related challenges that negatively affect their farming operations and income. The study collected first-hand information through field surveys, allowing researchers to hear directly from people facing the challenges of climate change in their daily lives. This chapter presents recommendations and conclusions based on a review of relevant literature and findings from the empirical study.

5.1: Conclusion

This study assessed how climate change affects smallholder farmers' income stability and agricultural productivity in Zimbabwe. The data analysis revealed that maize productivity is significantly affected by climate change, which leads to lower crop yields and threatens farmers' income stability. The increase in frequency and severity of extreme weather events, such as prolonged droughts and heavy rainfall, is linked to this decline in productivity. These events disrupt planting and harvesting schedules, reduce soil fertility, and cause crop failures.

The economic impact of climate change on farmers' income stability was profound. Many farmers reported lower income from crop sales due to decreased agricultural yields. The data indicated that farmers face a combination of reduced income and rising costs, which worsen their vulnerability to climate-related risks. These economic issues stem not only from poor yields but also from the high costs of adopting climate-smart practices without enough financial support. Consequently, as climate change makes agricultural production less stable and predictable, income stability has emerged as a serious problem, pushing farmers into cycles of poverty and food insecurity.

Furthermore, the research identified several key barriers that prevent smallholder farmers from fully implementing climate adaptation strategies like irrigation systems. Lack of financial resources stands out as the most significant barrier, with many farmers citing it as a major challenge. This issue limits their ability to invest in climate-smart technologies, such as drought-resistant seeds, and hampers their capacity to respond effectively to climate change. While some also point to limited access to information and extension services as barriers, the lack of financial resources remains the critical challenge preventing farmers from addressing climate-induced issues in their businesses.

Finally, despite these many barriers, the study found that sustainable agricultural practices, such as conservation agriculture and agroforestry, were adopted to mitigate the impacts of climate change. These practices improve soil health, water retention, and biodiversity, helping to maintain productivity during climatic stresses. The data collected and analysed in this thesis can provide valuable information to policymakers. This can assist them in creating inclusive policies that meet the needs of smallholder farmers and other marginalized groups, like women, facing the impacts of climate change on Zimbabwe's agricultural sector.

5.2: Policy Recommendations

Based on the findings of this research, several recommendations can be made for policymakers to help smallholder farmers adapt to the impacts of climate change and improve their agricultural and income stability.

5.2.1: Financial Support and Access to Credit

Since financial resources play a crucial role in enabling farmers to adopt climate-smart technologies, there is a need for subsidized loans, microfinance programs, and incentives to make climate-resilient practices more accessible to smallholder farmers.

5.2.2: Improved Extension Services and Training

Improving access to information and capacity-building programs is vital for equipping farmers with the knowledge and skills necessary to implement sustainable agricultural practices, especially in rural areas. Additionally, extension services should be expanded with a focus on practical training in climate adaptation technologies, soil management, and efficient water use.

5.2.3: Incentives for Sustainable Practices

Policymakers should create incentives for smallholder farmers who adopt sustainable agricultural practices, such as conservation agriculture and agroforestry. These incentives can include tax breaks, subsidies, or technical assistance, encouraging greater adoption of these practices.

5.2.4: Insurance and Risk Mitigation

Insurance is essential for protecting against the financial impacts of climate-related events. Policymakers should develop weather-indexed insurance schemes tailored to smallholder farmers, providing a safety net against crop failure due to droughts, floods, or other extreme weather events.

5.3: Areas of Further Research

This research addressed key issues regarding the impacts of climate change on agricultural productivity and income stability, not just in Zimbabwe's agricultural sector but also in other developing countries reliant on agriculture. While this study contributes to understanding the current situation, several areas still require further exploration to improve knowledge and inform better adaptation and policy decisions. The following areas warrant further investigation:

5.3.1: Climate Change Impacts on Specific Crops and Livelihoods

While the general impact of climate change on agriculture is well understood, more specific studies are needed to understand how different crops, such as tobacco and cotton, and livestock are affected under various climate scenarios. Research could investigate crop-specific vulnerabilities, focusing on how climate change impacts staple crops like maize, millet, and sorghum in Zimbabwe. Further studies should also explore the effects of climate change on the livelihoods of women and other marginalized groups, examining how climate-induced disruptions disproportionately impact vulnerable populations, including women, children, and disabled individuals in agricultural communities, particularly given the gendered nature of agricultural work in Zimbabwe.

5.3.2: Economic Modelling of Climate Change Impacts on Agricultural Income

Research on the economic impacts of agricultural income remains a vital area for further study. Potential studies could examine income stabilization mechanisms like social safety nets and government subsidies to see how they might mitigate climate change effects on smallholder farmers' incomes. Researchers could also investigate the cost and benefit of various adaptation strategies from an economic perspective, providing a clearer understanding of how these strategies affect long-term farm income stability.

5.3.3: Climate Finance and Investment

To adapt effectively to climate change, smallholder farmers in Zimbabwe often need access to financial resources. Research could explore climate finance mechanisms, looking at the availability and accessibility of climate finance from international funds, government programs, and private investors for smallholder farmers in Zimbabwe.

5.3.4: Social and Cultural Impacts of Climate Change on Agricultural Communities

Understanding social and cultural dynamics is crucial for analysing climate change effects on agricultural communities. Research could examine how climate-induced migration or displacement affects rural agricultural communities in Zimbabwe. Additionally, studies could investigate cultural perceptions of climate change by looking at local knowledge systems and practices related to climate adaptation in Zimbabwe, assessing how these can complement scientific approaches.

5.4: Limitations

During the research process, the researcher faced challenges like the lack of financial resources for data collection. To address this, structured online survey questionnaires were used to reduce costs, particularly transport expenses. The researcher also encountered time constraints when writing the thesis draft. To overcome this, the researcher worked during semester breaks to continue writing and to collect and analyse data for the research project.

REFERENCES

1. Below, T.B., et al. (2012) ‘Can farmers’ adaptation to climate change be explained by socio-economic household-level variables?’, Global Environmental Change, 22(1), pp. 223-235.

2. Bryan, E., Deressa, T.T., Gbetibouo, G.A. and Ringler, C. (2009) ‘Adaptation to climate change in Ethiopia and South Africa: options and constraints’, Environmental Science & Policy, 12(4), pp. 413-426.

3. Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S. and Herrero, M. (2013) ‘Adapting agriculture to climate change in Kenya: household strategies and determinants’, Journal of Environmental Management, 114, pp. 26-35.

4. Carleton, T.A. and Hsiang, S.M., 2016. Social and economic impacts of climate. Science, 353(6304), p. aad9837.

5. Dube, N., Sithole, M., Ngwenya, T., Muhwati, T., Moyo, E. & Manyanga, K., 2018. Impact of climate change on sustainability in semi-arid, rural Africa: Lessons from rural Zimbabwe. Cogent Social Sciences, 4(1), p.1553327.

6. Fischer, G., Shah, M., Tubiello, N. & Van Velhuizen, H., 2005. Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990–2080. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1463), pp. 2067-2083.

7. Fisher, M., et al. (2015) ‘Drought-tolerant maize for farmer adaptation to drought in sub-Saharan Africa: determinants of adoption in eastern and southern Africa’, Climatic Change, 133, pp. 283-299.

8. Hatfield, J.L., Boote, K.J., Kimball, B.A., Ziska, L.H., Izaurralde, R.C., Ort, D., Thomson, A.M. and Wolfe, D., 2011. Climate impacts on agriculture: implications for crop production. Agronomy journal, 103(2), pp.351-370.

9. Jiri, O., Mafongoya, P.L. & Chivenge, P., 2017. Building climate change resilience through adaptation in smallholder farming systems in semi-arid Zimbabwe. International Journal of Climate Change Strategies and Management, 9(2), pp.151-165.

10. Kansiime, M.K., et al. (2018) ‘Crop diversification as a potential strategy to mitigate food insecurity among smallholder farmers in Africa: a review’, Agriculture & Food Security, 7(1), pp. 1-15.

11. Kaponda, T. and Chiwaridzo, O.T., 2024. Enhancing Food Security Through Sustainable Agriculture: A Case Study of the Pfumvudza/Intwasa Program in Zimbabwe. In Sustainable Practices for Agriculture and Marketing Convergence (pp. 251-280). IGI Global.

12. Kucharik, C.J. and Serbin, S.P., 2008. Impacts of recent climate change on Wisconsin corn and soybean yield trends. Environmental Research Letters, 3(3), p.034003.

13. Khatri-Chhetri, A., et al. (2017) ‘Sources of climate risk and climate-smart agriculture options for smallholder farmers in South Asia’, Climate Risk Management, 16, pp. 124-136.

14. Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimah, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K. and Hottle, R., 2014. Climate-smart agriculture for food security. Nature Climate Change, 4(12), pp.1068-1072.

15. Mango, N., Siziba, S. and Makate, C. (2017) ‘The impact of the adoption of conservation agriculture on smallholder farmers’ income in Zimbabwe: a case study of Mashonaland West Province’, Journal of Agricultural Science, 9(4), pp. 57-69.

16. Mano, R. and Nhemachena, C., 2007. Assessment of the economic impacts of climate change on agriculture in Zimbabwe: A Ricardian approach. World Bank Policy Research Working Paper, (4292).

17. Mashizha, T.M., 2019. Building adaptive capacity: Reducing the climate vulnerability of smallholder farmers in Zimbabwe. Business Strategy & Development, 2(3), pp.166-172.

18. Mbow, C., Smith, P., Skole, D., Duguma, L. and Bustamante, M. (2014) ‘Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa’, Current Opinion in Environmental Sustainability, 6, pp. 8-14.

19. Muthee, K., Muriuki, J. and Muthini, D. (2017) ‘Adoption of agroforestry among smallholder farmers in Kenya: a case of Nakuru County’, International Journal of Agriculture Innovations and Research, 5(6), pp. 2319-1473.

20. Moeletsi, M.E., Mellaart, E.A.R., Mpandeli, N.S. & Hamandawana, H., 2013. The use of rainfall forecasts as a decision guide for small-scale farming in Limpopo Province, South Africa. Journal of Agricultural Education and Extension, 19(2), pp.133-145.

21. Moyo, A., 2016. Dry times in Mutoko district. The Sunday Mail, 6 March 2016.

22. Muzerengi, T. & Tirivangasi, H.M., 2019. Small grain production as an adaptive strategy to climate change in Mangwe District, Matabeleland South, in Zimbabwe. Jamba: Journal of Disaster Risk Studies, 11(1), pp.1-9.

23. Mvumi, B., Donaldson, T. & Mhunduru, J., 1988. A report on baseline data available for Mutoko District, Mashonaland East Province. University of Zimbabwe, Harare.

24. Nadi, P.M., 2014. Climate change adaptation for smallholder farmers in rural communities: The case of Mkomazi Sub-Catchment, Tanzania. Dissertation submitted in fulfilment of the requirement for the title of Doktor der Wirtschaftswissenschaften (Dr. rer. pol.) at Carl von Ossietzky University of Oldenburg.

25. Ndebele-Murisa, M. & Mubaya, C., 2015. Climate change: Impact on agriculture, livelihood options and adaptation strategies for smallholder farmers in Zimbabwe. In Beyond the crises: Zimbabwe’s prospects for transformation, p.198.

26. Nhamo, G., 2009. Climate change: Double-edged sword for African trade and development. International Journal of African Renaissance Studies, 4(2), pp.117-139.

27. Nhemachena, C., 2007. Assessment of the economic impacts of climate change on agriculture in Zimbabwe: A Ricardian approach. Policy Research Working Paper. The World Bank Development Research Group, Sustainable Rural and Urban Development Team, July 2007.

28. Niang, I., et al. (2014) ‘Africa’, in: Climate Change 2014: Impacts, Adaptation, and Vulnerability. IPCC Fifth Assessment Report.

29. Nielsen, J.Ø. & Vigh, H., 2012. Adaptive lives. Navigating the global food crisis in a changing climate. Global Environmental Change, 22(3), pp.659–669.

30. Niles, M.T., Lubell, M. & Haden, V.R., 2013. Perceptions and responses to climate policy risks among California farmers. Global Environmental Change, 23(6), pp. 1752–1760.

31. Nkoana, E.M., Verbruggen, A. & Hugé, J., 2018. Climate change adaptation tools at the community level: An integrated literature review. Sustainability, 10(3), pp.1-21.

32. Nyahunda, L. & Tirivangasi, H.M., 2021. Harnessing of social capital as a determinant for climate change adaptation in Mazungunye communal lands in Bikita, Zimbabwe. Scientific, 4(1), pp.1-9.

33. Nyakwawa, M.G., 2017. From beg basket to bread basket, mobile money can provide an alternative. Development Finance Agenda (DEFA), 3(1), pp.22-24.

34. Ogundari, K. and Bolarinwa, O.D. (2018) 'Impact of education on agricultural productivity in Africa: a meta-analysis', Food Policy, 77, pp. 1-18.

35. Olayide, O.E., Tetteh, I.K. and Popoola, L. (2016) 'Differential impacts of rainfall and irrigation on agricultural production in Nigeria', Environment, Development and Sustainability, 18, pp. 1445-1464.

36. Sanz Fernandez, M.V., Stoakes, S.K., Abuajamieh, M., Seibert, J.T., Johnson, J.S., Horst, E.A., Rhoads, R.P. and Baumgard, L.H., 2015. Heat stress increases insulin sensitivity in pigs. Physiological Reports, 3(8), p.e12478.

37. Schlenker, W. and Roberts, M.J., 2009. Nonlinear temperature effects indicate severe damages to US crop yields under climate change. Proceedings of the National Academy of Sciences, 106(37), pp.15594-15598.

38. Sivakumar, M., 2021. Climate change, agriculture adaptation, and sustainability. In *Climate resilience and environmental sustainability approaches: Global lessons and local challenges*, pp. 87-109.

39. Speranza, C.I., et al. (2010) ‘Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya’, Climatic Change, 100, pp. 295-315.

40. The Stimuli-Actions-Effects-Responses (SAER) framework for exploring perceived relationships between private and public climate change adaptation in agriculture, 2018. Journal of Environmental Management, 209(1), pp.286–300.

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

42. Thornton, P.K., et al. (2014) ‘Climate variability and vulnerability to climate change: a review’, Global Food Security, 3(2), pp. 77-84.

43. Wall, E. and Smit, B., 2005. Climate change adaptation in light of sustainable agriculture. Journal of Sustainable Agriculture, 27(1), pp.113-123.

44. Wako, G., Tadesse, M. and Angassa, A., 2017. Camel management as an adaptive strategy to climate change by pastoralists in southern Ethiopia. Ecological Processes, 6(1), pp.1-12. 1. Nyakwawa, M.G., 2017. From beg basket to bread basket, mobile money can provide an alternative. Development Finance Agenda (DEFA), 3(1), pp.22-24.

45. Wangmo, N., Jambay, D., Dorji, U. & Katel, O., 2022. Climate change and water sources: A case of Phobjikha and Gangtey Gewog, Wangdue Phodrang Dzongkhag, Bhutan. Indonesian Journal of Social and Environmental Issues (IJSEI), 3(1), pp.37-48.

46. Wheeler, T. and von Braun, J. (2013) ‘Climate change impacts on global food security’, Science, 341(6145), pp. 508-513.

47. Zong, X., Liu, X., Chen, G. & Yin, Y., 2022. A deep-understanding framework and assessment indicator system for climate-resilient agriculture. Ecological Indicators, 136, p.10859

APPENDICES

Appendix 1: Household Survey Questionnaire

Introduction

Ngundu Ahashveroshi is a student at Bindura University of Science Education (BUSE). He is conducting a research project called Assessing the Impacts of Climate Change on Agricultural Productivity and Income Stability in Marange. We have randomly selected 100 households. The information collected in this study will be kept safe and used only for research purposes. Your answers will be confidential, and the analysis will not include individual names. No one will be able to identify you or what you shared in this interview. Thank you for agreeing to participate in this study. You can stop the interview at any time and can choose not to answer any questions you do not want to. If a household does not consent to an interview, thank them and get a replacement from a supervisor. If a household agrees to an interview, continue with the interview.

Consent

Respondent consent to participate in this research study. (1=Yes or 0=No)

Contact information (phone or email) ____

Survey Administration

1. Interviewer name: ____

2. Survey administrator's name:

3. Date of survey administration: ____

District ……………………………………. Ward……………………...

Village……………………………

Section 1: Demographic Information

1. Name: ____

2. Household head age: ____

3. Household head (gender): 1=Male 2=Female______________________

4. Household head's education level: 0=None 1=Primary 2=Secondary 3=Tertiary (Diploma, Degree) 4=Vocational

5. Household farming experience in years…………………….

6. Number of household members who provide labour for agricultural operations………………………………

7. Household size: ____

8. Farm size (acres/ha): ____

9. Main soil type 1=Clay soils 2=Sandy soils 3=Loamy soils 4=Sandy loam soils 5=Clay loam soils, other specified

10. Household has access to remittances. 1=yes 0=no

Section 2: Climate Change Perception

1. Have you noticed any changes in temperature or rainfall patterns in the past 10 years? (Yes/No)

2. How concerned are you about climate change impacts on your farm? (Scale: 1-5) 1=Not concerned 5=Very concerned…………………

3. Have you experienced any climate-related shocks (droughts, floods, heatwaves) in the last 5 years? (Yes/No)

Section 3: Agricultural Resilience

1. What coping mechanisms do you use to adjust to climate variability? (Check all that apply.)

   1. Drought-tolerant crops 1=yes 0=no

   2. Diversification: 1=Yes 0=No

3. Irrigation: 1=Yes 0=No

4. Crop insurance: 1=Yes 0=No

5. Soil conservation: 1=Yes 0=No

6. Conservation Agriculture: 1=Yes 0=No

7. Agroforestry: 1=Yes 0=No

8. Infield water harvesting (tied ridges, potholing, infiltration pits, dead level contours): 1=Yes 0=No

9. Growing fodder crops (Mucuna, lablab, Bana grass, etc.): 1=Yes 0=No

10. Other (please specify).

____

2. How often do you adopt new farming practices? (Scale: 1-5, 1=Rarely, 5=Often)

3. Have you experienced any crop or livestock losses due to climate-related events? (Yes/No)

Section 4: Economic Sustainability

1. What is your annual farm income? ($______________)

2. How stable is your farm income? (Scale: 1-5) 1=Unstable 5=Stable

3. Have you accessed any climate-resilient agricultural finance options? (Yes/No)

Section 5: Adaptation and Support

1. Have you received any climate change-related training or support? (Yes/No)

2. If yes, who provided the training on climate-related topics? 1=Government extension 2=NGOs 3=Private sector 4=Other (specify)

3. What type of support do you need to adapt to climate change? (Check all that apply.) 1=Financial 2=Technical 3=Institutional 4=Other (specify)

4. Are you willing to pay for climate-resilient agricultural technologies? (Yes/No)

5. Does the household have access to market information for crops and animals? 1=yes 0=no

Section 6: Open-Ended Questions

1. What are the biggest challenges you face in adapting to climate change?

1= Lack of financial resources

2=Limited access to information and training

3= High upfront costs of climate-smart technologies

4=Limited labour and skills to operate climate-smart technologies

5=Other (specify)

2. How will climate change affect your farm in the next 5 years?

1____

2____

3____

4____

3. What suggestions do you have for policymakers to support climate-resilient agriculture?

1____

2____

3____

4____

Section 7: Income Stability

Income Variability

1. How often do you experience fluctuations in your income?

1=Frequently (more than 50% of the time)

2=Occasionally (20-50% of the time)

3=Rarely (less than 20% of the time)

2. What are the main causes of income variability for you? (Select all that apply.)

1=Climate-related shocks (e.g., droughts, floods)

2=Market fluctuations (e.g., changes in crop prices)

3=Pests and Diseases

4=Other (specify) 1______________________ 2__________________ 3__________________

3. How have these changes affected your income stability?

1=Reduced income from crop sales

2=Increased costs for inputs (e.g., seeds, fertilizers)

3=Increased costs for labour

4=Other (specify) 1. ________________________ 2. _________________________

Section 8: Income Stability Strategies

1. What strategies do you use to stabilize your income? (Select all that apply.)

1=Diversification of crops or animals

2=Use of irrigation or other climate-resilient technologies

3=Savings or insurance schemes

4=Off-farm employment or other non-farm income sources

5=Other (specify) 1__________________________ 2_________________________________

2. How effective do you think these strategies are in stabilizing your income? (Scale 1-5)
1=relatively effective 5=Very effective

Section 9: Impacts of Climate Change on Income Stability

1. How has climate change affected your income stability over the past 5 years?

1=Very negatively

2=Somewhat negative

3=No impact

4=Somewhat positively

5=Very positively

2. What specific climate-related shocks have had the greatest impact on your income stability? (only one, the greatest)

1=Droughts

2=Floods

3=Heatwaves

4=Other (please specify)

3. How have these changes in climate affected your agricultural income?

1=Reduced income

2=increased income

3=no income change

4. How often do you experience income shocks due to climate-related events? (Scale: 1-5, where 1 is "never" and 5 is "often"

Section 10: Productivity

Maize Productivity

1. What is the average maize area on your farm? ________________________ha/acres

2. How many kgs do you harvest from that area? --------------------------------------Kg

3. How has the maize yield on your farm changed over the past 5 years?

1=decreased

2=increased

3=remained the same

4. How many kg of basal fertilizer do you use for that area? ....Kg

5. How much top-dressing fertilizer do you use on that maize area? ………. Kg

6. What maize seed type do you use?

1=hybrids

2=OPV

3=Retained seed

7. What are the main factors that affect maize productivity on your farm? (Select all that apply.)

1=Climate-related factors (e.g., drought, floods, heatwaves)

2=Soil-related factors (e.g., soil degradation, nutrient deficiencies)

3=Pest and disease management

4=Other (specify please) ____

8. How often do you experience maize crop failures or significant yield reduction due to climate-related shocks? (Scale: 1-5)

1=relatively often

5=Very often

9. What strategies do you use to adapt to climate-related shocks that affect maize productivity? (Select all that apply.)

1=Crop diversification

2=Use of drought-tolerant or climate-resilient maize varieties

3=Irrigation or other water management strategies

4=Conservation agriculture practices

5=Others (please specify) ____

10. What percentage of the maize field has the above strategies … ………………. %

Section 11: Groundnut Production

1. What is the average area committed to groundnut by your household? ....

2. What do you normally harvest from that area? ....Kg

3. How has the yield of pulses on your farm changed over the past 5 years?

1=increased

2=decreased

3=remained the same

4. Do you apply any fertilizer to groundnut?

1=yes

0=no

5. What are the main factors that affect pulse productivity on your farm? (select all that apply)

1=Climate-related factors (e.g., drought, floods, heatwaves)

2=Soil-related factors (e.g., soil degradation, nutrient deficiencies)

3=Pest and disease management

4=Other (please specify)

What percentage of the field has the above strategies … ………………. %

6. How often do you experience groundnut crop failures or yield reductions due to climate-related shocks? (Scale: 1-5)

1=relatively often

2=Very often

7. What strategies do you use to adapt to climate-related shocks that affect groundnut productivity?

1=Diversification of crops

2=Use of drought-tolerant or climate-resilient groundnut varieties

3=Irrigation or other water management strategies

4=Conservation agriculture practices

5=Other (please specify) ____

Section 12: Livestock Ownership and Management

1. How much livestock do you own?

1=Cattle

2=Sheep and Goats

3=Goats

4=Pigs

5=Poultry (chickens, ducks, turkeys)

2. How often do you experience livestock mortality or health issues due to climate-related shocks?

1=Frequently (more than 50% mortality or morbidity rate)

2=Occasionally (20-50% mortality or morbidity rate)

3=Rarely (less than 20% mortality or morbidity rate)

3. What specific climate-related shock has had the greatest impact on your livestock productivity? (Choose one with the biggest impact.)

1=Droughts

2=Heatwaves

3=Floods

4=Other (please specify) ____

Section 13: Livestock Adaptation Strategies

1. What strategies do you use to adapt to climate-related shocks that affect livestock productivity? (Select all that apply.)

1=Diversification of livestock species

2=Use of climate-resilient livestock breeds

3=Improved supplementary feed management practices

4=Better disease management practices

5=Fodder production and processing

6=Other (please specify) ____

Appendix 2: Focus Group Discussions Guide

FOCUS GROUP DISCUSSION GUIDE **Research Topic** Assessing the impacts of Climate Change on Agricultural productivity and Income stability for smallholder farmers in Marange, Mutare District, in Manicaland province, Zimbabwe.
COMPILED BY: NGUNDU AHASHVEROSHI B211417B Phone Number: 0778428075 Email Address: ahashveroshingundu@gmail.com
Section 0: Introductions (10 minutes) **Welcome and Overview** Welcome everyone and thank you for coming today **Getting to Know Each Other**

Introduce myself and ask participants to briefly introduce themselves (name (first name only), village, type of crops grown, years of farming). Briefly tell us about your farming career and perception about climate change How big is your farm? Explain why we are doing this discussion: To understand the impacts of climate change on farming, income, and how farmers respond to these challenges and how we will use what you tell us The discussion will take about 2 hours Everything you say here stays private - we won't use your names in our reports Ask permission to record our conversation Ground rules: respect each other, one person talks at a time, no right or wrong answers
Section 1: Impacts of Climate Change on Maize and Groundnuts productivity **(30minutes)** **Questions** 1. In your experience, how has the climate, including rainfall, temperature, droughts, and floods, changed over the past 5 to 10 years? 2. How have these changes impacted your ability to grow maize? 3. What specific changes have you noticed in your maize yields, including quantity, quality, and timing, over recent years? 4. Can you share any examples of good or bad maize harvests due to climate conditions? 5. What is the average maize area on your farm in hectares or acres? 6. How many kilograms do you harvest from that area? 7. How has the yield of maize on your farm changed over the past 5 years?

8. What strategies do you use to deal with climate-related shocks that affect maize productivity? 9. What is the average area devoted to groundnut by your household? 10. What do you normally harvest from that area in kilograms? 11. How has the yield of pulses on your farm changed over the past 5 years? 12. What are the main factors that affect pulse productivity on your farm? 13. How often do you experience groundnut crop failures or significant yield drops due to climate-related shocks? 14. What strategies do you use to deal with climate-related shocks that affect groundnut productivity?
Section 2: Economic impacts and Income stability (30 minutes) **Questions** 1. How have changes in maize production affected your household income? 2. How often do you see fluctuations in your income? 3. What strategies do you use to handle periods of low income from farming? 4. What are the main reasons for income variability for you? 5. What strategies do you use to stabilize your income? 6. How effective do you think these strategies are in stabilizing your income? 7. Have you noticed more income fluctuations in recent years? If yes, what do you think causes them? 8. How has climate change affected your income stability over the past five years? 9. What specific climate-related shocks have had the biggest impact on your income stability?

10. How often do you experience income shocks due to climate-related events?
Section 3: Sustainable Agricultural Practices (15 minutes) **Questions** 1. What new farming practices or technologies have you adopted in response to climate challenges? 2. Which of these practices do you find most effective in handling climate-related challenges? 3. What are the biggest challenges or barriers you encounter when trying to adopt sustainable agricultural technologies for climate change? 4. How did you find out about these practices (extension officers, fellow farmers, NGOs)?
Section 4: Barriers to Climate Chage Adaptation (15 minutes) **Questions** 1. What challenges do you face in changing your farming practices due to climate change? 2. Are there any resources, information, or support you feel you need? 3. What kind of support do you need to adjust to climate change? 4. What would help you adjust better to changing climate conditions?
Chapter 5: Livestock Ownership and Management (15 minutes) **Questions** 1. How much livestock do you own? 2. How often do you see livestock deaths or health issues due to climate-related events? 3. What specific climate-related event has most affected your livestock productivity?

4. What strategies do you use to adjust to climate-related events that impact livestock productivity?
Closing (5 minutes) Do you have any other thoughts to share? Thank you for your time and honest answers. Please explain what happens next with our research. Share our contact information if you have questions later.

Appendix 3: Key Informant Interview Guide

Introduction

Purpose of the Interview: To gather insights on how climate change affects agricultural productivity and income stability for smallholder farmers in Zimbabwe.

Confidentiality Assurance: All responses will remain confidential and will only be used for research purposes.

Section 1: Background Information

Name of Informant: ______________________________

Organization/Position: ____________________________

Years of Experience in Agriculture/Climate Change: ______________________

Section 2: Impacts of Climate Change on Agricultural Productivity

1. Can you describe the changes in climate patterns in your area over the past few years?

2. How have these changes impacted maize production specifically?

3. What trends have you noticed in yield variability?

4. What are the main challenges smallholder farmers face in adjusting to these changes?

Section 3: Economic Impacts on Income Stability

1. How has climate change influenced the income stability of smallholder farmers in your community?

2. Can you provide specific examples or data?

3. What coping strategies do farmers currently use to handle income changes due to climate change?

4. Are there specific groups of farmers (such as by gender or age) that are more affected? Why?

Section 4: Sustainable Agricultural Practices

1. What sustainable farming practices have you seen being adopted by farmers to address climate change impacts?

2. How effective do you think these practices are?

3. What support (training, resources) is available to farmers for adopting these practices?

4. In your opinion, which practices should receive more promotion?

Section 5: Barriers to Adaptation

1. What are the major obstacles smallholder farmers face in adopting climate-resilient farming practices?

2. Think about factors like access to information, resources, and technology.

3. How do socio-economic factors affect farmers' ability to adapt?

4. What role do local governments and organizations play in helping to overcome these obstacles?

Section 6: Additional Insights

1. What policies or initiatives do you think could help farmers adapt to climate change?

2. Are there any successful stories or case studies you can share?

3. Do you have any other thoughts or recommendations regarding this topic?

Closing Remarks

Thank the informant for their time and insights.

Inform the participant about how the findings will be shared and if they would like to receive a summary of the results.