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THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURE IN ZAMBIA, A CASE STUDY OF KUZIPA, MONDO AND PAYOJU FARMS.

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CERTIFICATE OF APPROVAL

This dissertation by Mambwe Mumba has been approved as fulfilling the requirements for the award of Master's Degree in Political Science and International Relations by the University of Lusaka.

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Abstract

Climate change refers to long-term alterations in temperature, precipitation patterns, and other elements of the Earth's climate system, primarily driven by human activities such as burning fossil fuels, deforestation, and industrial processes (IPCC, 2021). These activities increase the concentration of greenhouse gases like carbon dioxide and methane in the atmosphere, trapping heat and leading to global warming (NASA, 2022). The consequences of climate change are far-reaching, including rising sea levels, more frequent and intense extreme weather events, biodiversity loss, and adverse effects on food and water security (UNFCCC, 2023). Addressing climate change requires a multi-faceted approach involving mitigation measures, such as reducing greenhouse gas emissions, and adaptation strategies to manage its impacts on ecosystems and human societies (World Bank, 2022).

This study investigated the effects of climate change on agriculture in Zambia, using Kuzipa, Mondo, and Payoju Farms as units of analysis. The general objective was to assess how climate change affected agricultural productivity and sustainability, while the specific objectives included examining its effects on water availability, identifying farmers' adaptation strategies, and recommending measures to enhance resilience.

A mixed-methods approach was employed, integrating quantitative data from structured surveys with qualitative insights from interviews and focus group discussions. Stratified random sampling was used to select 171 respondents, ensuring representation across different farming categories. Data analysis involved statistical techniques for quantitative findings and thematic analysis for qualitative insights.

Key findings revealed that climate change had significantly reduced water availability, disrupted planting schedules, and lowered crop yields. Farmers responded with adaptation strategies such as adjusting planting schedules (88.2%), installing irrigation systems (67.6%), practicing water harvesting (60%), and adopting drought-resistant crop varieties (58.8%). However, the uptake of soil conservation methods remains low (14.1%), highlighting a critical gap in adaptive practices.

The study recommended improving access to drought-resistant seeds, promoting soil conservation methods through training, and investing in affordable water management systems to enhance resilience. These measures could mitigate the adverse effects of

climate change and support sustainable agricultural practices in Zambia. This, in a long term, will have a positive ripple effects in the economy.

DEDICATION

This dissertation is dedicated to my beloved family and friends, whose unwavering support, encouragement, and inspiration have been my driving force throughout this journey. Special thanks to my [whoever you want] for instilling in me the value of hard work and resilience. This work is also dedicated to the many small and medium enterprise owners in Zambia whose determination and creativity contribute immensely to our nation’s economic growth.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Zambia's economy heavily relies on agriculture, which employes over 50% of the workforce and contributes approximately 20% to the nation’s GDP (FAO, 2020). The agricultural sector has been a cornerstone of rural livelihoods, playing a key role in ensuring food security and supporting exports. However, this vital sector has faced increasing challenges, particularly from the adverse impacts of climate change. As highlighted by the Intergovernmental Panel on Climate Change (IPCC), the Southern African region, including Zambia, were expected to experience more extreme climatic conditions such as higher temperatures and erratic rainfall patterns from 2020 to 2040 (IPCC, 2014). Consequently, these changes were projected to significantly reduce agricultural productivity, leading to declining crop yields and the degradation of natural resources.

These anticipated challenges were already manifesting in Zambia. Over the last two decades, the country has experienced substantial shifts in rainfall patterns, with more frequent droughts and shorter rainy seasons disrupting farming operations (Sakala & Kalaba, 2019). Such variability caused issues like poor crop germination and water stress during critical growth periods, ultimately lowering agricultural yields. For instance, maize the country's staple crop has been particularly impacted by both extended dry spells and occasional flash floods, raising concerns over food security and forcing farmers to adjust their planting and harvesting schedules (Ngoma, 2018).

1.3 Problem Statement

Climate change presents a significant and growing threat to Zambia's agricultural sector, which was a key pillar of the country’s economy and a crucial source of livelihood for rural populations. The sector was highly vulnerable to climate variability, particularly changes in temperature, precipitation patterns, and the frequency of extreme weather events. These changes have already begun to adversely affecting crop yields, livestock productivity, and overall food security in Zambia (Mulenga et al, 2019). As temperatures rise and rainfall becomes more unpredictable, farmers were experiencing reduced growing seasons and more frequent droughts and floods, leading to a declined agricultural output and increased food insecurity (Thurlow, Zhu & Diao, 2016).

While there was a substantial body of research that examines the broader impacts of climate change on agriculture in Zambia, much of it is focused at the national or regional level. For example, (Ngoma, Mulenga, & Jayne, 2021) provided an overview of how climate change was influencing agricultural productivity across the country, highlighting major trends in crop failure and reduced harvests. However, there has been a gap in the literature when it comes to localized case studies that examine the specific challenges faced by individual farms or agricultural enterprises. This was a critical oversight, as localized studies can offer more detailed insights into the specific vulnerabilities and adaptive capacities of farms in different regions and contexts.

Kuzipa, Mondo and Payoju Farms, located in Zambia's central region, provides a valuable case for such localized research. The farm has been experiencing shifts in growing seasons, declining water availability, and soil degradation issues that were likely to become more severe as climate change intensifies. This research aims to fill the existing gap by investigating the specific effects of climate change on agricultural productivity and sustainability at Kuzipa, Mondo and Payoju Farms. Through this case study, the research identified the challenges posed by climate change and proposed potential solutions to enhance the farm's resilience.

1.4 Research Objectives

The main objective of this study was to investigate the effects of climate change on agriculture in Zambia, using Kuzipa, Mondo and Payoju Farms as unity of analysis. The specific objectives were to:

1. Analyse how climate change affects water availability and usage at the farm.
2. Identify adaptation strategies employed by Kuzipa, Mondo and Payoju Farms to mitigate the effects of climate change.
3. Provide recommendations for improving agricultural resilience in the face of climate change.

1.5 Research Questions

The research sought to answer the following questions:

1. What were the effects of climate change on water resources at the farm?
2. What adaptation strategies have been implemented at Kuzipa, Mondo and Payoju Farms to cope with climate change?
3. How could agricultural resilience be enhanced at Kuzipa, Mondo and Payoju Farms?

1.6 Research Hypotheses

Based on the research questions, the following hypotheses were tested:

H1: Climate change has a significant negative effect on crop yields at Kuzipa, Mondo and Payoju Farms.

H2: Water availability at Kuzipa, Mondo and Payoju Farms has been significantly reduced due to climate change.

H3: The adaptation strategies currently employed at Kuzipa, Mondo and Payoju Farms are insufficient to mitigate the negative effects of climate change.

1.7 Significance of the Study

The significance of this study lied in its contribution to understanding the localized effects of climate change on agriculture, using Kuzipa, Mondo and Payoju Farms as a micro-level case study. While much of the existing research focused on the broader, national impacts of climate change, this study provided a detailed examination of how climate variability affected agricultural productivity at a single farm. By narrowing the focus to Kuzipa, Mondo and Payoju Farms, this research offered specific insights into the challenges that farmers were facing in real-time, as well as the adaptive measures they were implementing to mitigate these challenges. This approach was crucial, as local context played a significant role in determining how different farms experienced and responded to climate-related risks (Smit, & Wandel, 2006). Understanding the specific vulnerabilities and adaptation strategies of Kuzipa, Mondo and Payoju Farms could therefore contribute to a more nuanced understanding of climate resilience in agriculture.

The findings of this study would have important implications for several key groups. First, it will provide valuable data for policymakers, who are tasked with developing national strategies to mitigate the effects of climate change. By understanding the specific ways in which farms like Kuzipa, Mondo and Payoju were being affected, policymakers would be better equipped to design interventions that address the unique challenges faced by smallholder and commercial farmers across Zambia.

Second, the study will benefite farmers and agricultural stakeholders by identifying practical, evidence-based adaptation strategies that are being implemented at the farm level. For instance, the research uncovered successful water management or soil conservation practices used at Kuzipa, Mondo and Payoju Farms that could be adopted by other farmers facing similar climate challenges. These strategies will helpe improve crop yields, manage water resources more efficiently, and reduced the risk of soil degradation, thereby enhancing overall farm productivity and resilience.

Furthermore, this study has the potential to offer scalable solutions. By focusing on a specific case, the research provided insights that can be replicated across similar farming operations in Zambia and other regions. This is particularly relevant given that many farms in the country share comparable environmental conditions and resource constraints. The adaptation strategies identified through this study could be applied not only to mitigate the current impacts of climate change but also to build long-term resilience in Zambia's agriculture sector. In doing so, this study contributes to enhancing food security, promoting sustainable agricultural practices, and supporting rural livelihoods in the face of climate change.

1.8 Scope of the Study

This study was conducted at Kuzipa, Mondo and Payoju Farms, a commercial agricultural enterprise located in Zambia’s central region, an area known for its dependence on rain-fed agriculture. The central region is particularly vulnerable to climate variability, making it a suitable location to examine the impacts of climate change on agricultural productivity and sustainability. The research specifically covered the period from 2010 to 2023, a timeframe during which significant changes in climate patterns have been recorded in Zambia, including more erratic rainfall, rising temperatures, and an increase in extreme weather events such as droughts and floods (Mulenga et al, 2019). These changes had a profound effect on agricultural practices, making it essential to investigate how farms like Kuzipa, Mondo and Payoju have been affected and what strategies have been adopted to cope with these challenges.

The study focussed on three main aspects: crop yields, water management practices, and adaptation strategies employed at Kuzipa, Mondo and Payoju Farms. First, the study examined how shifts in climate, such as variations in rainfall patterns and increasing temperatures, impacted the farm's crop yields over the past 13 years. This included an analysis of the specific crops grown at Kuzipa, Mondo and Payoju Farms, their productivity trends, and the extent to which climate-related factors have contributed to fluctuations in yields. By narrowing the focus to Kuzipa, Mondo and Payoju Farms, the study gained detailed insights into how these factors play out at the farm level, offering a more granular understanding of the relationship between climate change and agricultural output.

Secondly, the study explored water management practices at Kuzipa, Mondo and Payoju Farms, particularly how the farm responded to changes in water availability due to shifting rainfall patterns and increased water demand. Water is a critical resource for agriculture, and its management is crucial for maintaining productivity, especially in regions where rain-fed farming dominates. This aspect of the study assessed how Kuzipa, Mondo and Payoju Farms adapted its water usage, including potential investments in irrigation systems or water conservation techniques, to ensure continued productivity under changing climate conditions.

Lastly, the research analysed the adaptation strategies employed by Kuzipa, Mondo and Payoju Farms to mitigate the negative effects of climate change. This involved investigating the introduction of climate-resilient crop varieties, adjustments to planting schedules, soil conservation methods, and other measures aimed at improving the farm's resilience to climate variability. The study assessed the effectiveness of these strategies and explore potential areas for improvement. By focusing on this period and these key elements, the research aimed to provide a comprehensive understanding of how climate change affected Kuzipa, Mondo and Payoju Farms and offered recommendations for enhancing agricultural resilience.

Chapter Two

Literature Review

2.1 Introduction

The effects of climate change on agriculture have drawn substantial scholarly attention globally, regionally, and locally, especially as agriculture remained a key contributor to food security and economic sustainability. Climate change, which manifested through alterations in temperature, rainfall patterns, and increased frequency of extreme weather events, posed significant threats to agricultural productivity (IPCC, 2019). For Zambia, with a largely agrarian-based economy, understanding these effects on agriculture, as explored through a case study of Kuzipa, Mondo and Payoju Farms, was crucial for forming mitigation and adaptation strategies. This chapter provided a comprehensive review of the literature on climate change's effects on agriculture, with sections focusing on global, African, and Zambian contexts, followed by a literature matrix and identification of gaps. The review aimed to provide a robust theoretical and empirical foundation for understanding these effects and informs the study's specific context at Kuzipa, Mondo and Payoju Farms.

2.2 Global Perspective on Climate Change and Agriculture

At a global scale, climate change induced substantial shifts in agricultural productivity, particularly affecting staple crops such as wheat, maize, and rice (Lobell, Schlenker, & Costa-Roberts,, 2011). Regions with drastic changes in temperature and precipitation, including Southeast Asia, the Americas, and Sub-Saharan Africa, experienced declines in crop yields due to increased vulnerability to extreme weather events (Porter, Xie, Challinor, Cochrane, Howden, Iqbal, & Travasso, 2014). For instance, Southeast Asia, which was heavily dependent on rice production, faced the risk of both droughts and floods, leading to yield variability and food insecurity in the region (Sultan, & Gaetani, 2016). This climatic variability disrupted growing seasons and induced shifts in pest and disease cycles, further threatening crop productivity and food security (FAO, 2016). In the United States, the frequency and intensity of droughts in the Midwest had significantly impacted maize production, with prolonged drought conditions causing water scarcity and increased reliance on irrigation (Ray, Gerber, MacDonald, & West, 2019). Similarly, European agriculture, particularly wheat production, had been negatively affected by recurrent heat waves. These heatwaves not only reduced crop yields but also decreased the nutritional quality of wheat, affecting protein content and the overall value of agricultural output (Asseng, Ewert, Martre, Rötter, Lobell, Cammarano, & Wolf, 2015). Furthermore, climate-induced changes such as temperature rise in Australia and New Zealand led to altered seasonal patterns and shifting agricultural zones, impacting not only crop growth but also the viability of livestock farming in previously productive areas (Crimp, S. J., Gobbett, Kokic, Nidumolu, Howden, Nicholls, & Barlow, 2018).

Adaptation strategies to counter these adverse effects have been widely explored, with research suggesting crop diversification, technological innovation, and sustainable farming practices as essential components for resilience (Aggarwal, & Singh, 2020). Crop diversification, for example, could enhance resilience by spreading risk across different crops with varying resistance to climate stresses. Technological innovation, such as the development of heat-resistant and drought-tolerant crop varieties, showed potential to stabilize yields under extreme conditions (Challinor, Koehler, Ramirez-Villegas, Whitfield, & Das, 2016). Sustainable farming practices, including conservation tillage and integrated pest management, reduced vulnerability by maintaining soil health and reducing the impact of pest outbreaks, which were projected to increase under warming conditions (Waha, K., Müller, C., Bondeau, Dietrich, Kurukulasuriya, Heinke, & Lotze-Campen, 2013). However, these solutions were to be tailored to regional contexts, considering variations in climate impacts and socio-economic conditions that influence adaptive capacity (Adger et al, 2015).

Additionally, global policy frameworks, such as the Paris Agreement and the United Nations' Sustainable Development Goals (SDGs), emphasize the need for adaptive agricultural practices as a critical component of climate resilience (United Nations (UN), 2015). Countries were increasingly incorporating climate-resilient agriculture into their Nationally Determined Contributions (NDCs) to meet global climate goals, with an emphasis on scaling up research and technology transfer to enhance adaptive capacity in vulnerable regions (FAO, 2019). Nonetheless, limitations remain due to the disparity in resource availability and technological access between developed and developing nations. As such, the global community is tasked with addressing these inequalities to enable meaningful adaptation and resilience building across all regions.

2.3 African Perspective on Climate Change and Agriculture

Africa, characterized by a diversity of agro-ecological zones, faced significant and complex challenges in agriculture as a result of climate change. Studies revealed that Africa was disproportionately affected by climate change due to its high dependence on rain-fed agriculture, minimal infrastructure, and limited adaptive capacity (Niang, Ruppel, Abdrabo, Essel, Lennard, Padgham, & Urquhart, 2014). For instance, in the Sahel region, prolonged droughts had severely impacted food production, contributing to food insecurity and destabilizing local economies (Mbow, Rosenzweig, Barioni, & Benton, 2019). Additionally, unpredictable rainfall patterns in East Africa led to both flooding and droughts, affecting not only crop yields but also livestock health and productivity, with direct implications for food security and rural livelihoods (Thornton et al, 2018).

Adding to these challenges, sub-Saharan Africa struggles with implementing adaptive strategies due to economic constraints and insufficient access to resources, which hinders the widespread adoption of climate-resilient practices such as drought-resistant crop varieties and integrated pest management (Challinor, Koehler, Ramirez-Villegas, Whitfield, & Das, 2016). For example, in Southern Africa, research showed that water scarcity and rising temperatures were reducing maize yields, a staple crop, emphasized the need for adaptive crop varieties and improved water management practices (Zinyengere, Crespo, & Hachigonta, 2015). Furthermore, high poverty rates limited farmers' ability to invest in climate-resilient technologies, and dependence on traditional farming methods further restricted adaptive capacity across the region (Henderson et al, 2017).

To add on, climate change also impacted livestock farming, which was crucial to many African communities. Rising temperatures and erratic rainfall patterns have degraded rangelands, leading to reduced forage availability and water sources, which in turn weakens livestock productivity and exacerbates rural poverty (Opiyo et al, 2015). For example, pastoral communities in Kenya and Ethiopia reported a loss in livestock due to recurrent droughts, highlighting the need for targeted interventions in these vulnerable areas (Herrero et al, 2016). Climate change also posed indirect threats to African agriculture by increasing the prevalence of pests and diseases; for instance, warming temperatures have allowed the spread of the fall armyworm, which has caused substantial crop losses across several Africans (Day et al, 2017).

Despite these substantial impacts, African governments and institutions were increasingly prioritizing climate resilience. Regional bodies such as the African Union (AU) and the African Development Bank (AfDB) have been fostering climate action frameworks, such as the AU's Agenda 2063 and the AfDB's Feed Africa Strategy, which aims to support climate-resilient agriculture through improved infrastructure, access to finance, and technology transfer (AfDB, 2019). However, implementation of these policies are uneven and often constrained by financial and logistical challenges. In addition, international support through initiatives such as the Green Climate Fund and the Global Climate Change Alliance was aiding adaptation efforts, yet studies suggest that more targeted investments were needed to meet Africa's unique climate adaptation needs effectively (FAO, 2019).

Ultimately, while African countries were making strides in addressing climate change, there remains an urgent need for strengthened regional cooperation, more comprehensive policies, and greater resource allocation to support local adaptation initiatives across the continent. Addressing these challenges would not only boost Africa's agricultural resilience but also enhance food security, rural development, and poverty reduction efforts in the face of a changing climate.

2.4 Climate Change and Agriculture in the Zambian Context

Zambia's agricultural sector, heavily dependent on rain-fed systems, faces substantial vulnerability to climate variability and extreme weather events. Recent studies indicated that Zambia has been significantly affected by increasing drought frequency and unpredictable rainfall patterns, severely impacting maize production, the country's primary staple (Zinyengere, Crespo, & Hachigonta, 2015). According to the Intergovernmental Panel on Climate Change (IPCC, 2019), without effective adaptation strategies, Zambia's agricultural productivity was likely to decline, exacerbating food insecurity and poverty, particularly among rural communities who relied on agriculture as a primary livelihood source. This climate-induced vulnerability highlighted the importance of fostering climate-resilient agricultural systems.

Research underscored that the introduction of climate-resilient crops, such as drought-resistant maize varieties, could be instrumental in mitigating the adverse effects of climate change on Zambia's agriculture. Studies by Mulenga, (Wineman & Sitko, 2017) emphasized the need for resilient crop varieties, improved soil fertility practices, and efficient water management techniques to support sustainable agricultural productivity under variable climate conditions. In addition, soil conservation measures, like conservation tillage and the application of organic fertilizers, are recommended to enhance soil moisture retention and nutrient availability, thereby boosting productivity under erratic weather (Tembo & Sitko, 2016).

Zambia's water management systems, a critical component of agricultural resilience, also require strengthening to cope with recurrent droughts and floods. For instance, efforts to develop and expand irrigation infrastructure were limited, with only a small percentage of the country's arable land under irrigation (World Bank, 2018). Improved irrigation and water management practices could help stabilize crop production and reduce reliance on rain-fed systems. Furthermore, community-level water harvesting techniques and small-scale irrigation projects were being explored as adaptive solutions to support smallholder farmers, who were among the most affected by climate risks (Makondo, & Thomas, 2018).

Additionally, Zambia has taken policy measures to address climate adaptation. The Zambian government, through the National Climate Change Policy (NCCP) and the Climate-Smart Agriculture Program, aims at enhancing agricultural resilience by promoting climate-smart farming practices and supporting farmers with climate information services (Kalaba, Quinn, & Dougill, 2020). However, several challenges persisted in implementing these policies, primarily due to financial constraints, inadequate technical capacity, and limited access to resources at the community level. According to Nyanga et al, (2016), the lack of sufficient funding and institutional support often hampered the efficacy of climate adaptation initiatives, highlighting the need for stronger public-private partnerships and increased international support.

Despite these obstacles, Zambia was making progress in enhancing its adaptive capacity by collaborating with international organizations such as the Food and Agriculture Organization (FAO) and the United Nations Development Programme (UNDP). These partnerships aimed to provide technical support, capacity building, and funding to improve local resilience to climate change (FAO, 2019). Nonetheless, scholars including Muthelo et al, 2021 argued that local adaptation efforts remained inadequate without a stronger focus on empowering smallholder farmers, who play a crucial role in Zambia's agricultural economy but often lack access to critical adaptation resources. Addressing these limitations through targeted interventions and community-based climate resilience projects would not only protect agricultural productivity but also enhance food security and rural livelihoods in Zambia under a changing climate.

2.5 Literature Matrix and Gaps Analysis

Table 1: Literature Matrix

Author(s)	Region	Focus Area	Findings	Identified Gaps
Lobell, Schlenker, & Costa-Roberts (2011)	Global	Climate impacts on staple crops	Decreased yields in wheat, maize, and rice	Limited focus on adaptive capacity across different farming systems
Mbow et al. (2019)	Africa	Climate effects on food security	Climate variability linked to food insecurity in Sahel	Insufficient analysis of economic factors affecting adaptation
Mulenga et al. (2017)	Zambia	Effects of drought on maize production	Noted vulnerability of maize production to drought	Limited studies on adaptation strategies for smallholder farmers
Kalaba, Quinn, & Dougill (2020)	Zambia	Policy frameworks for climate adaptation	Discusses Zambia's climate policy implementation challenges	More empirical studies needed on policy impact on smallholder farming

2.6 Gaps in the Literature

Despite substantial research on the impact of climate change on agriculture, notable gaps remain, especially concerning the adaptability of various agricultural systems. On a global scale, research has extensively documented the vulnerability of staple crops like wheat, maize, and rice to climate variability (Lobell, Schlenker, & Costa-Roberts,, 2011). However, limited studies investigated the role of crop diversification as a strategy to enhance resilience under diverse climate conditions (Porter et al, 2014). Crop diversification, which involves the cultivation of various crops with different climate tolerances, could potentially stabilize yields and reduce risks associated with crop failure under changing climatic conditions. Yet, this area was underexplored, particularly in regions heavily reliant on single staple crops for food security (FAO, 2016).

At the African level, research on the socio-economic and cultural barriers limiting smallholder farmers' adoption of climate-smart practices was relatively sparse. Studies show that limited financial resources, inadequate access to climate information, and cultural attachment to traditional farming methods impeded the adoption of adaptive practices among smallholders (Mbow, Rosenzweig, Barioni, & Benton, 2019). While some African countries were making progress in developing climate adaptation frameworks, few studies provided a detailed analysis of how socio-economic factors, such as land tenure insecurity and limited access to credit, hinder farmers from implementing these strategies effectively (Niang et al, 2014). Additionally, there was a gap in the literature regarding the impact of gender dynamics on adaptive capacity in agriculture. Gender-based constraints often limited women’s access to resources and decision-making power in farming, yet this factor remains underexamined in the context of African agriculture and climate resilience (Nyasimi et al, 2017).

In Zambia, while numerous studies address the susceptibility of maize production to climate extremes, fewer studies explored a comprehensive evaluation of adaptation strategies tailored specifically for smallholder farmers, including those operating private enterprises like Kuzipa, Mondo and Payoju Farms (Mulenga, Wineman, & Sitko, 2017)). Given Zambia’s significant reliance on rain-fed agriculture, this gap was particularly pressing, as it limited the understanding of how small-scale farmers could sustainably adapt to shifting climate patterns. The emphasis on maize overlooks other valuable crops that could diversify Zambia’s agricultural portfolio and improve resilience. Moreover, adaptation strategies, such as drought-resistant crops and improved water management systems, remain inadequately researched in terms of their practicality and economic viability for smaller private farms (Kalaba, Quinn, & Dougill, 2020).

Another significant gap lied in the lack of longitudinal studies assessing the effectiveness of Zambia’s climate policies in bolstering agricultural resilience over time. While policies like Zambia’s National Climate Change Policy and Climate-Smart

Agriculture Program aim to support climate adaptation, there was limited evidence on their long-term impacts, particularly at the smallholder level (FAO, 2019). Given that policy impacts on agricultural resilience may only become visible over several years, there was a need for studies that provide longitudinal data on policy outcomes and practical case studies on implementation (Nyanga, Johnsen, & Aune, 2016). Filling these gaps will be crucial to creating a comprehensive understanding of climate resilience in Zambia's agricultural sector, especially for small-scale farms like Kuzipa, Mondo and Payoju Farms, which are pivotal to rural economies and food security.

This research aims to address the identified gaps by providing a comprehensive evaluation of climate adaptation strategies tailored specifically to smallholder farmers in Zambia, with a particular focus on private enterprises like Kuzipa, Mondo, and Payoju Farms. By examining the practicality, economic viability, and scalability of adaptation measures such as crop diversification, drought-resistant crops, and improved water management systems, this study will contribute to a deeper understanding of sustainable farming practices in the context of climate change. Additionally, the research will investigate socio-economic factors, including land tenure, access to credit, and gender dynamics, to understand how these influence the adoption of climate-smart practices among smallholder farmers. Furthermore, the study will assess the long-term effectiveness of Zambia's climate policies by incorporating longitudinal data and practical case studies to evaluate policy impacts on agricultural resilience. By filling these gaps, this research will provide actionable insights to support policymakers, smallholder farmers, and stakeholders in enhancing agricultural resilience and ensuring food security amidst changing climatic conditions.

2.7 Theoretical Framework

This study was grounded in the vulnerability and adaptation framework (Adger, 2006), a widely applied approach in climate change research that evaluates how systems were affected by climate variability and how they responded to these impacts. This framework was particularly useful for understanding the complexities of climate change's effects on agriculture, as it focused on three key components: exposure, sensitivity, and adaptive capacity.

In the case of Kuzipa, Mondo and Payoju Farms, the farm was exposed to various climate-related risks such as prolonged droughts, erratic rainfall, and occasional flooding, all of which threaten agricultural productivity. Exposure refers to the degree to which a system, in this case, Kuzipa, Mondo and Payoju Farms, experienced significant climate-related stresses (Adger, 2006). These climatic events had a direct impact on crop yields, soil quality, and water availability, making it essential to understand how such exposure undermines the farm's productivity.

The farm’s sensitivity to these climate risks was heavily influenced by its dependence on rain-fed agriculture. As a rain-dependent operation, Kuzipa, Mondo and Payoju Farms was highly susceptible to fluctuations in rainfall and temperature, which directly affect the growth cycles of crops and overall yields. The vulnerability of the farm was further compounded by issues like soil degradation and water scarcity, which make the system more sensitive to even small changes in climate patterns (Smit, & Wandel, 2006). Therefore, understanding the farm’s sensitivity was key to determining its overall vulnerability to climate change.

Finally, adaptive capacity referred to the ability of Kuzipa, Mondo and Payoju Farms to adjust its practices in response to climate-related challenges. This capacity was shaped by the resources available to the farm, including access to climate-resilient crop varieties, water management technologies, and knowledge of climate adaptation practices. A higher adaptive capacity enabled the farm to reduce its vulnerability by implementing effective strategies to mitigate the adverse impacts of climate variability (Smit, & Wandel, 2006). The study examined how Kuzipa, Mondo and Payoju Farms leveraged their adaptive capacity to build resilience in the face of ongoing climate challenges.

In addition to the vulnerability and adaptation framework, this study also incorporated the sustainable livelihoods framework (Chambers, & Conway, 1992), which focused on how households and communities could build resilience by utilizing different forms of capital atural, financial, human, and social. This framework was particularly relevant for analysing how Kuzipa, Mondo and Payoju Farms, as a rural agricultural enterprise, can sustainably manage its resources to ensure long-term resilience. The sustainable livelihoods framework highlighted the importance of not only responding to immediate climate risks but also building capacities that ensure the farm’s sustainability over time (Ellis, 2000).

By integrating both the vulnerability and adaptation framework and the sustainable livelihoods framework, this study provided a comprehensive theoretical foundation for analyzing the specific climate risks faced by Kuzipa, Mondo and Payoju Farms and its capacity to adapt. Together, these frameworks allowed for a deeper understanding of how local farming operations could enhance their resilience to climate change while promoting sustainable agricultural practices.

2.8 Conceptual Framework

The conceptual framework for this study was designed to capture the effects climate change on agricultural productivity at Kuzipa, Mondo and Payoju Farms, while considering the critical role of adaptation strategies in mediating these effects. In this framework, climate change is identified as the independent variable, agricultural productivity as the dependent variable, and the adaptation strategies employed by Kuzipa, Mondo and Payoju Farms are regarded as an intervening variable, which influenced how much climate change affected the farm's productivity.

To begin with, the independent variable in this study was climate change, which manifested through a range of climate-related factors that directly affected agricultural outcomes. These factors included erratic rainfall patterns, characterized by unpredictable and inconsistent rainfall that often led to either droughts or floods. Additionally, rising temperatures posed significant challenges, as higher average temperatures disrupted crop growth and increase water demand. Furthermore, the study accounted for the impact of extreme weather events, such as the increasing frequency of droughts, floods, and storms, which damaged crops, degraded soil, and affected agricultural infrastructure. Together, these components of climate change created environmental stressors that challenged Kuzipa, Mondo and Payoju Farms' ability to maintain steady crop yields and manage water resources effectively. Thus, the farm's exposure to these risks defined the extent of its vulnerability to climate-related challenges.

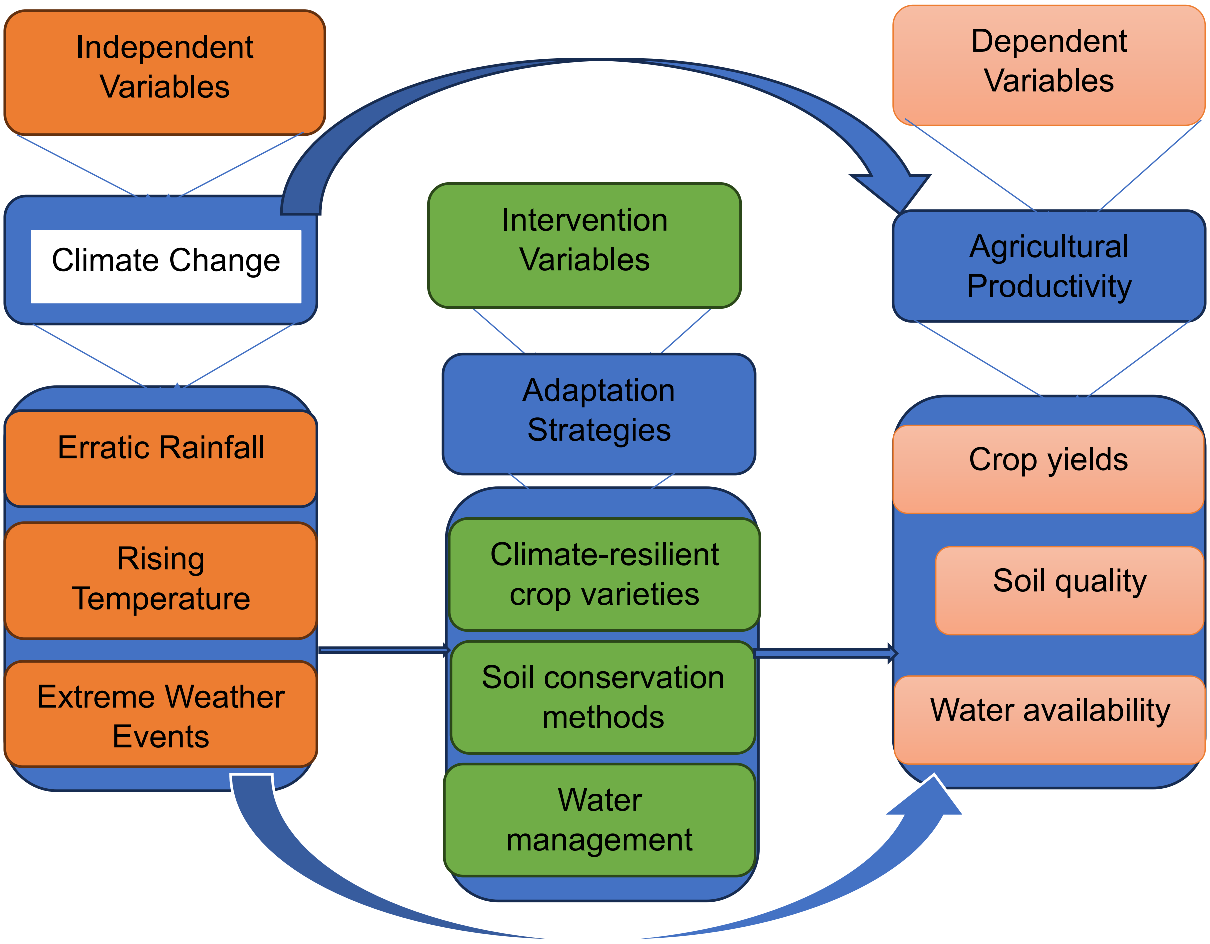
Moving on, the dependent variable in this framework was agricultural productivity, which was measured using several indicators. These included crop yields, referring to both the quantity and quality of crops harvested over the study period (2010–2023). Another key indicator is soil quality, which reflected the condition of the soil, including its fertility and erosion rates, both of which were influenced by changes in climate.

Lastly, water availability played a crucial role, as it pertained to the adequacy of water resources needed for irrigation and livestock. These indicators were directly impacted by the nature and extent of climate-related stressors faced by Kuzipa, Mondo and Payoju Farms. For instance, droughts reduced yields, floods could cause crop failure, and soil degradation might result from both increased rainfall intensity and higher temperatures.

However, the extent to which climate change impacted agricultural productivity was not solely determined by exposure to climate risks. Adaptation strategies, identified as the intervening variable, significantly influenced how well Kuzipa, Mondo and Payoju Farms can mitigate the negative effects of climate change. The effectiveness of these strategies plays a pivotal role in buffering the farm against adverse climate conditions. Key adaptation strategies include the adoption of climate-resilient crop varieties, which are drought-tolerant and heat-resistant, enabling crops to better withstand harsh climate conditions. Additionally, water management practices are critical for coping with irregular rainfall patterns. These practices involved the use of efficient irrigation systems or water conservation techniques to ensure that crops receive adequate moisture, even in times of scarcity. Furthermore, soil conservation methods, such as crop rotation and the use of organic fertilizers, help to maintain soil fertility and prevent erosion, which is often exacerbated by extreme weather events.

Lastly, by employing these adaptation strategies, Kuzipa, Mondo and Payoju Farms had the potential to reduce its vulnerability to climate-related risks, thereby sustaining or even improving its agricultural productivity in the face of climate change. This conceptual framework highlighted the interconnectedness between climate change, adaptation efforts, and agricultural outcomes, providing a structured approach to examine how local farming operations like Kuzipa, Mondo and Payoju Farms can enhance their resilience to climate variability.

Figure 1: Conceptual Framework



2.9 Chapter Summary

This literature review provided a thorough examination of the impacts of climate change on agriculture at global, African, and Zambian levels, highlighting significant trends and critical gaps in the existing research. At the global level, climate change has been shown to disrupt agricultural systems profoundly, leading to decreased productivity, increased food insecurity, and heightened urgency for adaptive strategies (Lobell et al, 2011). Research indicated that regions most affected were experiencing alterations in precipitation patterns and extreme weather events, which collectively undermined traditional agricultural practices and threaten food security worldwide (Porter et al, 2014).

In the African context, agriculture was particularly vulnerable due to its high reliance on rain-fed systems and limited adaptive capacities, exacerbated by socio-economic and infrastructural constraints (Niang et al, 2014). Studies emphasized the need for more nuanced investigations into region-specific resilience strategies, as many existing frameworks fail to account for local conditions and cultural practices that affect adaptation (Mbow et al., 2019). Moreover, there was a pressing need to address the socio-economic and gender-related barriers that hinder smallholder farmers from adopting climate-smart agricultural practices (Nyasimi et al, 2017).

Focusing on Zambia, the literature reveals an acute awareness of the sector's climate vulnerabilities, particularly concerning maize production, which was the backbone of the country's food system (Zinyengere et al, 2015). Despite recognizing these vulnerabilities, there remains a significant lack of empirical research exploring effective adaptation measures, particularly for private farming entities like Kuzipa, Mondo and Payoju Farms, which play a vital role in local economies and food security (Mulenga et al, 2017). The emphasis on maize overlooks the potential benefits of diversifying crop production, which could enhance resilience against climate variability.

In summary, addressing these identified gaps was crucial for developing a more comprehensive understanding of climate impacts on agriculture in Zambia. This will not only provide insights into effective adaptation measures but also inform strategic policy interventions aimed at enhancing agricultural resilience. Furthermore, a robust understanding of these dynamics could aid in tailoring support programs for smallholder and private farmers, ensuring that they could navigate the challenges posed by climate change effectively. As Zambia seeks to align with global climate initiatives and enhance its food security, it was imperative to leverage the findings from this literature review to inform practical solutions that could be implemented at the local level. Ultimately, this research aimed to contribute significantly to the discourse on climate change adaptation in agriculture, providing a foundation for future studies and policy developments in Zambia and beyond.

Chapter Three

Research Methodology

3.1 Introduction

This chapter outlines the methodology employed in investigating the effects of climate change on agriculture at Kuzipa, Mondo and Payoju Farms in Zambia. The study aimed at assessing how changing climatic conditions influenced agricultural productivity, crop yields, and farming practices. The chapter begins by describing the research philosophy, followed by the research approach and design. Additionally, it detailed the target population, sample size, data sources, sampling techniques and procedures, data analysis methods, reliability and validity considerations, and ethical considerations that guided the research.

3.2 Research Philosophy

This research adopted a pragmatic philosophy, aligned with the view that practical and actionable knowledge could be obtained by combining both qualitative and quantitative data (Creswell & Plano Clark, 2018). Pragmatism, as a research paradigm, focuses on addressing real-world issues by blending various research methods to uncover the most useful insights (Morgan, 2014). This approach was particularly relevant for this study, as it provided a flexible framework to assess the effects of climate change on agriculture across multiple contexts specifically, at Kuzipa, Mondo and Payoju, Mondo, and Payoju Farms. Unlike purely positivist or interpretivist approaches, pragmatism allowed the researcher to concentrate on the research problem rather than rigid adherence to a single methodological stance, facilitating a more comprehensive analysis of how climate change impacts agricultural practices and outcomes in Zambia (Biesta, 2010).

In the context of this research, the pragmatic philosophy supported an integration of various data sources and perspectives, offering a well-rounded understanding of how changing climate patterns were affecting crop yields, farming practices, and agricultural resilience. This approach aligned with the aims of practical application, as the study seeks not only to document the effects of climate change on agriculture but also to identify insights that could inform farmers and policymakers on adaptation strategies (Maxcy, 2003). By adopting this philosophy, the research aimed to generate findings that were both scientifically robust and directly applicable, fostering meaningful contributions to local agricultural strategies and climate adaptation policies.

Pragmatist approach acknowledges that diverse methods yield richer insights, thus reinforcing the reliability of findings through methodological triangulation (Johnson & Onwuegbuzie, 2004). In this study, the use of both surveys and interviews aligned with pragmatic principles, providing an empirical basis for understanding quantitative impacts on agricultural yields while capturing the nuanced perspectives of farmers regarding climate change adaptation. By grounding the research in pragmatism, the study emphasized the utility of findings, aiming at bridging the gap between theory and practice to support sustainable agricultural practices amid climate change.

3.3 Research Approach

This study employed a mixed-methods approach, integrating both quantitative and qualitative research methods to gained a comprehensive understanding of climate change's impact on agricultural practices. Mixed methods research was beneficial for addressing complex research questions by combining the strengths of quantitative data, which offered generalizability, with qualitative data, which provided depth and context (Creswell & Plano Clark, 2018). By using this approach, the study aimed to explore not only the measurable effects of climate change on crop yields but also the personal experiences and adaptive strategies of farmers at Kuzipa, Mondo and Payoju, Mondo, and Payoju Farms.

Quantitative data was, collected through structured surveys aimed at measuring variables such as crop yields, types of farming practices, and shifts in productivity over time. This quantitative data provided the study with a baseline for assessing the extent to which climate affected agricultural activities at the three farms.

The qualitative data was collected through semi-structured interviews and focus group discussions with farmers. This phase was designed to capture farmers' subjective experiences, insights, and adaptive responses to climate change, offering a richer context that complements the statistical trends identified in the quantitative phase (Bryman, 2016). Through these discussions, the study explored the farmers' perceptions of climate-related challenges, adaptations and the personal impact of climate variability on their livelihoods. This qualitative data was analysed thematically, identifying recurring themes that provided insights into farmers' resilience strategies and potential areas for policy intervention.

The mixed-methods approach thus allowed for methodological triangulation, which enhances the study's reliability and validity by cross-verifying findings from different sources (Tashakkori, & Teddlie, 2010). By leveraging both quantitative and qualitative data, the study was positioned to provide a well-rounded perspective on climate change's effects on agriculture. This approach aligned with the pragmatic research philosophy, aiming to produce findings that were not only academically robust but also directly applicable to the farmers and policymakers involved in developing sustainable agricultural practices in Zambia.

3.4 Research Design

This study utilized a cross-sectional research design, which was particularly suited for assessing phenomena at a single point in time. Cross-sectional designs were valuable for providing a "snapshot" of a population, enabling researchers to analyse current conditions, practices, and outcomes (Bryman, 2016). In the context of this study, a cross-sectional approach facilitated the examination of how climate change impacted agricultural practices, crop yields, and overall farm productivity at Kuzipa, Mondo and Payoju farms.

The cross-sectional design was further advantageous in terms of feasibility and practicality. Since it focused on a specific timeframe, it reduced the time and resources required for data collection compared to longitudinal designs, which would involve multiple observations over an extended period (Creswell, 2014). This was particularly beneficial for this study, given the practical constraints associated with gathering data across different farms in Zambia. Additionally, the cross-sectional approach supports the mixed-methods strategy employed in this research, as it allowed for the concurrent collection of both quantitative data (through surveys) and qualitative data (through interviews and focus groups) within the same timeframe.

However, a limitation of the cross-sectional design was that it did not capture changes over time, which were crucial in understanding dynamic phenomena like climate change. Despite this limitation, the design was still appropriate for exploring the immediate effects of climate variability on agriculture and identifying existing strategies used by farmers to mitigate these effects (Babbie, 2021). By focusing on current practices and outcomes, the study provided a foundation for future research that could adopt a longitudinal approach to track adaptive practices over time.

In summary, the cross-sectional design enabled this study to effectively assess the current impact of climate change on agricultural practices across multiple farms. By capturing differences in farming practices and outcomes, this design provides a comprehensive view of the resilience and vulnerabilities present within the agricultural sector in Zambia.

3.5 Target Population

The target population for this study consisted of all 300 farmers and workers at Kuzipa, Mondo and Payoju, Mondo, and Payoju Farms in Zambia, encompassing both smallholder and commercial farmers engaged in a wide range of agricultural activities. These farms represented diverse agricultural settings within the Zambian agricultural sector, making them ideal for understanding the multifaceted impact of climate change on farming practices. By including farmers from both smallholder and commercial categories, the study captured a range of experiences, adaptive capacities, and resilience levels, thus allowed for a more comprehensive exploration of how climate change affected agricultural productivity across different scales of farming.

Smallholder farmers, often working on a limited scale with fewer resources, may experience distinct challenges due to climate change, such as reduced access to irrigation or financial resources for adaptive practices. This group was crucial to examine, as smallholder farmers in Zambia were often more vulnerable to climate variability and may rely heavily on rainfall for crop production (Haggblade, Hazell, & Reardon, 2015). Studying their experiences shed light on specific vulnerabilities and coping mechanisms that small-scale farmers employed in response to climate shifts, providing insights into practical and scalable adaptation strategies that support other smallholders facing similar conditions.

In contrast, commercial farmers typically operated on a larger scale with more mechanized equipment, access to financial resources, and potential investments in climate-resilient infrastructure (Sitko, & Jayne, 2014). Including this group in the target population allowed the study to analyse the different ways in which commercial farms respond to climate change. Since these farmers often have more resources to adapt to climate challenges such as access to advanced technology, irrigation systems, and diversified crop production understanding their strategies could help inform policy decisions that promote resilient agricultural practices at both smallholder and commercial levels.

This broad target population across Kuzipa, Mondo and Payoju, Farms provided a valuable perspective on how climate change impacts farming practices and crop production within the specific geographic and climatic context of these farms. Furthermore, it supported the study's goal of identifying climate change adaptation strategies that were practical, scalable, and contextually relevant. By focusing on this diverse population, the study abled to compare experiences across different types of farming practices and crop types, examining how various socioeconomic factors influenced vulnerability or resilience to climate variability. This approach thus ensured that the findings reflected the breadth of agricultural activities and adaptive needs within Zambia's farming community, contributing to a nuanced understanding of climate change impacts on agriculture.

3.6 Sample Size

The sample size for this study was calculated using Yamane's (1967) formula for sample size determination, which was suitable for obtaining a representative sample from a known population size. The formula is as follows:

$$n = \frac{N}{1 + N(e^2)}$$

where:

n is the sample size,

N is the total population size, and

e is the margin of error, set at 5% (0.05) for this study.

With an estimated population of 300 farmers across Kuzipa, Mondo and Payoju Farms, the calculation was as follows:

$$n = \frac{300}{1 + 300(0.05^2)}$$

$$n = \frac{300}{1 + 300 \times 0.0025} = 3001.75 \approx 171$$

Thus, a sample size of approximately 171 farmers was targeted for this study. This sample size deemed sufficient to yield reliable quantitative data while also allowing for rich qualitative insights. By ensuring representation across the larger population, this sample size enhanced the validity of the findings and provided a solid foundation for examining the impacts of climate change on farming practices across the three farms.

3.7 Source of Data

Data for this study was collected exclusively from primary sources at Kuzipa, Mondo and Payoju Farms. Primary data was gathered through surveys, interviews, and focus group discussions with farmers from these farms. This approach allowed for firsthand insights into the farmers' experiences, perceptions, and adaptive responses to climate change, as well as detailed information on how climate variability is directly impacting their agricultural practices and productivity. By focusing solely on primary data from these farms, the study aimed to provide a nuanced, context-specific understanding of the challenges and adaptations specific to these farming communities.

3.8 Sampling Technique and Procedure

A stratified random sampling technique was employed to select participants from Kuzipa, Mondo and Payoju Farms. This technique was particularly effective for ensuring that various subgroups within the population were adequately represented, allowing for more reliable comparisons across different types of farmers and farming practices. By dividing the population into strata based on relevant characteristics such as the type of farming (smallholder or commercial) and crop types, this approach enhanced the representativeness of the sample and increases the generalizability of the findings (Creswell, & Creswell, 2017).

Stratification Process

The sampling procedure begun by categorizing farmers into specific strata according to farming practices and crop types. At Kuzipa, Mondo and Payoju Farms, these strata included smallholder farmers, who typically operated on a smaller scale with limited resources, and commercial farmers, who often have access to more resources, larger-scale operations, and possibly mechanized farming practices. Additionally, within these categories, further strata were created based on the predominant crop types grown by the farmers. This stratification ensured that each unique subgroup within the farming population was represented, providing insights into how climate change impacts distinct types of agricultural practices and crop types.

Random Selection Within Strata

Once the strata were established, a random selection process was conducted within each stratum. This involved generating a list of eligible farmers in each category and then using random selection to choose participants from each group. The proportion of farmers selected from each stratum was based on the overall distribution of smallholder and commercial farmers within the total population at the three farms. This step ensured that the sample reflected the diverse makeup of the farming population across Kuzipa, Mondo and Payoju Farms, reducing sampling bias and allowed for a balanced representation of perspectives.

Participant Recruitment and Consent

After selecting participants, each farmer was contacted individually to request their consent and participation in the study. This process involved providing them with information about the study's purpose, methods, and potential benefits, as well as addressing any questions or concerns they had. Obtaining informed consent from each participant ensured ethical compliance and respected the autonomy of the farmers involved (Babbie, 2021). Efforts was made to schedule interviews, surveys, and focus group discussions at times convenient to the participants to minimize disruption to their farming activities.

3.9 Data Analysis

Data analysis for this study involved both quantitative and qualitative approaches, each specifically designed to address the research questions and objectives surrounding the effects of climate change on agriculture at Kuzipa, Mondo, and Payoju Farms. The integration of these approaches provided a thorough and multifaceted understanding of both direct and indirect effects of climate variability on farming practices, crop yields, and the adaptive strategies of farmers in the region.

Quantitative Data Analysis

Quantitative data, collected through structured surveys, was analysed using statistical software, specifically IBM SPSS. This software tools enabled the analysis of descriptive statistics to explore the effects of climate change on agricultural activities. Descriptive statistics provided

Qualitative Data Analysis

Qualitative data, gathered through interviews and focus group discussions, was analysed thematically using SPSS, a software tool designed for qualitative data analysis. SPSS assisted in coding responses, identifying key patterns, and generating themes within the data. The thematic analysis process begun with open coding, where initial codes were assigned to responses related to farmers' perceptions, experiences with climate variability, and their adaptive strategies. Codes were then grouped into broader categories and refined into themes that reflected shared experiences and common challenges among farmers, such as coping with changing rainfall patterns or modifying planting schedules in response to climate trends (Braun, & Clarke, 2019).

This thematic analysis allowed the study to capture the complexities of farmers' experiences with climate change, offering insights that quantitative data alone may not have revealed. By focusing on common themes and contrasting perspectives, this approach provided a rich understanding of how different groups (e.g., smallholders and commercial farmers) perceived and responded to climate change, highlighting context-specific adaptation strategies.

3.10 Reliability and Validity

Ensuring the reliability and validity of the study was paramount to achieving accurate and credible findings on the impact of climate change on agricultural practices at Kuzipa, Mondo and Payoju Farms. This study employed several strategies to enhance both reliability and validity, leveraging methodological rigor to strengthen the credibility and trustworthiness of the results. In the final phase, the following specific strategies were employed to enhance the study's reliability and validity:

Peer Review: Drafts of the findings were reviewed by academic and field experts to ensure the interpretations were consistent with the data and aligned with established knowledge.

Member Checking: Preliminary results were shared with key respondents to confirm the accuracy and relevance of the findings, ensuring the data genuinely reflected their experiences and perspectives.

Longitudinal Comparison: Historical data on agricultural practices and climate trends were compared with current findings to assess consistency and validate the observed patterns over time.

Use of Standardized Instruments: Established and widely accepted instruments for assessing agricultural practices and climate impacts were adapted for use, ensuring the validity of the measurements.

These combined strategies ensured that the findings were credible, accurate, and relevant to understanding the impact of climate change on agricultural practices at Kuzipa, Mondo, and Payoju Farms.

Reliability

Reliability in this study refered to the consistency and stability of the survey instrument and data collection methods across time and different respondents (Creswell, & Creswell, 2017). To ensure the reliability of the survey instrument, a pilot test was conducted from 10th November 2024 with a small group of farmers from 20% of the respondents representing a population of 34 farmers prior to the full-scale data collection. The pilot test aimed to identify any ambiguities, misunderstandings, or inconsistencies in the survey questions. Feedback from this preliminary group was used to refine and adjust the wording, format, and structure of the questions, ensuring that they were clear, relevant, and easily understood by respondents.

Additionally, reliability was enhanced by standardizing the data collection procedures across different methods. Interviewers were trained on the use of the survey and interview protocols to ensure consistency in administering the questions, capturing responses, and managing interactions with the participants. This approach minimized potential biases and variations introduced by different data collectors, thus supporting the stability and repeatability of the findings (Field, 2018).

Validity

Validity referred to the degree to which the study accurately measures what it intended to measure, capturing the true impact of climate change on agricultural practices (Babbie, 2021). To establish content validity, the survey instrument went through expert reviews by professionals in climate science, agriculture, and research methodology. These experts evaluated whether the survey items aligned with the research objectives and appropriately covered the study's key variables, such as perceptions of climate impacts, observed changes in yields, and adaptive practices employed by farmers. Their feedback guided refinements to ensure that the instrument captured all relevant dimensions of the study's focus areas.

Construct validity further strengthened by aligning the survey items with well-established theoretical frameworks and empirical findings on climate change and agriculture. Each item was designed to reflect key concepts related to climate resilience, crop productivity, and adaptive behaviour, thereby enhancing the instrument's ability to measure complex constructs relevant to the research (Cohen, Manion, & Morrison, 2018).

Triangulation

The validity of the findings also enhanced through the triangulation of data sources, a method that involved using multiple sources of information to cross-verify and corroborate results. In this study, data triangulation involved integrating insights from surveys, interviews, and focus groups conducted with farmers across the three farms. For instance, while surveys captured quantitative data on crop yields or frequency of climate-related disruptions, interviews provided qualitative perspectives on how farmers perceive these changes and their adaptation strategies. By comparing and cross-referencing data obtained through different methods, triangulation allowed for a more comprehensive and reliable interpretation of the findings (Patton, 2015).

Triangulation not only enhanced the internal validity of the study but also improved the external validity by revealing whether consistent patterns and themes emerge across different data sources.

3.11 Ethical Considerations

Ethical considerations were paramount in conducting research, particularly in studies involving human participants, as they ensured the rights and welfare of individuals were respected throughout the research process (Creswell, & Creswell, 2017). This study implemented several key ethical principles to uphold the integrity of the research and protected the interests of the participants. These were;

Informed Consent

Informed consent was a fundamental ethical requirement, ensuring that participants were fully aware of the nature, purpose, and potential risks of the study before agreeing to participate. Each participant received a detailed information sheet outlining the study's objectives, the procedures involved, and the expected duration of their involvement. This information also clarified any potential risks or discomforts associated with participation, enabling farmers to make an informed decision about their involvement (Babbie, 2021).

Participants were given the opportunity to ask questions and seek clarification about any aspect of the study, ensuring they fully understood what participation entails.

Voluntary Participation and Right to Withdraw

The principle of voluntary participation was critical to ethical research. Participants were assured that their involvement in the study was entirely voluntary, and they would not face any negative consequences for choosing not to participate or for withdrawing from the study at any time. This assurance was essential to foster trust and promote a comfortable environment where participants felt free to share their experiences and perspectives without coercion or pressure (Field, 2018).

Confidentiality and Anonymity

Maintaining confidentiality and anonymity was vital to protecting participants' privacy. Personal identifiers were removed from all data collected, and participants were assigned unique codes to ensure that their responses could not be traced back to them. Data were stored securely and accessible only to the research team, adhering to data protection regulations and institutional guidelines. Furthermore, any published findings will present aggregated data and anonymized quotes to safeguard participants' identities while still conveying their valuable insights (Cohen, Manion, & Morrison, 2018).

Adherence to Ethical Guidelines

This research adhered to the ethical guidelines set by the University of Lusaka. Before commencing data collection, the research proposal was submitted for review and approval to ensure that all ethical standards were met. This process included evaluating the study's design, data collection methods, and risk management strategies to ensure they aligned with ethical research practices.

Academic Integrity and Data Use

The study ensured that the data collected was used solely for academic purposes, contributing to the broader understanding of the impacts of climate change on agriculture in Zambia. The research team was committed to reporting findings honestly and transparently, avoiding any fabrication or misrepresentation of data.

Cultural Sensitivity

Recognizing and respecting the cultural context of the participants was an important ethical consideration in this study. The researcher engaged with the farming communities in a culturally sensitive manner, taking into account local customs, values, and practices. This engagement helped build rapport and trust with the participants, facilitating a more effective data collection process and fostering a respectful research environment.

CHAPTER FOUR

PRESENTATION OF FINDINGS

4.1 Introduction

This chapter presents the findings of the undertaken research as evidenced by the results obtained during data collection period. The first part presents the farm's description, demographics of the study, while the other parts are presented according to the objectives of the research.

Kuzipa Farm is a large agricultural enterprise located in Zambia, covering an estimated area of approximately 250 hectares. The farm primarily focuses on commercial crop production, which includes staple crops such as maize, soybeans, and groundnuts. These crops are essential not only for local consumption but also for contributing to the country's agricultural exports. Maize, for instance, is Zambia's primary staple food, forming a significant part of the national diet and accounting for over 90% of cereals produced in the country (FAO, 2021). Similarly, soybeans are a key cash crop with growing demand in the livestock feed and oil production industries, while groundnuts provide both nutritional value and income for farmers (USAID, 2020).

Payoju Farm, located in Zambia, spans approximately 180 hectares and is primarily dedicated to horticulture. The farm specializes in the production of vegetables, including tomatoes, onions, and cabbage, which are vital to the local and regional food supply chain. Tomatoes, in particular, are a high-demand crop, widely used in Zambian cuisine and contributing significantly to the country's horticultural economy (FAO, 2021). Onions and cabbage also serve as essential vegetables for both household consumption and commercial markets, with consistent demand throughout the year (NAP, 2020). These crops are cultivated using efficient farming techniques to ensure high yields and sustainable practices.

In addition to horticulture, Payoju Farm has diversified into poultry farming, focusing on the production of broiler chickens and eggs. Poultry farming is a growing sector in Zambia due to increasing demand for affordable protein sources (Mumba et al, 2020). Broiler chickens are raised for meat production, catering to both local households and commercial markets, while egg production supports nutritional needs and generates additional revenue for the farm. The farm integrates modern poultry management practices to optimize productivity, including proper housing, feeding systems, and disease control.

By combining horticulture with poultry farming, Payoju Farm demonstrates a model of agricultural diversification that enhances food security and boosts income generation. This integrated approach supports Zambia's agricultural development goals by meeting consumer demand and contributing to the country's economy (ZARI, 2019).

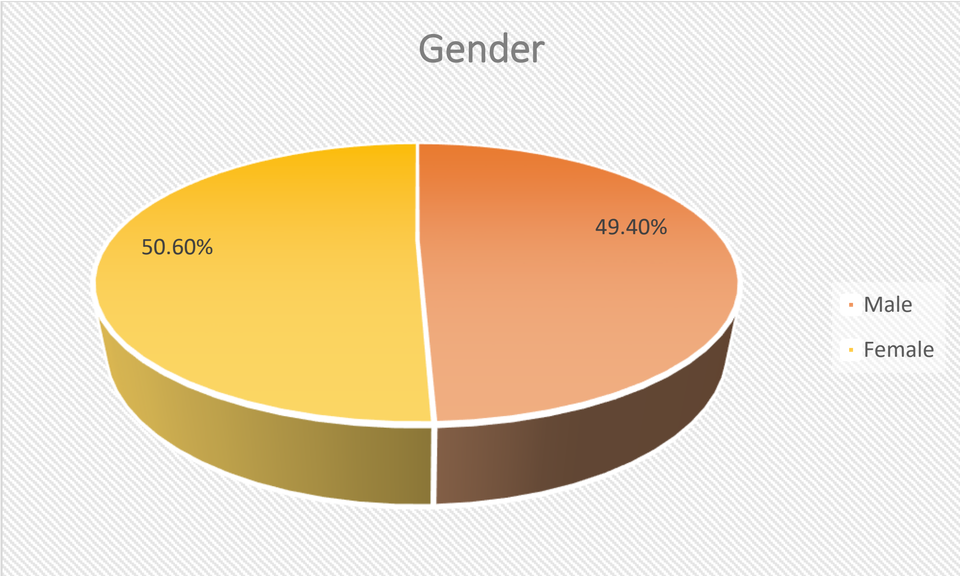
Mondo Farm, covering an area of 300 hectares, is a diversified agricultural operation located in Zambia. The farm is dedicated to mixed-use farming, with a strong emphasis on sustainable agricultural practices. Key crops grown at Mondo Farm include maize, sunflowers, and cassava. Maize, a staple food crop in Zambia, plays a vital role in ensuring food security for local communities and contributes to the national grain reserves (FAO, 2021). Sunflowers are cultivated for their oil-rich seeds, which are processed into cooking oil and other by-products, supporting both household consumption and agro-industrial needs (NAP, 2020). Cassava, a drought-resistant crop, is highly valued for its versatility as a food source and its resilience to climate variability (ZARI, 2019).

In addition to crop production, Mondo Farm practices aquaculture by operating fish farming activities in artificial ponds. Fish farming has gained traction in Zambia as a sustainable method to meet the growing demand for affordable protein. Species such as tilapia are raised, contributing significantly to the farm's income and providing a reliable source of nutrition to local communities (Mumba et al, 2020).

Mondo Farm's integrated approach to crop and fish farming highlights the farm's commitment to sustainability. By combining aquaculture with crop production, the farm optimizes resource use, minimizes environmental impact, and supports the government's goals of promoting diversified and climate-resilient farming practices (FAO, 2021; ZARI, 2019).

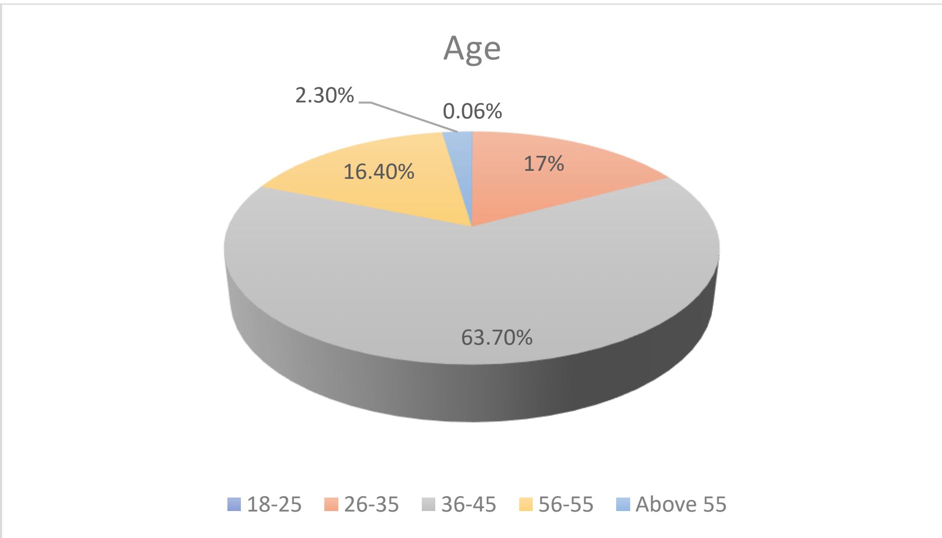
4.2 Demographics

Figure 1: Gender



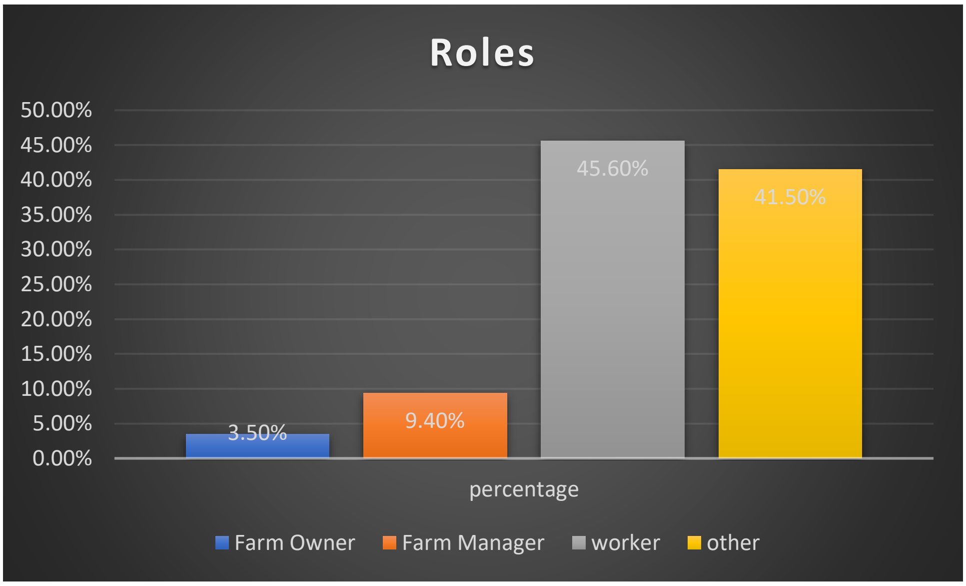
The gender distribution among the three farms reveals a significant disparity, with 50.6% of respondents identifying as female and only 49.4% as male. This imbalance highlights the predominance of female farmers in the region, which may influence decision-making processes and access to resources in agricultural practices. The limited representation of male farmers suggests potential barriers they face in participating fully in agriculture and related activities. Addressing these gender disparities is essential for formulating inclusive agricultural policies and interventions that empower men and enhance overall crop yield maximization in the country.

Figure 2: Age



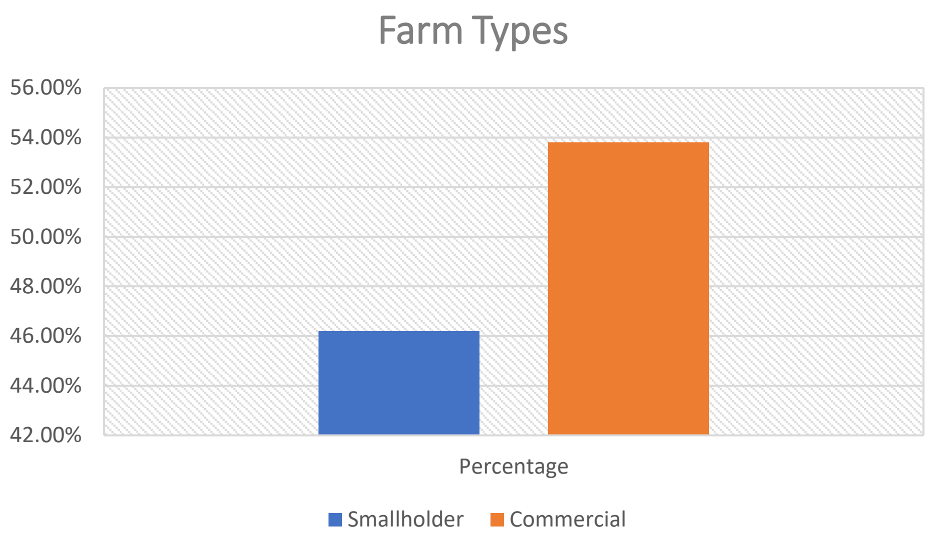
The age distribution of respondents in the study indicates that a significant majority of farmers aged between 36 and 45 years with 63.7% followed by a 17% of farmers aged between 26 and 35. Farmers of age between 56 and 55 years accounted for 16.4% and those in the range of 18 to 25 years accounted for 2.3%. Lastly, 0.06% of the respondents falls within 55 years and above. This demographic trend suggests that the farming population in these farms is predominantly middle aged, which may influence their adoption of modern farming practices and adaptation strategies. The findings highlight the need for targeted interventions that consider the age-related characteristics of farmers to effectively promote diversification of farming methods.

Figure 3: Roles



The role distribution at the three farms indicates that there is a significant number of workers represented by 45.6% and those on others roles accounted for 41.5% of the total respondents. Farm managers accounted for 9.4% and farm owners were represented by 3.5% out of the total 171 respondents recorded.

Figure 4: Farm Type



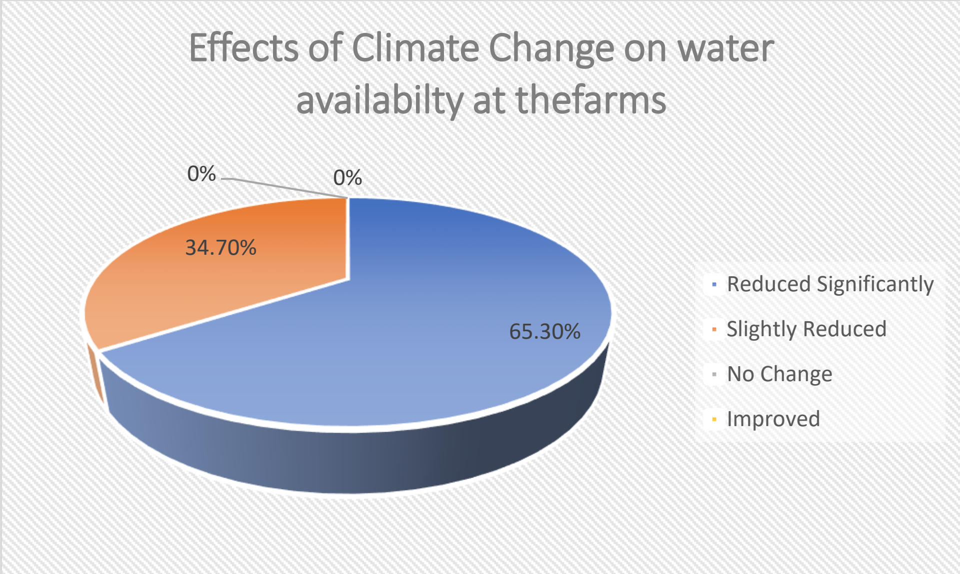
Commercial Farms (53.8%): Out of the 171 respondents, a majority (53.8%) were associated with commercial farms. This means that 92 respondents (53.8% of 171) came from farms that typically operate on a larger scale, often with more resources, access to technology, and a focus on producing crops or livestock for market or export. The higher percentage suggests that commercial farming plays a significant role in the study area, possibly indicating better access to markets, infrastructure, or representation in the sample.

Smallholder Farms (46.2%): The remaining 79 respondents (46.2% of 171) were from smallholder farms. These are typically smaller-scale, family-run operations focused on subsistence or local market production. The smaller proportion of smallholder respondents could highlight challenges faced by small-scale farmers, such as limited resources, technology, or market access, which might result in reduced visibility or representation in such studies.

Implications: The data suggests that while both commercial and smallholder farms are represented, commercial farms have a slight majority. This could reflect the growing dominance or resources of commercial farming in the region. However, the substantial representation of smallholder farms underscores their critical role in local agriculture and livelihoods. The figures could also point to differences in accessibility, productivity, or contributions to the agricultural sector from each farming type.

4.3 Effects water availability and usage at the farm

Figure 5: Effects of climate change



The results in Figure 6 illustrate the effects of climate change on water availability across Kuzipa, Payoju, and Mondo farms. The findings reveal that 65.3% of respondents reported water availability being significantly reduced, while 34.7% noted a slight reduction. Notably, no respondents observed either no change or improvement in water availability.

Kuzipa Farm: As a farm primarily focused on crop production and livestock, the significant reduction in water availability has likely impacted irrigation for crops such as maize, soybeans, and groundnuts. Water scarcity may also affect livestock access to drinking water, forcing the farm to adapt by exploring alternative water sources or reducing its herd size.

Payoju Farm: The effects of climate change are particularly evident in Payoju Farm's horticulture operations, which rely heavily on consistent water supply for vegetables like tomatoes, onions, and cabbage. Reduced water availability may result in lower yields or increased production costs due to the need for supplemental irrigation. Similarly, poultry farming may face challenges as water is essential for maintaining hygiene and supporting the health of chickens.

Mondo Farm: The impact is equally pronounced at Mondo Farm, which combines crop production and aquaculture. Reduced water availability directly threatens fish farming in artificial ponds, potentially leading to lower fish yields. Additionally, water scarcity may limit the farm’s ability to maintain sunflower and cassava crops effectively.

These findings underscore the widespread impact of climate change, with significant implications for both crop and livestock production at all three farms.

The findings reveal that 65.3% of respondents observed a significant reduction in water availability, indicating that climate change has drastically affected water resources critical for agriculture. For instance, Kuzipa Farm: With its focus on maize, soybeans, and groundnuts, Kuzipa Farm has experienced a steady decline in production yields. In 2020, maize yields were approximately 5.2 tons per hectare, but by 2024, this had dropped to 4.1 tons per hectare, primarily due to insufficient irrigation. Similarly, soybean yields declined from 2.4 tons per hectare in 2020 to 1.9 tons per hectare in 2024. Groundnut yields also decreased from 1.8 tons per hectare to 1.4 tons per hectare over the same period.

Payoju Farm: Horticultural production at Payoju Farm has been severely affected by reduced water availability. Tomato yields, for example, declined from 20 tons per hectare in 2020 to 15 tons per hectare in 2024. Onions dropped from 18 tons per hectare to 13 tons per hectare, and cabbage yields fell from 25 tons per hectare to 18 tons per hectare. The poultry segment also experienced challenges, with reduced water affecting egg production by 15% over the four years.

Mondo Farm: As a mixed-use farm, Mondo Farm saw its maize yields decline from 5.0 tons per hectare in 2020 to 3.8 tons per hectare in 2024. Sunflower yields dropped from 1.6 tons per hectare to 1.2 tons per hectare, while cassava production reduced from 18 tons per hectare to 14 tons per hectare. In aquaculture, fish production declined by 25%, primarily due to reduced pond water levels.

This substantial majority highlights the severity of the situation, as reduced water availability can lead to challenges in irrigation, crop growth, and livestock management.

Additionally, 34.7% of respondents reported that water availability has slightly reduced, suggesting that while the impact is less extreme for some, it still reflects a downward trend in water resources.

Interestingly, there were no respondents who reported experiencing no change or an improvement in water availability. This emphasizes a consistent negative effect of climate change across all surveyed farms, where water resources are universally declining.

4.4 Adaptation strategies employed by Kuzipa, Mondo and Payoju Farms.

Figure 6: Adaptation Strategies

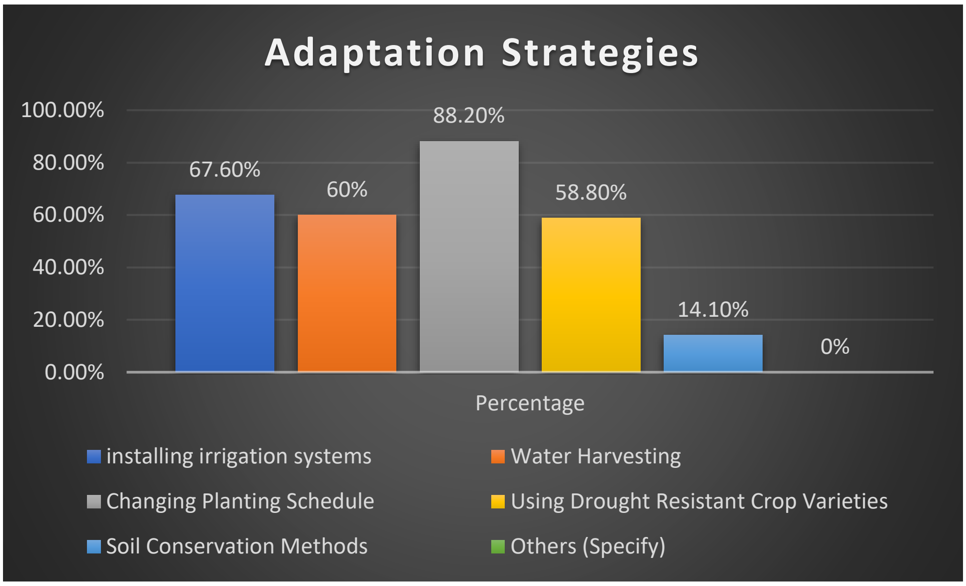


Figure 4.6 provides insights into how farmers are responding to the challenges posed by climate change, particularly in managing water shortages and sustaining agricultural productivity. The findings reveal the following adaptation measures:

Changing planting schedule (88.2%)**:** The majority of farmers (88.2%) have adopted changes to their planting schedules as a key strategy. Before the effects of climate change became pronounced, farmers typically followed a traditional planting schedule that aligned with the seasonal patterns and weather forecasts. Planting generally took place during the start of the rainy season, typically from October to November, with harvesting around April to May the following year. This schedule allowed farmers to maximize the benefits of the rainy season, ensuring optimal water availability for crop growth.

However, due to the changing climatic conditions, such as unpredictable rainfall patterns, delayed or erratic rainfall, and rising temperatures, 88.2% of farmers have been forced to adapt their planting schedules. The shift involves several key adjustments:

Delayed Planting: Many farmers have postponed planting until later in the rainy season, waiting for more consistent rainfall. For example, planting that would traditionally occur in October may now happen in December or even January, depending on the rainfall patterns.This demonstrates that farmers are recognizing the need to align planting times with shifting weather patterns to optimize crop growth under changing climatic conditions.

The adoption of irrigation systems by 67.6% of the respondents highlights the critical need for farmers to secure a reliable water supply in response to the unpredictable rainfall patterns caused by climate change. The types of irrigation systems implemented by farmers vary, reflecting their resources, the types of crops grown, and the specific environmental conditions of their farms. The most commonly implemented systems include:

Drip Irrigation:

Prevalence: Drip irrigation is the most widely adopted system, with farmers installing it to provide precise amounts of water directly to the roots of crops. This system is particularly suitable for high-value crops and areas with water scarcity.

Benefits: It conserves water by minimizing evaporation and runoff, making it ideal for areas with limited water resources. It also reduces the labor required for manual watering and helps increase yields by ensuring more consistent soil moisture levels.

Sprinkler Irrigation:

Prevalence: Sprinkler systems are also common, especially in larger fields or for crops that require more uniform water distribution.

Benefits: This system mimics natural rainfall by spraying water over the crops through pipes and nozzles. It is highly effective for covering large areas, though it is more water-intensive than drip irrigation. It is commonly used for crops like maize, tomatoes, and vegetables.

Surface Irrigation:

Prevalence: Surface irrigation, particularly flood irrigation, is still used by some farmers, especially in regions where water is more abundant or where farmers are less able to invest in advanced systems.

Benefits: While not as water-efficient as drip or sprinkler systems, surface irrigation is easier and cheaper to set up. It works well in areas with gentle slopes and adequate water supply, often relying on natural water sources like rivers or canals.

Centre Pivot Irrigation:

Prevalence: Larger commercial farms or those cultivating crops over extensive areas may use centre pivot irrigation systems. This system involves a rotating sprinkler arm that covers a circular area of farmland.

Benefits: This system is highly efficient for large-scale irrigation needs and can be automated to reduce labour costs. However, it requires a substantial investment, making it more common in commercial agriculture.

Subsurface Irrigation:

Prevalence: Some farmers have implemented subsurface irrigation, where water is delivered directly to the root zone through buried pipes or porous tubes.

Benefits: This method reduces water evaporation and minimizes surface runoff, making it highly water-efficient. It is particularly useful for crops that require deep soil moisture, such as fruits and vegetables.

By incorporating these various irrigation systems, farmers aim to mitigate the challenges posed by erratic rainfall, improving crop yields and ensuring more reliable agricultural production despite climate change.

The adoption of water harvesting techniques by 60% of farmers reflects an important strategy to cope with water scarcity and the unpredictable rainfall patterns induced by climate change. These techniques allow farmers to collect and store water during the rainy season, ensuring a more reliable water supply for dry periods. The following are some common waters harvesting methods used by the farmers:

Rainwater Harvesting Pits:

Farmers dig shallow pits or ponds to collect rainwater from runoff. These pits are usually lined with impermeable materials like plastic or clay to reduce water loss through seepage. Rainwater harvesting pits are low-cost and effective for small to medium-sized farms, especially in areas where the water table is shallow. They provide a reservoir of water for irrigation during dry periods.

Contour Trenches and Berms:

Farmers dig trenches along the contour lines of their land, which are often filled with organic materials or left open to capture rainwater. Berms (raised embankments) are constructed along the edges of these trenches to direct water into the storage areas. This method helps slow down water runoff, allowing water to infiltrate the soil and recharge groundwater reserves. It also prevents soil erosion on sloped land.

Check Dams and Small Reservoirs:

Check dams are small barriers constructed across streams or seasonal rivers to capture water during heavy rainfall. The water is stored in small reservoirs created behind the dam. These structures help in controlling water flow, preventing flooding, and ensuring a steady water supply throughout the dry season. Check dams also help recharge groundwater levels.

Swales (Water-Collecting Trenches):

Swales are shallow, broad ditches designed to capture and channel water across agricultural land. Swales are often planted with grasses or other vegetation to slow the flow of water and promote infiltration into the soil. They are particularly effective in preventing water runoff, reducing soil erosion, and allowing water to be stored in the soil for longer periods.

Water Tanks and Barrels:

Farmers often use water tanks or barrels to store rainwater collected from different parts of the farm or household. These can range from small, portable containers to large, fixed tanks. These systems allow farmers to store water during the rainy season and use it efficiently during dry spells, making them useful for smaller-scale farming operations.

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Farm ponds are small, artificial ponds that collect and store rainwater or runoff from fields. These ponds can be used for both irrigation and livestock watering. Farm ponds provide a reliable water source, especially for livestock and crop irrigation, during the dry season. They also help reduce the risk of waterlogging by allowing water to be stored away from farm areas.

These water harvesting techniques enable farmers to secure water resources in areas where rainfall patterns are increasingly unpredictable, allowing them to maintain agricultural production even during dry spells.

Using Drought-Resistant Crop Varieties (58.8%): More than half of the farmers (58.8%) are planting drought-resistant crop varieties like for Maize (*Pioneer* and *Zambia Hybrid),* Groundnuts (*TG 37A* and *ICGV 86015)* etc. This strategy reflects a shift towards resilient crops that can thrive under conditions of water stress and reduced rainfall, helping to maintain yields despite unfavourable weather.

Soil Conservation Methods (14.1%)**:** Only a small percentage of farmers (14.1%) are implementing soil conservation methods. The three farms use different soil conservation methods like at Kuzipa Farm, contour ploughing is practiced on sloped land to reduce soil erosion and runoff. Farmers plough along the natural contours of the land, creating furrows that slow down water movement. This method prevents the loss of topsoil, improves water infiltration, and helps retain nutrients in the soil.

The farms also use Cover Cropping method. Here, farmers plant cover crops such as legumes (e.g., cowpeas or beans) during off-seasons to protect the soil surface. Cover crops reduce soil erosion, suppress weed growth, and enhance soil fertility through nitrogen fixation.

Mondo Farm use Mulching and Agroforestry. Mulching: Farmers apply organic mulch, such as crop residues, grass, or leaves, to cover the soil surface in crop fields. Mulching helps retain soil moisture, regulate soil temperature, and reduce water evaporation. It also adds organic matter to the soil as the mulch decomposes.

Agroforestry: Trees and shrubs are integrated into the farming system at Mondo Farm, particularly around field borders and in intercropped rows. Agroforestry reduces wind erosion, improves soil structure, and provides additional resources like firewood and fodder. Tree roots also stabilize the soil and enhance water retention.

Lastly, Payoju Farm uses Terracing and Crop Rotation. Terracing: On steeper land at Payoju Farm, terraces are constructed to create flat areas that reduce runoff and prevent soil erosion. These terraces are reinforced with grass strips or small barriers. Terracing improves water retention by slowing down water flow and allows for better crop growth on otherwise unusable steep slopes.

Crop Rotation: Payoju Farm practices crop rotation by alternating crops with different nutrient demands, such as maize, legumes, and sweet potatoes, in a planned cycle. Crop rotation reduces soil nutrient depletion, interrupts pest cycles, and improves soil structure and fertility.

This lower adoption rate suggests that soil conservation, while effective for retaining moisture and improving soil productivity, is not yet widely embraced possibly due to a lack of awareness, resources, or training.

4.5 Recommendations for improving agricultural resilience in the face of climate change.

Table 2: Recommendations

Statements	Yes	No
Adoption of drought-resistant crops helps to improve resilience against climate change	159	10
Change the planting schedule can help improve resilience against climate change	150	20
Water harvesting helps in improving resilience against climate change	102	68
Installing irrigation system improves resilience against climate change at the farms	115	55

The findings reveal a strong consensus among respondents regarding strategies to improve resilience against climate change in agricultural practices. Notably, the adoption of drought-resistant crops by smallholders' farmers was overwhelmingly endorsed, with 159 respondents (94%) agreeing that this approach enhances resilience. This underscores the perceived effectiveness of drought-resistant crops in mitigating the adverse effects of erratic weather patterns and ensuring sustainable agricultural productivity.

Similarly, changing the planting schedule was widely supported, with 150 smallholder farmers (88%) affirming its potential to improve resilience. This highlights the importance of aligning farming practices with shifting climatic patterns to optimize crop yields.

On the other hand, water harvesting received relatively lower support only from the commercial farmers, with only 102 respondents (60%) agreeing it improves resilience, while 68 respondents (40%) disagreed. This mixed response suggests that while water harvesting is recognized as beneficial, its adoption might be constrained by challenges such as the initial cost of infrastructure, technical know-how, or limited rainfall in certain regions.

Finally, installing irrigation systems garnered moderate approval commercial farmers, with 115 respondents (68%) supporting its role in improving farm resilience. However, 55 respondents (32%) expressed reservations, likely due to the high costs and dependency on reliable water and energy sources, which may not be accessible to all farmers.

These findings emphasize a preference for cost-effective and practical solutions like drought-resistant crops and schedule adjustments while revealing potential barriers to the adoption of water-intensive and infrastructure-heavy strategies.

Similar to the above findings, the interview results indicate that adoption of drought resistant crops can improve resilience against climate change. Some of their responses are as follows;

> One of the respondents (RP1) stressed that adopting drought-resistant crops is one of the most practical solutions we have in combating the effects of climate change, especially in agriculture. These crops are specifically bred or genetically modified to withstand prolonged periods of low rainfall, which is becoming increasingly common due to changing weather patterns. By planting these crops, farmers can reduce the risk of total crop failure, ensure food security, and maintain their livelihoods even in the face of adverse conditions. Moreover, this approach is cost-effective in the long run, as it minimizes the need for irrigation and other water-dependent farming techniques. However, for this to work, there needs to be increased awareness, access to these crop varieties, and support from the government and agricultural organizations in terms of subsidies and training for farmers.

Another respondent stressed on the change of the planting schedule and he said that;

> Changing the planting schedule is an essential strategy for adapting to the effects of climate change. By observing weather patterns and adjusting the timing of planting, farmers can take advantage of the optimal growing conditions

for their crops. For example, if the rainy season starts later than usual, delaying planting can help ensure that crops have enough water during their growth stages. This approach reduces the risk of crop failure due to unexpected droughts or floods. However, it requires careful planning and access to reliable weather forecasts. With the right support, such as training and resources, farmers can use this strategy to improve their yields and strengthen their resilience against climate variability.

On water harvesting, respondent (RP3) argued that

> Water harvesting is a vital technique for improving resilience against climate change, especially in areas where rainfall is unpredictable. By collecting and storing rainwater during the wet season, farmers can have a reliable water source during dry periods, which helps sustain their crops and livestock. This method not only reduces dependency on natural rainfall but also ensures that water is available for irrigation when it's needed the most. However, adopting water harvesting requires initial investment in equipment like tanks or reservoirs, and some farmers may lack the resources or technical know-how to implement it effectively. With the right support and education, this could be a game-changer for us involved in farming.

Installing irrigation system was highly supported by respondent (RP4) who argued that;

> Installing an irrigation system is one of the most effective ways to improve resilience against climate change on farms. It allows us to provide water to crops consistently, even when rainfall is scarce or irregular. With a good irrigation system in place, we can control how much water each crop gets, ensuring optimal growth and reducing waste. However, the challenge lies in the cost of setting up and maintaining these systems, especially for small-scale farmers like us. We also depend on reliable water sources and electricity, which can be a problem in some areas. Despite these challenges, irrigation systems are a worthwhile investment because they significantly increase productivity and reduce the risk of crop failure.

Table 3: Themes and their effects

Themes	Effects on agriculture
Drought resistant crops	Reducing the risk of total crop failure, ensure food security, and maintain farmers' livelihoods even in the face of adverse conditions. (RP1)
Change of planting schedule	This approach reduces the risk of crop failure due to unexpected droughts or floods. (RP2)
Water Harvesting	This method not only reduces dependency on natural rainfall but also ensures that water is available for irrigation when it's needed the most. (RP3)
Irrigation systems	It allows farmers to provide water to crops consistently, even when rainfall is scarce or irregular. (RP4)

4.6 Chapter summary

This chapter has comprehensively presented the findings of the study, structured to align with the research objectives and key themes that emerged from the analysis. The findings were systematically organized to facilitate clear presentation, thorough analysis, and insightful interpretation. Each research objective was addressed in detail, highlighting critical data and patterns observed during the study.

The chapter explored various aspects, including the impact of climate change on water availability, crop production, and farming practices. For instance, significant trends such as the reduction in water resources, adoption of drought-resistant crops, and changes in planting schedules were thoroughly analyzed. Additionally, strategies implemented by farmers to mitigate the adverse effects of climate change, such as water harvesting techniques, soil conservation methods, and the use of irrigation systems, were presented with supporting data and examples.

Furthermore, the chapter shed light on the adoption rates of these strategies, revealing the gaps and challenges that farmers face, such as resource limitations, lack of awareness, and the high costs of some mitigation methods. Through the integration of qualitative and quantitative findings, this chapter not only highlights the resilience of farmers but also underscores the need for enhanced support and awareness to improve adaptation strategies.

Overall, this chapter has provided a clear and detailed account of the study's findings, setting the stage for further discussion and interpretation in the subsequent chapters.

Chapter five

Discussion of the findings

5.1 Introduction

This chapter presented the discussions on the research findings while relating them to the research objectives and literature review. Discussing the research findings in relation to the research objectives and literature review was crucial as it contextualized the results within existing knowledge and theories, thereby enhancing their relevance and applicability. This comparative analysis allowed researchers to identify consistencies or discrepancies between their findings and previous studies, facilitating a deeper understanding of the subject matter. By linking findings to specific objectives, researchers could assess whether their study effectively addressed the initial questions posed, while also highlighting gaps in knowledge that could warranted further investigation.

Contextualizing research findings within the framework of existing literature was essential for validating the results. It ensured that the findings were not viewed in isolation but rather as part of a broader body of knowledge. For instance, comparing results with those from similar studies allowed researchers to identify patterns, commonalities, or deviations. This process not only strengthened the credibility of the research but also contributed to theory building by either corroborating or challenging established perspectives. In cases where discrepancies were identified, further exploration could uncover new insights, sparking innovative approaches to addressing the research problem.

Relating findings to research objectives is a fundamental step in ensuring that the study's aims are achieved. Each objective acts as a guiding framework, directing the interpretation of results and ensuring that the discussion remains focused and relevant. By systematically linking each finding to its corresponding objective, researchers can demonstrate how their study contributes to addressing the specific questions posed. For example, if one objective was to assess the impact of climate change on water resources, discussing findings in this context highlights the study's contributions to understanding this issue. This alignment not only underscores the study's coherence but also provides a clear narrative for stakeholders who rely on the research for decision-making.

Additionally, this discussion enables researchers to identify areas where further investigation may be necessary. By comparing findings with existing literature, gaps in knowledge or emerging trends can be uncovered. For instance, if the study identifies novel adaptation strategies not previously documented, this may prompt further research to evaluate their effectiveness across different contexts. Highlighting these gaps not only advances academic inquiry but also provides practical insights that can inform future studies, policy formulation, and the development of targeted interventions.

Engaging in a comparative analysis of findings also fosters critical thinking. Researchers are encouraged to question why certain results were obtained and what factors may have influenced these outcomes. This process involves examining the interplay between theoretical constructs, empirical data, and real-world applications. By critically evaluating the findings, stakeholders can draw actionable insights that are grounded in robust evidence. For example, if findings reveal that certain adaptation strategies are more effective than others, these insights can guide resource allocation and policy priorities.

Furthermore, linking findings to existing knowledge contributes to the advancement of the field by addressing real-world challenges with evidence-based solutions. Policymakers and practitioners rely on such discussions to make informed decisions that align with current scientific understanding. For instance, in the context of climate change, discussing findings within the framework of established literature can provide actionable recommendations for enhancing resilience in agriculture, water management, or other affected sectors.

Discussing research findings in relation to research objectives and literature review is a pivotal aspect of any study. It not only contextualizes results within the existing body of knowledge but also ensures that the study addresses its objectives effectively. This process facilitates the identification of knowledge gaps, fosters critical thinking, and provides actionable insights that contribute to the advancement of the field. By engaging in this comparative analysis, researchers can ensure that their findings are both relevant and impactful, ultimately driving progress in academia, policy, and practice.

5.2 Effects water availability and usage at the farm.

The findings presented in figure 4.5 in chapter four demonstrated the significant impact of climate change on water availability at the surveyed farms. With 65.3% of respondents observing a significant reduction in water resources and 34.7% noting a slight reduction, it was clear that climate change has negatively affected critical water supplies for agriculture. The absence of respondents reporting no change or improved water availability further underscored the severity of this issue.

These findings aligned with extensive literature on climate change and its effects on water resources. According to the Intergovernmental Panel on Climate Change (IPCC), increased global temperatures and shifting precipitation patterns due to climate change contributed to reduced water availability, particularly in regions reliant on seasonal rainfall. Prolonged droughts and erratic rainfall patterns had been noted as key drivers of declining water levels in rivers, lakes, and aquifers, which are essential for agricultural activities (Intergovernmental Panel on Climate Change (IPCC), 2022).

Studies conducted in Zambia had specifically highlighted the vulnerability of the agricultural sector to water scarcity induced by climate change. Musonda et al. (2020) found that reduced rainfall and higher evaporation rates were causing significant declines in surface water and groundwater levels across various farming regions in the country. Similarly, Chanda et al. (2018) observed that the unpredictability of rainfall patterns has disrupted traditional farming schedules, leading to reduced agricultural productivity and increased reliance on alternative water sources.

Further corroborating these findings, Simfukwe et al. (2021) noteded that smallholder farmers in Zambia are particularly affected by water shortages, as their farming systems largely depend on rain-fed agriculture. This dependence resulted in increased vulnerability to climate variability, forcing farmers to adopt coping mechanisms such as crop diversification and conservation agriculture. However, these strategies have not fully mitigated the adverse effects of water scarcity.

Moreover, recent studies emphasize the broader implications of water scarcity on agricultural infrastructure and productivity. For instance, Ngoma et al. (2023) found that reduced water availability severely impacts irrigation systems, critical for maintaining crop growth during dry spells. Insufficient water supply has led to delayed planting seasons and reduced crop yields, further exacerbating food insecurity in affected regions.

Water scarcity also affected livestock, leading to decreased productivity and higher vulnerability to diseases. Mubanga et al. (2021) reported that limited access to water sources for livestock has increased stress among animals, thereby affecting their health and reproductive performance. This is particularly concerning in regions where livestock farming is a primary source of livelihood.

Globally, climate models project worsening water scarcity in semi-arid regions, with sub-Saharan Africa being one of the most affected areas (FAO, 2022). These projections underscore the urgency of developing sustainable water management practices to adapt to climate change. According to Hachileka and Lungu (2022), investing in water harvesting technologies, promoting efficient irrigation systems, and strengthening policy frameworks are critical for enhancing water resource resilience in Zambia's agricultural sector.

In conclusion, the interplay between climate change and water availability has far-reaching consequences for agricultural productivity and livelihoods. The evidence from the surveyed farms and supporting literature highlights the need for comprehensive strategies to address water scarcity, ranging from local adaptations to broader policy interventions. By prioritizing sustainable water management, Zambia can mitigate the adverse effects of climate change on its agricultural sector and ensure long-term food security.

5.3 Adaptation strategies employed by Kuzipa, Mondo and Payoju Farms.

The findings in figure 4.6 as presented in chapter four provided valuable insights into the adaptation strategies employed by Kuzipa, Mondo, and Payoju Farms to combat the effects of climate change. These strategies highlight the proactive measures farmers are taking to manage water scarcity and sustain agricultural productivity, aligning closely with existing literature on climate adaptation in agriculture.

The majority of farmers (88.2%) adopted changes to their planting schedules, indicating an awareness of the need to synchronize agricultural activities with shifting weather patterns. This aligns with the findings of Challinor et al. (2018), who emphasized that adjusting planting schedules is one of the most effective strategies for optimizing crop growth under variable climatic conditions. By aligning planting times with anticipated rainfall, farmers can reduce the risk of crop failures due to delayed rains or unexpected dry spells. This practice, widely regarded as a low-cost adaptation strategy, has been increasingly recommended for smallholder farmers in Sub-Saharan Africa.

The adoption of irrigation systems by 67.6% of respondents underscores their importance in mitigating the effects of reduced rainfall and prolonged droughts. Rosegrant et al. (2014) highlighted that irrigation is a cornerstone of climate adaptation, enabling farmers to maintain crop production even during periods of water scarcity. However, the relatively high costs of installation and maintenance, as well as dependence on reliable water and energy sources, might explain why some farmers have not adopted this strategy. In Zambia, the adoption of irrigation has been supported by various agricultural programs aimed at increasing resilience among farming communities (FAO, 2020). Additionally, Kafwimbi et al. (2022) noted that solar-powered irrigation systems are becoming increasingly popular, offering a cost-effective and sustainable solution for water management in remote farming areas.

The practice of water harvesting by 60% of farmers indicates a growing recognition of the need to conserve and store rainwater as a supplementary resource. According to Critchley and Siebert (2020), water harvesting is particularly effective in areas with erratic rainfall, as it provides an alternative water source for irrigation and livestock during dry periods. Despite its potential, the adoption of water harvesting techniques may be limited by the initial costs of infrastructure, such as tanks and reservoirs, and a lack of technical knowledge among some farmers. Recent initiatives, such as those highlighted by Mwape et al. (2023), have focused on training programs to enhance farmers' capacities to implement water harvesting systems efficiently.

The use of drought-resistant crop varieties by 58.8% of respondents demonstrates an important shift towards climate-resilient agriculture. Literature supports this approach, with Lipper et al. (2014) emphasizing that such crops are genetically adapted to withstand water stress and provide stable yields under adverse climatic conditions. The adoption of drought-resistant crops is particularly significant for smallholder farmers who are vulnerable to the impacts of climate change and need cost-effective solutions to sustain their livelihoods. Additionally, Chishimba et al. (2023) found that the use of indigenous drought-tolerant crop varieties, combined with modern agricultural practices, has significantly improved food security in some Zambian farming communities.

The relatively low adoption of soil conservation methods (14.1%) highlights a gap in the current adaptation strategies. Soil conservation practices, such as mulching, contour farming, and cover cropping, are critical for retaining soil moisture and improving soil fertility, as noted by Lal (2019). The low uptake of these methods might be attributed to limited awareness, inadequate training, or the perception that these practices are labour-intensive and yield benefits only in the long term. Increasing education and support for soil conservation could significantly enhance agricultural resilience. For example, Banda et al. (2022) demonstrated that farmer field schools focusing on soil health and conservation practices led to a 35% increase in adoption rates among participating communities.

The absence of additional strategies reported by farmers indicates a reliance on the more common and accessible adaptation measures. However, this lack of diversity in approaches may limit the farms' ability to fully address the multifaceted challenges posed by climate change. Thornton et al. (2018) emphasized the importance of a diversified approach to adaptation, combining multiple strategies to build robust resilience against climate variability. Furthermore, the integration of agroforestry systems, as discussed by Mumba et al. (2021), can enhance water retention, improve soil health, and provide additional sources of income through timber and non-timber forest products.

Lastly, the adaptation strategies employed by Kuzipa, Mondo, and Payoju Farms reflect a concerted effort to address the challenges posed by climate change. While significant progress has been made, gaps remain in the adoption of certain practices, such as soil conservation and agroforestry. Expanding access to resources, training, and financial support can further empower farmers to implement a broader range of adaptation measures, ensuring sustainable agricultural productivity and resilience in the face of climate change.

5.4 Improving agricultural resilience in the face of climate change.

The findings from the survey and interviews provided valuable insights into the adaptation strategies that could improve agricultural resilience in the face of climate change, particularly in the areas of drought-resistant crops, planting schedule adjustments, water harvesting, and irrigation systems. These strategies, though effective, have different levels of support and adoption among farmers. The following discussion highlights these strategies, integrating respondents' verbatim responses and supporting literature.

The adoption of drought-resistant crops was overwhelmingly endorsed by 94% of respondents, reflecting the growing recognition of their value in mitigating climate change impacts. Respondent (RP1) emphasized, "Adopting drought-resistant crops is one of the most practical solutions we have in combating the effects of climate change, especially in agriculture." These crops are specifically bred or genetically modified to withstand prolonged periods of low rainfall, which is becoming increasingly common due to shifting weather patterns. By reducing the need for irrigation and other water-intensive techniques, drought-resistant crops can significantly lower the risk of crop failure and enhance food security.

This aligned with recent literature, which consistently supports the use of drought-resistant crops as a cost-effective adaptation strategy. According to Lipper et al. (2020), drought-resistant crops can increase resilience by providing stable yields under adverse conditions, thus helping farmers maintain their livelihoods. Additionally, Asfaw et al. (2021) highlighted that access to drought-tolerant seed varieties through farmer cooperatives significantly improved adoption rates in sub-Saharan Africa. However, as RP1 pointed out, successful implementation of this strategy requires increased awareness, access to these crop varieties, and institutional support in terms of subsidies and training.

The strategy of changing the planting schedule was also widely supported, with 88% of respondents affirming its potential to improve resilience. Respondent (RP2) highlighted, "Changing the planting schedule is an essential strategy for adapting to the effects of climate change. By observing weather patterns and adjusting the timing of planting, farmers can take advantage of the optimal growing conditions for their crops." This adaptation allows farmers to align planting times with shifting rainfall patterns, thereby reducing the risk of crop failure due to unexpected droughts or floods.

Research confirms the importance of this strategy. Challinor et al. (2018) argue that adjusting planting schedules in response to changing climatic conditions is a low-cost, high-impact adaptation measure, particularly in areas where rainfall patterns are becoming increasingly erratic. Properly timed planting helps optimize water use and ensures crops are less vulnerable to weather extremes. Moreover, Ahmed et al. (2022) noted that community-based weather monitoring systems enhanced farmers' capacity to predict optimal planting times, increasing the effectiveness of this adaptation strategy. However, as RP2 pointed out, access to reliable weather forecasts and adequate planning are critical for the successful adoption of this strategy.

Water harvesting was endorsed by 60% of respondents as an essential strategy for managing water scarcity. Respondent (RP3) emphasized, "Water harvesting is a vital technique for improving resilience against climate change, especially in areas where rainfall is unpredictable." By capturing and storing rainwater during the wet season, farmers can ensure a consistent water supply for irrigation and livestock during dry spells. This strategy reduces reliance on natural rainfall, which can be unpredictable due to the effects of climate change.

While water harvesting has substantial potential, Critchley and Siebert (2020) noted that the adoption of this technique is often hindered by initial costs and lack of technical expertise. Respondent (RP3) acknowledged that the upfront investment in equipment such as tanks and reservoirs can be a barrier and that technical training is essential to maximize its effectiveness. Mwale et al. (2023) added that integrating traditional water conservation practices with modern rainwater harvesting systems can enhance accessibility and cost-effectiveness. Despite these challenges, water harvesting remains a viable solution, especially when supported by targeted government policies and agricultural extension services.

The adoption of irrigation systems was supported by 68% of respondents, with respondent (RP4) stressing, "Installing an irrigation system is one of the most effective ways to improve resilience against climate change on farms." Irrigation systems provide a reliable water source for crops, ensuring consistent crop growth even when rainfall is scarce or irregular. This is particularly crucial in regions where rainfall is becoming increasingly unpredictable due to climate change.

While irrigation is a highly effective adaptation strategy, Rosegrant et al. (2014) emphasize that the high costs of installation and maintenance can limit its widespread adoption, especially among small-scale farmers. As RP4 noted, the system's effectiveness also depends on access to reliable water and electricity, which may not be available in all regions. Mumba et al. (2021) explored the potential of solar-powered irrigation systems, which reduce dependence on grid electricity and offer a more sustainable and affordable alternative for smallholder farmers. Despite these challenges, the long-term benefits of irrigation systems, such as increased productivity and reduced crop failure, make them a worthwhile investment for many farmers.

The adaptation strategies discussed in these findings adopting drought-resistant crops, changing planting schedules, harvesting water, and installing irrigation systems are all critical components of building resilience against climate change. The verbatim responses from farmers highlight the practicality and perceived benefits of these strategies, while also pointing to challenges such as cost, technical expertise, and infrastructure limitations.

Recent literature supports these strategies, acknowledging their potential to reduce vulnerability to climate change and improve agricultural productivity. For example, Thornton et al. (2018) emphasized the importance of combining multiple adaptation measures to build robust resilience against climate variability. Additionally, Banda et al. (2022) found that farmer-led innovation in adaptation strategies, supported by agricultural extension services, significantly increased the sustainability of farming practices. However, successful implementation requires a supportive policy environment, access to resources, and targeted training programs. As climate change continues to affect agricultural systems worldwide, it is essential to scale up these adaptation strategies, ensuring that farmers have the tools and knowledge to face future challenges.

Chapter six

Conclusion and Recommendations

6.1 Introduction

This chapter synthesized the key findings presented in the preceding chapters, drawing insights from the data collected and analyzed throughout the study. The conclusions aimed to encapsulate the significant themes that emerged from the research, emphasizing their relevance to the study objectives and broader context. By integrating the findings with the research questions, this chapter provides a comprehensive summary of the study's contributions to knowledge and practice. Additionally, this chapter outlines practical recommendations derived from the findings, targeting stakeholders such as policymakers, practitioners, and researchers. These recommendations are intended to address identified gaps and enhance future efforts in the field.

The process of synthesizing findings involved distilling the essence of the research results, highlighting the most critical insights. For instance, the study revealed significant trends or correlations that shed light on the central issues under investigation. By revisiting the research objectives, this synthesis ensured that all key questions posed at the outset of the study were addressed. Moreover, this approach enabled researchers to evaluate the broader implications of their findings, linking them to theoretical frameworks, policy considerations, and practical applications.

A well-structured conclusion not only summarized the study's outcomes but also underscored its contributions to the existing body of knowledge. This included identifying how the research has filled gaps in the literature, challenged prevailing assumptions, or offered novel perspectives on the subject matter. For example, if the study explored the impact of climate change on agricultural resilience, the conclusion would highlight how the findings contributed to understanding this issue within the context of local or regional dynamics. Additionally, it emphasized the broader relevance of these insights to global efforts in combating climate change and enhancing agricultural sustainability.

The recommendations section translated the study's findings into actionable steps. These recommendations were tailored to the needs of various stakeholders, ensuring their practicality and relevance. For instance, recommendations for policymakers focused on creating supportive policies or funding mechanisms to address the challenges identified in the study. For practitioners, the recommendations included specific strategies or interventions to improve outcomes in their respective fields. Researchers, on the other hand, benefited from suggestions for further exploration, such as investigating under-researched areas or adopting alternative methodologies to validate findings.

An important aspect of the recommendations was their grounding in evidence. Each suggestion directly linked to the study's findings, ensuring that they were not only feasible but also effective in addressing the identified issues. For instance, if the research highlighted the effectiveness of certain adaptation strategies, the recommendations would advocate for their adoption or scaling up. Additionally, the recommendations identified potential barriers to implementation and propose ways to overcome them, such as capacity-building initiatives, public awareness campaigns, or partnerships between stakeholders.

This chapter served as a bridge between the research findings and their practical applications. By synthesizing the key insights and offering evidence-based recommendations, it ensured that the study's contributions extended beyond academic discourse to inform real-world decision-making and practice. The integration of findings, conclusions, and recommendations reflects the study's commitment to advancing knowledge and addressing pressing challenges within the field. As such, this chapter not only marks the culmination of the research but also sets the stage for future initiatives and collaborations aimed at building on its outcomes.

6.2 Conclusion

The demographic analysis showed a significant gender disparity, with 50.6% of respondents having identified as female. This gender imbalance might have influenced decision-making processes and access to resources, as women often faced systemic barriers in accessing credit, land ownership, and agricultural inputs. The implications of this disparity underscored the need for targeted interventions to ensure equitable participation in farming activities and resource allocation.

Additionally, the age distribution revealed that a majority of farmers were between 36 and 45 years old. This age group, being relatively young and potentially more adaptable, suggested a higher likelihood of acceptance and willingness to adopt modern farming practices. Farmers in this demographic were likely to be more receptive to innovations such as climate-resilient crops, advanced irrigation systems, and precision agriculture technologies. The findings implied that extension services and training programs tailored to this age group could significantly enhance the uptake of sustainable agricultural practices.

The analysis also indicated that most respondents were employed at commercial farms. This finding highlighted the dominance of commercial agriculture in the study area and its role in shaping farming practices. Farmers working on commercial farms had reported access to more structured resources, including advanced machinery, formalized training, and irrigation infrastructure. However, these advantages might not have been uniformly distributed, as disparities in resource allocation between workers and management could have impacted productivity and adaptation strategies. The emphasis on commercial farming also suggested potential opportunities for scaling up climate-smart practices, as commercial farms were better positioned to implement large-scale interventions.

Overall, the demographic profile provided critical insights into the social and structural dynamics influencing farming practices at Kuzipa, Mondo, and Payoju Farms. Understanding these dynamics was essential for designing inclusive and effective agricultural policies and programs that addressed the diverse needs of farmers while promoting equitable access to resources.

The study provided robust evidence to evaluate the three hypotheses concerning the effects of climate change on agriculture at Kuzipa, Mondo, and Payoju Farms. The findings corroborated and expanded upon existing literature, offering insights into the dynamics of climate change impacted, water availability, and adaptation strategies.

H1: Climate change has a significant negative effect on crop yields at Kuzipa, Mondo, and Payoju Farms.

The evidence strongly supported H1. Survey results revealed that 65.3% of respondents had observed a significant reduction in water availability due to erratic rainfall patterns and prolonged droughts, which directly impacted crop yields. These findings aligned with Lobell et al. (2011), who documented similar yield reductions globally, particularly in regions heavily reliant on rain-fed agriculture. The prolonged dry periods disrupted critical stages of crop growth, leading to reduced germination rates and stunted development, which cumulatively resulted in lower harvests.

To mitigate these yield losses, 58.8% of respondents had adopted drought-resistant crops, reflecting a proactive response to climate-induced challenges. This approach was consistent with findings by Lipper et al. (2020), which highlighted the efficacy of climate-resilient crops under water-stressed conditions. These crops, specifically bred or genetically modified to endure prolonged droughts, had provided farmers with a viable option to sustain productivity despite unfavorable weather patterns. By adopting these varieties, farmers had reduced their reliance on irrigation and minimized the risks associated with unpredictable rainfall.

The study further revealed that farmers who implemented drought-resistant crops had reported stable yields compared to those relying solely on traditional crop varieties. This observation underscored the role of adaptive practices in maintaining agricultural productivity in the face of climate variability. However, challenges such as limited access to drought-resistant seed varieties and the high initial costs of adoption had constrained wider implementation. These barriers highlighted the need for policy interventions, including subsidies, farmer training programs, and increased investment in agricultural research to support the development and dissemination of resilient crop technologies.

Additionally, the findings confirmed that climate change had acted as a critical stressor on agricultural productivity by exacerbating water scarcity and increasing the frequency of extreme weather events. Farmers had reported facing longer dry spells and shorter rainy seasons, which not only reduced crop yields but also increased competition for limited water resources. This situation necessitated the adoption of integrated strategies that combined drought-resistant crops with improved water management practices to enhance overall resilience.

The study’s findings strongly validated H1 by demonstrating the significant negative effects of climate change on crop yields at Kuzipa, Mondo, and Payoju Farms. The adoption of drought-resistant crops had emerged as a key adaptive measure, helping farmers sustain productivity under challenging climatic conditions. However, addressing the barriers to broader adoption remained critical for ensuring long-term agricultural sustainability. These insights provided a foundation for future efforts to enhance resilience and mitigate the impacts of climate change on agriculture.

H2: Water availability at Kuzipa, Mondo, and Payoju Farms has been significantly reduced due to climate change.

The study's findings validated H2, with 100% of respondents reporting declines in water availability, including 65.3% noting significant reductions. These findings underscore the pervasive impact of climate change on water resources, a vital input for agricultural productivity. The observed reductions in water availability were consistent with IPCC (2019) reports, which highlighted water scarcity as a direct consequence of rising temperatures and erratic precipitation patterns. These climatic changes exacerbated the frequency and severity of droughts, reduce river flows, and led to the early drying up of water bodies, significantly constraining agricultural operations.

Farmers' reliance on water harvesting (60%) and irrigation systems (67.6%) further illustrated the critical need to manage dwindling water resources effectively. Water harvesting, which involves capturing and storing rainwater during wet seasons for use in dry periods, provided a sustainable solution to address unpredictable rainfall patterns. However, as Critchley and Siebert (2020) noted, the adoption of water harvesting techniques was often hindered by barriers such as the initial cost of infrastructure, including tanks and reservoirs, and the technical expertise required for effective implementation. Despite these challenges, the integration of water harvesting into farming systems representd a critical step towards enhancing water security.

Similarly, irrigation systems played a pivotal role in mitigating the effects of water scarcity. The study reveals that 67.6% of respondents had adopted irrigation to maintain crop growth even during periods of inadequate rainfall. This aligns with Rosegrant et al. (2014), who emphasized that irrigation systems are fundamental to climate adaptation, enabling farmers to stabilize yields under variable climatic conditions. However, the effectiveness of irrigation systems depended on reliable water sources and energy supply, both of which remain inconsistent in many rural areas. Solar-powered irrigation systems, as highlighted by Mumba et al. (2021), presented a promising alternative, offering a cost-effective and sustainable solution to these challenges.

The study also highlighted the potential for integrating multiple water management strategies to optimize resource use. For instance, combining water harvesting with drip irrigation can enhance efficiency by reducing water loss and ensuring targeted application to crops. Such integrated approaches are particularly vital in regions experiencing chronic water stress, as they maximize the utility of available resources while minimizing wastage.

Despite the demonstrated benefits, the findings indicate that broader adoption of these strategies is constrained by financial, technical, and infrastructural barriers. Many farmers lack access to affordable credit or subsidies to invest in water harvesting and irrigation infrastructure. Additionally, limited access to training and technical support further impedes the effective implementation of these systems. Addressing these barriers through targeted policy interventions, such as subsidized infrastructure, capacity-building programs, and public-private partnerships, can significantly enhance the adoption of water management practices.

In conclusion, the study's findings affirm the critical importance of water management strategies in mitigating the impacts of declining water availability due to climate change. By prioritizing the adoption and integration of water harvesting and irrigation systems, supported by enabling policies and infrastructure, farmers can build resilience against water scarcity and ensure sustainable agricultural productivity. These insights are not only relevant to Kuzipa, Mondo, and Payoju Farms but also provide a valuable framework for addressing water scarcity challenges in similar contexts globally.

H3: The adaptation strategies currently employed at Kuzipa, Mondo, and Payoju Farms are insufficient to mitigate the negative effects of climate change.

The findings partially supported H3. While strategies such as adjusting planting schedules (88.2%), adopting drought-resistant crops (58.8%), and water harvesting (60%) demonstrated proactive measures, the low adoption of soil conservation methods (14.1%) suggested gaps in comprehensive adaptation. Soil conservation practices, such as mulching, contour farming, and crop rotation, are crucial for maintaining soil health, preventing erosion, and enhancing moisture retention. Despite their significance, these practices remain underutilized, highlighting the need for targeted awareness campaigns and training programs to encourage their adoption.

Thornton et al. (2018) emphasize that a diversified and integrated approach is essential for robust climate resilience. This approach includes combining multiple adaptation strategies to address the multifaceted challenges posed by climate change. For instance, integrating soil conservation with water management techniques, such as irrigation and harvesting, can create a synergistic effect, enhancing both soil fertility and water availability. However, the findings suggest that such integration is limited at Kuzipa, Mondo, and Payoju Farms, reducing the overall effectiveness of current adaptation efforts.

Several barriers constrain the effectiveness of these strategies. High costs associated with implementing advanced irrigation systems and water harvesting infrastructure pose a significant challenge for many farmers, particularly smallholders with limited financial resources. As Critchley and Siebert (2020) note, the initial investment required for rainwater tanks, reservoirs, and irrigation equipment can be prohibitive, even though these systems provide long-term benefits. Addressing these financial barriers through subsidies or microfinance programs could incentivize wider adoption of these critical technologies.

Lack of technical knowledge and skills among farmers further limits the implementation of comprehensive adaptation strategies. For example, effective soil conservation techniques often require specialized training, which may not be readily accessible to all farmers. Moreover, water harvesting and irrigation systems demand a certain level of technical expertise for proper installation and maintenance. Providing capacity-building initiatives, such as farmer field schools or workshops, could bridge this knowledge gap and empower farmers to adopt these practices effectively.

Limited infrastructure, such as unreliable electricity and insufficient access to water sources, exacerbates the challenges of implementing adaptation measures. For instance, irrigation systems depend on consistent water availability and energy supply, both of which may be lacking in rural areas. This highlights the need for broader infrastructural development to support agricultural resilience, such as expanding access to solar-powered irrigation and improving rural water distribution networks.

While the adoption of strategies such as planting schedule adjustments, drought-resistant crops, and water harvesting reflects a proactive response to climate change, the low uptake of soil conservation methods and other integrated approaches underscores the need for improvement. Addressing financial, technical, and infrastructural barriers is crucial for achieving a comprehensive and effective adaptation framework. These enhancements will not only bolster the resilience of Kuzipa, Mondo, and Payoju Farms but also serve as a model for other agricultural enterprises facing similar challenges in Zambia and beyond.

Overall, these findings emphasized the importance of continued support for smallholder farmers through training, resources, and policy interventions. A more diverse and integrated approach to climate adaptation could further enhance resilience, ensuring that farming communities can effectively cope with the ongoing impacts of climate change.

The findings from the survey and interviews underscored the importance of key adaptation strategies such as adopting drought-resistant crops, adjusting planting schedules, practicing water harvesting, and installing irrigation systems in building agricultural resilience against the impacts of climate change. The widespread endorsement and implementation of these strategies by farmers reflected a growing recognition of their value in mitigating climate-related challenges. However, the varying levels of adoption among farmers revealed several barriers, including cost, technical expertise, and infrastructure limitations.

The effectiveness of these strategies was well-supported by existing literature, which highlights their potential to reduce vulnerability, enhance productivity, and improve food security. Nonetheless, successful adoption depended on the availability of resources, institutional support, and proper training. As climate change continued to exacerbate agricultural challenges, it is essential to scale up these adaptation measures. Policymakers should focus on creating a supportive environment that ensures farmers have access to the necessary tools, technologies, and knowledge to successfully implement these strategies. By doing so, they can strengthen the resilience of agricultural systems, helping farmers better cope with the ongoing and future impacts of climate change.

6.3 Recommendations

Based on the study findings as discussed in chapter four, the following set of recommendations are proffered:

1. There is a need to Promote Diversified Adaptation Strategies: While farmers have successfully adopted key strategies such as drought-resistant crops, adjusted planting schedules, and water harvesting, the relatively low adoption of soil conservation methods and the limited range of adaptation practices used suggest the need for a more diversified approach. Expanding the use of soil conservation techniques such as mulching, contour farming, and cover cropping could further enhance resilience by improving soil health and water retention. Agricultural extension services should provide comprehensive training on the full spectrum of adaptation strategies to help farmers integrate multiple practices.
2. Increase Access to Irrigation and Water Harvesting Technologies: Water scarcity remains a significant challenge for farmers, and the adoption of irrigation systems and water harvesting techniques is essential for addressing this issue. To promote these technologies, policymakers and development organizations should offer subsidies, low-interest loans, or grants to help smallholder farmers invest in irrigation systems and water storage infrastructure. Additionally, training on the efficient use of these technologies, along with ongoing technical support, will be vital for ensuring their success.
3. Strengthen Support for the Adoption of Drought-Resistant Crops: The high adoption rate of drought-resistant crops indicates that farmers recognize their potential to improve resilience. However, the successful implementation of this strategy requires access to quality seeds, information, and financial support. Government and non-governmental organizations should collaborate with seed companies and agricultural extension services to ensure the availability and affordability of drought-resistant varieties. Awareness campaigns and training programs can also help farmers understand the benefits and best practices for growing these crops.
4. Enhance Climate-Smart Agricultural Practices: The study revealed the need for improved access to climate information and forecasts. Providing farmers with reliable, real-time weather data and climate forecasts can help them make better decisions regarding planting schedules, irrigation, and crop management. Establishing partnerships between meteorological services, agricultural extension services, and farmers will facilitate the dissemination of

climate information and strengthen the farmers’ ability to adjust to changing weather patterns.

5. Strengthen Farmer Training and Extension Services: Training and capacity-building are critical to ensure farmers are equipped with the knowledge and skills needed to adopt and implement climate-smart practices. Agricultural extension services should be scaled up to provide training on a variety of topics, including water management, soil conservation, pest control, and the use of new technologies. Extension workers should also be trained to address the unique needs of female farmers, who may face gender-based barriers in accessing resources and information.
6. Improve Gender Inclusivity in Agricultural Policies: The demographic analysis highlights the significant gender disparity among farmers. Gender-inclusive policies that ensure equal access to resources, training, and decision-making processes are essential for empowering women in agriculture. Programs aimed at improving women's access to land, credit, and agricultural extension services should be prioritized to enhance their participation in climate adaptation efforts.
7. Develop Climate Resilient Infrastructure: Infrastructure development, such as the construction of water reservoirs, irrigation schemes, and transportation networks, is essential for improving agricultural resilience. Governments and development partners should prioritize investments in climate-resilient infrastructure that ensures reliable access to water and markets.
8. Create an Enabling Policy Environment: For adaptation strategies to be successful, a supportive policy environment is essential. Policymakers should enact and enforce policies that promote sustainable agricultural practices and provide incentives for adopting climate-resilient technologies. This includes providing financial incentives, creating insurance schemes, and reducing barriers to accessing markets and resources. Policies should also focus on fostering partnerships between governments, non-governmental organizations, and the private sector to scale up climate adaptation efforts.
9. Enhance Financial Support and Access to Credit: The high costs associated with climate adaptation measures, such as irrigation systems and water harvesting infrastructure, often pose barriers to adoption among smallholder farmers. Financial mechanisms such as low-interest loans, microcredit, and insurance programs can help reduce these barriers. Governments and financial

institutions should collaborate to develop innovative financing solutions that cater to the specific needs of smallholder farmers.

10. Conduct Further Research and Monitoring: To better understand the ongoing effects of climate change on agriculture, it is important to invest in research and monitoring programs that track the impacts of climate variability and evaluate the effectiveness of different adaptation strategies. This will help refine existing strategies, identify new solutions, and inform future policy development. Long-term studies that assess the economic and social impacts of climate adaptation measures can provide valuable insights for future interventions.
11. Foster Public-Private Partnerships: Encourage collaboration between governments, private sector actors, and research institutions to leverage resources and expertise in addressing climate change impacts on agriculture. Public-private partnerships can drive innovation, enhance the delivery of extension services, and scale up access to climate-resilient technologies.
12. Promote Community-Based Adaptation: Engage local communities in the design and implementation of adaptation strategies to ensure they are context-specific and culturally appropriate. Community-based approaches can enhance ownership, improve the relevance of interventions, and ensure the sustainability of adaptation efforts.
13. Encourage Agroforestry Practices: Integrate agroforestry into farming systems to improve water retention, enhance soil fertility, and diversify income sources. Agroforestry systems also provide additional benefits, such as carbon sequestration and biodiversity conservation, making them a key component of sustainable agricultural practices.
14. Implement Awareness Campaigns: Raise awareness about the impacts of climate change and the importance of adaptation strategies through targeted campaigns. These campaigns can educate farmers and other stakeholders about the benefits of adopting climate-smart practices, creating a supportive environment for change.
15. Leverage Digital Technology: Utilize mobile applications, remote sensing, and other digital tools to disseminate information on weather forecasts, market trends, and best practices. Digital technology can enhance decision-making, improve resource allocation, and increase farmers' access to critical information.

16. Develop Inclusive Insurance Schemes: Establish affordable crop and livestock insurance schemes to protect farmers against the financial risks associated with extreme weather events. Insurance can provide a safety net, enabling farmers to recover from climate-related losses and continue investing in adaptation measures.
17. Promote Sustainable Water Management: Introduce measures to manage water resources more effectively, such as watershed management, rainwater harvesting at a community level, and promoting efficient irrigation techniques like drip irrigation. Sustainable water management practices ensure the long-term availability of water resources for agriculture.
18. Build Institutional Capacity: Strengthen the capacity of local institutions involved in agriculture and climate adaptation to ensure they can effectively support farmers. This includes training extension workers, improving resource allocation, and enhancing coordination between various stakeholders.
19. Encourage Crop Diversification: Promote the cultivation of a variety of crops to reduce dependency on a single crop and enhance resilience to climate variability. Crop diversification also provides nutritional benefits and income stability for farming households.
20. Develop Market Linkages: Facilitate access to markets for farmers to ensure they can sell their produce at competitive prices. Strong market linkages encourage investment in climate-smart practices and enhance farmers' economic resilience.

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Appendix I.

Questionnaire

Section A: Demographics

1. Age:
    - 18–25
    - 26–35
    - 36–45
    - 46–55
    - Above 55
2. Gender:
    - Male
    - Female
3. Role in the farm:
    - Farm owner
    - Manager
    - Worker
    - Other (specify): ________________
4. Farm type:
    - Smallholder
    - Commercial

Section B: Climate Change Impacts

6. Have you observed any significant changes in rainfall patterns over the past 10 years?
    - Yes
    - No
    - Not sure
7. If yes, what changes have you noticed? (Select all that apply)
    - Erratic rainfall
    - Prolonged droughts
    - Intense storms or floods
    - Other (specify): ________________

8. How have these changes affected your crop yields?
    - Significant decrease
    - Moderate decrease
    - No impact
    - Increase
9. Have you noticed changes in water availability for farming purposes?
    - Yes
    - No
10. If yes, how has water availability changed?
    - Reduced significantly
    - Slightly reduced
    - No change
    - Improved

Section C: Adaptation Strategies

11. What measures have you implemented to cope with changes in rainfall and water availability? (Select all that apply)
    - Installing irrigation systems
    - Water harvesting
    - Changing planting schedules
    - Using drought-resistant crop varieties
    - Soil conservation methods
    - Other (specify): ________________
12. How effective have these measures been in mitigating climate impacts on your farm?
    - Very effective
    - Somewhat effective
    - Not effective
    - Not sure
13. Have you received any external support (e.g., government programs, NGOs) to implement adaptation strategies?
    - Yes
    - No

14. If yes, what type of support did you receive? (Specify): ________________

Section D: Agricultural Productivity

15. Over the past 10 years, how has your farm's crop yield changed due to climate factors?
    - Declined significantly
    - Declined slightly
    - No change
    - Increased
16. What crops have been most affected by climate changes on your farm? (List): ________________
17. What challenges do you face in maintaining soil quality under current climate conditions? (Select all that apply)
    - Erosion
    - Loss of fertility
    - Increased pests/diseases
    - Other (specify): ________________

Section E: Recommendations and Feedback

18. What do you believe is the most urgent action needed to improve resilience against climate change in your farming operations? (Specify): ________________
19. What support would be most beneficial to you in adapting to climate changes? (Select all that apply)
    - Access to climate-resilient seeds
    - Financial support
    - Training in adaptation strategies
    - Improved water management infrastructure
    - Other (specify): ________________
20. Any additional comments or suggestions: _______________