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CLIMATE CHANGE EFFECTS, ADAPTATION STRATEGIES AND FACTORS INFLUENCING THEIR ADOPTION AMONG SMALLHOLDER FARMERS IN KAGADI SUB-COUNTY, UGANDA

BY

DESIRE MPARANA

22/BSU/MSCCFS/1832

**A DISSERTATION SUBMITTED TO BISHOP STUART UNIVERSITY
RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF A MASTER OF SCIENCE IN
CLIMATE CHANGE AND FOOD SECURITY,
OF BISHOP STUART UNIVERSITY**

SEPTEMBER, 2025



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DECLARATION

I, **Desire Mparana**, hereby affirm that this report titled “*Climate Change Effects, adaptation strategies and factors influencing their adoption among smallholder farmers in Kagadi Sub County, Uganda*” is my original work, and that no part or the entire report has ever been presented to any other institution of higher learning for any academic award.

Sign: 
Mr. Mparana Desire

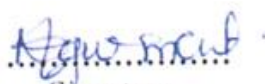

Date

APPROVAL

This to certify that this research report titled “*Climate Change Effects, adaptation strategies and factors influencing their adoption among smallholder farmers in Kagadi Sub County, Uganda*” has been done under the supervision of the following supervisors and it is ready for submission to the Bishop Stuart University.

M/s. Nagawa Mary Goretty

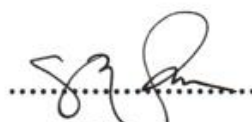
Supervisor

.....
Signature

.....*23rd Sept. 2025*.....
Date

Dr. Tumwesigye Wycliffe

Supervisor

.....
Signature

.....*23/9/25*.....
Date

DEDICATION

This research work is dedicated to my family i.e., My wife and children (Ayesiga Mary Trinity and Ajuka Mildred), friends, relatives and in-laws who sacrificed much of their desires and time to make this dream a reality; May the almighty God reward you abundantly.

ACKNOWLEDGEMENT

I would like to take this opportunity to express my honest and sincere appreciation to all the individuals and groups who made this research work possible.

First, I thank the almighty God who gave me the opportunity to do my Master of Science in Climate Change & food Security at Bishop Stuart University.

Special thanks to my supervisors **Dr. Tumwesigye Wycliffe and Madam Nagawa Mary Goretty** who natured, listened to and advised me throughout my study on how to prepare a good proposal and later a final report. I am equally impressed by your supervisory skills. May the almighty God bless you abundantly.

I would also like to thank my family and friends especially Mr. Tumusiime Edwards Brian and the entire classmates for all the support and understanding during my study, you are all true friends.

LIST OF ABBREVIATIONS AND ACRONYMS

CCA	Climate Change Adaptation
E/A	East Africa
ENSO	El Niño Southern Oscillation
GDP	Gross Domestic Product
NEMA	National Environment Management Authority
RCMs	Regional Climate Models
SSA	Sub-Saharan Africa
UBOS	Uganda Bureau of Statistics

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ABSTRACT

This study examines climate change effects and adaptation strategies among smallholder farmers in Uganda through a qualitative and quantitative methods combining survey data (N=348) with statistical analyses. The research had three key objectives: assessing climate change effects, identifying adaptation strategies, and analyzing adoption factors. Findings revealed that farmers experience severe climate impacts, with 82.2% reporting prolonged droughts and 79% facing soil erosion. Agroforestry emerged as the most widely adopted strategy (88.5%), followed by early planting (63.5%) and use of early-maturing varieties (67.5%). However, technologies like rainwater harvesting (37.9%) and irrigation (50%) showed lower adoption rates. Regression analysis identified extension services ($p<0.001$), education level ($p=0.020$), and household labor availability ($p=0.005$) as significant factors influencing adoption decisions. The study highlights critical gaps in resource access and knowledge dissemination that hinder effective adaptation. These findings suggest the need for integrated interventions combining financial support, capacity building through extension services, and improved climate information systems to enhance smallholder resilience. The research contributes to the growing literature on climate-smart agriculture by providing empirical evidence on adoption patterns and barriers in Uganda's smallholder farming context.

Keywords:

Climate change adaptation, smallholder farmers, agroforestry, drought resilience, extension services, adoption barriers.

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

Agriculture remains the backbone of Uganda's economy, contributing approximately 85.9% of GDP while serving as the most effective sector for poverty reduction, with growth impacts two to four times greater than other economic sectors (Adamseged et al., 2019; Ouma et al., 2023). This critical sector, however, faces unprecedented threats from climate change, particularly for the smallholder farmers who dominate Uganda's agricultural landscape. Defined as those cultivating ≤ 1 hectare using manual tools and producing primarily for household consumption with limited market surplus (UBOS UNHS 2023/2024), these smallholders constitute most of the Uganda's farming population while being disproportionately vulnerable to climatic shocks (Ackerl et al., 2023).

The climate crisis manifests through increasingly erratic rainfall patterns, rising temperatures, and more frequent extreme weather events (IPCC, 2021). Smallholder farmers across Sub-Saharan Africa, who produce over 70% of the region's food, are particularly affected due to their heavy reliance on rainfed agriculture and limited adaptive capacity (Aryal et al., 2021). In Uganda's bimodal rainfall zones, where most agriculture depends on predictable March-June and September-December rainy seasons, climate variability has disrupted traditional farming calendars and intensified production risks (Smit, 2023). The semi-arid northeastern regions face even greater vulnerability, with warming trends exacerbating water scarcity and pasture degradation (Teixeira et al., 2020).

Climate impacts on Ugandan agriculture are multidimensional. Rising temperatures have altered pest and disease dynamics, while erratic rainfall affects planting schedules and crop viability (IPCC, 2021; Mubiru et al., 2018). Projections suggest a 2.5°C temperature increase could cause \$16 billion in agricultural losses across Africa, with dryland systems suffering \$23 billion losses unless adaptation measures are implemented (Nsubuga, 2018). These changes threaten not only food production but also broader socioeconomic stability, as agriculture employs over 80% of Uganda's workforce and supports numerous ancillary industries (Kogo et al., 2021).

The vulnerability of smallholder systems stems from multiple intersecting factors. Most

farmers operate on marginal lands with limited access to irrigation, averaging 0.5-2-hectare plots that barely meet household needs (Pilling et al., 2020). Post-harvest losses are compounded by poor market access, forcing sales at farm-gate prices that rarely reflect true production costs (USAID, 2023). Women and children bear disproportionate labor burdens, while climate shocks further strain household resilience (Assan et al., 2020). Traditional coping mechanisms are increasingly inadequate against intensifying droughts, floods, and pest outbreaks (Mbogga, 2019).

Kagadi Sub-County exemplifies these challenges. Once reliable rainfall patterns have become unpredictable, with prolonged droughts and sudden floods damaging crops and soils (Barford et al., 2021). Farmers report declining yields of staple crops like beans and maize, with recent price fluctuations reflecting both climate impacts and market disruptions (Farm gate data, 2023). The area's heavy dependence on rainfed agriculture, coupled with limited adoption of climate-smart technologies, leaves households dangerously exposed to climatic variability (Mubiru et al., 2018).

1.2. Statement of the problem

The Eastern Africa region faces increasing climate variability, with projections indicating more intense climatic events and unpredictable impacts (IPCC, 2021). Uganda exemplifies this trend, having experienced significant climate change effects across multiple sectors (NEMA, 2019). Kagadi District serves as a microcosm of these challenges, with district reports documenting extreme weather events including intense rainfall, flooding, and prolonged droughts that have severely disrupted agricultural production (Kagadi District Local Government, 2023). These climatic shocks have led to water stress, crop failures, and threatened food security, yet critical knowledge gaps persist regarding how smallholder farmers are responding to these challenges.

Despite this growing vulnerability, there is limited empirical evidence on how smallholder farmers in Kagadi Sub-County are coping with these climatic changes. There is a clear knowledge gap regarding the specific adaptation strategies employed by farmers, the effectiveness of those strategies, and the socio-economic and institutional determinants that shape adaptation behavior. This gap is especially concerning in the context of declining agricultural productivity. This research addresses these gaps by systematically investigating the effects of climate change and variability, assess the adaptation mechanisms in use, and

identify the key determinants influencing the adoption of such strategies among smallholder farmers in Kagadi Sub-County.

1.3. Research objectives

1.3.1. General objective

To analyze the interplay between climate change effects, adaptation strategies, and the factors influencing adoption of these strategies among smallholder farmers in Kagadi Sub- County.

1.3.2. Specific objectives

1. To characterize the perceived and observed climate change effects and their attributed causes among smallholder farmers in Kagadi Sub- County.
2. To evaluate the spectrum of climate adaptation practices adopted by smallholder farmers in Kagadi Sub- County.
3. To determine the factors influencing the adoption of climate change adaptation strategies by smallholder farmers in Kagadi Sub- County.

1.4. Research questions

1. What are the perceived and observed climate change effects and their attributed causes among the smallholder farmers in Kagadi Sub- County?
2. What climate change adaptation practices have been adopted by smallholder farmers in Kagadi Sub- County?
3. What are the factors influencing the adoption of climate change adaptation strategies by smallholder farmers in Kagadi Sub- County?

1.5. Scope of the Study

This study focused on smallholder farmers in a Kagadi Sub- County, Kagadi district located in mid-western Uganda, examining the factors influencing their agricultural output and adaptation strategies to climate change. Geographically, the research was confined to a specific farming community known to be significantly affected by climate variability. The content scope encompassed an assessment of climate change impacts, adaptation practices, and the socioeconomic determinants shaping farmers' adoption of mitigation strategies. Data collection included household surveys capturing farmers' socioeconomic profiles, climate

perception, and adaptation behaviors, supplemented by meteorological records to analyze weather patterns and extreme events such as droughts, floods, and pest outbreaks.

1.6. Significance of the study

This study provides valuable insights for enhancing climate resilience among smallholder farmers by identifying key factors influencing their adoption of adaptation strategies. The findings will guide policymakers and development practitioners in designing targeted interventions to address knowledge gaps, resource constraints, and institutional barriers that currently limit effective climate adaptation. By documenting locally successful practices and analyzing adoption determinants, the research offers practical solutions that can be scaled up to improve agricultural productivity and food security in climate-vulnerable regions. The study's comprehensive approach bridges the gap between academic research and practical application, making its outcomes relevant for farmers, extension services, and government agencies working to strengthen climate-smart agriculture. Ultimately, this research contributes to sustainable rural development by providing evidence-based strategies to mitigate climate change impacts on smallholder farming systems.

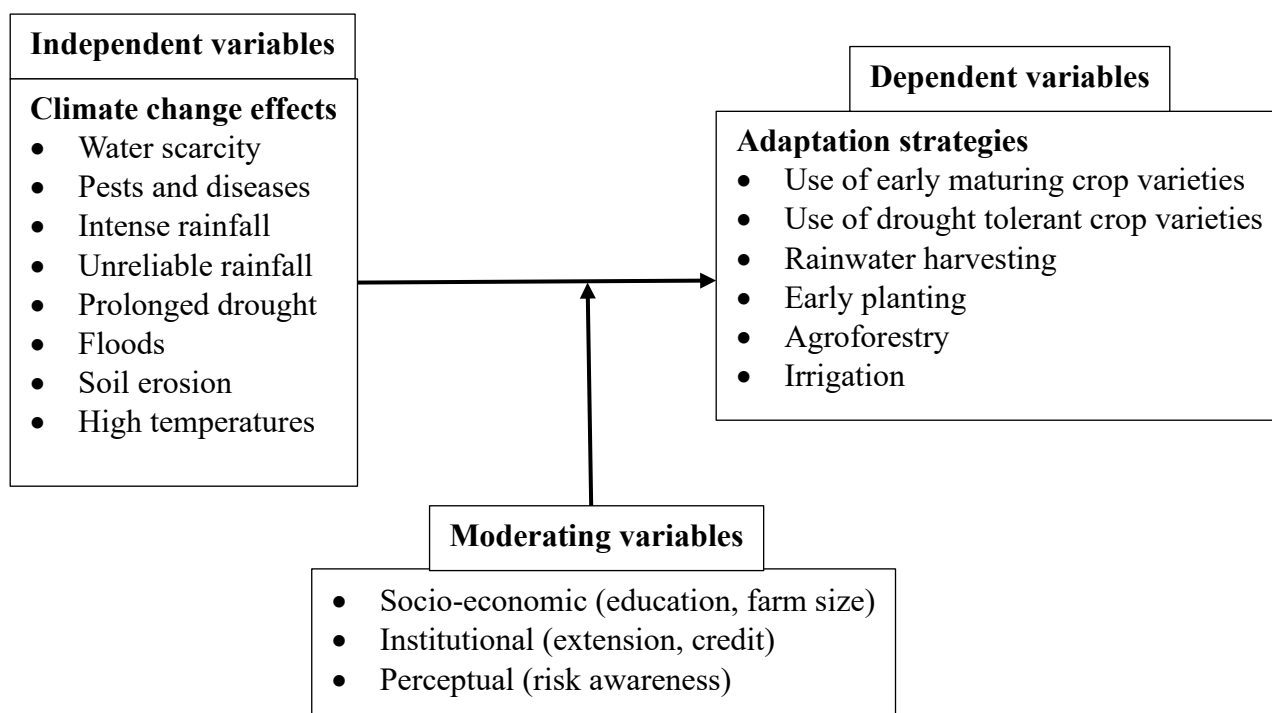
1.7. Justification of the study

Smallholder farmers in Uganda face escalating threats from climate change, yet there remains insufficient localized evidence on effective adaptation strategies tailored to their specific socio-economic and environmental conditions. This study is justified by the urgent need to understand actionable adaptation practices, how farmers perceive climate risks, what adaptation measures they employ, and which factors either enable or hinder their adoption of resilient practices. Without such knowledge, interventions risk being misaligned with farmers' realities, wasting limited resources on inappropriate solutions. By systematically examining these dimensions within Kagadi Sub-county, this research generates actionable insights that can inform policies and programs to strengthen climate resilience among vulnerable farming communities. The findings will fill critical gaps in understanding adaptation behaviors while providing a evidence base for designing context-specific support mechanisms that enhance agricultural sustainability amid changing climatic conditions.

1.8. Conceptual Framework

This study's conceptual framework examines the relationship between climate change effects,

adaptation strategies, and adoption factors among smallholder farmers in Kaggaji Sub-County, structured around three core objectives. First, building on IPCC (2021) and NEMA (2019), it conceptualizes climate change effects (e.g., erratic rainfall, droughts) as exogenous drivers that farmers perceive and respond to, addressing Objective 1. Second, aligning with Aryal et al. (2020) and Kurgat et al. (2020), the framework positions adaptation strategies (e.g., agroforestry, early planting) as dependent variables shaped by these climatic pressures, corresponding to Objective 2. Third, integrating Lamichhane et al. (2022) and Agyekum et al. (2024), it identifies socioeconomic (e.g., education, farm size), institutional (e.g., extension access), and perceptual factors (e.g., risk awareness) as key determinants of adoption, fulfilling Objective 3. The framework emphasizes how these components interact dynamically: climate effects create adaptation needs, while local contexts filter farmers' responses through resource constraints and institutional support (van Asseldonk et al., 2023), ultimately influencing strategy adoption. This tripartite structure mirrors the study's objectives while grounding each element in empirical evidence from smallholder systems in Sub-Saharan Africa.



Source: Adopted a from Atube *et al.* (2022) and modified by the researcher 2024

1.9. Operational definitions

Climate change: Climate change is a long-term (at least many decades) continuous change (increase or decrease) to average weather conditions (e.g. average temperature) (IPCC, 2022).

Climate variability: Climate variability refers to natural climate fluctuations, including changes of mean state and varying occurrence of extremes. Thus, climate is naturally in constant change. (IPCC, 2022).

Climate change effects: Climate change happens in different ways, ranging from increased climate variability and gradual changes in temperature and precipitation, to increased frequency and intensity of extreme events.

Adaptation: This refers to responses by individuals, groups and governments to actual or expected changes in climatic conditions or their effects. Adaptation is defined as activities that aim “to reduce the vulnerability of human or natural systems to the impacts of climate change and climate-related risks, by maintaining or increasing adaptive capacity and systems resilience” (IPCC, 2022).

Adaptation strategies: These include a broad set of activities ranging from activities that focus on reducing drivers of vulnerability to interventions aimed at confronting not yet experienced climate change impacts (IPCC, 2022). In between, there is a broad spectrum of activities with gradations of emphasis on vulnerability and impacts that aim to build response capacity and better manage climate risks.

Adoption: This refers to the action or fact of choosing to take up, follow, or use a certain climate change adaptation practice by a farmer (FAO, 2022).

CHAPTER TWO

LITERATURE REVIEW

2.0. Introduction

This chapter reviews relevant literature on climate change and agriculture, diffusion and adoption of agricultural practices and technologies, the role of socioeconomic and institutional factors in the adoption of climate change adaptation practices, and theories that guide the study including the diffusion of innovation, and theory of planned behavior.

2.1. Overview of climate change in Uganda

Climate change is a long-term (at least many decades) continuous change (increase or decrease) to average weather conditions (e.g. average temperature). Climate change directly affects agricultural production, as this sector is inherently sensitive to climatic conditions and is one of the most vulnerable sectors at the risk and impact of global climate change (IPCC, 2014). These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals (IFPRI, 2016). The negative impacts of climate change are being felt in the form of reduced yields and more frequent extreme weather events, affecting food production across the globe (FAO, 2013).

According to the National Adaptation Program of Action (NAPA), Uganda has recorded significant warming with an average temperature increase of 0.28°C per decade between 1960 and 2010. The frequency of hot days in the country has increased significantly, while the frequency of cold days has decreased (Kamesse, 2015). In addition, Uganda's climate projections indicate the possibility of an increase in the country's near-surface temperature in the order of +2°C in the next 50 years, and +2.5°C in the next 80 years using Representative Concentration Pathway (RCP) 4.5 scenarios. For RCP 8.5, the projected temperature increases are in the order of +2.5°C in the next 50 years, and +4.5°C in the next 80 years. Furthermore, the same report predicts a slight decrease in total annual rainfall in most of the country, with slightly wetter conditions over the west and north-west under both RCP 4.5 and RCP 8.5 scenarios, with rainfall totals likely to drop significantly over Lake Victoria (MWE, 2015).

Overall, Uganda is highly vulnerable to climate change and weather variability; the country already being susceptible to unreliable rainfall, frequent drought, periodic floods and seasonal

bush fires (CIAT; BFS/USAID, 2017). Furthermore, greenhouse gas (GHG) emissions are overriding the climate's natural variability and leading to potentially irreversible climate change (MWE, 2018). There are efforts underway in Uganda aimed at reducing pollution and greenhouse gases, but it will need new technologies to achieve sustainable development and transition to a low-carbon economy. As part of the development agenda, the National Climate Change Program (NCCP) was established to offer a framework for adapting to and mitigating climate change risks and vulnerabilities (MWE, 2018).

2.2. Review of the causes of climate change

The so-called greenhouse effect, which scientists refer to as the way some gases in the atmosphere "trap" heat that would otherwise radiate upward from the planet's surface into space, is the primary cause of climate change. One way that life on Earth is possible is because of the greenhouse effect; without it, the planet would be extremely cold and uninhabitable (Verma & Falendra, 2021). By mid-19th century, human activity such as deforestation, bush burning, among others began pushing the greenhouse effect to new levels (Pauline, 2023). As a result of this global warming, natural cycles and weather patterns have been drastically disrupted. These changes have resulted in greater flooding, prolonged droughts, violent storms, excessive heat, and rising sea levels. When combined, these unpleasant and occasionally fatal consequences have been known as climate change (Verma & Falendra, 2021).

Kogo et al. (2021), claim that industrialized agriculture has profoundly changed the delicate but essential link between soil and climate. The agricultural industry is particularly well-known for producing significant amounts of methane and nitrous oxide, two potent gases that are excellent heat-trapping agents. Almost three-quarters of the nitrous oxide in our environment comes from agriculture due to the extensive use of chemical fertilizers and some crop-management techniques that put high yields ahead of healthy soil. Methane is released into the atmosphere by the digestive processes of cattle and other ruminants, and large-scale industrialized livestock production is still a major source of this gas (Onoja *et al.*, 2016).

We produce a lot of greenhouse gasses from our home and business structures. Thirteen percent of global emissions in 2020 came from appliances, cooking, heating, cooling, and other building-wide systems (Kandira, 2021). Even worse, the average amount of energy wasted in buildings worldwide is about thirty percent. Energy efficiency is always improving,

enabling us to use less energy to obtain the same or even better results (Mukoya & Mulinya, 2018). According to research by Bedeke *et al.* (2018), almost all farmers saw decreasing precipitation quantities together with more hot, humid days and nights as a result of climate change. The findings show that farmers believe the seasonal rainfall period is shorter in terms of both late.

The decline of the wetlands and clearing of woodlands have an effect on the crop yields of small-scale producers. By retaining carbon beneath or at level with the earth, vegetation and soil store it (OECD, 2020). We are removing or digging up vegetative biomass and releasing all of its stored carbon into the atmosphere through logging and other forms of development. Clear cutting alone in Canada's boreal forest contributes to the annual release of over 25 million metric tons of carbon dioxide into the atmosphere, or the emissions of 5.5 million cars. Furthermore, everyday choices we make as individuals what we eat, how we travel around, what things we buy, and how much electricity we use add up to our individual, unique carbon footprints. The total carbon footprint of humans is the result of adding them all together (OECD, 2020).

In the end, our wants, demands, and priorities determine the major decisions that utilities, businesses, and governments make that have an impact on the environment. Rethinking those needs, increasing those demands, and resetting those priorities will be necessary if we are to succeed in the fight against climate change (SPREP, 2020). Long-term planning that builds communities and ensures everyone's health and safety must take precedence over short-term thinking that benefits companies. Furthermore, the notion of climate activism needs to evolve quickly from catchphrases to include group efforts driven, if not by justified rage, then at least by confidence in science and our capacity to improve the world (OECD, 2020)..

There is evidence that the ozone concentrations, temperatures, and winds in the stratosphere (the layer of the upper atmosphere beyond the troposphere, which lies usually from 12 to 50 km higher than the surface of the planet, subject to latitude and season) can be influenced by the Sun's 11-year solar cycle, which sees variations in the Sun's energy output of about 0.1%. Over the course of the 11-year cycle, these stratospheric shifts might have a negligible impact on the surface climate (Tidiane & Nurjihadi, 2024). The evidence that is now accessible, yet, does not show any discernible permanent shifts in the Sun's output over the previous century, when human-caused increases in CO₂ concentrations have dominated the long-term rise in global surface temperature. The temperature trends at various atmospheric altitudes provide

more proof that the current warming is not the product of solar changes (USAID, 2023)

The trend of tropospheric heating and stratospheric cooling that has been seen over the last forty years has been shown to be broadly consistent with computer model simulations that incorporate human-caused increases in CO₂ and losses in stratospheric ozone. El Niño and La Nina natural climate oscillations, eruptions, or shifts in the Sun's energy output alone are not commensurate to the exhibited trend (Tidiane & Nurjihadi, 2024).

2.3. Effects of climate change

The increasing risks and vulnerabilities brought about by climate change are clearly evident in the way that production levels in African dryland agricultural systems have fluctuated over time. For instance, there is a substantial correlation between crop yields and climate, with climate variability accounting for between 30% and 75% of the variation in crop yields across the continent (FAO, 2023). The regional seasonal climate, which is influenced by El Niño Southern Oscillation (ENSO) and monsoons, is still crucial for agricultural output, livelihoods, and the economy of the states that make up Sub-Saharan Africa (SSA) (Ochilo *et al.*, 2022) while regional climate models (RCMs) concur that the area will warm, the amount of warming that is anticipated varies greatly, with increases in temperature ranging from 0.5 to 2°C (Bamanyaki & Aogon, 2020).

Furthermore, the effects of climate change and variability in East Africa are exacerbated by the region's already pressing development issues, which include, among other things, high rates of population growth, high and rising rates of poverty, low per capita incomes, high levels of inequality, and declining GDP growth rates (VISO, 2016). The Greater Horn of Africa experienced a severe drought in 2017–2023, which affected nearly nine million people primarily in Somalia, Kenya, and Uganda. Other expected effects of climate change in East Africa include an increase in droughts that cause serious lack of water and stress, a greater prevalence of pests and diseases, and a decline in crop yields that could result in severe food insecurity (Mwadzingeni *et al.*, 2023).

FAO (2023), investigated how climate change will affect Kenya and discovered that while rising temperatures would benefit highland regions, they would have the opposite effect on lowland areas, particularly semi-arid ones. Hence, potential food production would rise in conjunction with rising temperatures and precipitation; yet, in semi-arid regions, yields would decrease due to inadequate precipitation. According to FAO (2023), there would be regional

variations in the overall favorable effect of climate change on food production in Uganda. In addition, they claimed that rising temperatures and carbon dioxide levels would lead to higher production if precipitation levels also rose.

2.4. Theoretical Review

Although a variety of theories that might serve as a framework for an administrative study like this one might be profiled, the researcher addressed the topic of theories from the perspective of relevance and applicability. This suggests that the theory and associated problems was explored in both exploratory and practical contexts.

2.4.1. Profit maximization theory

According to the profit maximization theory, which is well represented by the writings of academics like Schultz (1964), Lipton (1968), Stiglitz (1989), and others, the smallholder method of production maximizes profits (Bakht *et al.*, 2020). The homes are viewed as operating like agricultural enterprises, with resource allocation being the primary goal of production in order to maximize profit. They make the assumption that the smallholders face uniform resource and production conditions and that there is complete competition in the market places for land, labor, capital, and input/output goods (Uboegbulam *et al.*, 2023). Harris *et al.*, (2019), proposed that, given the available technical resources, factor and product-cost linkages, and subsistence farming, allocative efficiency was largely high. He clarified that the distribution of the factors of production in traditional agriculture had very few substantial inefficiencies.

Uboegbulam *et al.*, (2023), traditional agriculture is defined as "a particular type of economic equilibrium at which agriculture gradually arrives over a long period of time, provided that (1) the state-of-the-art remains constant, (2) the state of preference and motives for holding and acquiring sources of income remain constant, and (3) every one of these circumstances are unchanged for sufficient time for farming variables' marginal efficiency and intentions to acquire them to reach a point of balance alongside the latter considered as an investment in reliable revenue flows as well as the resulting savings nearing zero (Ansah, 2022).

According to Harris et al. (2019), the distinguishing feature of traditional agriculture is that farmers have reached a state of equilibrium where they optimize at the margins when it comes to resource allocation and investment decisions because the physical, economic, and

preference environments have remained stable for a considerable amount of time. Accordingly, restrictions faced by farmers both resource-related and institutionally imposed cause differences in their economic behavior between those in high-income and low-income countries, rather than differences in their economic motivation (Bakht et al., 2020). Therefore, in order to increase the productivity of traditional agriculture, farmers need to have access to high-yield inputs and new information.

According to Uboegbulam *et al.*, (2023), price incentives were well-received by smallholders in developing nations. He disproved the belief that cultural traits such as an absence of a job ethic, an absence of knowledge about conserving, or an overall lack of knowledge of how to make the greatest use of their resources were the reason why farming in developing nations were impoverished (Ansah, 2022). Harris *et al.*, (2019), contended that inadequate efficiency of the various production factors rather than inefficiencies in their allocation was the cause of low-income levels in developing country agriculture. This statement implied that outside experts could not help farmers increase productivity simply by recommending a reallocation of the available factors of production; as a result, education investments were necessary to promote the spread of new factors that could increase productivity (Ansah, 2022).

According to Schultz, farmers learn how to allocate the resources at their disposal in an efficient manner that is consistent with their own interests through experimentation over time in environments where the state-of-the-arts has not changed and where risk is inherent (Uboegbulam *et al.*, 2023). Kabadayi & Lerman (2021), Schultz's theory has significant ramifications for the long-term viability of a smallholder farmer's use of an individual development strategy. If farmers are at least somewhat efficient, then raising their level of efficiency further calls for applying more productive technologies and/or using more productive inputs in order to move the production frontier upward. On the other hand, an improvement in the institutional setting that includes input markets, infrastructure endowment, available extension systems, management, and training services should be targeted to increase efficiency at the farm level if current inputs and/or technology could be used more productively.

Schultz's concept has drawn criticism for his rigid definition of traditional agriculture and for not taking market failures into account while formulating his theories. According to Kabadayi & Lerman (2021), Schultz's theory only applied to the maximization of individual utility in the context of perfect competition. Even if farmers manage their resources well from the

perspective of each person, aggregate inefficiencies may nevertheless exist in the presence of market failures. Therefore, the effective but flawed theory may not hold up at the group or collective level (Bakht *et al.*, 2020).

The idea that smallholders operate in purely neoclassical profit-maximizing markets is predicated on such stringent assumptions about market competitiveness that it is unlikely that smallholder populations from which sample data are taken will meet these requirements (Harris *et al.*, 2019). Ansah (2022), However, contended that a substantial body of research indicates a major element of economic calculation on the part of smallholders worldwide, particularly with regard to their reaction to shifts in the relative market values amongst crops.

As an alternative, Kabadayi & Lerman (2021), suggested conditional profit maximization. Subject to (1) trade-offs with other objectives, (2) resource limitations, and (3) market dynamics, smallholders optimize earnings. Some economists have suggested that profit maximizing theory tends to disregard a significant component of the decision-making process that smallholder households face, namely, the consumption side of the process because smallholder families make decisions based on both production and consumption considerations. The assumption-based nature of the profit maximization theory is often criticized for not applying to African smallholder societies. Numerous case studies have demonstrated the extreme heterogeneity of production and resource situations in smallholder societies. In African smallholder societies, land is customarily allocated and used based on social, political, and cultural relationships rather than being sold (Bakht *et al.*, 2020). In many smallholder societies, labor is not widely available for sale, and family labor is the main source of labor. Within the household, there exist several labor divisions that further restrict the ability to allocate labor competitively. Smallholder societies obviously have limited access to finance, and they lack robust, competitive capital markets (Harris *et al.*, 2019).

2.4.2. Utility maximization theory

These theories consider the consumption aspect of smallholder decision making because they recognize the dual nature of smallholder households as both families and businesses (Harris *et al.*, 2019). Utility maximization, according to Ayres & Sandilya (1987), prioritizes survival in the face of uncertainty. There is not a single marginal physical product for any component under imperfect knowledge (uncertainty); rather, there is a probability range that may be large that contains the real marginal physical product for any particular factor in a given year. In

uncertain times, smallholders prioritize survival strategies over profit maximization (Laciana *et al.*, 2021).

Ndwiga (2019) proposed that simple reproduction, as opposed to profit maximization, should be the primary objective of any smallholder household. He suggested that smallholders make decisions differently from any other type of production unit under capitalism because of the way that manufacturing and consumption interplay inside the home. A smallholder home would use its own labor force to apply it to agricultural output in accordance with its internal equilibrium, according to Park *et al.*, (2022). The drudgery involved in meeting the wants and requirements of the household is equaled to define this equilibrium.

Mhagama & Mmasa (2022), examined the impact of shifting household composition on income and production over the course of a smallholder household's life cycle using the notion of the consumer/producer ratio. Subsequently, he proposed that the ratio of workers to consumers determines the intensity of farming or the use of family labor, and that the economic distinction between smallholders based on farm size is more a reflection of relative family size than of differences in economic performance. The utility maximization theories have been criticized for their narrow scope of analysis, which leaves them unable to address issues related to the evolution of human civilization throughout its entirety. Additionally, they disregard gender dynamics, the division of work, and the external relationships of small-scale farmers, seeing the entire family as one body for making decisions (Ndwiga, 2019).

2.4.3 The diffusion theory

The adoption of CCA practices is an essential component of economic growth (Perla & Tonetti, 2014) in this era of climate change. Farmers need to be convinced to use these practices (Doss, 2006), the underlying rationale being that “to increase the adoption of a practice, farmers assumed to be unaware and uninformed about technology first need information to later consider adopting that practice (Conley & Udry, 2001; Kabunga *et al.*, 2012; FAO, 2013).

The adoption of CCA practices takes place within a socio-cultural environment and requires key capital inputs such as labor, finances, produced and social capital (FAO, 2013). Better organization and allocation of the various forms of capital enhances efficiency, which is important for the adoption and diffusion of interventions to achieve increased productivity, adaptation to, and mitigation of climate change among smallholder farmers in any farming

system (Mutoko et al., 2014). Effective partnerships and collaboration with other interested organizations is another avenue that can generate substantial synergy to accelerate the adoption rate of the promoted CCA practices (Odongo, 2010). According to Rogers (2003), *innovation diffusion*, *social learning*, and *network* theories are paramount for the diffusion and hence the adoption of CCA practices among the developing poor.

The theory of diffusion of innovation seeks to explain how, why, and at what rate new ideas and technology spread (Rogers, 2003). Based on this theory, effective communication of a specific CCA practice can be achieved through various channels in a social system (Rogers, 2003). Rogers also identifies five main steps in the technology adoption process; awareness, interest, evaluation, trial, and adoption. The diffusion of innovation theory puts the importance of the social networks and interpersonal channels above the mass media when it comes to technology adoption decisions, emphasizing several key agents – farmers, opinion leaders, electronic communications, extension agents, social and organizational hierarchies - as triggers for change. According to Simpson (2005), individuals adopt a technology based on the subjective recommendation by fellow farmers, who have evaluated and adopted that idea previously, and the recommendation by extension agents.

2.5. Empirical review of the factors influencing the adoption of change adaptation practices among smallholder farmers

The urgent issue of climate change is one that smallholders are unable to address on their own (IPCC, 2021). Household demography, farm size, income, market accessibility, availability of climate information and extension, and animal output all have a favorable effects on farmers' ability to select appropriate adaptation strategies (Ouma et al., 2023). This suggests that a variety of institutional, policy, and technological supports, some of which are directed towards smaller, poorer, or female-headed families, are required to help the smallholder farmers' indigenous adaption techniques. Furthermore, it is critical to create options for non-farm revenue streams because doing so encourages farmers to participate in less climate change-sensitive activities. Moreover, it is critical to create access to markets, offer extension services, and disseminate information about climate change (Belay et al., 2017).

Zelege (2023) found that over a 33-year period, temperature climbed dramatically while rainfall decreased significantly in the East Hararghe Zone, Eastern Ethiopia. The study focused on smallholder farmers' perceptions of climate change and their choice of adaption

measures. Farmers have regularly seen this gradual change in climate. Improved crop varieties, crop diversification, date adjustments for planting, conservation of soil and water, lowering animal numbers, planting of trees, and small-scale irrigation adaptation techniques are all employed by smallholder farmers. Additionally, this study showed that the following factors have a major effects the agricultural community's decisions about adjusting techniques: the head of the household's sex, the quantity of the property, possession of animals social assets, market distance, access to extension, access to credit, nonfarm income, agro-ecological setting, and poverty status of the households (Zeleeke, 2023).

Teixeira *et al.* (2017), demonstrated that reducing the negative effects of climate change on grain productivity might be accomplished by planting early and utilizing superior cultivars of maize that had longer maturation times and larger kernels. The northern Midwest US's rotational cropping systems of maize, soybeans, and wheat are susceptible to extreme weather events and climate change, according to FAO (2019). When compared to previous climates, maize grain yield is expected to decrease under present climate variability, while wheat grain yield is expected to grow under the two projected climatic scenarios (Choi *et al.*, 2020). The production of maize and wheat is reduced by extreme occurrences that occur either early or late in the growing season, such as an extended drought followed by significant rainfall events. When extreme precipitation events happened in the late season rather than the early season for maize, the drop in grain yield that resulted from them was greater (Willbroad, 2018).

Furthermore, by speeding up the sequestration of atmospheric carbon, the introduction of enhanced crop varieties that are adapted to enhance soil carbon storage (Wood *et al.*, 2024). For example, shifting from annual to perennial energy crops can affect farmer income and offer a range of ecosystem services, such as energy supply, water quality regulation, carbon sequestration, and pollinator abundance. Plant breeding can offer a portfolio of variations of a wide range of crops to help agricultural systems adapt to climate change in addition to using genotypes that are already in place (Gil, 2020).

Crops that are suited to various stresses are required in different parts of Africa. For example, certain locations may require crops that can withstand severe temperatures and/or drought, while other regions may be more susceptible to pests and diseases (Acevedo *et al.*, 2020). The most effective adaptation approach to deal with climate change may be species and kinds bred to withstand these circumstances. Pre-breeding and other crop variety development

procedures are made more effective by the use of high-throughput genotyping and phenotyping systems (Ubisi *et al.*, 2017).

More stable, higher-yielding, and higher-quality modern enhanced cultivars are available. According to Bedeke *et al.* (2018), the new cultivars can be used in rainfed agriculture in regions with inconsistent and little rainfall. The tropical highlands found in a number of East African nations meet the requirements for varietal alteration outcomes that are more transparent and result in increased output (Gil, 2020). Greater tolerance/resistance to diseases, insect pests, drought, heat, cold, parasitic weeds, and other stress conditions are among the benefits they give, along with greater and more consistent harvests. Large gains in bread-making quality, nutritional content, and other characteristics are also provided by certain types (Walker & Alwang, 2020).

Some of the environmentally friendly strategies recommended by the United Nations Food and Agriculture Organization (FAO) for risk reduction, soil and water conservation, and effective water management is the use of adaptable enhanced crop varieties, including both herbaceous and tree crops (FAO, 2020). In addition to ensuring steady agricultural output, the introduction of better crop types that are suited to climate change, whether annual or perennial, helps to mitigate its negative effects on farming systems (Walker & Alwang, 2020).

Ubisi *et al.* (2017), the results of the study showed that long-lasting droughts were viewed by subsistence farmers as the primary shock that stressed crop productivity. A common result of droughts was low agricultural output and significant crop failure. Different genders used different tactics to adjust to the current climate. For example, 41% of female farmers changed the date of planting, whereas 35% of male farmers used crop variety and diversification and 15% used mixed cropping. Smallholder farmers faced vulnerabilities and had little ability to adjust to climate change since their financial, physical, natural, and social assets were at risk. The findings demonstrated that smallholder farmers who have access to extension agents typically adapt better.

Mwadzingeni *et al.* (2023), demonstrate the necessity for farmers to include crop species rotation in their list of adaptation methods in order to diversify crop production at the field scale. Recent developments in plant sciences have provided consistent evidence that producing a diversity of crops improves biomass output and stability at various spatial scales, hence endorsing the benefits of doing so (Renard and Tilman 2019, Bowles *et al.*, 2020).

Farmers will require access to new and improved technology, infrastructure, skills and expertise, and financial outlets to adapt to climate change. The creation and successful adoption of innovative farming techniques and technologies will have a significant impact on how well farmers adjust to climate change (Acevedo *et al.*, 2020). In areas with higher and more certain production potential where farmers are employing enhanced inputs like chemical fertilizers and pesticides, the adoption of improved varieties is frequently manifested most frequently by an increase in productivity per hectare (Bedeke *et al.*, 2018). Since household consumption is spread over a longer period during the same cropping year, higher yields from better cultivars immediately improve food security.

Diversifying agricultural production through the introduction of new crops or varieties or the revival of heritage crops benefits biodiversity and ecosystem services, especially when combined with conservation agriculture practices (minimum soil disturbance, permanent soil organic cover, and crop species diversification) (Smit, 2023). Additionally, it lowers the chance of a crop failing completely and improves the agro-ecosystem's capacity to respond to biotic and abiotic challenges (Bedeke *et al.*, 2018).

According to Rosa *et al.* (2022), small-scale irrigation greatly raises farm households' standard of living and lessens the effects of climate change by strengthening their resistance to unpredictable weather occurrences. Small-scale irrigation techniques should therefore be given top priority by policymakers in order to enhance the standard of living for rural households and farmers in regions with erratic rainfall and a high risk of drought.

Dawid *et al.* (2023), stated that the recent rise in world hunger and the serious food issues that are plaguing the globe are mostly caused by climatic variability and extremes. Because over 70% of the population in sub-Saharan Africa heavily depends on dryland agricultural and pastoral rangeland systems, the region is especially vulnerable to climate shocks. This means that the region is where climate change has the greatest and most complex effect on output and livelihoods (FAO, 2019).

CHAPTER THREE

METHODOLOGY

3.1. Introduction

The information in this chapter covers the design and conduct of the study, description of the study area, study population, sampling technique, sample size and selection, data collection methods, instruments, validity and reliability, data collection procedures, data analysis, and ethical considerations.

3.2. Description of the study area

This study was conducted in Kagadi Subcounty, Kagadi in mid-western Uganda i.e., was scheduled to take place in 0°49'30"N and 30°53'30"E. It lies 245 kilometers to the west of Kampala - capital city of Uganda. The study district shares boundaries with the following areas: Kyenjojo District to the south, Kikuube District to the north, Ntoroko District to the west, and Kibaale District to the east. It was selected because several reports were released that demonstrated how the district's smallholder farmers' yields had been impacted by climate change (Kagadi District Production Department Report, 2022).

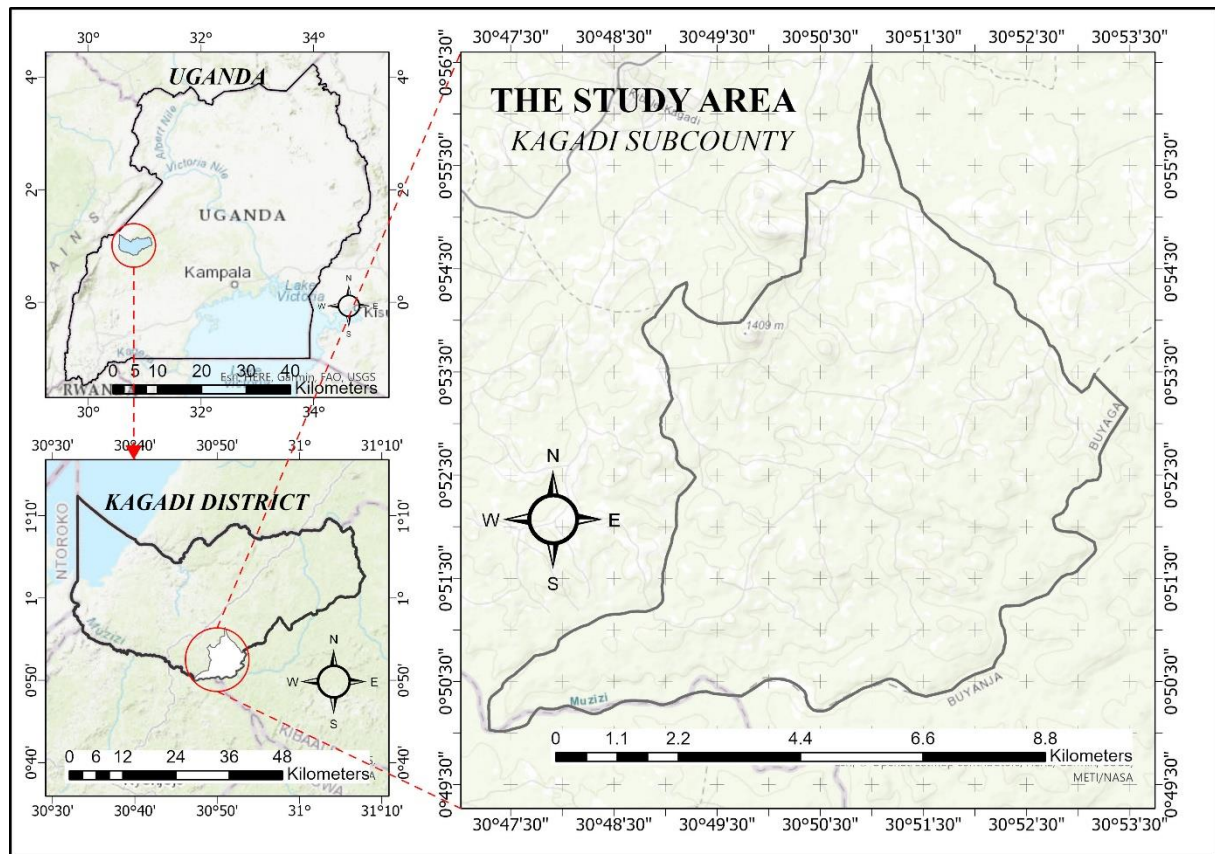


Figure 1: Map of the study area

3.3. Research Design

"Research design" refers to organizing a research strategy. It outlines the following: what will be observed, how, when, and where it will be observed, along with the reason for the observation, how to record the observations, analyze and interpret the observations, and make generalizations (Asenahabi , 2019). Thus, a research design is a thorough blueprint outlining how the objectives of the study will be met (Creswell, 2014). In this study, cross sectional research design was used to attain the realization of the research goal through a controlled scientific inquiry process as detailed: a multifaceted study approach and triangulation were mixed (both qualitative and quantitative) study approach was used for accomplishing the investigation's main objective of climate change adaptation objectives

3.4. Study Population

The term "population" describes the collection or grouping of all the units to whom the study conclusions should be addressed (Shukla, 2020). For this study, the population was comprised of smallholder farmers' households, village leaders and sub county leaders in Kagadi Sub

County. According to the District planning unit report 2023, there are 4 parishes comprising of 2,649 households in Kagadi Sub County. The study focused on all the smallholder farmers' households because they are the ones affected by climate change and variability.

3.5. Sampling and sample size determination

3.5.1. Sampling technique

Purposive and simple random sampling techniques used in this study. The study area was divided into four parishes (Busirabo, Kanyangoma, Kenga and Kihayura) from which the researcher randomly selected respondents. Only smallholder farmers who had lived in the village for thirty years or more and are familiar with trends in periodic variations in the climate were given preference. To minimize bias, a simple random selection technique was employed to choose respondents from the homes of smallholder farmers. This technique ensures that each candidate has an equal chance of being chosen (Shukla, 2020).

3.5.2. Sample size determination

According to Shukla (2020), a sample is any subset of the population that includes every possible combination of population elements. This means that the units chosen as an example from the entire population must encompass all the various features of the various kinds of demographic units. Yamane (1967) formula was used to determine the sample size.

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

where N = population and n = desired sample size; e is the significance level with a significance threshold of 5% (0.05).

$$n = \frac{2687}{1 + 2687(0.05)^2} = 348$$

So, the the number of smallholder farmers that participated in the study totaled to 348, a number whose results are presented in chapter four. The key informants were selected purposively and these included four (4) parish chiefs, one subcounty chief, one agriculture extension officer and one community development officer.

3.6. Data Collection methods and tools

This research used questionnaire and interview guide that were administered by trained

research assistants where both qualitative and quantitative data was collected. Secondary data on climate variables was also abstracted from reviewing Uganda National Meteorological Authority available data on climate variability.

3.6.1. Questionnaire

A tool for gathering data is the use of questionnaires, which consist of a predetermined list of questions that respondents must respond to based on predetermined study objectives (Syeda et al., 2021). The questionnaire was utilized because certain characteristics, such as the respondents' views, opinions, perceptions, and feelings, cannot be observed (Creswell, 2014). The approach is appropriate for the subject matter since individuals are inherently drawn to total seclusion and anonymity. The method was also used because it allows the researcher to save money, time, and effort when gathering data. Additionally, a large sample size can yield a wealth of information quickly, making it a worthwhile time investment (Creswell, 2014). A research assistant interfaced with the participants in this study during which households of smallholder farmers answered the questions in the questionnaire that were moderated by the researcher and the university supervisors.

3.6.2. Interview

Interviews are useful methods for probing and obtaining unbiased interpretations of the study's observable facts. Qualitative data was gathered through interviews. Using this approach, the researcher conducted in-depth interviews with the chosen participants to gather detailed information about the study variable that may be applied to the data analysis (Creswell, 2014). The key informants, i.e., the local leaders, extension officers, community development officer, District Agricultural officer, District Forest officer and the district planner were interviewed by the researcher to obtain information related to agriculture return in terms of climate change and people's livelihood, extent of degradation and other human activities that accelerate climate change.

3.7. Reliability and validity of the data collection instruments

3.7.1. Validity

The degree of correctness of the study's findings is referred to as validity (Creswell, 2014). After the form is drafted, it was given to the supervisor and other experts for feedback on the

items to guarantee and maintain a high degree of validity in this study. All changes to the questionnaire's items were guided by the feedback received. To prevent unclear questions, the researcher pre-tested the questionnaires. To make sure that the directions and the meanings of the questions are straightforward, unambiguous, and helpful to the subjects, a pretest was conducted in one village and on twenty community families that are not sample responders.

3.7.1. Reliability

The consistency of an instrument in measuring what it is intended to assess is referred to as reliability (Bornstein, 2018). The interview schedule was pre-tested by the researcher and the enumerators, and its reliability was calculated and confirmed through Cronbach's Alpha coefficient of 0.85 (Santos, 1999).

3.8. Data Analysis

The data from the field was coded, corrected, and then imported into R Version 4.5.1 for analysis (R Core Team, 2025). Both descriptive (frequencies and percentages) and inferential statistics i.e., chi-square were applied on the perceived effects and causes of climate change as well as on the climate change adaptation practices adopted by the smallholder farmers. Multivariate probit regression model was employed to evaluate the factors influencing the adoption of climate change adaptation (CCA) strategies among the smallholder farmers. The main advantage of this model is that it allows the analysis of potential correlation between unobserved disturbances (error terms) and the correlation between the adoption of each CCA strategy (Young et al., 2009).

3.9. Ethical Considerations

In order to be granted permission to collect data in the study area, the researcher received an Ethical Clearance letter from Bishop Stuart University Research Ethics Committee and an introductory letter from Bishop Stuart University introducing him to the leaders of the local Governments in the villages, the Kagadi District Local Government, the Sub County Lower Local Government, the Parishes, and the study area. Respondents were also asked for formal consent, with stringent guarantees of anonymity, secrecy, and privacy. The consent statement was created at the onset of the questionnaire, and it was presented to the respondent at the start of the interview. Before the study begins, the researcher also explained to the participants its goals and advantages.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSIONS

4.0. Introduction

This section presents the results, their analyses, interpretation, and discussion. These include demographic characteristics, climate change effects experienced by the smallholder farmers, the climate change adaptation strategies being implemented by the farmers, and the regression outputs of factors influencing the adoption of Climate Change Adaptation practices.

4.1. The demographic characteristics of the smallholder farmers

The data reveals key trends in gender distribution, age, education level, farm size, access to support services, and household economic conditions, which collectively shape agricultural productivity and livelihoods in the study area.

Table 1: Descriptive statistics of categorical demographic characteristics.

Characteristic	Frequency (N=348)	Proportion (%)
Gender		
Female	123	35.3
Male	225	64.7
Age		
Below 30	29	8.30
30 – 39	101	29.0
40 – 49	105	30.2
50 – 59	70	20.1
Above 60	43	12.4
Level of education		
None	83	23.9
Primary	157	45.1
Secondary	90	25.9
Tertiary	14	4.00
University	4	1.10
Farm size		
Below 1 acre	84	24.1
1 - 2 acres	236	67.8
Above 3 acres	28	8.00
Access to extension services		
No	163	46.8
Yes	185	53.2
Access to credit		
No	238	68.4

Characteristic	Frequency (N=348)	Proportion (%)
Yes	110	31.6
Access to climate information		
No	210	60.3
Yes	138	39.7

The findings in Table 1 indicate that male farmers dominate the sample, comprising 64.7% compared to 35.3% female farmers, suggesting gender disparities in agricultural participation. This imbalance may reflect socio-cultural barriers that limit women's involvement in farming, highlighting the need for gender-sensitive policies to ensure equal access to resources and training. Additionally, the age distribution shows that most farmers fall within the 30–49 age range, with only 8.3% below 30 years old, raising concerns about the aging farming population and the potential shortage of young farmers in the future. Encouraging youth engagement through incentives and modern farming techniques could help sustain agricultural productivity.

Education levels among farmers remain low, with nearly 70% having only primary education or none, which may hinder the adoption of improved farming methods. Strengthening extension services and providing basic literacy programs could enhance farmers' capacity to adopt new technologies. Farm sizes are predominantly small, with 67.8% of farmers cultivating 1–2 acres, limiting economies of scale. Promoting cooperative farming or high-value crop production could help maximize output on limited land. Access to critical support services is another challenge, as nearly half of the farmers lack extension services, over two-thirds have no credit access, and 60.3% do not receive climate information. Expanding financial inclusion through microfinance and improving climate advisory systems would enable farmers to invest in better inputs and adapt to environmental changes.

Table 2: Descriptive statistics of continuous demographic characteristics

Characteristic	Mean (SD)	Median [Min, Max]
Household size	5.56 (2.36)	5.00 [0, 13.0]
Household income	1,980,000 (805,000)	1,850,000 [1,000,000, 6,500,000]

The study found that the average household size among smallholder farmers was approximately 6 members, with a median household income of UGX. 1,980,000/= . This large household size, combined with relatively low income, suggests significant economic pressure, as families must support multiple dependents on limited earnings. In the study area, where

subsistence farming is common, such large households often rely heavily on farm output for food security, leaving little surplus for investment in improved inputs or diversification. The reported income levels, though modest, are likely to vary considerably, as indicated by the wide range (1,000,000 to 6,500,000 UGX), reflecting disparities in land productivity, market access, and off-farm opportunities.

4.2. The climate change effects experienced by the smallholder farmers.

The study findings reveal a complex pattern of climate change impacts affecting smallholder farmers, with statistically significant variations across different phenomena. The high prevalence of soil erosion (79.0%, $\chi^2=117.253$, $p<0.001$) indicates a severe and systemic challenge for Ugandan smallholders, likely exacerbated by intensive farming on degraded soils and erratic rainfall patterns. This finding aligns with Mubiru et al.'s (2018) research showing similar soil degradation trends across East African farmlands. The extreme statistical significance confirms this is not a random occurrence but a fundamental threat to agricultural sustainability, requiring immediate conservation measures like terracing and agroforestry to maintain productive soils. Farmers experiencing erosion will likely see declining yields over time without intervention, potentially worsening food insecurity in vulnerable households.

Table 3: The climate change effects experienced by the smallholder farmers.

Effect	Frequency (n=348)	Proportion (%)	χ^2	p-value
Water scarcity				
No	197	56.6	6.080	0.014*
Yes	151	43.4		
High temperatures				
No	162	46.6	1.655	0.198
Yes	186	53.4		
Soil erosion				
No	73	21.0	117.253	<0.001***
Yes	275	79.0		
Unreliable rainfall				
No	189	54.3	2.586	0.108
Yes	159	45.7		
Floods				
No	326	93.7	265.563	<0.001***
Yes	22	6.3		
Prolonged drought				
No	62	17.8	144.184	<0.001***
Yes	286	82.2		
Intense rainfall				

Effect	Frequency (n=348)	Proportion (%)	χ^2	p-value
No	286	82.2	144.184	<0.001***
Yes	62	17.8		
Pests and diseases				
No	178	51.1	0.184	0.668
Yes	170	48.9		

Prolonged drought affects 82.2% of farmers ($\chi^2=144.184$), making it the most widespread climate challenge documented. This overwhelming prevalence suggests rainfall patterns have become increasingly unreliable, consistent with IPCC (2022) projections for East Africa. The drought conditions threaten both crop production and livestock survival, particularly for farmers without irrigation access. As Amare and Simane (2017) found in Ethiopia, such persistent drought conditions force farmers to abandon traditional crops and adopt drought-resistant varieties, while also increasing dependence on off-farm income during dry seasons. The near-universal experience of drought across the sample indicates it should be a top priority for adaptation programs.

Water scarcity is experienced by 43.4% of farmers ($\chi^2=6.080$, $p=0.014$), showing significant but less universal prevalence than drought. This partial penetration suggests water stress is concentrated in specific agro-ecological zones or among farmers without access to water storage. The finding supports Aryal et al.'s (2021) observation that water scarcity is becoming a critical constraint for rainfed agriculture. Farmers facing water shortages often must prioritize certain crops or reduce planted area, as Diallo et al. (2020) documented in Mali, leading to lower overall production and household food supplies. The statistical significance confirms this is a climate-driven pattern rather than random variation.

High temperatures affect 53.4% of farmers ($\chi^2=1.655$, $p=0.198$), showing moderate prevalence but lacking statistical significance. This suggests while many farmers perceive temperature increases, the experience is not uniform across the study area. The pattern aligns with Addis and Abirdew's (2021) findings in Ethiopia where temperature impacts varied by elevation. Rising temperatures can reduce crop yields through heat stress and increased evaporation, particularly for temperature-sensitive crops like beans, though some farmers may adapt by shifting planting dates or crop types as Anderson et al. (2020) observed.

Unreliable rainfall is reported by 45.7% of farmers ($\chi^2=2.586$, $p=0.108$), showing moderate prevalence but not reaching statistical significance. This indicates rainfall variability is a

common concern, but its impacts are unevenly distributed. The finding echoes Asante et al.'s (2021) work in Ghana showing rainfall unpredictability is reshaping farming calendars. Farmers facing erratic rains often struggle with planting timing and crop establishment, leading to lower productivity. Those able to access weather information or diversify crops tend to cope better, as Djido et al. (2021) found in West Africa.

Floods impact only 6.3% of farmers but show extreme significance ($\chi^2=265.563$, $p<0.001$), indicating concentrated devastation in vulnerable areas. This pattern matches Aryal et al.'s (2020) findings about localized flood risks in coastal Bangladesh. Though few farmers are affected, floods can be catastrophic by destroying crops, eroding soils, and damaging infrastructure. Flood-prone areas need targeted protection measures like drainage systems or flood-resistant crops, as Niang et al. (2014) recommended. The extreme chi-square value confirms these are climate-driven events rather than random occurrences.

Pests and diseases affect 48.9% of farmers ($\chi^2=0.184$, $p=0.668$), showing nearly even distribution without statistical significance. This suggests pest outbreaks are common but not clearly linked to climate trends in this study. The finding contrasts with Deutsch et al.'s (2018) projections but supports Atube et al.'s (2021) Ugandan fieldwork showing pest dynamics depend heavily on local factors. Farmers typically respond with increased pesticide use or crop diversification, though integrated pest management would be more sustainable, as van Asseldonk et al. (2023) advocated. The non-significant result implies pest control programs should be tailored to specific local outbreaks rather than broad implementation.

4.3. The perceived causes of climate change among smallholder farmers

The table below presents smallholder farmers' perceptions regarding various potential causes of climate change, showing significant disparities in awareness and agreement levels across different factors, as indicated by the frequency distributions and highly significant chi-square values (all $p<0.001$).

The perception that large-scale livestock farming causes climate change shows a divided opinion among farmers, with only 4.9% strongly agreeing but 50% being uncertain ($\chi^2=411.052$, $p<0.001$). This polarization suggests limited understanding of livestock's role in methane emissions, consistent with Addo et al.'s (2020) findings in Niger where livestock emissions were poorly understood. The high uncertainty indicates a need for targeted education about livestock's climate impacts, particularly since many smallholders rely on

animals for livelihoods. The strong statistical significance reveals this is a meaningful pattern in farmer perceptions rather than random variation, highlighting an important knowledge gap that extension services should address through climate-smart livestock training programs like those studied by Kurgat et al. (2020).

Farmers showed mixed views on wood fuel use as a climate change cause, with 8.6% strongly agreeing but 52.3% disagreeing ($\chi^2=391.425$, $p<0.001$). This reflects the complex relationship between energy use and environmental awareness in rural areas, similar to findings by Alidu et al. (2022) in Ghana. The high disagreement rate suggests many farmers don't connect their daily fuel practices with climate impacts, despite wood fuel's documented contribution to deforestation and emissions (Ariom et al., 2022). The significant chi-square value confirms this is a structured perception pattern, indicating that interventions promoting alternative energy sources must first address these knowledge gaps, building on approaches tested by Zakari et al. (2022) in Niger.

Table 4: Perceived causes of climate change among smallholder farmers

Cause	Frequency (N=348)	Proportion (%)	χ^2	p-value
Large-scale livestock farming				
Strongly agree	17	4.90	411.052	<0.001***
Agree	0	0.00		
Not sure	174	50.0		
Disagree	149	42.8		
Strongly disagree	8	2.30		
Use of wood fuel				
Strongly agree	30	8.60	391.425	<0.001***
Agree	0	0.00		
Not sure	132	37.9		
Disagree	182	52.3		
Strongly disagree	4	1.10		
Inefficient animal waste management				
Strongly agree	16	4.60	410.736	<0.001***
Agree	0	0.00		
Not sure	162	46.6		
Disagree	162	46.6		
Strongly disagree	8	2.30		
Deforestation				
Strongly agree	97	27.9	622.517	<0.001***
Agree	0	0.00		
Not sure	7	2.00		
Disagree	241	69.3		
Strongly disagree	3	0.90		
Digging up vegetative biomass				

Cause	Frequency (N=348)	Proportion (%)	χ^2	p-value
Strongly agree	19	5.50	395.851	<0.001***
Agree	0	0.00		
Not sure	191	54.9		
Disagree	121	34.8		
Strongly disagree	17	4.90		

Regarding inefficient animal waste management, farmers were evenly split between uncertainty (46.6%) and disagreement (46.6%), with only 4.6% strongly agreeing it causes climate change ($\chi^2=410.736$, $p<0.001$). This near-even division mirrors Belay et al.'s (2022) findings in Ethiopia about low awareness of manure management's climate impacts. The statistical significance shows these perceptions follow clear patterns rather than random variation, suggesting that while few farmers recognize the methane potential of animal waste, many remain unconvinced or unaware - a critical gap since proper manure management could both mitigate emissions and improve soil health, as demonstrated in climate-smart programs reviewed by Agyekum et al. (2024).

Deforestation emerged as the most recognized climate change cause, with 27.9% strongly agreeing ($\chi^2=622.517$, $p<0.001$), though 69.3% still disagreed. This relatively higher recognition aligns with Asfaw et al.'s (2019) work in Ethiopia showing farmers often link visible environmental changes like tree loss to climate shifts. The extreme statistical significance confirms this is a robust perception pattern, suggesting farmers may be more likely to acknowledge climate causes they can directly observe. However, the majority disagreement indicates many still don't connect forest loss with broader climate systems, highlighting a need for education connecting local deforestation to global impacts, following approaches used by Mwinkom et al. (2021) in Ghana.

For digging up vegetative biomass, most farmers were uncertain (54.9%) or disagreed (34.8%), with only 5.5% strongly agreeing it causes climate change ($\chi^2=395.851$, $p<0.001$). This mirrors low awareness found by Myeni and Moeletsi (2020) in South Africa about how soil disturbance affects carbon cycles. The significant chi-square value shows these are structured perceptions rather than random opinions, suggesting farmers may not understand the relationship between soil organic matter and greenhouse gases. Since maintaining vegetative cover is a key climate-smart practice (Aryal et al., 2020), extension services should emphasize this connection, building on successful messaging strategies documented by Musafiri et al. (2022) in Kenya.

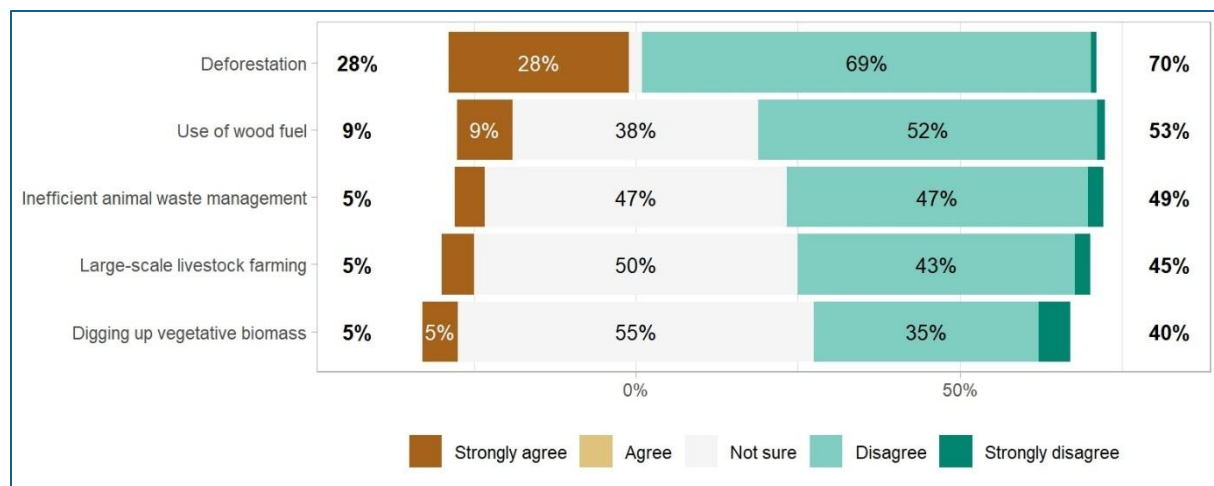


Figure 2: Perceived causes of climate change among smallholder farmers

4.4. The adaptation strategies adopted by smallholder farmers

The table below presents the adoption rates of various climate change adaptation strategies among smallholder farmers, showing significant adoption of certain practices ($p < 0.001$) while revealing others that remain underutilized or show no clear adoption patterns.

Table 5: The adaptation strategies adopted by smallholder farmers

Practice	Frequency (n=348)	Proportion (%)	χ^2	p-value
Using early maturing crop varieties				
No	113	32.5	42.770	<0.001***
Yes	235	67.5		
Early planting				
No	127	36.5	25.391	<0.001***
Yes	221	63.5		
Agroforestry				
No	40	11.5	206.391	<0.001***
Yes	308	88.5		
Rainwater harvesting				
No	216	62.1	20.276	<0.001***
Yes	132	37.9		
Use of drought tolerant crop varieties				
No	183	52.6	0.931	0.335
Yes	165	47.4		
Irrigation				
No	174	50.0	0.000	1.000
Yes	174	50.0		

The adoption of early maturing crop varieties by 67.5% of farmers ($\chi^2=42.770$, $p < 0.001$) demonstrates that this as a widely accepted strategy to cope with shortened growing seasons, consistent with findings by Aryal et al. (2021) in South Asia where such varieties helped

farmers manage unpredictable rainfall patterns. The high statistical significance confirms this is a deliberate adaptation choice rather than random behavior, likely because these varieties reduce exposure to end-of-season droughts while maintaining productivity, as observed in climate-smart agriculture programs studied by Kurgat et al. (2020). However, the 32.5% non-adoption rate suggests barriers like seed access or knowledge gaps that need addressing through extension services and seed distribution systems like those reported by Zakaria et al. (2020) in Ghana.

Early planting is practiced by 63.5% of farmers ($\chi^2=25.391$, $p<0.001$), showing it as another key strategy to align crop cycles with shifting rainfall patterns, echoing results from Diallo et al. (2020) in Mali where adjusting planting dates was among the most accessible adaptations. The significant chi-square value indicates this timing adjustment is a purposeful response to climate variability rather than chance, though the 36.5% non-adoption suggests some farmers may lack climate information to guide planting decisions or face labor constraints during early planting windows, the challenges also documented by Ncoyini et al. (2022) among South African smallholders. This highlights the need for climate services that provide localized planting recommendations while considering farmers' operational capacities.

Agroforestry shows remarkably high adoption at 88.5% ($\chi^2=206.391$, $p<0.001$), making it the most prevalent strategy, which aligns with Mwinkom et al.'s (2021) findings in Ghana where trees were valued for both climate resilience and livelihood benefits. The extreme statistical significance confirms this is a dominant, intentional adaptation approach rather than random behavior, likely because agroforestry systems buffer against multiple climate risks while improving soil fertility - advantages well-documented by Ariom et al. (2022) across African smallholder systems.

Rainwater harvesting has been adopted by only 37.9% of farmers despite high significance ($\chi^2=20.276$, $p<0.001$), indicating substantial untapped potential for this strategy, like the findings by Musafiri et al. (2022) in Kenya where water capture technologies showed high impact but low adoption. The significant chi-square value confirms adoption follows clear patterns rather than randomness, with the low overall rate likely reflecting infrastructure costs and technical knowledge requirements that constrain poor farmers, as observed by Lamichhane et al. (2022). The 62.1% non-adoption suggests need for subsidized micro-catchment systems and training programs like those successfully implemented by Rockström et al. (2010) in semi-arid regions.

Drought-tolerant varieties show nearly even adoption (47.4%) and non-adoption (52.6%) without statistical significance ($\chi^2=0.931$, $p=0.335$), contrasting with Aryal et al.'s (2020) findings where such varieties were widely embraced in drought-prone areas. The non-significant result suggests adoption is not systematically linked to climate adaptation in this context, possibly because available drought-tolerant varieties don't match farmer preferences for taste or marketability, a challenge also noted by Ojo and Baiyegunhi (2020b) in Nigeria. This highlights the need for participatory crop breeding that incorporates both climate resilience and consumer traits, following models developed by Gebre et al. (2023).

Irrigation shows a perfect 50-50 split with no statistical significance ($\chi^2=0.000$, $p=1.000$), indicating random rather than climate-driven adoption patterns, differing from Shikuku et al.'s (2017) findings where irrigation was strategically adopted in drought-vulnerable areas. This suggests irrigation use in this context is constrained by factors like water access and pump costs rather than being a deliberate climate response, consistent with barriers identified by Autio et al. (2021) in Kenya. The equal division implies irrigation expansion requires addressing structural constraints through water user associations and affordable technologies as promoted by van Asseldonk et al. (2023).

4.5. The factors influencing the adoption of climate change adaptation strategies among smallholder farmers.

The factors influencing smallholder' adoption of the six climate change adaptation strategies were grouped into two main categories (i.e., socio-demographic and institutional characteristics). The statistical relationships between the dependent variable (i.e. adoption of the six climate change adaptation strategies) and explanatory variables (i.e. socio-demographic and institutional characteristics) were estimated using the Multivariate Probit Model (MVP) using the *mvProbit()* function from the *mvProbit* package (R Core Team, 2025).

4.5.1. Use of early maturing crop varieties

Table 6: Regression results for the use of early maturing crop varieties

Variable	Estimate	Std. Error	t-value	p-value
(Intercept)	1.673	0.141	11.836	<0.001***
Gender (Male)	-0.057	0.052	-1.106	0.269
Age (30 – 39)	-0.000	0.100	-0.004	0.997
Age (40 – 49)	0.079	0.104	0.766	0.444
Age (50 – 59)	-0.050	0.111	-0.454	0.65
Age (Above 60)	-0.142	0.121	-1.171	0.242
Education level (Primary)	-0.044	0.062	-0.714	0.476
Education level (Secondary)	-0.091	0.073	-1.234	0.218
Education level (Tertiary)	-0.217	0.133	-1.631	0.104
Education level (University)	0.288	0.242	1.188	0.236
Farm size (1 - 2 acres)	-0.078	0.058	-1.337	0.182
Farm size (Above 3 acres)	-0.136	0.102	-1.328	0.185
Access to extension services (Yes)	0.239	0.051	4.725	<0.001***
Access to credit (Yes)	0.076	0.053	1.437	0.152
Access to climate information (Yes)	-0.039	0.051	-0.769	0.442
Household size	0.003	0.011	0.290	0.772
Household income	0.000	0.000	0.038	0.97

The regression analysis reveals that access to extension services emerges as the only statistically significant factor ($p < 0.001$) influencing the adoption of early maturing crop varieties, with a positive coefficient (0.239) indicating farmers receiving extension support are more likely to adopt this strategy. This finding aligns with Ado et al. (2020) who found extension services crucial for technology adoption in Niger, and Zakaria et al. (2020) who demonstrated how extension programs in Ghana effectively promoted climate-smart practices. The strong positive relationship ($t\text{-value} = 4.725$) suggests extension services play a vital role in disseminating knowledge about early maturing varieties and overcoming adoption barriers, consistent with Atube et al.'s (2021) findings in Uganda where extension agents helped farmers understand the benefits of adapted early maturing crop varieties. The significance of extension services while controlling for other variables underscores their unique importance compared to factors like education or farm size, reinforcing Lamichhane et al.'s (2022) argument about the critical role of agricultural advisory systems in climate adaptation. Interestingly, contrary to some literature (e.g., Aryal et al., 2021), neither access to credit nor climate information showed significant effects in this model, suggesting that for this specific adaptation strategy in this context, knowledge transfer through extension may be more impactful than financial resources or climate data alone. This finding has important policy

implications, supporting investments in strengthening extension systems as reported by van Asseldonk et al. (2023), particularly for promoting time-sensitive adaptations like early maturing varieties that require precise agronomic guidance. The non-significance of demographic factors (gender, age) and socioeconomic variables (income, education) further highlights how extension services can effectively reach diverse farmer groups when properly implemented, as observed in effective programs documented by Kurgat et al. (2020) in Tanzania.

4.5.2. Adoption of Early planting

The regression analysis for early planting adoption reveals three statistically significant factors: access to extension services shows the strongest positive influence ($p=0.002$, coefficient=0.161), demonstrating that farmers receiving extension support are significantly more likely to adjust planting dates, aligning with findings by Aryal et al. (2021) who highlighted extension agents' role in disseminating climate-informed planting calendars across South Asia. Household size also emerges as significant ($p=0.035$, coefficient=0.024), suggesting larger families may have greater labor capacity to implement time-sensitive planting adjustments, a pattern observed by Atube et al. (2021) in Uganda where labor availability facilitated climate adaptation.

Table 7: Regression results for Early planting practice

Variable	Estimate	Std. Error	t-value	p-value
(Intercept)	1.687	0.147	11.472	<0.001***
Gender (Male)	-0.084	0.054	-1.560	0.12
Age (30 – 39)	-0.098	0.104	-0.946	0.345
Age (40 – 49)	-0.111	0.108	-1.032	0.303
Age (50 – 59)	-0.160	0.115	-1.388	0.166
Age (Above 60)	-0.104	0.126	-0.826	0.409
Education level (Primary)	0.035	0.064	0.545	0.586
Education level (Secondary)	-0.063	0.076	-0.822	0.412
Education level (Tertiary)	-0.187	0.138	-1.349	0.178
Education level (University)	0.275	0.252	1.090	0.277
Farm size (1 - 2 acres)	-0.079	0.061	-1.305	0.193
Farm size (Above 3 acres)	-0.157	0.106	-1.480	0.14
Access to extension services (Yes)	0.161	0.053	3.057	0.002**
Access to credit (Yes)	-0.001	0.055	-0.021	0.983
Access to climate information (Yes)	0.096	0.053	1.830	0.068
Household size	0.024	0.011	2.112	0.035*
Household income	-0.000	0.000	-1.212	0.226

While access to climate information approaches significance ($p=0.068$), its borderline p -value indicates a potential trend where weather advisories may influence planting decisions, consistent with Djido et al.'s (2021) findings in West Africa about the growing importance of climate services. The prominence of extension services over other factors reinforces Kurgat et al.'s (2020) evidence from Tanzania about the critical role of agricultural advisory systems in promoting climate-smart practices, particularly for time-dependent strategies like early planting that require precise technical guidance. Interestingly, the absence of significant effects from education, credit access, or farm size contrasts with some literature (e.g., Ojo et al., 2021), suggesting that for this specific practice, institutional support (extension) and household characteristics (labor availability) may outweigh socioeconomic factors in driving adoption decisions in this context. These results collectively emphasize the need for targeted extension programs that consider household labor dynamics when promoting planting date adjustments, as successfully implemented in climate adaptation initiatives documented by van Asseldonk et al. (2023).

4.5.3. Adoption of Agroforestry practice

The regression analysis for agroforestry adoption reveals two statistically significant factors: household size demonstrates a strong positive relationship ($p=0.005$, coefficient=0.022), indicating that larger families are more likely to practice agroforestry, likely due to greater available labor for tree planting and maintenance, a finding consistent with Atube et al.'s (2021) research in Uganda where labor-intensive climate adaptations were more feasible for larger households. Surprisingly, tertiary education shows a negative association ($p=0.021$, coefficient=-0.215), suggesting that farmers with post-secondary education may be less inclined toward agroforestry, possibly because they pursue alternative livelihoods or perceive trees as competing with crops, echoing Jellason et al.'s (2021) findings in Nigeria where educated farmers sometimes favored more "modern" practices over traditional agroecological approaches.

Table 8: Regression results for Agroforestry practice

Variable	Estimate	Std. Error	t-value	p-value
(Intercept)	1.826	0.099	18.497	<0.001***
Gender (Male)	-0.067	0.036	-1.848	0.065
Age (30 – 39)	-0.061	0.070	-0.880	0.38
Age (40 – 49)	-0.087	0.072	-1.206	0.229
Age (50 – 59)	-0.149	0.077	-1.930	0.054
Age (Above 60)	-0.034	0.084	-0.406	0.685
Education level (Primary)	0.035	0.043	0.810	0.418
Education level (Secondary)	-0.002	0.051	-0.043	0.966
Education level (Tertiary)	-0.215	0.093	-2.318	0.021*
Education level (University)	0.041	0.169	0.243	0.808
Farm size (1 - 2 acres)	0.049	0.041	1.207	0.228
Farm size (Above 3 acres)	0.025	0.071	0.357	0.722
Access to extension services (Yes)	0.045	0.035	1.277	0.202
Access to credit (Yes)	-0.038	0.037	-1.020	0.309
Access to climate information (Yes)	0.037	0.035	1.038	0.3
Household size	0.022	0.008	2.834	0.005**
Household income	-0.000	0.000	-0.239	0.811

The significance of household size while controlling for other variables supports Mwinkom et al.'s (2021) argument from Ghana that labor availability critically influences agroforestry adoption, though the negative education effect contrasts with some literature (e.g., Zakaria et al., 2020) and may reflect unique local perceptions about tree-crop interactions or land use priorities among educated farmers in this context. These results collectively suggest that agroforestry promotion strategies should particularly target larger households while addressing potential misconceptions among educated farmers about the practice's benefits, as successfully done in programs documented by Ariom et al. (2022) that combined labor mobilization with awareness campaigns about agroforestry's dual economic and ecological advantages.

4.5.4. Rainwater harvesting practice

The regression analysis for the adoption rainwater harvesting reveals several significant demographic and institutional factors shaping adoption patterns. Farmers aged 40-49 ($p=0.003$, coefficient=-0.317), 50-59 ($p=0.001$, coefficient=-0.389), and above 60 ($p=0.004$, coefficient=-0.362) show significantly lower adoption rates compared to younger farmers, suggesting an age-related adoption barrier that aligns with findings by Nyberg et al. (2021) where older farmers in similar contexts were less likely to adopt infrastructure-intensive

adaptations. In contrast, institutional factors demonstrate positive influences: access to extension services shows the strongest effect ($p < 0.001$, coefficient=0.189), reinforcing evidence from Kurgat et al. (2020) about extension agents' critical role in promoting water management technologies, while access to climate information also proves significant ($p = 0.035$, coefficient=0.110), supporting Djido et al.'s (2021) findings about how weather advisories can motivate water conservation investments.

Table 9: Regression results for Rainwater harvesting

Variable	Estimate	Std. Error	t-value	p-value
(Intercept)	1.538	0.145	10.600	<0.001***
Gender (Male)	-0.025	0.053	-0.462	0.644
Age (30 – 39)	-0.170	0.102	-1.656	0.099
Age (40 – 49)	-0.317	0.106	-2.975	0.003**
Age (50 – 59)	-0.389	0.114	-3.426	0.001**
Age (Above 60)	-0.362	0.124	-2.918	0.004**
Education level (Primary)	-0.066	0.064	-1.033	0.302
Education level (Secondary)	0.059	0.075	0.787	0.432
Education level (Tertiary)	-0.149	0.137	-1.088	0.277
Education level (University)	0.115	0.249	0.463	0.644
Farm size (1 - 2 acres)	0.008	0.060	0.141	0.888
Farm size (Above 3 acres)	-0.096	0.105	-0.913	0.362
Access to extension services (Yes)	0.189	0.052	3.639	<0.001***
Access to credit (Yes)	0.000	0.054	0.004	0.996
Access to climate information (Yes)	0.110	0.052	2.114	0.035*
Household size	-0.002	0.011	-0.215	0.83
Household income	0.000	0.000	0.239	0.811

The stark age gradient in adoption rates may reflect both physical constraints in implementing water harvesting structures and cognitive barriers to adopting new practices among older farmers, patterns observed by Lamichhane et al. (2022) in their systematic review of adaptation barriers. Meanwhile, the positive institutional effects highlight how extension systems and climate services can overcome these demographic challenges, as demonstrated in successful programs documented by van Asseldonk et al. (2023) that combined technical training with climate risk communication. These results collectively suggest rainwater harvesting interventions should prioritize younger farmers as early adopters while developing age-sensitive extension approaches to engage older farmers, alongside strengthening institutional support systems that have proven effective in facilitating adoption across diverse farmer groups.

4.5.5. Use of drought-tolerant crop varieties

The regression analysis reveals that education level emerges as the most significant factor influencing adoption of drought-tolerant crop varieties, with farmers possessing tertiary education showing substantially higher adoption rates ($p=0.020$, coefficient=0.346), while university education approaches significance ($p=0.077$, coefficient=0.478). This strong positive education gradient aligns with findings by Gebre et al. (2023) in Kenya, where educated farmers demonstrated greater capacity to understand and evaluate new crop varieties' drought resilience attributes. The pattern suggests that higher education levels enhance farmers' ability to process technical information about variety characteristics and make informed adoption decisions, as observed in Ojo and Baiyegunhi's (2020b) Nigerian study where educated farmers more readily appreciated the yield stability benefits of drought-tolerant varieties.

Table 10: Regression results for adoption of drought-tolerant crop varieties

Variable	Estimate	Std. Error	t-value	p-value
(Intercept)	1.665	0.157	10.604	<0.001***
Gender (Male)	0.099	0.057	1.719	0.087
Age (30 – 39)	-0.146	0.111	-1.313	0.19
Age (40 – 49)	-0.159	0.115	-1.379	0.169
Age (50 – 59)	-0.122	0.123	-0.989	0.323
Age (Above 60)	-0.129	0.134	-0.962	0.337
Education level (Primary)	-0.011	0.069	-0.159	0.874
Education level (Secondary)	0.048	0.082	0.587	0.558
Education level (Tertiary)	0.346	0.148	2.343	0.02*
Education level (University)	0.478	0.269	1.774	0.077
Farm size (1 - 2 acres)	-0.019	0.065	-0.301	0.763
Farm size (Above 3 acres)	0.016	0.114	0.142	0.887
Access to extension services (Yes)	-0.005	0.056	-0.088	0.93
Access to credit (Yes)	-0.091	0.059	-1.551	0.122
Access to climate information (Yes)	-0.023	0.056	-0.404	0.687
Household size	-0.007	0.012	-0.577	0.565
Household income	-0.000	0.000	-0.863	0.389

The non-significance of extension services contrasts with many studies (e.g., Kurgat et al., 2020), potentially indicating that for this specific technology, formal education may outweigh extension outreach in driving adoption decisions, or that extension messages about drought-tolerant varieties may not be effectively reaching less-educated farmers. The results underscore the need for agricultural extension programs to develop simplified communication strategies that make technical information about drought-tolerant varieties accessible to

farmers across all education levels, while also highlighting the potential role of educated farmers as early adopters who can demonstrate benefits to their communities, an approach successfully implemented in climate-smart agriculture programs documented by van Asseldonk et al. (2023). The education effect persists despite controlling other factors like farm size and income, reinforcing Aryal et al.'s (2021) findings about education's unique role in facilitating complex agricultural adaptations.

4.5.6. Adoption of Irrigation practice

The regression analysis for irrigation adoption reveals several significant determinants, with household size showing the strongest positive relationship ($p < 0.001$, coefficient=0.045), indicating that larger families are more likely to adopt irrigation, likely due to greater labor availability for system operation and maintenance, consistent with findings by Atube et al. (2021) in Uganda where labor-intensive technologies depended on family workforce.

Table 11: Regression results for adoption of Irrigation

Variable	Estimate	Std. Error	t-value	p-value
(Intercept)	1.419	0.147	9.663	<0.001***
Gender (Male)	-0.013	0.054	-0.248	0.805
Age (30 – 39)	-0.128	0.104	-1.231	0.219
Age (40 – 49)	-0.293	0.108	-2.722	0.007**
Age (50 – 59)	-0.309	0.115	-2.690	0.008**
Age (Above 60)	-0.213	0.126	-1.695	0.091
Education level (Primary)	0.099	0.064	1.532	0.127
Education level (Secondary)	0.062	0.076	0.807	0.42
Education level (Tertiary)	-0.221	0.138	-1.601	0.11
Education level (University)	0.344	0.252	1.365	0.173
Farm size (1 - 2 acres)	-0.064	0.060	-1.057	0.291
Farm size (Above 3 acres)	-0.058	0.106	-0.546	0.585
Access to extension services (Yes)	0.129	0.053	2.455	0.015*
Access to credit (Yes)	-0.008	0.055	-0.152	0.879
Access to climate information (Yes)	0.172	0.053	3.280	0.001**
Household size	0.045	0.011	3.954	<0.001***
Household income	-0.000	0.000	-1.408	0.16

Access to climate information emerges as another key driver ($p=0.001$, coefficient=0.172), supporting Djido et al.'s (2021) evidence from West Africa that weather advisories motivate water management investments, while extension services also show significant positive influence ($p=0.015$, coefficient=0.129), aligning with Kurgat et al.'s (2020) Tanzanian studies on extension's role in promoting irrigation. Interestingly, farmers aged 40-49 ($p=0.007$,

coefficient=-0.293) and 50-59 ($p=0.008$, coefficient=-0.309) demonstrate significantly lower adoption rates, suggesting age-related barriers to implementing irrigation infrastructure, a pattern observed by Lamichhane et al. (2022) where older farmers faced physical and cognitive challenges with technical adaptations. These results collectively highlight irrigation's labor demands and knowledge requirements, emphasizing the need for targeted support programs that address age-specific barriers while leveraging household labor potential and climate information services, as successfully implemented in initiatives documented by van Asseldonk et al. (2023) that combined family labor mobilization with climate-smart irrigation training. The findings particularly underscore how irrigation adoption depends on both labor resources and institutional support systems, rather than solely on financial factors like credit access or farm size that proved non-significant in this context.

4.6. Strategies for improving the adoption of climate change adaptation strategies

The table presents smallholder farmers' preferred strategies for enhancing climate change adaptation adoption, revealing strong support for financial interventions, capacity-building approaches, and climate information services, with all options showing statistically significant endorsement ($p<0.001$).

The results in Table 12 demonstrate strong farmer support for multiple intervention strategies to enhance climate change adaptation, with low-interest loans showing the highest endorsement (70.7%, $\chi^2=59.586$, $p<0.001$), followed closely by government subsidies (67.0%, $\chi^2=40.011$, $p<0.001$) and climate information services (65.5%, $\chi^2=33.517$, $p<0.001$). This pattern aligns with van Asseldonk et al.'s (2023) findings that financial mechanisms combined with technical support most effectively promote climate-smart agriculture adoption. The overwhelming preference for financial interventions (loans, subsidies, grants) reflects the economic barriers smallholders face in implementing adaptations, consistent with Ojo et al.'s (2021) evidence from Nigeria about credit constraints limiting climate resilience investments. The nearly equal popularity of workshops/field demonstrations (64.7%) and subsidized drip systems (64.7%) (both $\chi^2=29.897$, $p<0.001$) suggests farmers value both knowledge-based and technological solutions, supporting Aryal et al.'s (2021) argument for integrated approaches combining training with input support.

Table 12: Strategies for improving the adoption of climate change adaptation strategies

Strategy	Frequency (n=348)	Proportion (%)	χ^2	p-value
Workshops & field demonstrations				
Yes	225	64.7	29.897	<0.001***
No	123	35.3		
Low-interest loans for climate change adaptation technologies				
Yes	246	70.7	59.586	<0.001***
No	102	29.3		
Government subsidies				
Yes	233	67.0	40.011	<0.001***
No	115	33.0		
Provision of climate information services				
Yes	228	65.5	33.517	<0.001***
No	120	34.5		
Provision of subsidized drip systems.				
Yes	225	64.7	29.897	<0.001***
No	123	35.3		
Grants for adaptation technologies				
Yes	227	65.2	32.287	<0.001***
No	121	34.8		

The high demand for climate information services reinforces Djido et al.'s (2021) findings about the growing importance of weather advisories for agricultural decision-making in West Africa. These results collectively indicate that smallholders prefer a package of complementary interventions addressing financial, informational, and technological barriers simultaneously, rather than single solutions, an approach successfully implemented in climate adaptation programs documented by Kurgat et al. (2020) in Tanzania. The statistically significant results (all $p < 0.001$) confirm these are robust preferences rather than random distributions, suggesting policymakers should prioritize these interconnected strategies when designing climate adaptation support systems for smallholder farmers.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary of findings

This study presents a thorough investigation into the climate change effects, adaptation strategies and factors affecting their adoption among smallholder farmers in Kagadi Sub-County, Uganda. Employing a carefully designed qualitative and quantitative approach, the research combines quantitative surveys with qualitative interviews to provide a nuanced understanding of how farmers are coping with changing climatic conditions. The methodology was specifically structured to capture both the prevalence of various adaptation strategies and the underlying factors influencing their adoption, while maintaining scientific rigor through appropriate sampling techniques and validated research instruments.

The research population encompassed farming households across four distinct parishes, along with local leaders possessing extensive knowledge of historical climate patterns. A multi-stage sampling strategy ensured representation across different geographical areas while accounting for variations in local farming systems. Data collection incorporated structured questionnaires to quantify adaptation behaviors, complemented by in-depth interviews that revealed the reasoning behind farmers' choices. This dual approach allowed for comprehensive analysis that considered both statistical patterns and the human dimensions of climate adaptation decision-making.

Findings regarding climate change effects paint a concerning picture of the environmental challenges facing smallholder farmers in the region. Prolonged droughts emerged as the most widely reported issue, significantly affecting agricultural productivity and household food security. Soil degradation problems were nearly equally prevalent, with many farmers observing worsening erosion that threatens the long-term viability of their lands. Changes in water availability and rainfall patterns were also commonly reported, creating additional complications for crop planning and management. While extreme weather events like floods were less frequent, their occurrence caused insignificant damage when they did take place.

In response to these climate challenges, farmers have adopted various adaptation strategies with differing levels of frequency and success. Agroforestry practices stood out as the most widely implemented approach, valued by farmers for their multiple benefits beyond climate

adaptation alone. Adjustments to planting calendars and the use of faster-maturing crop varieties were also common responses to shifting seasonal patterns. However, more technologically advanced or resource-intensive adaptation methods showed much lower adoption rates, suggesting significant barriers that prevent their widespread use despite potential benefits.

The study's analysis of adoption behaviors revealed several important insights about what influences farmers' decisions regarding climate adaptation. Access to agricultural extension services proved to be the most consistent positive factor across different strategies, highlighting the crucial role of knowledge dissemination and technical support. The relationship between education levels and adaptation adoption presented interesting complexities, with more educated farmers being more likely to adopt some strategies but less likely to adopt others. Household characteristics like family size played varying roles depending on the labor requirements of specific adaptation methods, while some conventional assumptions about factors like farm size and credit access were not strongly supported by the findings.

These results have significant implications for policymakers and organizations working to support climate resilience in smallholder farming communities. The demonstrated importance of extension systems suggests that strengthening these services should be a priority in climate adaptation programming. The mixed adoption patterns for different strategies indicate that a one-size-fits-all approach to promoting climate-smart agriculture would be inadequate, and that interventions need to be tailored based on the specific characteristics and requirements of each adaptation method. The findings also point to the need for more nuanced understanding of how different farmer characteristics influence their capacity and willingness to adopt various climate adaptation practices.

The study makes several important contributions to both academic understanding and practical efforts regarding climate change adaptation in smallholder agricultural systems. By combining quantitative and qualitative methods, it provides a more complete picture of adaptation processes than could be achieved through either approach alone. The identification of extension services as a key determinant of adoption offers concrete guidance for where investments in climate resilience might have the greatest impact. At the same time, the complex relationships between farmer characteristics and adoption decisions challenge some conventional assumptions and point to areas needing further research.

From a theoretical perspective, the findings contribute to ongoing discussions about technology adoption in agricultural systems, particularly in the context of climate change adaptation. The results suggest that existing models may need to account more carefully for the specific characteristics of different adaptation technologies and how these interact with local socio-economic conditions. The unexpected findings regarding factors like education and farm size indicate that the dynamics of climate adaptation adoption may differ in important ways from the adoption of other agricultural innovations.

5.2 Conclusions

This study reveals the complex interplay between climate change effects, adaptation strategies, and the socio-economic factors shaping smallholder farmers' resilience. The findings demonstrate that while farmers are actively responding to climate stressors through various coping mechanisms, their adaptive capacity remains constrained by systemic barriers. Agroforestry and adjusted planting calendars have emerged as widely adopted solutions, reflecting farmers' preference for strategies that align with existing knowledge systems and require minimal external inputs. However, the limited uptake of more technologically advanced adaptations points to deeper structural challenges in knowledge dissemination, resource accessibility, and institutional support. The critical role of extension services underscores the value of localized, farmer-centered advisory systems in bridging the gap between climate science and practical farming solutions. At the same time, the paradoxical relationship between education levels and certain practices suggests that technical knowledge alone cannot drive adoption without addressing perceived trade-offs in productivity and livelihood security. These insights call for a fundamental rethinking of climate adaptation as not merely a set of practices to be adopted, but as an ongoing process of innovation and institutional learning that must account for the diverse realities of smallholder agriculture. The study ultimately highlights the need for transformation in how climate adaptation is conceptualized, communicated, and supported within agricultural development frameworks to achieve meaningful adaptation options.

5.3. Recommendations

Based on the findings of this study, several critical recommendations emerge to enhance climate change adaptation among smallholder farmers.

First, there is an urgent need to strengthen and expand agricultural extension services through increased government funding and training programs to equip extension workers with the latest climate-smart agricultural techniques, as the study clearly demonstrated their pivotal role in facilitating the adoption of adaptation strategies.

Second, financial institutions and development agencies should develop accessible credit schemes with favorable terms specifically tailored for smallholder farmers to invest in adaptation technologies like irrigation systems and drought-resistant crop varieties, addressing the financial barriers identified in the research with enhance adoption of several adaptation strategies.

Third, policymakers should prioritize the establishment of reliable, localized climate information systems that provide timely weather forecasts and planting advisories through mobile platforms and community radio stations, given the significant influence of climate information on farmers' decision-making.

Fourth, agricultural research institutions should intensify participatory research programs to develop crop varieties that combine climate resilience with the taste and market preferences important to farmers, as the study revealed mixed adoption rates of drought-tolerant varieties this will increase farmer's adoption.

Fifth, targeted training programs should be implemented to address the knowledge gaps and misconceptions among more educated farmers about particular adaptation practices, while also designing age-appropriate extension approaches for older farmers who showed lower adoption rates of labor-intensive strategies.

Sixth, the government should implement and encourage co-funding programs for critical adaptation technologies like rain water harvesting equipment and other micro-scale irrigation systems to make them more accessible to resource-constrained farmers.

Finally, there should be a concerted effort to document and integrate successful indigenous adaptation practices with modern techniques through comprehensive farmer training program and demonstrations, fostering a more holistic approach to climate resilience that builds on both scientific and local knowledge systems.

These recommendations, if implemented through coordinated efforts between government

agencies, NGOs, research institutions, and farmer organizations, would significantly enhance the adaptive capacity of smallholder farming communities in the face of increasing climate variability and change.

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APPENDICES

Appendix 1: Household survey questionnaire

Dear respondent,

I am **Desire Mparana** student of Master of Science Degree in Climate Change and Food Security of Bishop Stuart University. As partial fulfillment of my study program, I am carrying out a study on the topic, “*Climate Change Effects, adaptation strategies and factors influencing their adoption among smallholder farmers in Kagadi Sub-county, Uganda*”. You have been selected as a respondent for this study as you have information that is necessary for the successful completion of this research project. Therefore, I kindly request you to spare a few minutes of your busy schedules to respond to this questionnaire to enable me to accomplish this task. The information that you provide will be treated as a high level of confidentiality and strictly used for the purpose of this study. Your honesty and sincere responses are highly appreciated for academic purposes. Thank you very much for your cooperation.

Section A: Socio-Demographic Characteristics

A1: What is your gender?

Male Female

A2: What is your age?

Below 30 30 – 39 40 – 49
50 – 59 Above 60

A3: What is your highest education level?

No formal education Primary Secondary
Tertiary University

A4: How many members do you have in your household? _____

A5: What is the size of your land? (Acres/Hectares)

Below 1 acre 1 - 2 acres Above 3 acres

A6: What is your seasonal income from farming activities? _____

Section B: Perception of Climate Change

B1: Have you observed changes in climate patterns over the past 30 years?

Yes No

B2: If yes, what changes or effects have you noticed? (Tick any that apply)

Increased temperatures Unpredictable rainfall
Longer droughts Increased floods
Stronger winds/storms

B3: What do you think are the major causes of climate change in your area?

Large-scale livestock farming Use of wood fuel
Inefficient animal waste management Deforestation

Digging up vegetative biomass	Others (Specify.....)
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B4: How has climate change affected your farming activities?

Water scarcity	High temperatures
Soil erosion	Unreliable rainfall
Floods	Prolonged drought
Intense rainfall	Pests and diseases
Others (Specify.....)	

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Section C: Climate Change Adaptation Strategies

C1: What strategies have you used to adapt to climate change? (Tick any that apply)

Using early maturing crop varieties	Use of drought tolerant crop varieties
Early planting	Agroforestry
Rainwater harvesting	Irrigation
Others (Specify.....)	

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C2: What motivated you to adopt adaptation strategies stated above?

Access to credit/loans	Government/NGO support
Training/awareness programs	Availability of improved seeds/technologies
Peer/farmer group influence	Other (Specify) _____

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C3: What challenges do you face in adopting these strategies?

High costs	Lack of information
Limited access to inputs	Land tenure issues
Cultural barriers	Other (Specify) _____

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C4: Have you received any support (training, inputs, funding) to cope with climate change?

Yes No

C5: Do you have access to credit needed to cope with some of the climate change effects?

Yes No

C6: What additional support do you need to better adapt to climate change effects?

More training	Affordable irrigation technology
Better access to weather forecasts	Financial support (loans/grants)
Other (Specify) _____	

Thank you for your participation!

Appendix 2: Interview guide

Dear respondent,

I am **Desire Mparana** student of Master of Science in Climate Change and Food Security of Bishop Stuart University. As partial fulfillment of my study program, I am carrying out a study on the topic, “*Climate Change Effects, adaptation strategies and factors affecting their adoption among smallholder farmers in Kagadi Sub-county, Uganda*”. You have been selected as a respondent for this study as you have information that is necessary for the successful completion of this research project. Therefore, I kindly request you to spare a few minutes of your busy schedules to respond to this interview to enable me accomplish this task. The information that you provide will be treated as a high level of confidentiality and strictly used for the purpose of this study. Your honesty and sincere responses are highly appreciated for academic purposes. Thank you very much for your cooperation.

1. What are the most significant changes in weather patterns you've observed in Kagadi Sub-County over the past 10 years?
2. How would you describe the major impacts of these climate changes on smallholder farming activities in this area?
3. What do farmers in this community perceive as the root causes of these climate changes?
4. What are the most common climate adaptation practices you've observed farmers using in this sub-county?
5. Which adaptation strategies have proven most effective in addressing climate challenges here, and why?
6. Are there any traditional or indigenous adaptation methods that farmers still rely on?
7. What major factors enable or prevent farmers from adopting climate adaptation practices in this area?
8. How accessible are agricultural extension services and climate information to farmers in this community?
9. What role do local institutions play in supporting farmers' adaptation efforts?
10. Based on your experience, what would most improve farmers' ability to adapt to climate change here?

Thank you for your participation!