EFFECTS OF CLIMATE VARIABILITY ADAPTATION STRATEGIES ON KENYAN AGRO-PASTORALISTS' RESILIENCE AND FOOD SECURITY: A CASE OF LAIKIPIA WEST SUB-COUNTY

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A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Master of Science Degree in Agricultural and Applied Economics of Egerton University

EGERTON UNIVERSITY

OCTOBER, 2025

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented for an award of a degree, diploma, or certificate in Egerton University or any other University.

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Recommendation

This proposal has been submitted with our approval as Egerton University supervisors.

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DEDICATION

This work is dedicated to my lovely grandfather, Arthur Stancefield Otieno Oyule, and my late grandmother Judith Otieno, who have always invested their time and resources to enable me to pursue my education. To my mother, Rose, and Siblings Mitchell, Phoebe, Noel, and Fidel for their undying love, moral support, and for making my life joyful.

ACKNOWLEDGEMENTS

I am grateful to God the Almighty for the gift of life, care, love, and knowledge throughout my studies, especially during the entire period of research work. I would also extend my sincere gratitude to Egerton University for giving me the opportunity to pursue the Collaborative Master of Science (MSc) in Agricultural and Applied Economics (CMAAE), which is a rare chance. Further appreciation goes to the African Economic Research Consortium (AERC) for funding this research and my entire Master of Science program. Also, the opportunity presented by the Collaborative Master of Science in Agricultural and Applied Economics (CMAAE) secretariat to pursue specialized and elective course training at the University of Pretoria, South Africa, which has been the hallmark of my studies, is abundantly appreciated.

My sincere gratitude to my supervisors, Prof. Gideon Aiko Obare and Dr. John Olwande, for their relentless support during the supervision, mentorship, and motivation throughout my research process. Their comments, encouragement, guidance, persuasiveness, keen interest, and challenges were insightful, valuable, and sharpened my thinking. I am further indebted to the course lecturers for their constructive criticisms, insights, and advice during the defense and write-up of the thesis. Their priceless efforts in guiding me from the development to the maturity of the thesis are much appreciated.

My appreciation also goes to Mr. Victor Wabwile Kilui for the encouragement, sharing with me useful ideas, support, and guidance during the entire period of my study and research. Many thanks also go to my colleagues, friends, and agro-pastoral farmers in Laikipia West Sub-County for their support, enthusiasm, and collaboration during my study and the entire period of my fieldwork. Finally, l am very grateful to all the enumerators who assisted during the data collection exercise.

ABSTRACT

Climate variability is a global phenomenon that negatively affects agricultural production. Kenya is one of the countries with livelihoods, particularly in arid and semi-arid areas, that depend on natural resources sensitive to climate variability. ASAL agro-pastoralists are constantly engaging in adaptation strategies whose effectiveness relies on the extent of adoption to mitigate the negative impacts of climate variability. Generally, the study aimed to contribute towards improved livelihood through enhancing agro-pastoralism adaptation strategies to climate variability in Laikipia West sub-county, Kenya. Specifically, identifying and characterizing dominant adaptation strategies used by agro-pastoralists, analyzing socio-economic and institutional factors influencing the number and choice of adaptation strategies adopted, examining the effects of adaptation strategy packages on resilience to climate variability, and lastly, determining the effects of adaptation strategy combinations on food security. Data from 308 households were analyzed through Factor Analysis, Poisson Regression, Multivariate Probit, Principal Component Analysis, Instrumental Variable Regression, and a generalized ordered probit model using Stata and the R program. Exploratory factor analysis results indicated that seven packages explained 57.4 of % variation in the data. Household dependency ratio, education level, gender of the household head, group memberships, and household wealth positively influenced the intensity of the package used. In contrast, age, interaction between gender and farming experience, years of education, and unmet credit needs negatively affected package use. The marginal effect of Multivariate probit revealed mixed effects of the dependency ratio, education, and distance to extension agents. Group memberships, lack of credit demand, and wealth index for households positively influenced the choice. In contrast, age, gender, farm size, and livestock holdings had negative impacts. Farm risk reduction practices, diversification practices, adult equivalent household size, years of education of the household head, and access to agroweather information were associated with higher resilience. Consumption equivalent household size, farming experience of household head, household education stock, tropical livestock unit, access to agroweather information, and a combination of risk reduction, cultural farm, and sustainable agricultural practices were associated with a higher food security score. The study recommends that interventions intended to manage agroweather shocks in ASAL should account for improved resilience and food security. There is a need for future studies to analyze the role of quality education when integrated with indigenous knowledge on adaptation.

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LIST OF ABBREVIATIONS AND ACRONYMS

ASALs:	Arid and Semi-arid Lands
ASs	Adaptation Strategies
CC	Climate Change
CCAS	Climate Change Adaptation Strategies
EUT	Expected Utility Theory
FA	Factor Analysis
FAO	Food and Agriculture Organization of the United Nations
FIES	Food Insecurity Experience Scale
GHG	Greenhouse gases
GOK	Government of Kenya
IPCC	United Nations Intergovernmental Panel on Climate Change
KNBS	Kenya National Bureau of Statistics
LCG	Laikipia County Government
NBRM	Negative Binomial Regression Model
NCCAP	National Climate Change Action Plan
PCA	Principal Component Analysis
PRM	Poisson Regression Model
RUT	Random Utility Theory
SDGs	United Nations Sustainable Development Goals
SEM	Structural Equation Model
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Agency
WFP	World Food Program
ZINB	Zero inflated Negative Binomial
ZIP	Zero Inflated Poisson

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Climate variability and change have not only affected the productivity of the world's agricultural system but have also negatively affected the food security of global economies (De Pinto *et al.*, 2019; IPCC, 2022; Muchuru & Nhano, 2019; Musafiri *et al.*, 2021; Zewdie, 2014). The uncertainty with climate variability has had devastating effects on the biodiversity and agro-pastoral livelihood (Maoncha *et al*., 2016). The outcome risks from climate variability have manifested themselves in prolonged drought, more intensive flooding, rampant soil erosion, landslides, warming, and drying (CDKN, 2014; Niang *et al.*, 2014).

According to the United Nations Food and Agriculture Organization (2019), nearly 40 percent of the world's population is exposed to the effects of climate variability, which affects access to water and reduces crop production (Nahid *et al.*, 2021). A report by FAO (2018) estimated that 10 percent of the world's population (770 million) is faced with severe food insecurity because of climate effects. Further, most of the farmers are already exposed to several threats, and climate variability has worsened the situation through losses in farm outputs.

In Sub-Saharan Africa, climate variability has increased in recent times and is a threat to the sustainability of food production among agro-pastoralists who depend on rain-fed agriculture (Atube *et al.*, 2021; Fadina & Dominique, 2018). By 2050, IPCC predicts that in sub-Saharan Africa, crop productivity will reduce with maize having a reduction of 5%, rice 14% and wheat 22%. This will push the large number of agro-pastoralists who rely on agriculture for their livelihoods much deeper into poverty and food insecurity (IPCC, 2018). Further projections by IPCC (2018) predict decreased food availability by 500 calories per person and an increase in the number of children that are malnourished by over ten million to a total of fifty-two million in 2050 in Sub-Saharan Africa.

Building resilience to climate variability in agriculture can ensure that the livelihoods that depend on the sector are not vulnerable to climate effects (Singh *et al*., 2022). Therefore, resilience is primarily important and can be achieved by reducing vulnerabilities, improving the adaptive capacity of the local community, and enhancing the resilience of the livestock and crop systems of agro-pastoralists to adapt to different types of shocks (Mung'ong'o, 2022). To increase resilience to climate variability, farming households have implemented several adaptation strategies (Keshavarz & Soltani, 2021). Moreover, according to Alinovi *et al.* (2010), the effectiveness of these adaptation strategies in promoting resilience will depend on agro-pastoralists' access to food and income, their assets (agricultural and non-agricultural), their access to basic services, their stability, their social safety nets, and their adaptive capacity. However, constraints such as socioeconomic inequality, poverty, low levels of development, governance failures, institutional failures, and limited economic capacity, according to CDKN (2014), have resulted in low adaptive capacity and a significant adaptation deficit in Sub-Saharan Africa (Niang *et al*., 2015).

Kenya's National Climate Change Action Plan (NCCAP 2018-2022) has prioritized the techniques and approaches aimed at achieving climate resilience and food security. Therefore, to reduce the adverse effects of Climate variability on agriculture, adaptation is viewed as a vital component of any policy response to climate effects (Mary *et al.*, 2017). Maoncha *et al*. (2016) and Tibesigwa *et al*. (2015) showed that adaptation to climate variability enhances agro-pastoralist welfare because it is an intrinsic part of the production system. These adaptations reduce risk and are more likely to minimize the severity of climate variability effects.

Further, according to Ali and Erenstein (2017), farm households using adaptation techniques are more likely to be food secure compared to those not undertaking such techniques. Bryan *et al*. (2013) and Ng'ang'a *et al.* (2020) identified livestock manure, seasonal and strategic migration of livestock, destocking, improved livestock breeds, irrigation, diversifying animal feeds, and the use of crop residue as fodder as adaptation strategies undertaken by agro-pastoralists in Kenya. The stated adaptation strategies implemented by national and county governments include index-based livestock insurance, improvement of livestock breeds, provision of water for irrigation, allocation of land and seeds for fodder production, and extension services for livestock (GOK, 2013). Despite their use, agro-pastoral resilience is still very low, to the extent of increasing their vulnerability, particularly in the most fragile semi-arid areas.

Several rural populations in Kenya depend on agriculture for income; therefore, adaptation is important in enhancing the resilience of the sector, protecting the livelihood of many poor households, and ensuring food security (Ochieng *et al*., 2017). Nonetheless, the scope and severity of climate variability shocks have grown among agro-pastoralists, which has prompted concerns regarding the current adaptation strategies in place. Several studies, for example, have focused on the impact of climate variability adaptation on agricultural productivity (Di Falco *et al.*, 2011;

Kabubo-Mariara & Mulwa, 2012) or farm income (Di Falco & Veronesi, 2013; Teklewold *et al.*, 2017). None of these has addressed the local capacity of agro-pastoralists to respond to climate shocks via their adaptation strategies. Furthermore, the effects of climate variability adaptation on food security and resilience have not been widely discussed.

Studies by Atsiaya *et al.* (2019), Ndiritu (2020), and Ng'ang'a *et al*. (2020) identified response strategies to climate effects in Laikipia County. However, these studies lack detailed analysis after identifying response strategies. Furthermore, most adaptation studies did not consider the influence of the strategies in improving resilience and food security. Unlike previous studies, this study examined the intensity of adaptation strategy use among agro-pastoralists. Also, the study identified the barriers to the use of these strategies. This addressed shortcomings of other adaptation studies (Atsiaya *et al.,* 2019; Ndiritu,2020; Ng'ang'a *et al.,* 2020), which didn't consider the intensity of agro-pastoralists' adoption of climate adaptation strategies.

In Laikipia County, several agro-weather shocks like uncertainty in the onset and duration of seasons, moisture stress, and prolonged drought pose threats to the agricultural sector, which leads to a decline in livestock and crop production, and food insecurity (GOK, 2018a). According to Laikipia County Climate Change Action Plan (2023-2027), there is a substantial increase in temperature, precipitation, and dry spells (MOALF, 2016). Further, prolonged drought has been noted to extend into the rainy seasons while at the same time being long and intense (Government of Kenya, 2018). Also, long rainy seasons have become shorter and drier, while short rainy seasons are longer and wetter, leading to floods. This called for an analysis of the influence of existing climate variability adaptation strategies on reducing vulnerability and securing the livelihoods of agro-pastoralists who reside in the county.

Rapid demographic growth has led to chronic poverty levels within the county. Further, depletion of natural resources has degenerated into conflict over scarce resources between smallholder farmers, pastoralists, and the agro-pastoralists community. The negative effects of agro-weather shocks, coupled with small land holdings and severe land degradation, result in low productivity due to crop failure. According to Laikipia CIDP (2018) has affected the livelihood of agro-pastoralists within the county.

1.2 Problem Statement

Climate variability effects such as prolonged droughts, crop pests and diseases, shift in rainfall patterns, and livestock parasites and diseases have impeded agro-pastoralists, who mainly depend on livestock and crops for a living. Several formal adaptation strategies have been developed by national and county governments, including index-based livestock insurance, government destocking programs, together with existing informal strategies like migration. Despite the efforts, the uptake of strategies in ASAL areas is low compared to other ecological zones. Additionally, agro-pastoralists are still vulnerable to climate variability extremes due to low levels of resilience. Further, agro-pastoralists may use some of the strategies, but it is not clear which of these improves their food security status. This study is geared towards filling these knowledge gaps among agro-pastoralists in Laikipia West Sub-County.

1.3 Research Objectives

1.3.1 General Objective

The general objective of the study was to contribute towards improved food security and resilience of agro- agro-pastoralists through the adoption of adaptation strategies to climate variability in Laikipia West sub-county of Kenya.

1.3.2 Specific Objectives

i. To identify and characterize dominant agroweather shocks and adaptation strategies used to reduce the effects of agroweather shocks among agro-pastoralists' households in Laikipia West Sub-County.

ii. To analyze socio-economic and institutional factors influencing the number and choice of adaptation strategies used among agro-pastoralists in Laikipia West Sub-County.

iii. To determine the resilience pillars and effects of adaptation strategy packages on resilience to climate variability among agro-pastoralists in Laikipia West Sub-County.

iv. To establish the effects of adaptation strategy package combinations on food security among agro-pastoralists in Laikipia West Sub-County.

1.4 Research Questions

i. What are the adaptation strategies used to reduce the effects of climate variability among agro-pastoralists' households in Laikipia West County?

ii. What are the socio-economic and institutional factors influencing the number and choice of adaptation strategies used among agro-pastoralists in Laikipia West Sub-County?

iii. How do adaptation strategies affect agro-pastoralist resilience to climate variability in Laikipia West sub-county?

iv. How do adaptation strategy combinations affect agro-pastoralists' food security in Laikipia West Sub-County?

1.5 Justification of the Study

Adaptation strategies have been promoted as one of the ways of increasing resilience and food security due to climate variability. However, most of the studies on adaptation strategies have focused much on smallholder farmers' adaptation to climate variability with little attention on resilience and food security. In the study area, Atsiaya *et al.* (2019) have shown that climate variability has a significant negative effect on agro-pastoralists. Understanding the current effects of climate variability, autonomous adaptation strategies, and local adaptive capacity is critical in designing effective strategies for future adaptation planning that will improve the resilience and food security of agro-pastoralists.

Further, the study is unique since it ascertained that agro-pastoralists undertake climate adaptation strategies once they consider the options available. This is different from other studies that focused on limited strategies (Ndiritu, 2020; Ng'ang'a *et al.*, 2020). Additionally, the study is on agro-pastoralists who live in arid and semi-arid areas of Kenya and cultivate maize and beans and keep both local and improved goats, sheep, and cattle, where climate variability is increasing the odds of extreme events occurring, thereby making economies harsher for survival in the absence of proper adaptation strategies, this is in contrast with previous studies that have focused on either crops or livestock farmers adaptation strategies to climate variability separately (Khatri *et al.*, 2017; Kpadonoua *et al.,* 2017; Mugi *et al.*, 2016)

Further, the study assists in developing adaptation and mitigation techniques that are related to Sustainable Development Goals (SDGs) two and thirteen that will be possible to sustain beyond 2030. The study further contributes to Agenda 2063 goal five, which seeks to promote modern agriculture for increased productivity and production, as well as goal seven, which focuses on environmental sustainability and climate-resilient economies and communities. Additionally, this study contributes towards the realization of Laikipia County's integrated development plan since climate change effects have had devastating effects in the county.

1.6 Scope and Limitations

The study was conducted among the households that are involved in crop and livestock farming in Laikipia West Sub-County. The households that were picked were interviewed based on their perception of climate variability and the strategies used to mitigate climate variability effects. The findings only apply to the area of study; therefore, they may not apply to other agro-pastoralists in Kenya since the strategies used differ from one local area to another. Moreover, the inadequacy of proper records on seasons of extreme climate variability effects and subsequent strategies used thereafter may affect the accuracy of the estimates, and therefore, the study has relied on the respondent's ability to recall information. However, this will be addressed by the respondents identifying the major season when climate variability effects were severe within the last production year.

1.7 Operational Definition of Terms

Adaptive capacity- is the ability of a system to adjust to impacts to moderate potential damage, so that it continues functioning without significant change in system structures (IPCC, 2001).

Adaptation strategies are measures required to mitigate climate change while increasing agricultural productivity and welfare (Schlenker & Lobell, 2010; Skoufias & Vinha, 2012).

Agro-pastoralists- agro-pastoralists, in this case, are defined as a livelihood system where households derive a large share of their income from crop production and less from animal production.

Climate resilience is the ability of individuals and mechanisms used by individuals to cope with external shocks, self-organize after experiencing a shock, and adapt to shocks through social learning (Osbahr *et al*., 2010).

Climate change- in this case, climate change is defined as a combined decrease in rainfall amount, an increase in drought frequency, and high temperature/high warming conditions.

Climate variability- refers to variation in the average state and occurrence of extremes of the climate on all temporal and spatial scales beyond that of individual events.

Food security- food security in this case is a situation in which everyone has physical, social, and economic access to sufficient food for an active and healthy life.

Food systems-Food systems, in this case, are a situation where there is continuous production of livestock and crop products.

Household: Defined as an independent male or female producer and his/her dependents, who must have lived together for a period not less than six months. The members are answerable to one person as the head and share the same eating arrangement.

Welfare: In this study, it is measured in terms of resilience and food security status of agro-pastoralists.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The section reviews current and past empirical literature. It first reviews literature on climate variability and change effects. Literature on factors influencing the adoption of adaptation strategies to climate variability and change is provided. Furthermore, the chapter provides a review of empirical studies on the concept of resilience and resilience measurement to climate variability. Moreover, household food security and adaptation strategies are also discussed within the chapter. Finally, it provides the theoretical basis of the study and a conceptualization of the relationship between different factors that influence the adoption of climate adaptation strategies in agro-pastoral areas and their effect on food security and resilience.

2.2 Overview of Climate Variability and Change Effects

The United Nations Framework Convention on Climate Change (UNFCCC) defines CC as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere (IPCC, 2001). Climate variability, on the other hand, according to the IPCC (2007), refers to variations in the mean state and other statistics, such as standard deviation and the occurrence of extreme climate events, across all temporal and spatial scales, beyond those of individual events. It includes indicators such as floods, extended droughts, and conditions that result from periodic La Niña events and El Niño. According to Abbas *et al*. (2017) and Bokhari *et al*. (2017), evidence of climate change has been through an increase in temperature from 0.78°C to 1.5°C during the past three decades, and high rainfall variability and humidity that have altered the living conditions of the species on earth (Kgosikoman & Batisane, 2014). This has affected the agricultural sector, which is most sensitive to changes in climatic conditions (Menike & Arachichi, 2016).

In Africa, evidence of climate change has been noted through an increase in surface temperature from 0.72°C to 0.85°C (Nyboer *et al.*, 2019). Further, IPCC projections indicate that the temperature is likely to exceed 1.5°C by the end of the twenty-first century (Gemeda *et al.*, 2021) and increase by 4°C by 2100 (Masroor *et al.*, 2020). According to FAO (2016), agriculture in Africa supports the livelihood of 80 per cent of the population, making it a dominant economic activity, particularly in rural households, to which agro-pastoralists belong. Further, estimation indicates that 70% of livelihoods in Africa rely on rain-fed agriculture, which is susceptible to a variety of stresses, climate change being one of them (Connolly *et al*., 2016). According to the World Bank (2010), climate variability would cause a decline in the annual gross domestic product of 4% in Africa if no adaptation measures are taken. The situation is of greater concern in Sub-Saharan Africa, where per capita food production has been declining (World Bank, 2010). The recent rampant food crisis experienced in most sub-Saharan African countries is a reminder of the continuing susceptibility of the region to the impacts of climate variability. This has been primarily linked to low participation in environmental and adaptation issues, weak institutional capacity, and a lack of emphasis on local knowledge (Adepoju & Obayelu, 2013).

Climate variability, according to Omoyo *et al*. (2015), contributes to increased droughts, food insecurity, reduction in animal herd sizes, and deepening poverty. Droughts experienced in ASAL areas once every five years further exacerbate food insecurity and poverty. On agricultural production, the challenges posed by climate variability range from pronounced seasonality of rainfall to severe and recurrent droughts. Further, the interaction between precipitation and high temperature is likely to lead to loss of arable land due to depletion of groundwater, increased salinity, increased aridity, and decreased soil moisture (Kandji, 2006). Additionally, a decrease in precipitation and an increase in temperature are the main causes of decline in agricultural productivity and high prevalence of pests and diseases (Tesfahunegn *et al.*, 2016).

In Kenya, nearly 89 per cent of the land mass is arid and semi-arid, making climate variability a more critical aspect since 38 per cent of the population, who are mainly agro-pastoralists and pastoralists and depend on climate-sensitive sectors for their livelihood and food security, occupy these areas (Government of Kenya, 2012). Further, climate variability has presented a significant threat to food security in Kenya through its effect on production, soil moisture, and rainfall distribution. The direct effect of climate variability on agricultural production and food security has affected the livelihood of most rural areas that depend on agriculture as a source of revenue. The situation is exacerbated by the virtue of fact that in Kenya, smallholder farmers' agriculture is predominantly rain-fed and the options available for diversification of their income and resources are limited (Ochieng *et al.*, 2016).

The impact of climate variability and change in Kenya, according to Downing (1992), indicates that higher temperatures would have a positive effect in highland areas but a negative impact in lowland areas, specifically semi-arid zones. This implied that with rising temperature and rainfall, food production would increase and decrease because of insufficient precipitation. Temperature, according to Bilham (2010), has more impact on crop yield than rainfall.

In response to challenges of climate variability, the Kenyan government has put in place the National Climate Change Response Strategy (NCCRS), which seeks to strengthen actions towards adapting and mitigating against climate variability and change (GoK, 2010). The NCCRS recognized that adaptation can decrease the negative impacts of climate variability. This was further supported when the government launched an irrigation project in Galana Kulalu in Tana River.

A report by Laikipia County Government, LCG (2013), indicates that the areas that are most vulnerable to climate change effects are the agro-pastoralist semi-arid areas. Additionally, the severity and frequency of floods and droughts are already high, and evidence shows that they could increase in the coming years (LCG, 2013, 2018). Therefore, special attention is required for agro-pastoralists if Kenya is to attain sustainable economic development.

2.3 Factors that Influence the Adoption of Adaptation Strategies to Climate Variability and Change

Access to climate information, livestock ownership, off-farm income, and age, according to Gebeyehu *et al*. (2021), in a study on how agro-pastoralists cope with climate change in Ethiopia, are significantly associated with the use of adaptation strategies. Likewise, Mengistu and Haji, (2015) surveyed factors affecting the choice of coping strategies for climate extremes in Ethiopia using primary data from Yabello District. The results revealed that the size of livestock, access to credit, access to early warning information, access to training, and gender have a strong positive and significant influence on the use of adaptation techniques. The two studies used a multinomial logit model. However, the limitation of independence of irrelevant alternatives of the multinomial logit model, which states that the ratio of the probabilities of choosing any two alternatives is independent of the attributes of any other alternative in the choice set (Hausman & McFadden,1984), may result in biased estimates (Xie & Wang, 2025). To counter this, the study adopted a different approach by employing a multivariate probit model, which allowed the error terms of different adaptation packages to be correlated. This ensured that the robustness of the results was assessed to gain a deeper understanding of agro-pastoralist decision-making regarding the packages (Shah & Alharthi, 2024).

A study that evaluated and analyzed climate change adaptation strategies for agro-pastoralists in Tanzania by Sewando (2023) used a multivariate probit model to examine the factors influencing the use of adaptation practices by agro-pastoralists. Age, household size, and education level of the household head were positively significant covariates that affected the overall use of adaptation strategies. The study did not consider the intensity of the adoption of the strategies. This was addressed by the current study through employing a Poisson regression model, which analyzed the number of strategy packages as a function of the explanatory variables.

While examining climate change perception and adaptation strategies of agro-pastoralists and pastoralists across different agro-ecological zones in Burkina Faso, Zampaligré *et al*. (2014) found a significant and positive effect ($P<0.01$) of household size, education level, and age of the household head on strategies undertaken to climate change. The study examined the determinants using Binary logistic regression with stepwise backward elimination. The regression assumes that the relationship between explanatory variables and explained variables is linear on a logit scale. Therefore, the model may not be appropriate where there is a complex non-linear relationship between strategies undertaken and the corresponding determinants. In the current study, a Poisson regression model was used to account for the non-linearity by incorporating probabilities.

According to Xie *et al*. (2021), membership in the association, age, education level, and household size were the major positively significant factors determining adaptation. By using probit regression to analyze data, the study revealed that farming experience has a positive and significant effect on adaptation strategies employed. These observations are consistent with the study findings of Johnson and Brown (2017) and Shahid *et al*. (2021). However, with the Probit regression model, it is difficult to estimate the choice of strategy packages when the alternative strategy package choice set is more than three. Therefore, the study adopted a multivariate probit model to analyze the likelihood of adopting the strategy packages jointly and further captured complementarity between the packages.

2.4 The Concept of Resilience and Measurement

According to Alinovi *et al*. (2008), resilience is a complex, multidimensional latent construct that is not directly captured in the field. Therefore, most studies have made use of measurable indicators or proxies (Jones & Tanner, 2015), which have no standard procedure for measuring resilience (Quandt, 2018). Furthermore, resilient agro-pastoralists possess interrelated capacities, including adaptive, absorptive, and transformative capacities, which help mitigate and adapt to the negative impacts of climate change shocks. According to Alinovi *et al*. (2010), FAO (2016), resilience is determined by several pillars, like income and food access, access to basic services, social safety nets, assets, stability, and adaptive capacity.

Absorptive capacity, according to Ultrichs *et al*. (2019), is the capability to withstand and recover from the climate variability-associated stresses and shocks before, during, and post-occurrence. On the other hand, Adaptive capacity is the potential to adjust in anticipation of or in response to change, to improve future flexibility (Jeans *et al*., 2019). Transformative capacity is more of an institutional capability of the system to change the structure and use new adaptation mechanisms to enable recovery from shocks that surpass the earlier susceptibility threshold (Carr, 2019).

Tofu *et al.* (2023) examined agro-pastoralists' livelihood resilience to climate-induced risks in the Borana zone, south Ethiopia. The results revealed that assets and adaptive capacity are significantly related to resilience capacity, which implies that households with high adaptive capacity are more resilient. Furthermore, food expenditure was significantly and positively influenced by resilience capacity. Likewise, Weldegebriel *et al*. (2017), while examining livelihood resilience in the face of recurring floods, indicated that land holding and education, as well as involvement in more diversified activities, had a positive and significant influence on the resilience of the households. The studies used descriptive statistics and content analysis using Principal Component Analysis. However, principal component analysis only computes the eigenvectors and eigenvalues of the covariance or correlation matrix of the variables, but fails to address the endogeneity problem. This empirical work employed an instrumental variable regression model to address the endogeneity problem.

A study on building pastoralists' resilience to shocks for sustainable disaster risk mitigation from West Pokot County in Kenya (Muricho *et al.*, 2019). Assets like the value of Total Livestock Units, the value of land, and farm implements had significant factor values on resilience. This was concordant with Alinovi *et al*. (2010); Ciani and Romano (2014). Income from selling other farm products and livestock, and income from formal and informal employment, had the highest significant impact on resilience, which explains how income allows households to access basic services like healthcare and food. Furthermore, access to basic services computed through expenditure on healthcare had a positive factor value, implying that more resilient households can afford to spend more on healthcare services. Adaptive capacity computed through dependency ratio had a significant negative factor value on household resilience, which implies few economically active members must meet the needs of all people in the household. The study used access to clean water and health services to compute access to basic services, which complements healthcare expenditure.

2.5 Household Food Security and Adaptation Strategies

Food security exists when safe, nutritious, and sufficient food is available such that basic dietary requirements for an active and healthy life are achieved (FAO, 2006). Food security has four main dimensions, which include availability, accessibility, utilization, and stability. According to FAO (2008), seasonal food insecurity reflects temporal changes in cropping patterns, employment and income opportunities, and climate. Moreover, transitional food insecurity is temporary and relatively unpredictable, whereas chronic food insecurity is persistent and long-term.

Use of livestock feed management practices, water conservation techniques, and income diversification strategies, according to Lemma *et al*. (2013), is significantly associated with food security of the household. The Ordered Logit regression results indicated that water conservation techniques such as ridging, positively and significantly affected household food security. These results are like McHugh *et al*. (2007); Tesfaye *et al*. (2010). However, the studies used adaptation strategies in isolation. In the study, strategies were grouped using Factor Analysis, which allowed examination of potential synergies and trade-offs between different strategies. Moreover, the climate change adaptation strategies (CCAS) are often complex and multifaceted; therefore, clustering captured the cumulative effects of the strategy package combinations, thereby enabling a more comprehensive understanding of how each package combination contributes to food security.

In his study, Umar (2023) evaluated the nexus of climate change adaptation and food security in sub-Saharan Africa. The results from the ordinal logit regression model indicated use of adaptation strategies against climate change significantly and positively affected the food security situation of the households at 5% level of statistical significance. The results were similar to the findings of Zakari *et al*. (2022) using propensity score matching, which indicated a negative impact of adaptation strategies on household food insecurity. The findings imply that households that use more adaptation strategies are more likely to be food secure than those with zero adaptation strategies. In ordinal logit regression, cumulative logistic distribution misspecification of the error distribution can lead to inconsistent and biased estimators (Greene & Honster, 2010). Therefore, this study allowed errors to take a more generalized distributional specification, which reduced the problem of distributional misspecification and led to more efficient estimators.

Diallo *et al*. (2020), while examining climate change adaptation strategies, productivity, and sustainable food security in southern Mali, found a significantly positive relationship between the use of short-duration crops and household food security. However, the use of organic fertilizers and the change of planting date as adaptation strategies had no statistical significance to food security. The results indicate that changing planting dates does not necessarily lead to a decrease in food insecurity. But according to Douxchamps *et al*. (2016), crop diversification, soil and water conservation, improved crop varieties, and the use of organic fertilizers are significant and improve the food security of households. The studies categorized households as either food secure or insecure; such disintegration doesn't significantly indicate the seriousness of food poverty, thereby inhibiting the identification of severe cases of food insecurity. However, the study addressed this by disentangling food security into food secure, mildly food insecure, moderately food insecure, and severely food insecure using an internationally recognized measure, the food insecurity experience scale (FIES)

2.6 Theoretical Framework

2.6.1 Expected Utility Theory

The Expected Utility theory assumes that individuals are rational in decision-making and they choose options that result in higher utility. Therefore, agro-pastoralists' preference to undertake the strategy is based on the expected utility from undertaking the strategy (Hardaker *et al*., 2015). In the context of adaptation, the utility derived from taking up a strategy could yield stability and the reduction in climate variability risk (Ojo & Baiyegunhi, 2018). The EUT holds that if an agro-pastoralist's choice of one strategy is preferred over the other strategy, the utility expected from the first strategy is greater than the expected utility of the second. Therefore, according to Teklewold *et al*. (2013), an agro-pastoralist adopts a certain strategy if the utility of adopting is more than the utility of not adopting.

Expected Utility theory includes the risk attitudes of the decision makers. Furthermore, according to Jin *et al.* (2016), decision makers are found to be risk-averse, which means that they prefer a safe choice over a risky choice with the same expected outcome. Additionally, the theory postulates that decision makers have more knowledge of the likelihood of climate vagaries as well as the costs and benefits of actions while ignoring the complexity of human adaptation decisions, which largely affects the evaluation of climate shocks, leading to imperfect judgments (Bryan *et al.*, 2013; Silvestri et al., 2012; Waldman *et al.*, 2020).

2.6.2 Random Utility Theory

The underlying assumption of the study was that agro-pastoralists use adaptation strategies that result in yield stability and improved resilience. The yield stability translates into food security, which positively impacts welfare. Therefore, agro-pastoralists undertake strategies that maximize their perceived utility. The utility gained by the agro-pastoralist can therefore be explained by McFadden's (1973) random utility theory, since adaptation strategies undertaken can be analyzed within the random utility framework. According to this theory, individuals are rational and uncertain, and they make the choices they prefer. However, when they cannot make such choices, their behavior can be explained by random factors.

The utility of choice was made up of a deterministic and an error component. The error component was exogenous to the deterministic part and followed a predetermined distribution. This showed that it was always possible to predict with certainty the alternative that the decision-maker selects. However, according to Cascetta (2009), Luce (1959), it is possible to express the probability that the perceived utility associated with a particular option is greater than other available alternatives.

Therefore, the linear equation of the random utility model of the utility generated by individual P from undertaking strategy y was given by:

$$U_{py} = K_{py} + \mathrm{E}_{py} \quad (2.1)$$

where U_{py} is the expected utility from strategy y, K_{py} is the deterministic part, and E_{py} is the stochastic error term. The deterministic part (K_{py}) captures the observable components of the utility function while the random error part (E_{py}) entails the unobservable components of the function.

According to Cascetta (2009), we assume that utility U relies on decisions derived from some set of y strategy packages. An individual is assumed to obtain a utility function of the form:

$$U_{py} = K\left(X_y, Z_p\right) \quad (2.2)$$

An Agro-pastoralist who is rational and seeks to maximize the present value of benefits of production that leads to food security and improved resilience over a specified period must choose among a set of y adaptation strategies. The p agro-pastoralist uses y adaptation strategy package if the perceived benefit from that strategy package is greater than the utility from other strategy package j if $U_y > U_j$. According to Cascetta (2009), utility derived from any adaptation strategy package is assumed to depend on the features of the adaptation strategy package itself. X_y and the socio-economic characteristics of the agro-pastoralists Z_p:

$$U_{py} = K(X_y, Z_p) = \beta X_y + \beta Z_p + E_{py} \tag{2.3}$$

The agro-pastoralists' use of a particular strategy package was formulated based on the probability that an alternative strategy package undertaken was based on its utility in terms of its contribution to resilience and food security. Therefore, the probability that the utility of a certain strategy package y is higher than the utility of another alternative j can be defined as follows:

$$Pr(y) = Pr[U_{py} > MaxU_{pj}] = Pr[K_{py} + E_P > MaxK_{pj} + E_j] \qquad j \neq y \tag{2.4}$$

To estimate equation 2.4, the study assumed that the error is Gumbel-distributed and independently identically distributed (MacFadden, 1973).

In modeling choices under uncertainty, both expected utility theory and random utility theory can be used (Polak & Liu, 2006). EUT assumes that the farmers’ decision-making process for choosing a given strategy/practice captures their attitude towards risk. However, EUT fails to accommodate uncertainty regarding farmers' behavior and taste. RUT, conversely, is concerned with choosing climate response strategies under a situation of risk-free choice. Further, farmers’ utility is a linear function of farm-specific and individual farmer characteristics; therefore, this study was guided by RUT because of its linearity over EUT, which employs a non-linear composition rule (Mogaka *et al*., 2021)

2.7 Conceptual Framework

In ASAL areas, agro-pastoralists are faced with a wide array of climate variability effects (**V**), amongst them droughts, floods, inconsistent rainfall patterns, together with pest and disease outbreaks. These effects directly affect the agricultural productivity of agro-pastoralists, thereby prompting climate adaptation strategies (***J***) such as early maturing crops, irrigation, organic manure, destocking, improved breeds, crop residue as fodder, herd-splitting, water conservation, crop diversification, changing planting dates, migration, drought-resistant crops, hay making, and fodder cropping to be undertaken as responsive techniques. The uptake of the strategies is a manifestation of the adaptive capacity, which is demonstrated by adaptation strategies that agro-pastoralists engage in. Successful adaptation reduces vulnerability by strengthening existing adaptation strategies.

From literature, the first set of factors (**X_1**), institutional factors; access to credit services, climate information, extension services, training services, market distance, distance to the extension officer, group membership, and Land tenure were presumed to directly affect agro-pastoralists' pursuit of any adaptation strategy. Furthermore, agro-pastoralists have different (**X_2**) socio-economic factors, which include varying household sizes, age of household head, education level of household head, gender, wealth, off-farm income, number of livestock, and farming experience, which may positively or negatively influence the decision to use different strategies. Additionally, farm characteristics such as farm size, slope of the farm, and soil fertility could directly influence the strategy undertaken to mitigate climate-related effects.

The two sets of factors (institutional and socio-economic factors) act as the deterministic factors. They determine agro-pastoralists' adoption of several different strategies over time. Government policy (**X_3**) is intervening in the framework for the use of the strategies. Having appropriate and well-institutionalized strategies increases yield stability in crops and livestock products (**Y**). The strategies, in turn, improve the resilience (**R**) of agro-pastoralists. The pursuit of these strategies has implications for agro-pastoralists' welfare (**Z**) as indicated in

Figure ***0.1***.

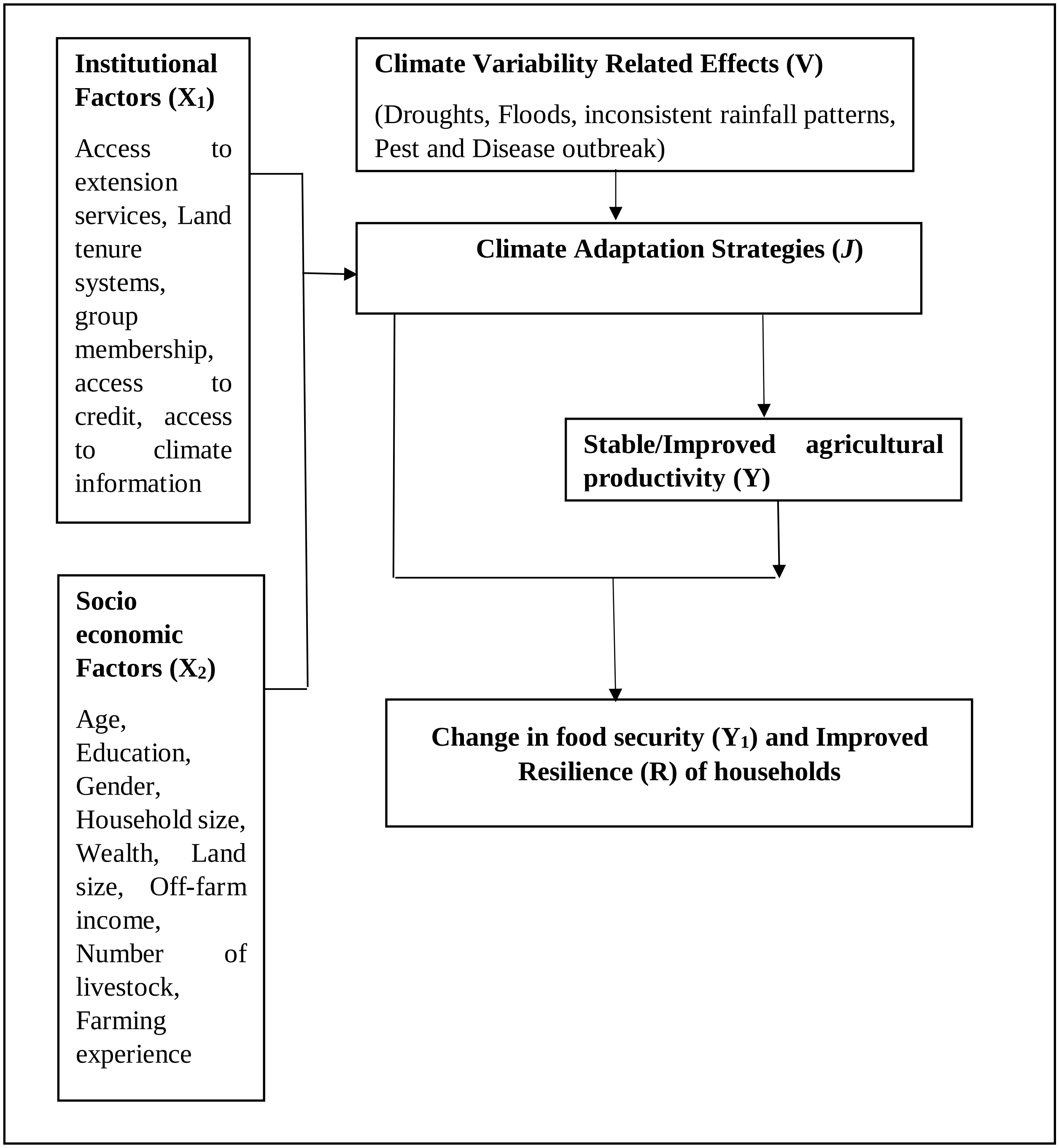

Figure 0.1: Conceptual Framework Showing Adaptation to Climate Variability

(Source: Adopted from O'Brien *et al*. 2007; Oremo, 2013; Smit & Olga, 2001, and modified**)**

CHAPTER THREE

DOMINANT ADAPTATION STRATEGIES TO CLIMATE VARIABILITY AMONG AGRO-PASTORALISTS' HOUSEHOLDS IN LAIKIPIA WEST SUB-COUNTY

Abstract

Although adaptation strategies literature abounds, little focus has been paid to the dominant climate adaptation strategies among agro-pastoralists. This study identified dominant adaptation strategies among agro-pastoralist households. The study used exploratory factor analysis to cluster adaptation strategies and descriptive statistics. Descriptive results showed that the majority, at 89.29% of households, observed drought, whereas only 2.27% observed floods over the last 10 years. Further, cross-tabulation of agroweather shocks indicates that approximately 62.66% of respondents reported more frequent drought, while 44.48% indicated more severe drought. The results from exploratory factor analysis indicate that seven packages explained 57.4 of % variation in the data. The package with the highest variation explained 13.7% while the least factor explained 5.5% of the variance. Additionally, the most used package was farm risk reduction practices at 78.25%, and the least used package was traditional practices at 6.82%. In response to observed drought, the most common strategies used were changing planting date at 40.96% for crops, use of crop residue as animal feed at 54.79% for livestock activity, and harvesting rainwater at 74.47% regarding response to water shortage. The results suggest that adaptation strategies may alleviate efforts to address the climate variability problem. Policy interventions should strengthen different adaptation strategies to contribute to improved agricultural production.

3.1 Introduction

Climate variability is a concern worldwide due to its effect on the livelihood systems, food security, and the agricultural sector of the agro-pastoral communities. Climate variability manifests through changes in precipitation patterns, temperature extremes, disease prevalence, drought, floods, and wind patterns (Ayal *et al.*, 2019; Bereket *et al.*, 2021). The climate variability and extremes cause a shortage of water and pasture for livestock, increase crop and livestock diseases, increase management costs, reduce agricultural production, and reduce market value for livestock. In sub-Saharan Africa, 40% of the total available land is occupied by 240 million agro-pastoralists who rely on crops and livestock as the major source of food and income (Worku *et al.*, 2014). Further, to some agro-pastoralists, livestock serves as a means of security and social pride. As a result, agro-pastoralists have developed strategies that have allowed them to adapt to a highly uncertain environment, particularly climate variability (Worku *et al.*, 2014).

Climate variability, according to Omoyo *et al.* (2015), is more evident in the Arid and Semi-Arid lands than in high agro-ecological zones. Food production in ASAL areas is mainly through rain-fed agriculture, where water is one of the major important factors to crop growth. According to Aseyehegn *et al*. (2017), the poor and vulnerable bear the brunt of climate variability extremes. This has led to acceptance of adaptation as an important response to vagaries posed by current and future climate variability (Mavhura *et al*., 2017)

Agriculture contributes to Kenya's economic growth with an input of 52% to gross domestic product (Elbehri, 2015). In terms of the economic priorities, agriculture is among the economic pillars of the Kenya Vision 2030 (GoK, 2010), whose objective is to achieve a commercially driven and modern agricultural sector through increased productivity, increased access to markets, institutional reforms, and development of Kenya's ASALs and innovation. Furthermore, 98% of agriculture in Kenya is rain-fed and depends on the seasonal rainfall pattern. About 16% of the land mass receives rainfall, which is sufficient and reliable, and suitable for crop farming; 84% of the remaining land in ASAL areas receives an average rainfall of 400mm yearly (Kalele *et al*., 2021). The ASALs have continuously experienced changes in climate variability patterns, such as changes in rainfall and temperature. These changes have increased the variability of extreme temperatures, seasonal rainfall and increased the occurrence and intensity of extreme climate events like floods and drought (Bryan *et al.*, 2013). Despite the climate variability predicaments in ASAL counties, Laikipia included, agriculture is important, contributes to livelihoods, and up to 70 percent of most incomes in the households. Improved use of adaptation strategies to climate variability is of paramount significance for increasing agricultural production among the agro-pastoralists in ASAL areas.

According to Stringer *et al.* (2009), adaptation is a process of change in reaction to multiple pressure that affects people's lives. The Intergovernmental Panel on Climate Change (IPCC, 2014, P.1132) defines climate change as an adjustment in economic, social, or ecological systems to expected or actual climatic stimuli and their effects or impacts. Additionally, regarding climate change, adaptation is the adjustment in economic, social, or ecological systems to reduce any damage or benefit from opportunities related to climate change (Smit *et al*., 2001). Cooper *et al.* (2008) argued that adaptation strategies are practices that have evolved because of people's experience in dealing with known and understood natural variation that they expect in seasons, combined with their specific responses to the season as it unfolds. Therefore, adaptation is well thought-out as a way of reducing the unwanted impacts of climate variability. Through the adaptations, farmers can maintain livelihood, food, and income security while experiencing changes in climate and socio-economic conditions (Kandlikar & Risbey, 2000). Climate adaptation strategies include selective keeping of livestock in areas where rainfall is insufficient and the adoption of innovative technologies such as planting early maturing crops. In agriculture, climate adaptation strategies according to IPCC (2007) include approaches aimed at increasing or reducing the sinks of greenhouse gases. According to Marie *et al.* (2020), small-scale farm strategies to alleviate crop failure due to climate variability include changing planting dates, crop diversification, drought-resistant crop varieties, and soil water conservation.

Over time, the Kenyan government has developed policies and strategies such as the Strategy for Revitalizing Agriculture 2004-2014 (SRA) to enhance climate change and variability mitigation, increase agricultural growth, and natural resource management (GoK, 2004). The SRA sought to provide a framework for sustainable exploitation of the ASALs using several climate adaptation strategies. The strategies promoted by SRA include progress and growth of crops that mature early, drought and pest tolerance, use of irrigation technology, harvesting water, improved market for livestock, and use of agroforestry. The ASAL communities are creating awareness and adopting strategies such as destocking, changing livestock breeds, livestock migration, and diversifying livestock breeds to cushion against climatic shocks such as prolonged droughts and delayed onsets of rains, which threaten their livelihoods (Bryan *et al*., 2013). In the recent past, the Kenya Climate-Smart Agriculture Strategy (KCSAS) 2017-2026 (GOK, 2017) has been developed to respond to climate change and variability impacts. The KCSAS contains farming approaches that increase productivity in the farm and improve food security while strengthening farm system resilience and farmers' capacity to adapt to climate variability (Lipper *et al.,* 2008).

This study sought to identify and characterize dominant adaptation strategies used among agro-pastoralists' households in Laikipia West Sub-County to reduce the impacts of climate variability. Most studies on adaptation strategies to climate variability are based on climate extremes such as drought and changes in rainfall patterns. While such studies are unquestionably important, they tend to focus on mitigation strategies to drought and change in rainfall patterns, but fail to consider strategies undertaken regarding other climate extreme shocks. This study incorporates other climate variability extremes, such as crop pests and diseases, and livestock parasites and diseases, in addition to drought and changes in rainfall patterns. More specifically, the study focuses on how the strategies adopted could lead to an increase in agricultural production among the agro-pastoralists. The study further incorporates the idea of stochastic dominance to show which adaptation strategy package is more likely to be adopted among the agro-pastoralists. Such a sophisticated analysis and information about the dominant strategy package can assist in the development of mitigation measures and policies for the improvement of the livelihoods of agro-pastoralists in ASAL areas.

3.2 Methodology

3.2.1 The Study Area

The study area was Laikipia West Sub–County in Laikipia County. It has a total area of approximately 3,372.2 Km^2 with a population density of 38 persons per square kilometer and a population of 129,263 (KNBS, 2019). The sub-county has five wards, namely Salama, Olmoran, Rumuruti, Marmanet, and Githiga, which lie between latitudes 0°20'N and 0°40'N and between longitudes 36°20' E and 37°20' E which as presented in Figure **3.1**.

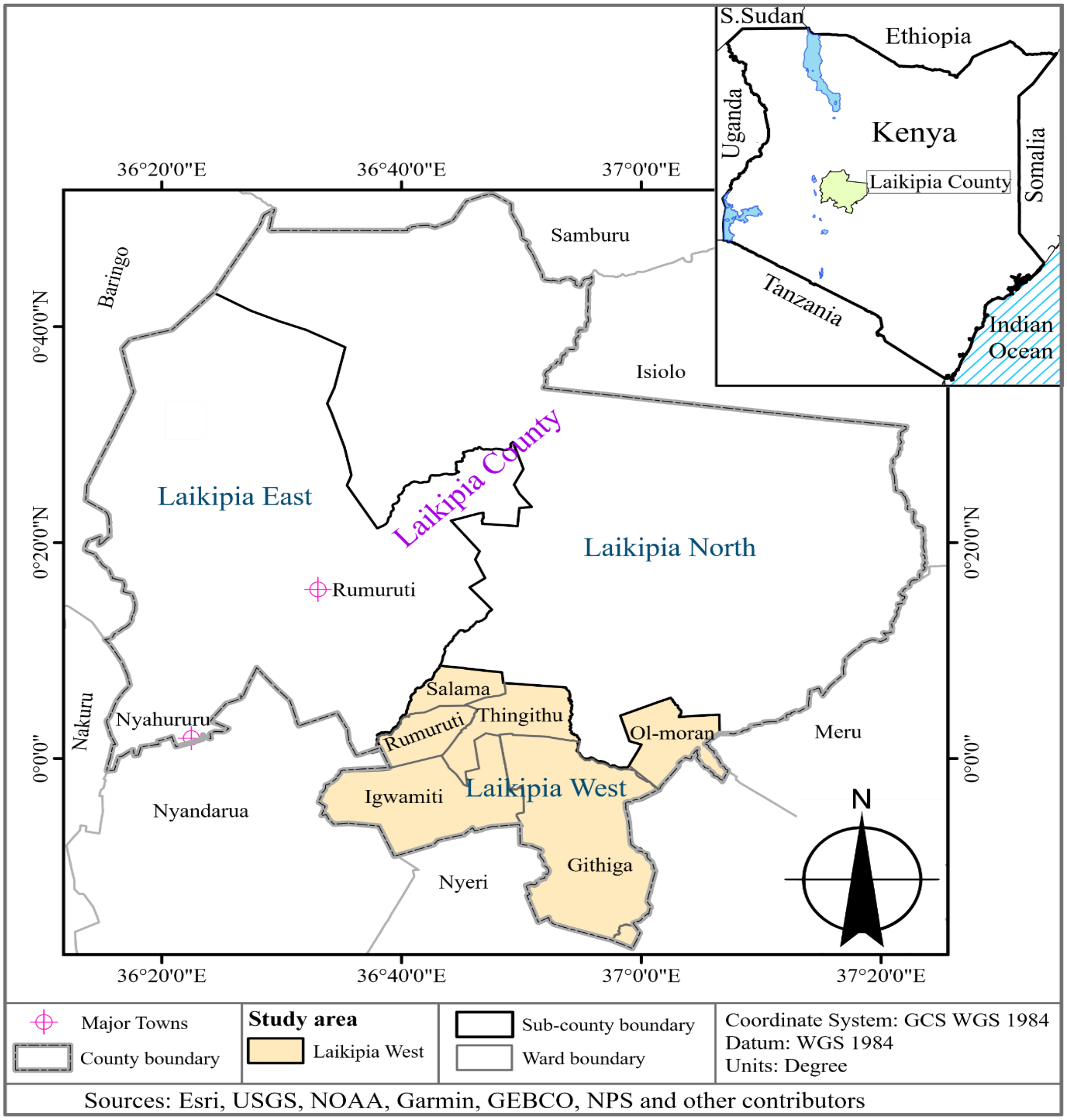

Figure 0.1: Map of the Study Area

The altitude ranges between 1500-2611m above sea level. As a result of the altitude, the county receives a type of relief rainfall, with annual average rainfall ranging between 400mm and 750mm. Higher annual rainfall totals are normally observed in the areas bordering the slopes of Mt. Kenya and the Aberdare ranges. The long rains occur from March to May, while short rains are experienced in October and November. Annual Mean temperature ranges between 16^{o}C and 26 ^{o}C. The county is endowed with pastureland, rangeland, forests, wildlife, and an undulating landscape. High and Medium land constitutes 20.5 per cent and is suitable for crop farming. The remaining 79.5 per cent is low potential, which is suitable for livestock. Crops such as maize, beans, wheat, Irish potatoes, sorghum, sweet potatoes, and vegetables are the major crops planted.

This area was selected due to its susceptibility to the impacts of climate variability. The effects of frequent droughts, floods, crop pests and diseases, and livestock parasites and diseases, which lead to low productivity, have had repercussions on the livelihood and welfare of the local communities. Therefore, agro-pastoralists, being part of the local communities, adopted climate adaptation strategies to mitigate the effects of climate variability.

3.2.2 Research Design

The study employed a cross-sectional quantitative research design to provide statistical answers to the research questions. The method was useful because the study sought to establish a cause-and-effect relationship between explanatory and dependent variables. The design enabled the collection of relevant cross-sectional data from different agro-pastoralists within the study area. This ensured the collection of representative samples of data from the population that gives a good characteristic of the population (Frantael *et al*., 2009).

3.2.3 Sampling Procedure

The target population was agro-pastoralists within Laikipia County. They were selected using a multi-stage sampling approach. In stage one, purposive sampling of Laikipia County was done due to its trends in climate variability that show a rise in temperature, an increase in frequency and intensity of dry seasons, and a reduction in the frequency and intensity of the wet seasons and occurrence of crop and livestock pests, parasite and disease (MoALF, 2017; Muchiri *et al.*, 2020). In the second stage, Laikipia West Sub–County was selected purposively because of its fragile environment and susceptibility of the area to drought. Lastly, systematic random sampling was used to select the respondents who participated in the study. This was assisted by a list of agro-pastoralist households obtained from the County KNBS office.

3.2.4 Sample Size Determination

The study used cross-sectional data collected from agro-pastoralists in Laikipia County. A list of agro-pastoralist households was obtained from the County KNBS office and used as the sampling frame to obtain 275 respondents, as shown in Table 0.1. The study further applied a 12% variability level to obtain 33 more respondents to cater for missing households and non-responses, considering that data was collected during the planting season, and many households relied on human labor for planting. A similar approach was applied by Melketo *et al.* (2021). In sum, a total of 308 households were sampled[1]. The formula is as indicated[2]

Table 0.1: Sample Size Distribution

Laikipia- West Sub-County Wards	Number of Households	Proportion (%)	Sample
Salama	2,609	12	37
Olmoran	4,938	23	71
Rumuruti	5,182	25	77
Marmanet	6,040	29	89
Githiga	2,420	11	34
Total	21,189	100	308

Source: KNBS, 2019

3.2.5 Data Collection and Analysis

A semi-structured questionnaire was employed for the data collection from the households practicing agropastoralism. A face-to-face approach was used with research assistants from the locality-enabling overcome the language barrier challenge. Before data collection, pre-testing of the survey tool was done to validate the tool and make relevant adjustments, before the data collection process. SurveyCTO collect tool was used as opposed to paper questionnaires to minimize errors during entry and save resources. Data from the field were cleaned and coded for uniformity, accuracy, and consistency, and analyzed using STATA software version 18.

3.2.6 Analytical Framework

The first objective was to assess and identify dominant adaptation strategies used to reduce the effects of climate variability among agro-pastoralist households. The strategies were identified

[1] The required sample size was determined using the formula by Yamane (1967).

[2] $n=\frac{N}{1+Ne^2}$ where; n is the sample size, N is household size, e is level of precision or error reliability level of 0.06.

$n = \frac{21{,}189}{1+(21{,}189)(0.06^2)}$, where n= 274.183, thus 275, $n_v = \frac{\text{variability level}}{100} * n = \frac{12}{100} * 275 = 33.$

Therefore, the total sample size= n+n_v, = 275+ 33 = 308 and grouped by Factor Analysis (FA). According to Otitoju (2013), the FA technique has the capability of reducing the large sets of measured variables to a few manageable dimensions called factors. This enabled subsequent analysis by fitting the groups into the model and reaching conclusions. Furthermore, the FA technique was used as opposed to other multivariate statistical techniques like Principal Components Analysis (PCA) because it identified the least number of factors that accounted for the unique item variance, which is shared by a set of variables and produces consistent and optimal results because it recognizes errors (Costello & Osborne, 2005). Additionally, FA provided a descriptive framework that showed covariance relationships among various covariates of random factors through weightings of the various variables into loadings, which are organized into a matrix of factor loadings (Hair *et al.,* 1995). The Kaiser–Meyer–Olkin (KMO) and Bartlett's Test of Sphericity were used to test sampling adequacy and correlation of the variables, respectively, for selecting the underlying factors. Thereafter, descriptive statistics such as percentage distribution were used since they allowed for the strategies to be ranked in terms of numbers used by agro-pastoralists. Following Otitoju (2013), FA is expressed as:

$$Y_i = \gamma f + \varepsilon \tag{3.1}$$

where Y_i represents the vector of observable variables, γ is the loading matrix, f is the vector of unobserved variables, and ε represents the stochastic error term.

3.3 Results and Discussion

3.3.1 Descriptive Results for Climate-Related Agro-weather Shocks

Several agro-weather shocks were reported by agro-pastoralists as presented in Table 0.2, where approximately 89.29% of households observed drought in the last 10 years. The proportion of households that reported crop pests and diseases was 48.05%. Approximately 46.43% of respondents observed rainfall change. Livestock parasites and diseases came fourth at 15.58% and observed flood at 2.27%. The results imply that there is a high occurrence of agro-weather shocks, and that the approach that can be used to reduce their effects is to promote the use of climate adaptation strategies.

Table 0.2: Reported Percentage of Climate-Related Agro-weather Shocks

Agro-weather Shock	Percentage Reported
Drought Observed	89.29
Crop Pests and Diseases	48.05
Rainfall Change Observed	46.43
Livestock Parasites and Diseases	15.58
Flood Changes Observed	2.27

Source: Survey Data, 2024

Different agro-weather shocks portrayed different sub-components of occurrence. Table 0.3 presents the proportion of cross-tabulation of agro-weather shocks. Approximately 17.86% of households perceived drought to be more frequent and severe. 62.66% of respondents perceived drought to be more frequent, while 44.48% perceived drought as more severe. The proportion of households that perceived a shift in the onset and short duration of rainfall was 23.38%. Approximately 34.42% of respondents perceived a shift in the onset of rainfall compared to 35.39% who perceived rainfall as having a short duration. Turning to crop pests and diseases, approximately 3.25% of the respondents perceived increased frequency and high severity. The proportion of households that perceived crop pests and diseases to have increased in frequency was approximately 38.31% while approximately 12.99% perceived crop pests and diseases as having high severity. These results corroborate Sodokin & Nyatefe's (2021) findings, where more than 80% of respondents reported climate threats as affecting their living conditions severely or more severely.

Table 0.3: Reported Percentage of Cross-Tabulation of Sub-Components of Climate-Related Agro-weather Shocks

Agro-weather Shocks	Percentage Reported
Drought Observed	
More Frequent and Severe Droughts	17.86
More Frequent Drought	62.66
More Severe Drought	44.48
Rainfall Changes Observed	
Shift in Onset and Short-Duration Rainfall	23.38
Shift in the Onset of Rainfall	34.42
Short-Duration Rainfall	35.39
Crop Pests and Diseases	
Increased Frequency and High Severity	3.25
Increased Frequency	38.31
High Severity	12.99

Source: Survey Data, 2024

Twenty-one climate response strategies are actively in use by agro-pastoralists, as shown in Table 0.4. The practices were grouped using Factor Analysis (FA), where practices related were grouped into clusters (factors). This was significant as it reduced the strategies into smaller variables, established the underlying dimensions between measured variables and latent construct, and enabled parsimonious analysis by fitting the factors into the model. The approach is superior to conventional methods of grouping as it provides construct-valid evidence of reported responses, where few practices could represent the larger group of practices.

Table 0.4: Exploratory Factor Analysis Loadings for Crop and Livestock Response Strategies

Variable	**Factor1**	**Factor2**	**Factor3**	**Factor4**	**Factor5**	**Factor6**	**Factor7**	**Uniqueness**
Change planting date	0.300	0.336	**0.609**	-0.040	-0.090	-0.065	0.003	0.412
Use organic manure	0.183	-0.099	**0.413**	0.153	0.400	-0.203	0.166	0.534
Use inorganic fertilizer	-0.317	**0.585**	0.184	-0.003	0.356	-0.153	-0.037	0.371
Plant drought-tolerant varieties	**0.555**	0.170	-0.071	0.435	-0.069	-0.021	0.059	0.460
Intercrop	0.235	**0.680**	0.116	0.016	0.118	0.037	0.015	0.453
Crop rotation	0.112	**0.606**	-0.025	0.347	-0.090	0.256	0.197	0.387
Early cropping	**0.611**	0.081	0.072	0.203	0.006	-0.071	0.059	0.565
Plant Agroforestry	0.198	0.235	0.151	**-0.360**	0.296	-0.337	0.138	0.533
Herbicide use	0.374	**0.474**	0.115	-0.136	0.123	-0.006	-0.060	0.585
Crop residue	-0.017	0.043	**0.816**	0.128	0.056	0.127	-0.123	0.281
Supplementary feeding	**0.653**	0.073	-0.059	0.157	0.199	-0.044	-0.144	0.478
Sell livestock	**0.465**	0.005	0.185	-0.107	0.164	0.058	0.398	0.550
Improved livestock breed	0.060	0.127	-0.021	-0.012	**0.781**	0.095	0.102	0.351
Diversified livestock	0.084	0.130	0.011	-0.040	-0.002	**0.767**	0.011	0.386
Forage	**0.571**	0.133	0.012	0.285	0.285	0.124	-0.228	0.426
Fodder	0.449	0.048	0.080	0.206	**0.598**	0.077	-0.232	0.330
Spraying	0.297	0.294	-0.249	**0.495**	0.015	0.283	-0.019	0.437
Harvest	**0.656**	0.039	0.364	-0.194	0.088	0.035	0.108	0.377

rainwater								
Surface water	0.076	0.014	0.206	**0.791**	0.110	-0.106	0.052	0.300
Communal grazing	0.101	0.111	-0.185	0.018	-0.223	**-0.641**	0.036	0.481
Livestock movement	-0.049	0.048	-0.093	0.054	0.008	-0.015	**0.857**	0.250
Eigenvalue	4.146	1.798	1.456	1.336	1.145	1.135	1.039	
Cumulative	13.7	22.1	29.9	37.6	45.2	51.9	57.4	
Kaiser-Meyer-Olkin Measure of Sampling Adequacy				0.770				
Bartlett test of sphericity χ^2				1152.434				
Degrees of freedom				210.000				
p-value				0.000				

Note: The extraction method that was used was a factor rotation matrix

Source: Survey Data, 2024

The factor scores were computed using the weighted sum approach propounded by Bartlett (Bartlett, 1937). According to Hershberger (2005), Bartlett's approach provides relatively unbiased estimates of the correct factor scores; therefore, a small number of highly correlated practices were included under each factor for ease of interpretation and conclusion about the group. The study further applied Bartlett's test of sphericity to check whether the practices were orthogonal (Chartterje et al., 2015; Tobias & Carlson, 1969). From the orthogonal rotation, seven (**7**) factors were extracted from the 21 practices with an eigenvalue greater than 1.0 following the Kaiser criterion (Kaiser, 1958). Table 3.4 contains the coefficients of factors called loadings. To maximize dispersion of loadings within each retained factor, the study applied the varimax rotation approach (Kaiser, 1958). A common measure of goodness of fit in multivariate analysis is the percentage of explained variation. The higher the percentage of explained variation by a proposed model, the more reliable the model fits the data. Therefore, the results in Table 0.4 reveal that 7 factors explained 57.4% of the variation in the data set. This represents an acceptable fit, indicating that FA explained the variation in the data. Table 0.4 indicates each factor according to the strongly correlated practices. The first factor explains 13.7% variance and is positively associated with planting drought-tolerant varieties, early cropping, supplementary feeding, forage, harvesting rainwater, and the sale of livestock. This factor thus represents farm risk reduction practices. Factor two explains 8.4% of the variance and correlates with the use of inorganic fertilizer, intercrop, crop rotation, and herbicide use; this too had a positive factor loading, hence can be viewed as cultural farm practices. The third factor explains 7.8% of the variance and, with positive loadings, correlates with changes in planting date, use of organic manure, and crop residue, thus representing sustainable agricultural practices. Factor four, with positive loadings for spraying and surface water, and negative loadings for planting of agroforestry trees, explains 7.7% of the variance thus referred to as farm management practices. The fifth factor correlates with improved livestock breeds and use of fodder, both with highly positive loadings, explains 7.9% of the variance, and was referred to as livestock management practices. Diversification practice, which is associated with keeping diversified improved animal breeds and communal grazing, explains 6.7% of the variance, with highly positive and negative effects (loadings), respectively, and was the sixth factor. Finally, the seventh factor explains 5.5% of the variance and, with a high positive loading, associates with livestock movement, thus was viewed as a traditional practice. The results imply that the first seven factors have more significance in explaining the variance in the data set.

To measure the sampling adequacy of the data, the study applied Kaiser-Meyer-Olkin (KMO) statistics, and values above 0.5 were considered as the model selection criterion (Field, 2013). The uniqueness column indicates the amount of variation unique to each retained variable in six factors. According to MacCallum *et al.* (2001), uniqueness levels correspond inversely to the levels of importance of communality factors, i.e., Uniqueness 1-Communality. Therefore, wide uniqueness in the range of 0.2 to 0.8, as noted by MacCallum *et al.* (2001), was applied to the study to justify performing Factor analysis. The uniqueness presented in Table 0.4 meets the wide range criteria as they represent unique variable variance of the factors.

To clearly indicate the composition of the adaptation strategy packages, descriptive statistics were used as shown in Table 0.5. The results showed that the widely used factor was risk reduction practices, with 78.25% of agro-pastoralists using at least one of the practices of this cluster. This factor comprised planting of drought-tolerant varieties, early cropping, supplementary feeding, use of forage, harvesting rainwater, and sale of livestock. The second most used factors were cultural farm practices and sustainable agricultural practices, used by 73.70% of agro-pastoralists. Cultural farm practices entailed the use of inorganic fertilizer, intercropping, crop rotation, and the use of herbicides. Sustainable agricultural practices include: change of planting date, use of organic manure, and use of crop residue. The fourth factor was farm management practices by 48.70% of agro-pastoralists. The dominant practices were spraying, planting agroforestry trees, and the use of surface water. Livestock management practice was the fifth factor adopted by 43.13% of agro-pastoralists, and it entailed improved livestock breeds and the use of fodder. The second least used factor was diversification practice at 37.34% by agro-pastoralist households. The dominant practices were keeping diversified improved animal breeds and communal grazing. Finally, the least used factor comprised traditional practices, with the only strategy being livestock movement. This factor was practiced by 6.82% of agro-pastoralists.

Table 0.5: Crop and Livestock Components, Respective Practices, and Adoption Percentage

Factor	Practices	Percentage of Users
Farm Risk Reduction Practices (R)	Plant drought-tolerant varieties	78.25
	Early cropping	
	Supplementary feeding	
	Use of forage	
	Harvest rainwater	
	Sell livestock	
Cultural Farm Practices (C)	Use of inorganic fertilizer	73.70
	Intercropping	
	Crop rotation	
	Use of herbicides	
Sustainable Agricultural Practices (S)	Change Planting dates	73.70
	Use of organic manure	
	Crop residue	
Farm Management Practices (F)	Spraying	48.70
	Plant Agroforestry trees	
	Use of shallow wells and construction of ditches	
Livestock Management Practices (L)	Improved livestock breeds	43.13
	Use of fodder	
Diversification Practices (D)	Keeping diversified improved animal breeds	37.34
	Communal grazing	
Traditional Practices (T)	Livestock movement	6.82

Source: Survey Data, 2024

Several response practices were used in response to agro-weather shocks. However, different farming categories adopted different dominant response practices as shown in Table 0.6. The most common adaptation strategies to observed drought were a change of planting date at 40.96% for crops, use of crop residue as animal feeds at 54.79% for livestock, and use of harvested rainwater at 74.47% for water management. These strategies may be viewed as common responses that do not require technical expertise, hence can be carried out by many agro-pastoralists. In response to observed rainfall changes, agro-pastoralists identified planting of early maturing crops at 52.89% for crops, supplementary feeding at 43.80% for livestock, and harvest rainwater at 81.82% for water management. These responses could be preferred, perhaps due to the availability of information about rainfall changes and relatively low levels of investment in the practices.

Table 0.6: Reported Percentage of Practices Used in Response to Climate-Related Agro-weather Shocks

Agro-weather shocks	**Categories of farming activities**	**Dominant Response Practices**	**Percentage**
Drought Observed	Crop activity	Change planting dates	40.96
	Livestock activity	Crop residue as animal feed	54.79
	Water management	Use harvested rainwater	74.47
Rainfall Changes Observed	Crop activity	Plant Early maturing crops	52.89
	Livestock activity	Supplementary feeding	43.80
	Water management	Harvest rainwater	81.82
Crop Pests and Diseases	Crop activity	Use of herbicide	78.23
Livestock Parasites and Diseases	Livestock activity	Sale of livestock	27.45

Source: Survey Data, 2024

Use of herbicides at 78.23% was the strategy that was used for crop pests and diseases. This could be attributed to the farming experience of the agro-pastoralist, hence the knowledge about crop pest and disease identification. Lastly, the dominant strategy used in response to livestock parasites and diseases was the sale of livestock at 27.45%. Perhaps this could be attributed to the agro-pastoralist preference to buy other inputs used for production as opposed to spending on the livestock, which may not directly translate into immediate output. In conclusion, the result corroborates with Mulwa *et al.* (2017) finding that due to climate risk, farmers used crops that are tolerant to drought, planted early maturing crops, planted crop varieties that are pest and disease tolerant, and diversified the crops that they planted.

3.4 Conclusion

The study identified agro-weather shocks and adaptation strategies. While various weather shocks and strategies were reported, different trends were identified. First, drought was the highly reported agro-weather shock. Secondly, contrary to expectations, most respondents reported crop pests and diseases as the second most experienced shock. Thirdly, rainfall change was identified as another important shock that affects agro-pastoralists in the area. The largest number of respondents observed drought, possibly due to their dependence on rainfed agriculture, which may have been affected by the increased frequency and severity of drought in the area. Turning to adaptation strategies, uptake of the climate adaptation strategies was still low, with farm risk reduction practices being the most dominant, perhaps to increase agricultural production to meet food demand among the subsistent agro-pastoralists. Diversification practices and traditional practices, from the findings, were the least used practices. This could be because of high investment cost and knowledge required to implement diversification practices, and traditional practices are outdated and have low returns, and require resources such as a large piece of land.

This study's finding implies that any effective policy interventions in agro-pastoral areas that seek to improve agricultural production amid climate variability should be based on the analysis of adaptation strategies that are in practice. For instance, policy interventions should emphasize planting of drought-tolerant crop varieties and early cropping, which can mature despite the occurrence of agro-weather shocks. A clear understanding of dominant adaptation strategies among agro-pastoralists should be the initial step in developing and implementing interventions geared towards supporting households in ASALs.

CHAPTER FOUR

INFLUENCING FACTORS FOR CHOICE AND NUMBER OF ADAPTATION STRATEGIES TO CLIMATE VARIABILITY

Abstract

Climate variability increases vulnerability among agro-pastoralists, stressing the need for effective adaptation strategies. However, how these communities respond to such changes is still unclear. Using a multistage sampling technique to collect data from 308 households to explore how socio-economic and institutional factors impact the adoption of responsive strategies in Laikipia West Sub-County, Kenya. Poisson regression was used to evaluate the number of strategies adopted, while a multivariate probit model analyzed the effects of socio-economic and institutional variables on strategy selection. The results showed that the household dependency ratio, education level, gender of the household head, group memberships, and household wealth positively influenced the number of strategies adopted. Specifically, a one-unit increase in education level was associated with a 0.25 increase in the intensity of adaptation strategies adopted ($p < 0.05$). In contrast, the age of the household head, the interaction between gender and farming experience, years of education, and unmet credit needs were negatively affected by variables that influenced strategy adoption. The magnitude and direction of the multivariate probit marginal effect revealed mixed effects of the dependency ratio, education, and distance to extension agents. Group memberships, lack of credit demand, and wealth index for affluent households increased the probability of adopting strategies. In contrast, age, gender, farm size, and livestock holdings variables reduced the probability of using the strategies. These findings imply the need to consider socio-economic and institutional dynamics to improve adaptation strategies for agro-pastoral communities facing climate change and variability.

4.1 Introduction

Climate variability presents a significant and escalating threat to agricultural systems globally, with particularly acute impacts in the arid and semi-arid regions where farming systems are heavily reliant on rainfall (IPCC, 2022). Smallholder agro-pastoralists, whose livelihoods are intricately linked to the natural resource base, are disproportionately vulnerable to climate-induced shocks such as prolonged droughts, erratic rainfall patterns, and rising temperatures (Gerber *et al.*, 2013). In response, a wide array of adaptation strategies has been proposed and promoted, ranging from sustainable farming practices and livelihood diversification to improved livestock management and the revitalization of traditional coping mechanisms (Adger *et al.,* 2003; Tarekegn *et al.,* 2024).

In Sub-Saharan Africa (SSA), where agro-pastoralism supports millions of livelihoods, especially in the arid and semi-arid lands (ASALs), the challenges are particularly pronounced. These regions are characterized by frequent and intense droughts and highly variable rainfall, which have a direct and detrimental impact on crop yields and livestock productivity (Atinkut & Mebrat, 2016; Schlenker & Lobell, 2010). Consequently, farmers across SSA have adopted a diverse range of coping measures to enhance their resilience to these climatic shocks. However, the adaptive capacity of these communities is often severely constrained by a complex interplay of factors, including widespread poverty, limited institutional support, and restricted access to essential resources (Morton, 2007).

Kenya is a good example of these challenges, with over 80% of its landmass classified as ASALs, where agricultural production is predominantly rain-fed (KNBS, 2023). Agro-pastoralists in Laikipia County, situated in one of these vulnerable regions, are confronted with recurrent droughts and rainfall variability that perennially threaten their food security and livelihoods (MoALF, 2017; Muchiri *et al.,* 2020). Despite the promotion of various adaptation practices, their uptake remains limited, hindered by a confluence of institutional, socio-economic, and informational constraints (Musafiri *et al.,* 2022).

Understanding the adoption behavior of farmers in the context of climate adaptation requires a multi-faceted theoretical lens. The economic constraints model emphasizes the role of resource limitations, such as land and credit, as key determinants of adoption (Makokha *et al.,* 1999). In contrast, the adoption perception model highlights the significance of individual characteristics, including education, experience, and perceptions of climate risks (Sarker *et al.,* 2008). The innovation diffusion model further underscores the importance of information access through extension services, demonstration plots, and mass media (Wejnert, 2002). A holistic understanding of the factors driving adaptation strategy adoption among agro-pastoralists necessitates an integration of these theoretical perspectives (Kumasi *et al.,* 2019; Opiyo *et al.,* 2016).

However, a critical review of the existing literature reveals several significant research gaps that this study aims to address. While previous studies have made valuable contributions to our understanding of climate change adaptation, they often focus on the adoption of single strategies or bundles of strategies in isolation, thereby overlooking the complex interdependencies and potential synergies or trade-offs between different adaptation options (Nhemachena & Hassan, 2007; Musafiri *et al.*, 2022). Furthermore, much of the existing research inadequately addresses the intensity of strategy adoption, failing to quantify the number of strategies adopted and the factors influencing this intensity. This is a critical omission, as the level of resilience is likely to be influenced not just by the type of strategies adopted, but also by the number and combination of strategies employed.

Moreover, a significant body of research has yet to move beyond adoption to systematically assess the long-term effectiveness and sustainability of these strategies in enhancing resilience and improving livelihoods. There is also a pressing need for more research that employs a systems-thinking approach to understand how multiple, interacting stressors—including climate change, land degradation, and tenure insecurity—collectively shape adaptation pathways. The gendered dimensions of adaptation also warrant deeper investigation, moving beyond a simple binary of male- or female-headed households to explore the nuanced ways in which gender roles and relations influence vulnerability and adaptive capacity. Finally, there remains a persistent gap in our understanding of how to effectively scale up successful adaptation strategies and bridge the research-policy-practice divide.

This study makes a novel contribution to the literature by addressing several of these gaps. It employs a robust, multi-pronged analytical approach to provide a more comprehensive and nuanced understanding of climate change adaptation among agro-pastoralists in Laikipia County, Kenya. Specifically, this study analyzes the factors influencing the intensity of adaptation, as measured by the number of strategies adopted, a dimension often overlooked in previous studies. Second, it assesses the factors determining the choice of specific adaptation strategy packages, using a multivariate probit model to account for the interdependence between different strategies. Lastly, it identifies the key barriers hindering the adoption of adaptation strategies, providing crucial insights for policy and practice. By doing so, this study provides a more all-inclusive and policy-relevant understanding of climate change response in a highly vulnerable agro-pastoral system, offering important insights for researchers, policymakers, and development practitioners working to enhance the resilience of similar communities across SSA.

4.2 Methodology

4.2.1 Study Area, Research Design, Sampling Procedure, Sample Size Determination, and Data Collection and Analysis

The research was carried out in arid and semi-arid areas of Laikipia West sub-county (refer to section 3.2.1). The research design was a cross-sectional quantitative research design as detailed in (section 3.2.2). The sampling procedure was a multi-stage sampling technique, and respondents were chosen using simple random sampling as discussed in (Section 3.2.3). The sample size was determined using Yamane's (1967) method and distributed proportionally across the five wards as outlined in (section 3.2.4). The data was collected was cleaned, coded, and analyzed following the procedure as outlined in (section 3.2.5).

4.2.2 Analytical Framework

The analytical framework involved three main steps: (1) Factor Analysis (FA) to group adaptation strategies; (2) Poisson Regression Model to analyze the factors influencing the intensity of adaptation; and (3) Multivariate probit model to assess the factors determining the choice of specific response strategy packages. However, Factor Analysis was not discussed in this section, as it was discussed in the previous chapter.

4.2.2.1 Poisson Regression Model for The Intensity of Adaptation

For the intensity of adaptation strategies, Count data are non-normal and hence are not well estimated using Ordinary Least Squares (Maddala & Flores-Lagunes, 2001). According to Cameron and Trivedi (2001), Poisson Regression Model, Negative Binomial Regression Model, Zero Inflated Poisson, and Zero Inflated Negative Binomial are the most common regression models used to analyze count data. Further, Green (2008); Kirui *et al.* (2013) posit PRM and NBRM as the standard models for analyzing a dependent variable with a non-negative integer. Additionally, ZIP and ZINB are used specifically when the dependent variables have frequent cases of zero counts, i.e., more zeros than would be expected. Therefore, the Poisson Regression Model was used to determine factors influencing the number of adaptation strategies used by agro-pastoralists. Poisson regression is a widely used count model for assessing adoption intensity. It remains a suitable model for analyzing count data, especially when the dependent variable is discrete and contains nonnegative integers (Hayat & Higgins, 2014).

Before using the Poisson Regression model, a goodness-of-fit chi-square was estimated to check the statistical significance of the data to the model. Further, a likelihood ratio test was conducted to check for over-dispersion or under-dispersion in the data. A significant alpha=0 would be an indication of a potential over-dispersion problem, in which case Negative Binomial Regression would be appropriate.

The assumption that agro-pastoralists chose a certain number of strategies that offer maximum utility was made. According to Park and Lohr (2005), utility obtained from a particular strategy package depends on the household characteristics *M* and observed farm vector factors *K*, such that:

$$U_{ij} = \delta_j(M_i K_i) + \varepsilon_{ij},\ j=0,1,2\ldots n,\ i=1,2\ldots.\ q \qquad (4.1)$$

where j indicates the number of strategies used by the *i*th agro-pastoralist, while δ is a vector of parameters to be estimated, and ε_{ij} is the error term. The *i*th agro-pastoralist uses *j=1* or more if $U_{ij} > U_{0i}$.

Following Nkegbe and Shankar (2014), the Poisson regression model is stated as follows:

$$Prob(Y_i = y_i/x_i) = {e^{-\mu_i}\mu_i^{yi}}\Big/{y_i!}\ \ j = 0,1,2 \ldots\ldots\ldots.n, = 1,2\ \ldots q \qquad (4.2)$$

and

$$\mu = E(y_i/x_i) = \exp(x'\beta) \qquad (4.3)$$

where Y_i represents the intensity of response strategies adopted, x_i is a vector of covariates, y_i Indicate specific count value for the *i*th agro-pastoralist, μ mean parameter, β is the parameter coefficient, μ_i Indicate both the conditional mean and variance of the Poisson distribution. The mean number of adaptation strategies undertaken and their variance is given by:

$$E(Y_i) = Var(\ Y_i) = \mu_i = e^{\beta'(M,K)}\ i =\ 1,2 \ldots.q \qquad (4.4)$$

where $E(Y_i)$ is the mean value of the dependent variable for the *i*th agro-pastoralist

According to Greene (1997), PRM assumes equal-dispersion; if not overdispersion or underdispersion is present, then it fails to give appropriate results. Therefore, in such a case Negative Binomial Regression (NBR) model would be recommended as the alternative.

4.2.2.2 Multivariate Probit Model for Choice

When agro-pastoralists experience extreme agro-weather shocks, they may opt to adopt a mix of strategies to mitigate the shock instead of relying on a single response to exploit positive or negative correlations among alternatives. Thus, agro-pastoralists may choose other strategies in addition to adopting specific adaptation strategies. Their response is considered multivariate, and the use of univariate modeling will likely omit important information in the interdependence of simultaneous response decisions. Based on this, the study further adopted the Multivariate Probit approach to model the effect of a set of independent variables for every adaptation strategy package simultaneously while allowing the free correlation among the unobserved factors (Lin *et al*., 2005). According to Belderbos *et al.* (2004), the source of correlation might be substitutability and complementarity between different adaptation strategy packages used in the model or the existence of unobserved socio-economic factors that are specific to a household and can affect the choice of adaptation options but cannot be measured easily, like indigenous knowledge.

Studies on factors influencing the choice of adaptation strategies to climate variability have employed discrete choice models such as binary logit (Fosu-Mensah *et al*., 2012) and Multinomial Probit or logit (Hassan and Nhemachena, 2008; Nhemachena and Hassan, 2007). However, the models did not consider the possible inter-relationships between various adaptation strategies (Yu *et al*., 2008). MVP model recognizes the inter-relationships and allows the error terms of different choices to freely correlate (Belderbos *et al*., 2004; Lin *et al*., 2005). The correlation can either be positive or negative between different strategy packages (Belderbos *et al*., 2004).

Before using the MVP model, an estimation of correlation coefficients of the error terms was conducted to check for complementarity and substitutability between different adaptation strategy packages being used by agro-pastoralists. Further, a likelihood ratio test based on the log-likelihood values was carried out to check for significant correlations of the explanatory power of the MVP model.

Following Lin *et al.* (2005), the multivariate probit model is represented by a set of n binary dependent variables. Y_i observation subscripts specified as follows:

$$Y_{ik}{}^{*} = \beta_k X_{ik} + \varepsilon_{ik} \qquad (4.5)$$

where $Y_{ik}{}^{*}$(i=1..., k) represent the vector of unobserved latent variables of adaptation strategies packages adopted by the i^{th} agro-pastoralist. (k=1...., n), k strategies packages adopted by agro-pastoralists. X_{ik} is a $1 \times k$ vector of explanatory variables that influence the choice of adaptation strategies, the variables include household socio-economic and institutional factors. β_k is a $1 \times k$ vector of unknown parameters to be estimated, ε_{ik}, k= 1, ..., k is a random error term distributed as a multivariate normal distribution with zero means, unitary variance on the leading diagonal. Equation 4.5 is a system of equations as represented in equations 4.6 and 4.7 below:

$$Y_1{}^{*} = X_1\beta_1 + \varepsilon_1 y_1 = 1 \text{ if } Y_1{}^{*} > 0 \; Y_1 = 0 \;\text{ Otherwise} \qquad (4.6)$$

$$Y_n{}^{*} = X_n\beta_n + \varepsilon_n y_n = 1 \text{ if } Y_n{}^{*} > 0 \; Y_n = 0 \text{ Otherwise} \qquad (4.7)$$

The systems of equations (4.6 & 4.7) are jointly estimated using the maximum likelihood estimation method. The implicit functional form of the model is expressed as:

$Y_n{}^*$=f_0(β_0+$\beta_1$hhsize+$\beta_2$age+β_3(age*age^2)+β_4D_ratio+$\beta_5$gender+$\beta_6$log_educ+$\beta_7$educ stock+$\beta_8$wealthindexdummy 1+$\beta_9$wealthindexdummy2+β_{10}farmsize+β_{11}TLU+β_{12}dis_extens+β_{13}accesstrain+β_{14}(grpmbrshp*nbrgrp)+ β_{15}grpmbrshp+β_{16}nbrgrp+β_{17}credit dummy1+β_{18}credit dummy3)+ ε

4.2.3 Description of Variables

The description of variables used in econometric estimations is provided in

Table **0.1**. The variables were picked based on information derived from empirical literature. Additionally, the description involves how the variables were measured and the expected influence.

Table 0.1: Description of Variables for Poisson Regression and Multivariate Probit Model

Variable	Description	Measurement
Dependent Variable Adaptation Packages	1. Adaptation Packages (1, 2,3,4,5,6,7) 2. Binary (1= Yes, 0= No)	Discrete
Independent Variables		
Age	Household head age in years	Continuous
Age squared	Household head age squared	Continuous
Age &Age^2 interaction	Interaction term for age and age squared of the household head	Continuous
Farming experience	Farming experience of the household head in years	Continuous
Gender	Gender of household head	Dummy
Gender Farming Interaction	Interaction of gender and farming experience of the household head.	Continuous

Household size	Household size (adult equivalent)	Discrete
Dependency Ratio	Household dependency ratio (number of children below the age of 15 years plus adults above 65 years, divided by active members of the household)	Continuous
Head's education	Household head's education (Years of schooling)	Continuous
Education stock	Household education stock (sum of years of schooling over members)	Continuous
Distant extension	Distance to extension office	Continuous
Training access	Access to adaptation strategy training	Dummy
Credit access	Access to credit services	Categorical
Farm size	Farm land holding	Continuous
Group Interaction	Interaction of the Number of organizations a farmer organization belonged to and group membership	Discrete
Group membership	Membership in a farmer group	Dummy
Number of groups	The number of groups a household belongs to	Discrete
TLU	Tropical Livestock Unit	Continuous
Wealth index	3 quantiles of wealth index	Categorical

4.3 Results and Discussion

4.3.1 Descriptive Results

4.3.1.1 Descriptive Results for Continuous Variables

The study calculated descriptive statistics for socio-economic and institutional characteristics of agro-pastoralists based on intensity and choice of adaptation strategy package, and the results are presented in Table 0.2. The average age of the household head was 52 years. The household head had an average of 24 years of farming experience. The finding implies that at least the household head had practiced agro-pastoralism for almost half of their lives. The average of the interaction term of gender and farming experience of the household head was 15.15. This indicates the significant combined negative effect of the variables. The log of household head education was 1.96, which implies that, on average, the household head had 7 years of education. This indicates that the household head had at least a primary level of education. It further indicates that most household heads were able to read and write, which is in accordance with the national literacy levels, as shown by an upsurge in the number of primary school pupils transitioning to secondary schools (KNBS, 2023). The average education stock of the household was 9.04. The overall household size in adult equivalent terms was 3 members. According to Kassa and Abdi (2022); Tadesse and Ahmed (2023), household size affects the use of climate adaptation practices. For instance, Agbenyo *et al.* (2022) indicated that among cocoa farmers who used irrigation had a smaller household size; however, those who used organic fertilizer had a large household size, which implies that a large household size favors labor-intensive adaptation practices. Additionally, the household dependency ratio was one (1) among the agro-pastoralists. Further, agro-pastoralists on average had a farm size of 2.34 acres. The mean of the combined effect between group membership and number of groups was 1.31, suggesting a high combined positive effect of the variables. The average number of groups that household members belonged to was 1.48. Household members, on average, walked 3.88 Km to get to the extension agents' office. Lastly, on average, a household had a tropical livestock unit of 1.44.

Table 0.2: Descriptive Statistics of Continuous Household Characteristics

Variable	Mean	Std. Dev.
Age of household head	52.11	13.62
Interaction of gender and the farming experience of the household head	15.15	14.70
Farming experience of the household head	24.33	10.34
Years of Education of the Household head	7.10	1.95
Adult Equivalent household size	2.92	1.19
Dependency Ratio	0.34	0.34
The education stock of the household	9.04	2.40
Farm size	2.34	1.85
Interaction term for group membership and number of groups	1.31	1.10
The number of groups a household member belongs to	1.48	1.04
Distance to Extension agent	2.76	1.81
Tropical Livestock Unit	1.07	1.21

Source: Survey Data, 2024

4.3.1.2 Proportion of Number of Packages Used by Gender of Household Head

Agro-pastoralist households were headed by either male or female, and this might affect the use of different packages due to resource access and cultural beliefs. To ascertain this, Table 0.3 presents the proportion of each package as used by households headed by males and females. The results indicate that approximately 1.07% and 0.00% of male and female respondents used a factor with at least one practice. The male-headed households were higher compared to female-headed households by 1.07%. This result could be due to the higher possibility of male-headed households having greater autonomy in control of agricultural resources such as capital, labor, and land, which are significant for the use of the practices (Peterman *et al.,* 2014). The proportion of households that adopted a factor with at least two strategies was 13.22% and 10.70% for female and male respondents, respectively. Households headed by females used approximately 2.77% more of the factors with at least three practices compared to male-headed households. Approximately 1.99% of households headed by males used more factors with at least four practices compared to female-headed households. Turning to factor five, approximately 21.49% and 21.39% of female and male-headed households used a factor with at least five practices. Approximately 10.74% and 10.16% of female and male-headed households used a factor with at least six practices. Lastly, approximately 0.83% and 3.74% of female and male-headed households used factors with at least seven practices, which was the highest possible number of practices. The low proportion could be due to the high investment cost needed to implement the strategies.

Pearson's χ^2 was employed to compare differences in the use of the number of packages disaggregated by the gender of the household head. The result of the test (χ^2 (6)=4.4987, *p*=0.610 which is greater than 0.01, suggests no significant differences in the intensity of packages among the male and female-headed households. This result demonstrates that the gender differences are not because of the underlying economic, social, and cultural differences.

Table 0.3: Proportion of Number of Adaptation Strategies Used by Gender of Agro-pastoralist Household Head

Factor Count	Female	Male	χ^2	Total
1	0.00 (0)	1.07 (2)	4.4987	0.65 (2)
2	13.22 (16)	10.70 (20)		11.69 (36)
3	21.49 (26)	18.72 (35)		19.81 (61)
4	32.23 (39)	34.22 (64)		33.44 (103)
5	21.49 (26)	21.39 (40)		21.43 (66)
6	10.74 (13)	10.16 (19)		10.39 (32)
7	0.83 (1)	3.74 (7)		2.60 (8)

Note: figures in parentheses represent frequencies

Source: Survey Data, 2024.

4.3.1.3 Proportion of Number of Packages Used by Agro-pastoralist.

The study generated a total of seven packages and went further to find out which one was used by most agro-pastoralists, and the results are presented in Figure 0.1. The range of intensity of factors was between 1and 7 for low adopters and full adopters, respectively. The results reveal that approximately 0.65% of the agro-pastoralists used factor one. The proportion of households that used factor two was approximately 11.69%. Turning to factor three, approximately 19.81% of households used the factor. Most respondents, 33.44% had adopted factor four. Further, approximately 21.43% used the factor with five practices, while approximately 10.39% of agro-pastoralists used a factor with six strategies. Approximately 2.6% of agro-pastoralist households adopted a factor with seven practices.

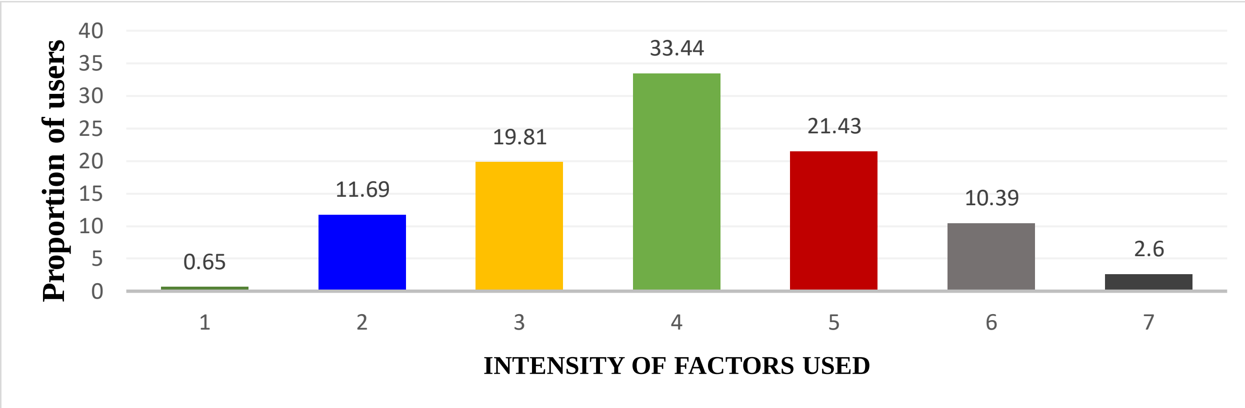

Figure 0.1: Agro-pastoralist Level of Usage of Adaptation Strategy

4.3.1.4 Perceived Barriers to Adaptation Among Agropastoral Households

The study identified agro-pastoralists' perceived barriers to using various adaptation strategies. Results on barriers to uptake of adaptation strategies are presented in Figure 0.2. The results indicate that approximately 27.92% of agro-pastoralists perceived a shortage of money as a barrier to adaptation. Shortage of money limits the ability of agro-pastoralists to acquire the important resources necessary to adopt the strategies. Resource limitation could imply that agro-pastoralists fail to meet the transaction costs necessary to get the adaptation strategy they might demand. The proportion of respondents who perceived a lack of information concerning adaptation to climate variability was 18.83%. This result could be attributed to resource limitations among agro-pastoralists, which leads to competing priorities, therefore, resulting in neglect of important information about effective adaptation strategies. Approximately 7.79% of agro-pastoralists perceived a shortage of land as a barrier to adaptation. This perhaps could imply that agro-pastoralists who have less sufficient land have a lower probability of taking up adaptation strategies. Further, approximately 3.9% of agro-pastoralists perceived slow technology adoption as a barrier to adaptation. This result suggests that with access to technology, agro-pastoralists can take up adaptation strategies and improve their production techniques. Lastly, 3.57% perceived a shortage of labor as a barrier. Some of the strategies are labor-intensive, and therefore, a labor shortage could be indicative of reduced adoption of the strategy.

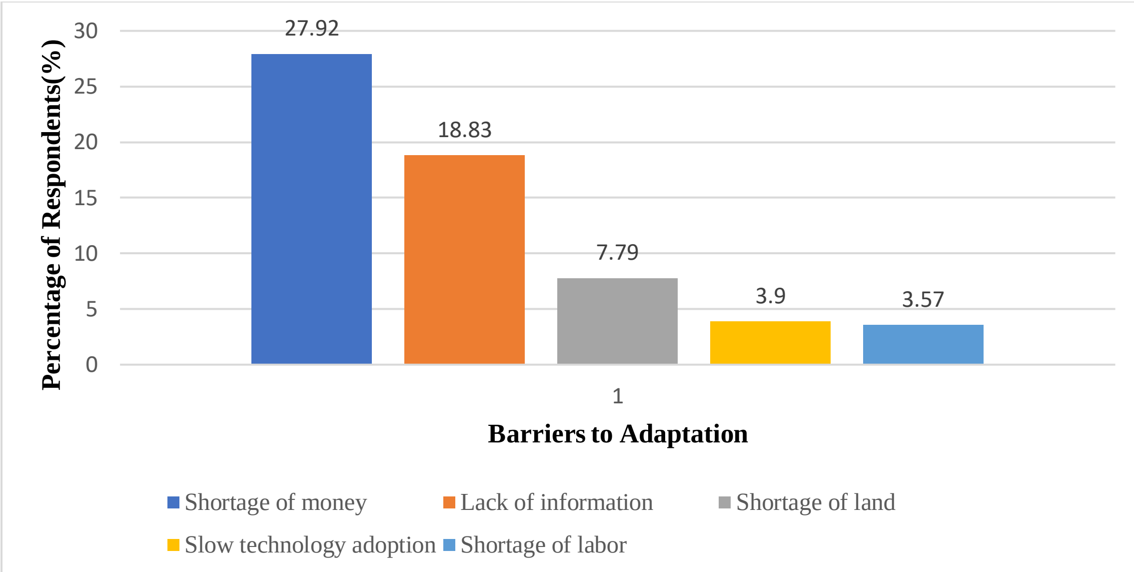

Figure 0.2: Agro-pastoralist Perceived Barriers to Adaptation of Strategies

4.3.2 Empirical Results

4.3.2.1 Model Diagnostics and Fitness

The study conducted post-estimation to identify the problem of multicollinearity and heteroscedasticity in socio-economic and institutional variables. To detect multicollinearity, Variance Inflation Factors (VIFs) for continuous variables and Contingent Coefficients (CCs) for categorical and dummy variables were checked. Table 0.4 presents the VIF for multicollinearity. Multicollinearity leads to unstable parameter estimates, inflated standard errors, and inaccurate hypothesis tests (Daoud, 2017). Further, it poses challenges in interpreting the importance of individual variables and may affect the validity and reliability of the regression model. The results in Table 10 confirmed that there were no severe inter-associations or inter-correlations among the continuous predictor variables tested. A VIF value of 1 indicates the absence of multicollinearity. Values greater than one suggest increasing multicollinearity. The result indicates the absence of severe multicollinearity since VIF values are less than 10.

Table 0.4: Variance Inflation Factor Test Results for Continuous Explanatory Variables

Variables	**VIF**	**1/VIF**
Age of household head squared	3.088	0.324
Farming experience of the household head	3.840	0.260
Interaction of gender and the farming experience of the household head	1.383	0.723
Dependency Ratio	1.110	0.901
Log of Years of Education of Household head	1.234	0.810
The education stock of the household	1.265	0.790
Adult Equivalent household size	1.524	0.656
Farm size	1.163	0.860
The number of groups a household belongs to	1.302	0.768
Interaction term for group membership and number of groups	1.157	0.864
Distance to Extension agent	1.087	0.920
Tropical Livestock Unit	1.011	0.989
Mean VIF	1.597	.

Source: Survey Data, 2024

The contingency coefficient measures the strength of the linear association of categorical and dummy variables. The result in Table 0.5 confirmed that there was no serious linear association among both the categorical and dummy variables since the contingency coefficient results were less than 0.75 for all the covariates. By rule of thumb, there was no severe association in all the proposed explanatory variables. Therefore, all the hypothesized variables were used for regression.

Table 0.5: Contingency Coefficient Test Results for Categorical and Dummy Explanatory Variables

Variables	Gender	Wealth index	Credit	Access to Training	Group Membership
Gender	1.000				
Wealth index	0.034	1.000			
Credit	0.013	-0.022	1.000		
Access to Training	0.069	-0.039	-0.006	1.000	
Group Membership	0.024	0.027	-0.113	0.031	1.000

Source: Survey Data, 2024

Heteroskedasticity, a state of non-constant variance of error terms across all observations, was tested through the white test as indicated in Table 0.6. The study preferred the white test as opposed to the Breusch-Pagan test, which only detects linear forms of heteroskedasticity, because the white test incorporates both the direction of change as well as the magnitude for non-linear forms of heteroskedasticity (Williams, 2015). Further, the white test is a special case of the Breusch-Pagan test since it's not sensitive to the deviation of errors from the normal distribution. The result indicates the model's residuals fail to reject the null hypothesis of homoskedasticity. The Heteroskedasticity, Skewness, and Kurtosis p-values of 0.0463, 0.0019, and 0.9069, respectively, imply no strong evidence of heteroskedasticity. However, robust standard errors were reported in subsequent analysis.

Table 0.6: Test for Heteroskedasticity

Source	χ^2	Df	*P*
Heteroskedasticity	112.59	89	0.0463
Skewness	31.16	12	0.0019
Kurtosis	0.01	1	0.9069
Total	143.77	102	0.0041
Prob > χ^2		0.0463	
χ^2 (89)		112.59	

Source: Survey Data, 2024

4.3.2.2 Econometric Results

The results for the Poisson regression model are presented in Table 0.7. A goodness of fit for Pearson and Deviance χ^2 estimated after regression had a value of χ^2 (286) =1.0000, which is not statistically significant, implying that the data fitted the model well. Further confirmation with the Negative Binomial model regression presented in Appendix II indicated the likelihood ratio test for alpha = 0 was not significant, indicating that the Poisson model was appropriate.

The study presents results of Poisson regression estimates in Table 0.7, where 10 factors were significantly associated with influencing the number of adaptation strategy packages adopted. They included: age squared of the household head, household dependency ratio, gender of the household head, interaction of gender and farming experience of the household head, log of years of education of household head, education stock of the household, wealth index for middle and poor, number of groups the household belonged and households who needed and didn't receive credit completely.

Table 0.7: Standard Poisson Results for Socio-Economic and Institutional Factors Affecting the Number of Adaptation Strategies Used

Variable	**Coefficients**	**Robust standard errors**	***P>Z***
Adult Equivalent household size	0.003	0.014	0.838
Age squared of the household head	-0.000 **	0.000	0.018
Age of household head in years	-0.003	0.003	0.339
Dependency Ratio	0.233 ***	0.040	0.000
Gender of household head (male)	0.177 **	0.077	0.021
Interaction of gender and the farming experience of the household head	-0.007 **	0.003	0.012
Farming experience of the household head in years	0.005	0.004	0.195
Log of Years of education of household head	-0.162 ***	0.019	0.000

Education stock of the household in years	0.041 ***	0.006	0.000
Wealth Index			
2. Middle	0.068 **	0.032	0.031
3. Poor	0.185 ***	0.037	0.000
Farm size	0.006	0.008	0.501
Tropical Livestock Unit	-0.002	0.009	0.796
Institutional Characteristics			
Distance to extension agents' office	-0.003	0.007	0.623
Annual Access to training	-0.009	0.028	0.752
Interaction of group membership and number of groups	-0.001	0.011	0.945
Group membership	-0.039	0.041	0.342
Number of groups a household belonged to	0.035 **	0.015	0.019
Household Access to Credit			
2. Received Amount Needed	0.030	0.032	0.350
3. Didn't receive the amount needed	0.007	0.035	0.850
4. Needed and didn't receive completely	-0.191 ***	0.038	0.000
Constant	1.305 ***	0.121	0.000

Notes: ***, **, * indicate significance at 1%, 5% and 10% levels, respectively. Since the goodness of fit chi-square is not statistically significant indicates that the Poisson Regression Model is a better model.

Source: Survey Data, 2024

Age squared of the household head was negatively associated with the number of adaptation strategy packages used at 5% level of significance. This finding suggests that as the age of the household head increases, the probability of taking up many adaptation strategy packages increases up to a particular age and then declines. The decline may be due to older household heads being risk-averse, having a short planning horizon, and not being willing to give up familiar strategies. This finding is concurrent with Aryal and Marenya (2021), who argued that the likelihood of adopting an ex-ante adaptation strategy increases with the age of the household head up to a certain age and then decreases.

The household dependency ratio had a significant and positive influence on the number of AS packages adopted at 1% significance level. The finding implies that higher dependency is associated with the likelihood of adopting more packages of AS. Explained differently, the dependency ratio increases the chances of a household taking up more packages to reduce pressure on the strained resources. Consequently, if more packages are not adopted, resource-constrained households with more dependents are likely to experience a decline in production. This result reemphasizes Kirui *et al*.'s (2022) position that household with a higher dependency ratio normally strain their assets to meet important needs.

Gender of the household head was positive and statistically significant in determining the number of AS packages taken up. Compared to households headed by females, male-headed households are more likely to take up a high number of AS packages due to more access and control over productive agricultural resources such as land. Further, a household headed by a male could imply more control by the male over financial resources, hence can make decisions on the packages that require substantial investment. The result may also imply that males still have exclusive dominant rights to make both short- and long-term farm investment decisions. The results are, however, contrary to Nhemachena and Hassan (2007), who revealed that female-headed households are more likely to adopt more strategies to climate change.

The interaction of gender and the farming experience of the household head was negative and significant at 5 percent. This can be interpreted as farming experience increases, male-headed households are likely to take up fewer AS packages relative to female-headed households. As the farming experience increases an indication of aging, there is a likelihood of reduced involvement in decision-making because of loss of energy. The implication of this is low adoption of adaptation packages. The finding agrees with Opiyo *et al.* (2016), who noted that there is a higher probability of female-headed households adopting adaptation strategies because of their involvement in many welfare activities of the households, which provides better experience on several farm-based production techniques.

The log of years of education of the household head was negative and significantly associated with the number of AS packages taken up. This finding implies that an increase in years of education is likely to reduce the proportion of the AS package adopted. Higher levels of education could imply more access to non-farm income-generating opportunities, which enable the agro-pastoralists to venture into new production pathways when they experience agroweather shocks. Further, agro-pastoralists with higher education are likely to pursue other high-paying jobs, which can cushion them during extreme weather shocks. This reemphasizes Wardekker *et al.* (2011)'s position that farmers with high income attributed to high education levels are less vulnerable to climate variability situations and may be less likely to respond through mitigation practices. In contrast, Gebre *et al.* (2023) found that educated farmers are more likely to be aware of climate variability and be more interested in taking up practices that improve their adaptive capacity.

The study's findings indicated that household education stock had a positive and significant association with the use of AS packages. In other words, the more educated the members of the household, the higher the demand for AS packages. Household education stock reflects the human capital of the household. Therefore, households with more educated members probably have more information on strategies to adopt against climate variability. A similar result was reported by Ochieng *et al.* (2016), who linked more years of education of the household head to a higher likelihood of adopting climate change adaptation strategies. This indicates that adaptation practices are information sensitive, and efforts should focus on promoting education that would enhance adaptation. Contrary to the findings, Qazlbash *et al.* (2020) reported that education decreased the level of adaptation among Pakistani communities. This was attributed to the increased dissemination of adaptation strategies among illiterate households.

The Poisson model results indicated that wealth indexes of the household were associated with the adoption of AS packages. More precisely, relative to the rich households, middle households were positive and significant at 5 percent. This can be interpreted that compared to rich households, middle households are likely to adopt more AS packages to climate variability. The results imply that rich households may be more likely to have other forms of survival, such as savings, which reduces their need to adopt the packages. Further, middle households may have limited resources, which increases their vulnerability to the effects of climate variability. Additionally, middle households may be aware of climate variability and therefore innovate strategies that suit their resource base. On the other hand, compared to the rich households, poor households are positively and significantly associated with AS packages at 1 percent. This implies that relative to rich households, poor households are more likely to take up many AS packages to cushion them against agroweather shocks. The finding highlights that poor households may likely regard themselves as being at greater risk and very vulnerable, and therefore adopt more packages compared to middle households. The results support earlier findings by Taylor *et al*. (2021), who established a negative relationship between farmers in the top wealth quartiles and adaptation capacity.

The number of household groups households belonged to was positive and significantly associated with the intensity of AS packages at 5 percent. In particular, the more the number of groups a household belonged to, the higher the likelihood of that household taking up more packages. This is likely the case since many groups facilitate the sharing of new knowledge, access to training and credit, discussing problems related to climate effects, and taking collaborative actions and decisions. Further, different groups provide information about agro-pastoralists who have previously adopted the strategies successfully, which in turn will encourage others to adopt the strategy. The increased likelihood of the agro-pastoralists to adopt the packages could imply that the groups acted as sources of information on adaptation to climate variability. Earlier research findings by Kimaru-Muchai *et al*. (2020) also showed that the number of groups to which a household belonged increased the adoption of response strategies. However, contrary to this study's finding, Musafiri *et al.* (2022) noted that the number of groups had a negative association with taking up of adaptation strategies. The study attributed negative effects to groups having specific objectives, ranging from commercialization and value addition as opposed to climate variability adaptation.

Financial capital, for households that needed and didn't receive credit, was negative and significantly associated with the number of AS packages. Relative to households that did not need credit, households that needed and didn't receive credit were likely to adopt fewer AS packages. The finding implies that households that needed and didn't receive credit have increased liquidity constraints and are priced out of purchasing important farm inputs. Further, the households cannot use capital-intensive packages as well as pay costs for labor-intensive practices. In other words, adopting the packages was more likely to be affected by the credit market imperfections. The findings mirrored Musafiri *et al.'s* (2022) position that credit access motivates farmers to take up strategies. However, this is only as long as the benefit of the practices supersedes other investment alternatives available to the agro-pastoralists.

In response to climate variability and its related negative effects, combinations of different practices are employed by different agro-pastoralist households in the study area. The practices are categorized into packages depending on their relatedness, as shown in Table 0.5. The determinant socio-economic and institutional factors that influence the choice of packages were modeled using the Multivariate Probit model, and the marginal effects results are presented in Table 0.8.

The results on the coefficient correlation of error in Table 0.8 are positive and significant for any pair of the packages. This implies that the packages adopted are positively correlated. Further, the rho's indicate complementarity between various packages. The log likelihood ratio test value indicates significant correlations $\chi^2 (133) = 544.11$; probability > $\chi^2 = 0.0000$, which supports the use of MVP as opposed to a univariate model, as agro-pastoralists use more than one AS package. The likelihood ratio test, therefore, affirms the assumption of interdependence between different packages adopted by agro-pastoralists.

Table 0.8: Marginal Effects from Multivariate Probit Model Results for Socio-Economic and Institutional Factors Affecting the Choice of Adaptation Strategies

Adaptation practices	**Risk**	**Cultural**	**Sustainable**	**Farm**	**Livestock**	**Diversification**	**Traditional**
Variable	**dy/dx**	**dy/dx**	**dy/dx**	**dy/dx**	**dy/dx**	**dy/dx**	**dy/dx**
Age of household head	-0.008	0.022	0.001	0.037 **	-0.004	-0.050 ***	0.053**
	(0.016)	(0.017)	(0.015)	(0.017)	(0.015)	(0.016)	(0.027)
Age squared of the	-0.000	-0.001 **	0.000	0.000	-0.001*	-0.000	0.001 **
household head	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age and age-squared	0.000	0.000	-0.000	-0.000	0.000 **	0.000	-0.000 ***
interaction	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dependency Ratio	0.260	-0.259	-0.527 **	0.581 **	-0.309	0.048	1.390 ***
	(0.261)	(0.263)	(0.241)	(0.257)	(0.251)	(0.259)	(0.380)
Gender of household	0.069	-0.198	-0.298 *	-0.057	0.048	-0.172	-0.126
head (male)	(0.168)	(0.166)	(0.165)	(0.162)	(0.160)	(0.163)	(0.269)
Log of Years of	-0.078	-0.012	-0.103	-0.431 ***	-0.441 ***	0.162	-0.216
education of household head	(0.156)	(0.139)	(0.138)	(0.131)	(0.138)	(0.132)	(0.201)
Education stock of the	0.004	0.041	0.018	0.069 **	0.054	0.096 **	-0.217 ***
household in years	(0.038)	(0.036)	(0.036)	(0.035)	(0.035)	(0.038)	(0.066)
Wealth Index dummy							
1. Rich	-0.112	0.330	-0.031	0.058	0.488 **	-0.155	0.477
	(0.243)	(0.249)	(0.246)	(0.245)	(0.243)	(0.233)	(0.408)

2. Middle	0.181	0.247	0.018	0.193	0.374 *	-0.283	0.181
	(0.238)	(0.232)	(0.234)	(0.229)	(0.223)	(0.226)	(0.397)
Farm size	0.023	-0.057	-0.003	0.026	-0.058	-0.115 **	0.068
	(0.052)	(0.047)	(0.044)	(0.045)	(0.046)	(0.048)	(0.061)
Tropical Livestock Unit	0.039	-0.171***	0.029	-0.078	-0.136 **	0.031	0.166
	(0.068)	(0.064)	(0.066)	(0.065)	(0.065)	(0.064)	(0.101)
Institutional Characteristics							
Annual Access to training	-0.004	0.108	-0.018	-0.124	-0.029	0.220	-0.133
	(0.186)	(0.183)	(0.176)	(0.178)	(0.190)	(0.180)	(0.287)
Group membership	-0.045	-0.029	0.525 **	0.083	0.142	-0.150	-0.950 **
	(0.267)	(0.274)	(0.266)	(0.273)	(0.269)	(0.297)	(0.481)
Group membership and the number of group households belong interaction	-0.020	0.036	0.044	0.094	-0.015	-0.151 **	0.156
	(0.070)	(0.084)	(0.082)	(0.074)	(0.072)	(0.081)	(0.116)
The number of groups a household belongs to	0.260 **	0.191 *	-0.071	0.391 ***	0.466 ***	0.427 ***	0.419 **
	(0.126)	(0.114)	(0.111)	(0.116)	(0.111)	(0.113)	(0.192)
Credit Access dummy							
1. Did not need credit	0.210	0.250	0.154	0.324 *	0.048	0.163	0.166
	(0.192)	(0.188)	(0.185)	(0.184)	(0.187)	(0.188)	(0.284)

2. Didn't receive the amount needed	0.219	-0.059	0.139	-0.194	0.039	0.223	-0.889 *
	(0.222)	(0.214)	(0.208)	(0.210)	(0.197)	(0.206)	(0.501)
Distance to extension agents' office	-0.012	-0.031	-0.002	0.004	-0.002	0.136 ***	-0.239 ***
	(0.047)	(0.043)	(0.043)	(0.045)	(0.048)	(0.044)	(0.080)
rho2	0.221 ***						
rho3	0.400 ***	0.213 ***					
rho4	0.246 ***	0.139 **	0.139 **				
rho5	0.371 ***	0.260 ***	0.216 ***	0.344 ***			
rho6	0.049	0.065	0.004	0.000	0.008		
rho7	-0.013	-0.014	-0.014	0.046	-0.057	-0.076	
Observations				308			
Log Likelihood				-979.432			
Wald χ^2 (133)				544.11			
Prob > χ^2				0.0000			

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho32 = rho42 = rho52 = rho62 = rho72 = rho43 = rho53 = rho63 = rho73 = rho54 = rho64 = rho74 = rho65 = rho75 = rho76 = 0: χ^2 (21) = 149.358   Prob > χ^2 = 0.000

Note: ***, **, * indicates Significant at 1%, 5% and 10% probability level, respectively; Marginal effects (dy/dx); Figures in parenthesis represent *p*-values

Source: Survey Data, 2024

The age of the household head was statistically significant with a positive and a negative coefficient. The positive sign implies that it has a positive influence on adopting a strategy for climate change. As the age of the household head increases by one year, the probability of the household head taking up farm management practices as an adaptation strategy increases by 3.7% with a p-value of 0.035, keeping other variables constant. Similarly, a one-year increase in age of the household head, the probability of an agro-pastoralist using traditional practices as an adaptation strategy increases by 5.3% with a p-value of 0.047, keeping other variables constant. The higher likelihood of the use of the practices may be attributed to older agro-pastoralists' tendency to get used to a particular way of adapting to climate shocks. Further, farm and traditional strategies are local adaptations that are based on copied experiences learned over time and which are passed on from generation to generation. The finding is similar to Challa and Tilahun (2014), who argued that the age of agro-pastoralists increased the probability of taking up climate response strategies due to their farming experience. The results further show that as the age of the household head increases by one year, the probability of not using diversification practices as an adaptation strategy decreases by 5.0% with a p-value of 0.002, keeping other variables constant. The finding implies that older agro-pastoralists are less educated, which may limit the information about different practices. Additionally, they may be more risk-averse and less energetic, which reduces their likelihood of adopting diversified practices. A similar position was reported by Bernier *et al.* (2015), who noted that age had a negative association with adaptation to climate variability due to low education levels and more risk aversion of older agro-pastoralists.

The results of the analysis reveal that the age squared of the household head had a negative and significant influence on using cultural farm and livestock management practices. Each additional year increase in the age squared of the household head is associated with reduced use of cultural farm and livestock management practices by both 0.1% with p-value of 0.041 and 0.074, respectively, holding other variables constant. Likewise, a one-unit increase in age squared of the household head resulted in a 0.1% increase in the probability of agro-pastoralists using traditional practices as an adaptation strategy, with a p-value of 0.042. The interaction between age and age squared of the household head had a significant and positive influence on livestock management practices and a negative influence on traditional practices. A one-unit increase in the combined effect resulted in a 0% increase in the probability of agro-pastoralists using livestock management practices, with a p-value of 0.045, holding other covariates constant. The findings appear to imply that as age increases, initially the use of the packages decreases, but after a certain age, the use increases. In other words, as the age increases, there is a high probability of continued adoption of a particular familiar package. Presumably, the result indicates that old agro-pastoralists are likely to be less familiar with new adaptation practices, which may limit their access to current strategies. The result indicates that an increase in the combined effect reduced the probability of adoption of traditional practices by 0% with a p-value of 0.008. This could imply that old agro-pastoralists are initially likely to adopt these practices at an increasing rate, then reduce their use at some point. A plausible explanation could be that old agro-pastoralists have accumulated vast experience over the years, and therefore, they tend to be cautious of their effect in handling climate shocks.

Household dependency ratio was another regressor that was statistically significant in the model, indicating that agro-pastoralists' use of adaptation strategy to climate variability is significantly influenced by household dependency ratio. A one unit increase in the number of dependents in the household resulted in a 52.7% decrease in the probability of agro-pastoralists' using sustainable agricultural practices as a package of adaptation strategy, with a p-value of 0.028, holding other variables constant. Children and the elderly are more likely to be economically less active and are likely to represent an economic burden to the active economic members of households. A high dependency ratio will increase the demand for basic needs, which burdens the economically active household members. The resources produced by economically active members are more likely to be channeled to meeting demand for basic needs instead of investment in sustainable agricultural practices. The findings of this study are in line with Amusa *et al.* (2015), who reported that high dependents may reduce the number of economically active members in the household and consequently have low adaptive capacity to climate variability. The results further indicate that a unit increase in the number of dependents in a household resulted in a 58.1% and 139% increase in the probability of agro-pastoralists implementing farm management and traditional practices, with p-values of 0.024 and 0.000, respectively. This implies that the higher the number of dependent persons within the household, the more likely the household will adopt farm management and traditional practices. The strategies are presumably more likely to be adopted based on accumulated knowledge and experience, which do not require substantial resource investment.

The gender of the household head negatively influenced taking up of sustainable agricultural practices. The probability of a household headed by a male adopting sustainable agricultural practices was reduced by 29.8% with a p-value of 0.071, than female-headed households. The finding contradicts previous literature that male dominates productive agricultural resources and may be more likely attributed to female empowerment in the study area. Currently, a good number of agricultural empowerment programs target women (Diiro *et al*., 2018), and this increases the adoption of good agricultural practices among female agro-pastoralists. The finding recognizes the vital responsibility of female agro-pastoralists to adapt to climate change and sustainable agricultural practices. A similar result was reported by Musafiri *et al.* (2022), where the propensity of females who adopted sustainable practices was higher than males.

The findings of this study showed that the log of the household head's education had a negative influence on the choice of farm and livestock management practices as AS packages. Precisely, a one percent increase in years of education decreases the probability of adopting farm and livestock management practices by 43.1% and 44.1% with both p-values of 0.001. The finding contradicts previous literature that education increases the ability to acquire, analyze, and interpret information, which may influence the adoption of strategies and could be more likely attributed to agro-pastoralists' loyalty to their obsolete traditional strategies that have enabled their survival during extreme climate variability events. Higher education level may more likely enhance access to off-farm income-generating opportunities, which may reduce the likelihood of adopting strategies that require more resources to implement. This is contrary to Mihiretu *et al.* (2019), where the education level of farmers increased the probability of using agro-ecological and livestock productivity practices as strategies to climate change.

Household education stock influence on adaptation to climate change is two-fold; In fold one, household education stock had a positive and significant influence on the use of farm management and diversification practices; hence each additional unit increase in household's education stock results in 6.9% and 9.6% increase in probability of using farm management and diversification practices with p-value of 0.050 and 0.012 respectively. Likewise, it had a negative and significant influence on the adoption of traditional practices. Each additional unit increase in household education stock results in a 21.7% decrease in the probability of taking up traditional practices, with a p-value of 0.001, holding other variables constant. Higher education stock of household members enhances information access and influences the decision to take up adaptation practices. Further, education may more likely expose agropastoral households to new experiences, which could increase their access to current adaptation technologies, which may positively influence their risk-averse character. Similar results were reported by Getahun *et al.* (2021), who indicated that education positively influences the decision of farmers to adopt climate change response actions.

The study's findings reveal that the wealth index dummy had a positive and significant influence on the use of livestock management practices. Households in the middle wealth group have a higher probability of 48.8% of using livestock management practices as a package for adapting to climate change, with a p-value of 0.044, relative to poor households, keeping other variables constant. Likewise, households in the rich wealth group have a higher probability of 37.4% of using livestock management practice, with a p-value of 0.093, compared to poor households. The finding could imply that rich and middle households have more assets are more likely to implement livestock practices than poor households with fewer assets. Additionally, agro-pastoralist households regard livestock as assets; therefore, strategies that favor livestock are more likely to be prioritized over other strategies. With regards to poor households, during extreme climate events, they are more likely to prefer non-farm activities, which reduces their propensity to use livestock management practices, which are regarded as long-term strategies that might not provide an immediate cushion against agroweather shocks. This finding is in line with Kidane *et al.* (2019), who indicated that poor farmers favor non-farm income strategies during extreme drought times.

The number of agro-pastoralists' farm size had a negative and significant influence on the choice of adaptation package to climate change. As household farm size reduces by one acre, the probability of agro-pastoralists adopting diversification practices reduces by 11.5% with a p-value of 0.016, holding other variables constant. Diversification practices require large farm size, and therefore, agro-pastoralists with small farm sizes are more likely to be constrained from implementing the practice. Further, agro-pastoralists with small farm sizes are less likely to benefit from economies of scale and therefore more likely not implement diversified practices. A small farm size is less likely to allow prior trials on the proposed diversified practices, which reduces risk and affirms the significance of the practice before full-scale implementation. The finding of the study affirms Khan *et al.* (2020) and Mihiretu *et al.* (2019)'s position that farmers who have access to large farming land are more likely to take adaptation decisions because they have resources(land) to implement adaptation practices.

The finding of the marginal effect indicates that tropical livestock unit reduced the probability of adopting cultural farm and livestock management practices by 17.1% and 13.6% with p-values of 0.007 and 0.036, respectively. The finding suggests that higher livestock holding is more likely to utilize important farm resources such as land and capital and may reduce the likelihood of economic impact realized when cultural farm and livestock management practices are adopted. Furthermore, livestock management and cultural farm practices are labor-intensive, and a high livestock holding may presumably reduce the labor allocated to the practices. Higher TLU is more likely to increase demand for grazing space, thus reducing the likelihood of adopting the practices to create space for livestock grazing. This finding contradicts Musafiri *et al.* (2022), who argued that TLU positively influenced livestock-crop integration uptake.

The results indicate that group membership was statistically significant with positive and negative coefficients. The positive influence implies that households belonging to a group are more likely to adopt a strategy for climate change. Precisely, group membership increases the likelihood of taking up sustainable agricultural practices by 52.5%, with a p-value of 0.049, relative to households that are not group members, holding other variables constant. Likewise, group membership reduces the probability of using traditional practices by 9.5%, with a p-value of 0.048, compared to households that are not group members. Membership in a farmer organization is more likely to enhance awareness and define how agro-pastoralists process and understand information related to sustainable agricultural practices. Groups facilitate access to credit, training, and workshops where stakeholders gather and share ideas. Additionally, the groups assist members in understanding the usefulness of sustainable agricultural practices regarding climate change. A similar result was reported by Amare and Simane (2017) that social capital proxy for group, improves awareness and adoption of climate adaptation strategies. The negative effect could be attributed to agro-pastoralists receiving information that relates only to sustainable agricultural practices, but regarding traditional practices, the information is more likely to be limited.

The results of the marginal effect of the model indicate that the interaction between group membership and the number of groups agro-pastoralists belonged was significant and negative. The negative influence suggests that being a member of an agricultural group initially increases strategy use; however, belonging to many groups may decrease the probability of using a strategy. Precisely, each additional group to which agro-pastoralists belonged results in a 15.1% decrease in the probability of using diversification practices, with a p-value of 0.063, holding other variables constant. Households that belong to many groups may possibly spend much of their financial resources and a significant amount of time in group activities, which may reduce the likelihood of diversifying farm practices. Many local farmer groups may likely promote specialization and carry out similar farming practices, which is likely to discourage diversification of farming practices. Further, the substitution effect of many groups could imply that agro-pastoralists are likely to rely on knowledge shared on farming practices as opposed to developing personal innovative practices. The finding contradicts Zampaligré and Fuchs (2019), who noted that membership in a farmer group increases access to information, knowledge, and training required to adopt emerging strategies.

The number of groups had a positive impact and significantly affected the choice of package on climate change. For each additional group that agro-pastoralists joined, the probability of using the risk reduction practice package increased by 26% with the p-value of 0.039, holding other variables constant. In addition, each additional group agro-pastoralist household joined, the probability of taking up cultural farm, farm management, livestock management, diversification and traditional practices increases by 19.1% with the p-value of 0.094, 39.1% with the p-value 0.001, 46.6% with the p-value 0.000, 42.7% with the p-value 0.000 and 41.9% with the p-value of 0.029 respectively, keeping other variables constant. This indicates the importance of group heterogeneity in enabling agro-pastoralists to adopt a variety of practices. The level of group heterogeneity is an indication of a high level of diversity among group members. Further, heterogeneity is likely to determine the quality and variety of knowledge, information, and experiences exchanged among group members during meetings. This finding agrees with the study result reported by Mbaziira *et al.* (2023) in Uganda, where membership in associations increases access to information on crop and livestock practices, which are responsible for improving adaptive capacity.

The financial capital dummy was significant with positive and negative influences on the adoption of adaptation packages. Precisely, if agro-pastoralists did not need credit, then the probability of adapting farm management practices would increase by 32.4% with a p-value of 0.079. The finding highlights that sufficient financial capital is more likely to increase the adoption of practices due to the possibility of overcoming financial constraints, which might hinder adoption. Further, households who didn’t need credit are more likely to have diversified sources of income and savings, which provide resources to finance farm management practices. The positive influence affirms the earlier conclusion by Asayetegn *et al.* (2017) that the choice of a good combination of adaptation strategies is high among farmers with sufficient income. Further, for households that didn't receive the amount needed, their probability of using traditional practices decreased by 88.9% with a p-value of 0.076. This could be attributed to households' preference to use strategies that are highly cost-effective compared to traditional practices. Access to sufficient and affordable credit increases the financial capital of agro-pastoralists, which helps in overcoming the transaction costs related to various adaptation practices to be adopted (Berman, 2014).

Finally, the findings of this study indicate that distance to extension agents' offices had a positive and negative influence on adaptation options. A one-unit increase in distance to the extension agents' office by one kilometer results in a 13.6% increase in probability of adopting diversification practices, with a p-value of 0.002. The result could imply that agro-pastoralists who are far away from the extension office are more self-reliant, more responsive to adopting different strategies when reached, and might have received targeted interventions. Likewise, the marginal effect results indicate that a one-unit decrease in distance to extension agents' office by one kilometer reduces the probability of taking up traditional practices by 23.9% with the p-value 0.003, keeping other variables constant. The result could be attributed to the short distance increasing frequency of contact with extension agents who are more likely to provide training, essential information, and knowledge concerning new adaptation strategies. Further, a shorter distance would increase the probability of accessing essential inputs required for enhanced adaptation. It is presumed that a short distance is more likely to reduce transport and transaction costs and increase the incentive to participate in agricultural extension activities. A similar result was reported by Zagre *et al.* (2024), that the adoption of improved varieties was adversely affected by distance to the extension agents' office.

4.0 Conclusion

Despite the significance of adopting multiple bundles of strategies to mitigate climate change-related shocks, most of the respondents adopted factors with at least four practices due to limited money, which was a major constraint to taking up the practices. The monetary constraint limits the ability of already poor agro-pastoralists to acquire the resources needed to adopt the strategies.

Further, the adoption of AS packages reduces the negative impact of climate variability on agricultural production. The findings from the study suggest that agro-pastoralists respond to climate variability by adopting adaptation strategy packages as both ex-ante and ex-post risk mitigation strategies. Additionally, agro-pastoralists do not use the packages independently. Instead, the packages are used as complements to enhance agricultural production and, indirectly, increase income and resilience of the households. The study established that using packages as complements reduces households' vulnerability to climate shocks. The findings justify the possibility of AS packages mitigating risks associated with climate change as propounded in the literature. The results affirm a national agricultural policy that promotes the dissemination and continued adoption of multiple adaptation strategy packages.

CHAPTER FIVE

THE EFFECT OF ADAPTATION STATEGIES ON RESILIENCE TO CLIMATE VARIABILITY AMONG AGRO-PASTORALISTS

Abstract

Climate change poses significant challenges for agricultural systems in Africa, particularly affecting agro-pastoral communities dependent on crops and livestock for their livelihoods. This study investigates the impact of response strategies on climate resilience among agro-pastoral communities in Laikipia County, Kenya. It applies the Food and Agriculture Organization's RIMA-II framework to analyze data collected from 308 households selected through multistage sampling. Principal Component Analysis is used to calculate resilience pillars, and Structural Equation Modeling (SEM) with instrumental variable regression (IVR) to estimate the Climate Resilience Index while addressing potential endogeneity. Our findings reveal that household resilience is significantly influenced by three key pillars: access to basic services ($\beta = 1.643$, $p < 0.05$), assets ($\beta = -3.422$, $p < 0.01$), and adaptive capacity ($\beta = -4.034$, $p < 0.01$). Farm risk reduction practices, diversification strategies, and access to agro-weather information demonstrated strong positive associations with increased resilience, while households with higher education levels and larger adult equivalent size showed greater capacity to implement effective adaptation strategies. The study contributes to the literature on climate resilience by providing empirical evidence on the effectiveness of specific adaptation strategies. Policies aimed at improving access to basic services, promoting agricultural diversification, and strengthening education and information systems could significantly boost the resilience of agro-pastoral communities in similar arid and semi-arid regions.

5.1 Introduction

Climate change poses unprecedented challenges to agricultural systems in arid and semi-arid lands (ASALs), manifesting through increased frequency and severity of extreme weather events such as floods, droughts, and erratic rainfall patterns (Ayugi *et al*., 2020; MoALF, 2016). These challenges are precisely severe in Sub-Saharan Africa (SSA), where high dependence on rainfed agriculture, coupled with weak adaptive capacity and widespread poverty, amplifies vulnerability to climate shocks (FAO, 2021). The impacts are especially severe for agro-pastoral communities, who face declining crop yields, increased livestock mortality, and growing food insecurity (Debela *et al*., 2019).

Adaptation strategies have emerged as crucial mechanisms for building resilience and reducing vulnerability to climate-related shocks. These strategies encompass a range of practices, from farm-level interventions to broader socio-economic adjustments, aimed at maintaining agricultural productivity and food security in the face of climate variability (Belay *et al.,* 2005; Nyong *et al.,* 2007). According to Ouédraogo *et al.* (2016), Richards *et al.* (2016), Richards (2019), and Cacho *et al.* (2020), some policy packages promote adaptation through investments in irrigation facilities, use of heat- and drought-tolerant crop varieties, and adjusting planting dates and crop mixes in sub-Saharan Africa.

Moreover, the negative impacts of climate variability and change in East African states have made it important to explore strategies such as intercropping, minimum tillage, crop rotation, index-based insurance, mulching, use of mineral fertilizers and organic manure, water harvesting and storage, livestock management and agroforestry by majority of farmers despite their need for more financial investment (Akinyi *et al.,* 2021; FAO *et al.,* 2018). According to the World Bank (2019b), agriculture accounts for 56% of employment opportunities and 30% of GDP in Kenya despite the adverse effects of climate change. To mitigate these effects, adaptation strategies not limited to crop rotation, shifting planting time, planting drought-tolerant crop varieties, crop diversification, sowing early maturing crop varieties, and use of water harvesting techniques and irrigation (Arya *et al*., 2021; De Pinto *et al*., 2019; Kabubo-Mariara & Mulwa, 2019; Kogo *et al*., 2020; Mairura *et al*., 2021; Musafiri *et al*., 2021) have been adopted. However, while this clearly indicates the importance of adaptation, there remains limited empirical evidence on how specific adaptation strategies contribute to building household resilience, particularly in ASAL regions (Harvey *et al.,* 2018).

Resilience, defined as the capacity of systems to absorb disturbance while maintaining essential functions, has become a central concept in climate change adaptation discourse (Walker *et al*., 2002). The Food and Agriculture Organization (FAO) operationalizes resilience through four key pillars: social safety nets, access to basic services, assets, and adaptive capacity (FAO, 2016). This framework provides a comprehensive approach to understanding and measuring resilience, particularly in agricultural contexts where multiple factors influence households' ability to withstand and recover from climate shocks (Alinovi *et al.,* 2008).

In Kenya's ASALs, which comprise 89% of the landmass in the country and host 38% of its population, the need for effective resilience-building strategies is particularly pressing (Government of Kenya, 2018). These regions face frequent droughts, unpredictable rainfall, and rising temperatures, threatening the livelihoods of agro-pastoral communities. While several adaptation strategies have been promoted in these areas, there is limited understanding of their effectiveness in enhancing household resilience to climate shocks (Alfani *et al.*, 2015).

This study addresses this knowledge gap by evaluating the effects of adaptation strategy packages on building household resilience to agroweather-related shocks in Laikipia-West Sub-County, Kenya. Using the FAO's RIMA-II framework, we assess how different combinations of adaptation strategies contribute to household resilience across the four resilience pillars. Our analysis focuses particularly on autonomous adaptation strategies, which are locally developed and implemented by households in response to experienced climate variability (Nelson *et al.*, 2007).

The study makes several significant contributions to the literature on climate resilience. First, it provides empirical evidence on the effectiveness of specific adaptation strategies in building resilience, moving beyond theoretical frameworks to practical applications. Second, it employs a comprehensive methodology that captures both the direct and indirect effects of adaptation strategies on household resilience. Finally, it offers insights into the relative importance of different resilience pillars in the context of ASALs, informing more targeted interventions for building climate resilience (Grasham *et al.*, 2021).

The remainder of the sections are as follows: methodology, including the study area, research design, sampling procedure, sample size determination and data collection, and analytical framework. The section that follows discusses the results, focusing on the relationship between adaptation strategies and resilience outcomes and a discussion of the findings and their implications for policy and practice, while the last section concludes with recommendations for enhancing climate resilience in ASAL regions.

5.2 Methodology

5.2.1 Study Area, Research Design, Sampling Procedure, Sample Size Determination, and Data Collection and Analysis

The research was carried out in arid and semi-arid areas of Laikipia West sub-county (refer to section 3.2.1). The research design was a cross-sectional quantitative research design as detailed in (section 3.2.2). The sampling procedure was a multi-stage sampling technique, and respondents were chosen using simple random sampling as discussed in (Section 3.2.3). The sample size was determined using Yamane's (1967) method and distributed proportionally across the five wards as outlined in (section 3.2.4). The data was collected was cleaned, coded, and analyzed following the procedure as outlined in (section 3.2.5).

5.2.2 Analytical Framework

The analytical framework involved four main steps: (1) Factor Analysis (FA) to cluster adaptation strategies; (2) Principal Component Analysis (PCA) to construct resilience pillars; (3) Structural Equation Modeling (SEM) to estimate the Climate Resilience Index (CRI); and (4) Instrumental Variable (IV) regression to assess the causal effects of adaptation strategies on resilience, addressing potential endogeneity. Despite mentioning FA, a full discussion has been done in Chapter Three.

5.2.2.1 Principal Component Analysis (PCA) for Resilience Pillars

To measure the resilience levels of agro-pastoralists, a composite climate resilience index (CRI) was employed. The CRI is calculated as a function of four pillars: access to basic services (ABS), assets (AST), social safety nets (SSN), and adaptive capacity (AC), following the RIMA-II approach (FAO, 2016). The RIMA-II framework differentiates two types of proxies; the first is descriptive, which, according to Alinovi *et al.* (2008, 2010), implies that a household's resilience is a complex concept dependent on a combination of factors, known as pillars. It aims to rank households. The second is inferential, which assesses determinants of resilience. Further, the descriptive analysis is also a two-part procedure. The first part employs PCA to estimate resilience pillars from a set of observed variables. PCA was preferred to FA because the study applied Kaiser-Meyer Olkin statistics to measure the sampling adequacy of the data, and values above 0.5 were considered as a model selection criterion (Field, 2013). Further, Kaiser's criterion rule (Kaiser, 1960) of eigenvalue greater than 1 was used to select components, and observed covariates were estimated for each pillar as a product of component loading and explained variation of components (Adane, 2018). The study reports the first and second components except for the asset pillar, where only the first component is reported since it was highly appropriate in determining the pillars.

5.2.2.2 Structural Equation Modeling (SEM) and Climate Resilience Index (CRI)

In step two, CRI is estimated through a structural equation model (SEM). A SEM is a system of equations that can be visualized by a graphical path diagram. The nodes represent variables with rounds for latent variables (LVs), squares for manifest variables (MVs), and arcs for the model causality. SEM employs the Multiple Indicators Multiple Causes model (MIMIC) to explain the relationship between manifest variables (MV), latent variables (LV), and indicators of food security (D'Errico *et al.*, 2020; FAO, 2016; Nasr *et al.*, 2021). In this study, the indicators of food security used in the MIMIC model are the Food Insecurity Experience Scale (FIES), food expenditure, and household dietary diversity score (HDDS). The main reason for employing the MIMIC model in step two is due to its ability to allow for the inclusion of indicators of food security in the measurement part of estimation. Therefore, the CRI is simultaneously linked to the indicators of food security (Bruck *et al.,* 2019). Mathematically, the classical MIMIC model employed for the RIMA-II analysis in the study is given as:

$$\begin{aligned} y_1 &= \beta_o + \beta_1\delta + \varepsilon_1 \\ y_2 &= \beta_o + \beta_2\delta + \varepsilon_2 \\ &\vdots \\ y_n &= \beta_o + \beta_n\delta + \varepsilon_n \end{aligned} \tag{5.1}$$

with,

$$\delta = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + ... + \alpha_n x_k + \omega \tag{5.2}$$

where δ is the latent variable (resilience),y_1, y_2, y_3 -- y_n Are multiple indicators linearly related to δ (food security outcome),x_1 , x_2 -- x_k Are the multiple causes linearly related to δ (the pillars of resilience), and ω represents Berkson error.

The path diagram on the MIMIC model in Figure 0.1 is a model that forms the basis for CRI analysis. From Figure 0.1, the measurement equation (5.1) shows that the observed indicators of food security are imperfect indicators of resilience capacity, and the structural equation (5.2), which correlates the approximated attributes of resilience (DFID (Department for International Development) 2013).

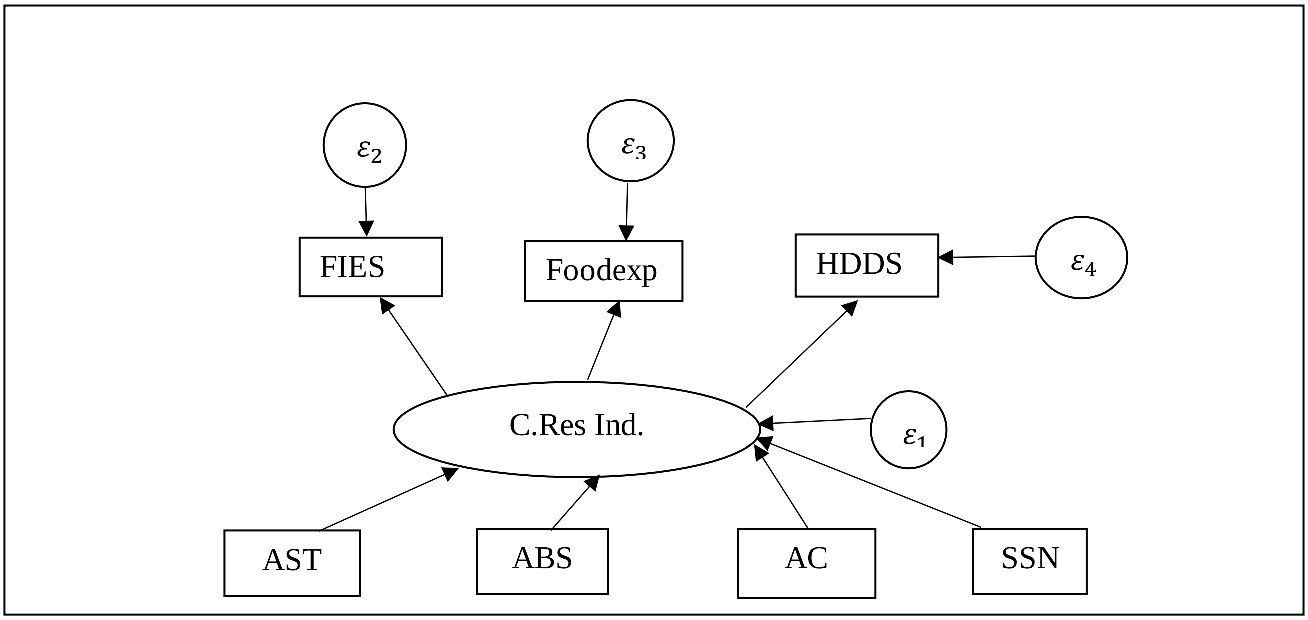

Figure 0.1: Resilience Path Diagram

Source: Adopted from FAO (2016) and Modified

Key: Assets (AST), Access to basic services (ABS), Social safety nets (SSN), Adaptive capacity (AC), Food insecurity experience scale (FIES), Food expenditure (Foodexp), Household dietary diversity score (HDDS), Climate Resilience Index (C. Res Ind.)

The climate resilience index for the household was thereafter rescaled to the zero to one range using the min-max method (Giuseppe *et al*., 2016; Nahid *et al*., 2021; Tambo, 216). Rescaling of the index helps in easier interpretation of regression results, evaluating the effect, and easier establishment of the cut-offs that are similar and valid across countries. Higher scores of the climate resilience index would indicate that the household is more resilient and vice versa (Boukary *et al.*, 2016). According to FAO (2016), to determine whether resilience has increased or decreased, effect determinants are regressed against the resilience score. Therefore,

$$CRI_1 = \frac{S_1 - S_{min}}{S_{max} - S_{min}} \quad (5.3)$$

where CRI_1 is the transformed climate resilience index, $S_1$is the untransformed climate resilience index and S_{max} and S_{min} Represents the climate resilience index not changed.

5.2.2.3 Instrumental Variable (IV) Regression Analysis

Agro-pastoralists who use adaptation strategies may be systematically different from those who do not use the strategies with respect to observed and unobserved characteristics (Asiimwe *et al.*, 2020). Further, there may be unobservable factors other than the explanatory variables in the model that affect resilience and adaptation, which may lead to an endogeneity problem, biasing and making the parameter estimates. The instrumental variable regression method was used to address the potential endogeneity problem. The Durbin-Wu-Hausman test was implemented to check the existence of the endogeneity problem. Further, Kleibergen's and Hansen's statistics were used to check under- and over-identification, respectively, of the model. Additionally, Kleibergen's F-statistic was applied to check the instruments' diagnostic validity tests.

A good instrument must be correlated with adaptation but not directly with resilience (Chege *et al.*, 2015). According to Gbetibouo (2009), adaptation to climate variability involves two stages: perception and adaptation. This study, therefore, used perception of climate variability shocks as one of the instruments since it can only affect resilience through the adaptation strategy adopted. Additionally, the study also used knowledge and experience of various climate adaptation phenomena as instruments. Therefore, the IV regression is given as:

$$Y_1 = \beta_1 y_2 + \beta_2 X_i + \varepsilon_1 \tag{5.4}$$

$$y_2 = P_i \delta_1 + \delta_2 X_i + \varepsilon_2 \tag{5.5}$$

where;

Y_1 is the resilience of agro-pastoralists to climate variability, y_2 is the use of an adaptation strategy, Package with parameter estimate β_1, X_i indicates individual agro-pastoralists' household-level control variables with parameter estimates β_2. P_i, is the perception on the severity of livestock parasites and diseases, conflicts, and awareness about climate variability adaptation with parameter estimate δ_1 , ε_1 and ε_2 Are the error terms with zero means and nonzero correlations?

5.2.3.1 Description of Variables

The description of variables used in econometric estimation is provided in .

Table *0.1*. The choice of the variables was informed by empirical literature. Further, the description involves how each of the variables was measured.

Table 0.1: Description of Variables for Instrumental Variable Regression Model

Variable	Description	Measurement
Dependent Variable		
CRI	Climate Resilience Index	Continuous (from 0 to 1)
Endogenous variables		
Risk	Farm risk reduction practices	Dummy, 1=Yes, 0= No
Livestock	Livestock management practices	Dummy, 1=Yes, 0= No
Diversification	Diversification practices	Dummy, 1=Yes, 0= No
Instrumental Variables		
Awareness parameters		
Awareness	Awareness about climate variability	Dummy, 1=Yes, 0= No
Awareness drought	Awareness about adaptation strategies to drought	Dummy, 1=Yes, 0= No

Awareness rainfall	Awareness about adaptation strategies to rainfall changes	Dummy, 1=Yes, 0= No
Awareness of crop pests	Awareness about adaptation strategies to crop pests and diseases	Dummy, 1=Yes, 0= No
Awareness of livestock parasites	Awareness about adaptation strategies to livestock parasites & diseases	Dummy, 1=Yes, 0= No
Experience parameters		
Conflict	Household experience agro-pastoral conflict	Dummy, 1=Yes, 0= No
Drought	Household experiences drought	Dummy, 1=Yes, 0= No
Crop pest	Household experiences crop pests & diseases	Dummy, 1=Yes, 0= No
Livestock parasite	Household experiences livestock parasites & diseases	Dummy, 1=Yes, 0= No
Perception of agroweather shocks		
Drought severity	Perceived drought severity	Perceived drought severity=1, 0=otherwise
Livestock parasite & disease severity	Perceived livestock parasites & diseases severity	Perceived livestock parasite & disease=1,0=otherwise
Exogenous control variables		
Age	Age of household head in years	Continuous
Ages squared	Age squared of the household head	Continuous
Gender	Gender of household head	Dummy, 1= Male, 0= Female
Household size	Household size (Adult equivalent)	Continuous

Head's education	Household head's education (years of schooling)	Continuous
Education stock	The education stock of the household	Continuous
Agroweather information	The household received agroweather information	Dummy, 1= Yes, 0= No

5.3 Results and Discussion.

5.3.1 Component Loading of Variables Determining Resilience Pillars.

The study computed resilience using four pillars, ABS, A, SSN, and AC as propounded in the RIMA-II framework. This is an attempt by the study to operationalize absorptive, adaptive, and transformative capacity. Further, RIMA-II methodology allows modeling of the effects of different mitigation strategies on households' resilience when faced with different agroweather shocks. The loadings of component indicators used to compute manifest variables are shown in the tables below. The decision rule by Kaiser (1960) was used to retain components with eigenvalues equal to or greater than one and their component loadings reported. Additionally, Kaiser-Meyer-Olkin statistics were applied, and the results showed that all the pillars had values above 0.5. The study reported the first and second components, except for the asset pillar, where only the first component was reported, since they were highly appropriate in determining the pillars.

5.3.1.1 Access to Basic Services

The manifest variable access to basic services (ABS) was composed of access to water, access to education, access to health services, access to crop and livestock market, and access to transport services, and results are presented in Table 0.2. All these variables were measured in minutes for the duration taken to reach the destinations of interest. The first and second component loadings were retained because they had an eigenvalue greater than one, which makes the components more relevant in determining the pillar. In component one, access to transport services, crop market, and health services contributed more to access to basic services to a relatively higher degree than access to education, water, and livestock market. Likewise, from component two, access to the livestock market contributed the highest to ABS compared to other variables. This finding suggests that agro-pastoralists who can obtain public basic services are more likely to have better access to information and be more resilient than those who lack such services. A Similar finding was reported by Alinovi *et al.* (2010), who noted that access to basic infrastructure contributes significantly to household resilience to various shocks due to the ability to access assets. Poor physical infrastructure inhibits access to basic services such as health and may likely contribute to socioeconomic marginalization in society (Gerlitz *et al.*, 2014).

Table 0.2: Component Loadings for Access to Basic Services Pillar

Variable	Comp1	Comp2
Distance (minutes)		
To the closest water source	0.337	-0.602
To the closest school	0.355	-0.257
To the closest public hospital	0.451	0.161
To the closest livestock market	0.212	0.720
To the closest crop market	0.477	0.163
To the closest public transport	0.533	-0.016

Source: Survey Data, 2024

5.3.1.2 Assets

In the asset pillar, the first component was reported since it had an eigenvalue greater than one and was, therefore, most relevant in defining the pillar, as shown in Table 0.3. The pillar comprises of agricultural and nonagricultural asset index. The agricultural asset index was defined by variables such as farm size, tropical livestock unit, agricultural wealth index, total crop harvested, and agricultural input use. Farm size, tropical livestock unit, and total crop harvest positively influenced the agricultural asset index to a similar degree, which may be attributed to agro-pastoralist households in the study area's reliance on agricultural production.

The nonagricultural asset index included: the number of cars, bicycles, and mobile phones. Mobile phones and bicycles contributed most to the index, which may be attributed to the need for information access, dissemination, and affordable transport means to access essential services like health, education, and the market. Interestingly, the results indicate that the agricultural and nonagricultural asset index positively contributed to the agro-pastoralists' asset pillar, and their loadings were similar, implying equal effect. Agricultural assets such as farm size and tropical livestock units signify wealth and are significant factors affecting a household's resilience to shocks. Additionally, they are likely to present an opportunity for income diversification, such as crop-livestock integration, and prioritize investments that are long-term; this is more likely to improve resilience against shocks. Results by Tesso *et al*. (2012) in central Ethiopia reported similar findings that access to natural resources, like farm size, enhances communities' resilience against the effects of shocks. Similar results were also reported by d'Errico *et al.* (2018) in Uganda and Tanzania, where wealth index and tropical livestock unit were the most important variables in the asset pillar.

Table 0.3: Component Loadings for Asset Pillar

Variable	Comp1
Agricultural asset index	
Farm Size	0.474
TLU	0.486
Agricultural Wealth Index	0.451
Total Crop Harvest	0.491
Agricultural Input Use	0.308
Non-agricultural asset index	
Number of cars	0.418
Number of bicycles	0.601
Number of mobile phones	0.682
Asset Pillar	
Nonagricultural asset index	0.707
Agricultural asset index	0.707

Source: Survey Data, 2024

5.3.1.3 Adaptive Capacity

Adaptive capacity was estimated by variables such as years of education of the household head, household head literacy level, average years of education of members of working age, years of education of household member with the highest education, household income portfolio, main source of income, and different types of crops grown, and the results are presented in Table 0.4. The result shows that in component one, years of education of the household head and years of education of the household member with the highest education contributed positively and with the highest score to the pillar. The result implies that education is likely to provide knowledge and skills to agro-pastoralists and increase their ability to learn from technological development, which improves their capacity to absorb shocks. The results affirm d'Errico *et al.* (2018), where education was the most relevant variable for adaptive capacity in Uganda and Tanzania.

Furthermore, a relatively high level of education implies household members are better placed in the labor market, which is likely to enable access to a variety of high-paying jobs and improve resilience to climate shocks. Likewise, in component two, households' main source of income and types of crops grown had the highest positive influence on the pillar. Diversification of crop types is more likely to reduce vulnerability of agricultural production systems against climate variability shocks. Having a reliable source of income that can withstand climate hazards reduces households' vulnerability and increases their capacity to withstand idiosyncratic shocks. Asmamaw *et al*. (2019) reported that households that had access to livestock were more likely to diversify their sources of income and were more resilient to shocks induced by climate variability.

Table 0.4: Component Loadings for Adaptive Capacity Pillar

Variable	**Comp1**	**Comp2**
Years of education of the member with the highest education	0.553	-0.122
Average years of education of members of working age	0.443	-0.267
Years of education of the household head	0.556	0.142
Household head literacy level	0.432	0.262
Household income portfolio	-0.033	0.381
Main source of income	0.032	0.571
Different types of crops are grown	-0.020	0.595

Source: Survey Data, 2024

5.3.1.4 Social Safety Net

For the social safety net, two components were retained based on the extraction criteria applied and the eigenvalue cut-off as indicated in Table 0.5. The first component consisted of the amount of formal transfer received and the number of social networks, while the second component was defined by the amount of informal transfer received and the amount of loan received. Further, the sub-indicators had different strengths, and the majority had a positive influence on SSN. The result indicates that SSN among agro-pastoralists is significant in promoting resilience to climate variability. Similar results were reported by Atara *et al.* (2020) that groups and social networks are significant in promoting rural households' capacity to resist shocks.

Table 0.5: Component Loading for Social Safety Net Pillar

Variable	Comp1	Comp2
Amount of loan received	0.428	-0.521
Amount of formal transfer received	0.657	0.186
Amount of informal transfer received	0.353	0.765
Number of social networks	0.511	-0.330

5.3.2 Component Loadings of The Resilience Pillars

The manifest variables estimated in stage one were utilized to calculate the climate resilience index (CRI) in

Table 0.6. The four manifest variables were subjected to PCA to determine CRI. Despite the sign, all the manifest variables influenced CRI. Further, two components were retained based on eigenvalues equal to or greater than one.

Assets, adaptive capacity, and social safety nets indicated a positive effect and loadings on the first component, implying an important contribution to CRI. Only access to basic services is not positively related to the first component because it is negatively associated with the other variables. However, it had a positive effect and high loading on the second component, suggesting the highest contribution to the resilience index. As the intensity of shock increases, households are more likely to prioritize basic services essential for survival. However, adaptive capacity had a negative effect and loading on the second component. This implies that as the duration of climate shock increases, the level of adaptive capacity of the households decreases. The result is not in agreement with the hypothetical association between resilience capacity and adaptive capacity in the conceptual framework of resilience (Alinovi *et al*., 2010; FAO, 2016), which employed a coping strategy index that considered ex-ante strategies available to the household irrespective of whether they were adopted or not. The study deviated from the approach by adopting only ex post strategies considered by the agro-pastoralist households.

Table 0.6: Component Loadings for The Resilience Pillars

Variable	**Comp1**	**Comp2**
Access to basic services	-0.176	0.905
Asset	0.615	0.292
Adaptive capacity	0.600	-0.213
Social safety net	0.482	0.223

Source: Survey Data, 2024

The study used the SEM to develop a resilience path diagram as represented in Figure 0.2. SEM has the advantage that the latent variable is linearly correlated with the pillars (Acock, 2013). The findings indicate that access to basic services and social safety nets had a positive effect on household resilience to climate shocks. The PCA results are also very consistent with the SEM findings, where one can observe a higher loading of ABS in component_2, as shown in

Table 0.6. Similar results were reported by d'Errico *et al*. (2018) in Uganda and Tanzania, where access to basic services strongly correlated with resilience, with distance to school being the most relevant indicator in the pillar. In addition, assets and adaptive capacity negatively influenced resilience to agroweather shocks. This may be due to households adopting only

agricultural mitigating mechanisms as opposed to informal and non-economic approaches regarding adaptive capacity. Similar results were reported by Tefere *et al.* (2025) in Ethiopia, where AC negatively contributed to the resilience of households but contradicted studies by Ado *et al*. (2019); Atara *et al.* (2020); Egamberdiev *et al.* (2023), who found that AC most significantly enhances resilience. A contrary result was further reported by Opiyo *et al.* (2014), who found that having off-farm income as well as complementary sources of income was positively associated with reduced vulnerability to climate-related shocks, thus increasing resilience among pastoral households in Kenya.

The positive association of SSN and resilience suggests that as SSN increases, the level of resilience decreases. Additionally, access to SSN is an indication of agro-pastoralists' household vulnerability. The higher the level of vulnerability, the greater the demand for a stronger social safety network. This is supported by Alinovi *et al*. (2009), who noted that an increase in social safety networks reduces the level of resilience of a household. Studies by D'errico *et al.* (2016) in Uganda and Tanzania and Alinovi *et al.* (2010) in Kenya further reported similar results. They argued that receiving assistance for a long period of time increases dependence on assistance rather than developing own means of survival.

Agricultural and non-agricultural asset ownership is critical in building households' resilience and may likely be used as a buffer when agroweather shocks arise. The negative association of assets and resilience indicates increased vulnerability of the agro-pastoralists' households. The result implies that when severe agroweather shocks arise, possessing many assets, precisely livestock, can itself be a challenge. This suggests that agro-pastoralists with many livestock are likely to be more severely affected. A plausible explanation could be due to a lack of adequate resources to purchase feeds and use different coping strategies. A similar result was reported by Tofu *et al.* (2023), where assets negatively influenced the resilience capacity index of agro-pastoralists, but contradicts d'Errico *et al*. (2023)'s finding, where access to non-productive and productive assets is significant for households to bounce back after a shock. Further, Alinovi *et al.* (2010) also reported a positive influence of assets on agro-pastoralists' resilience. World Bank (2017) reports that households in vulnerable areas that solely rely on vulnerable assets for their livelihood are likely to be two to three times more affected when agro-weather shocks occur relative to households relying on non-vulnerable assets.

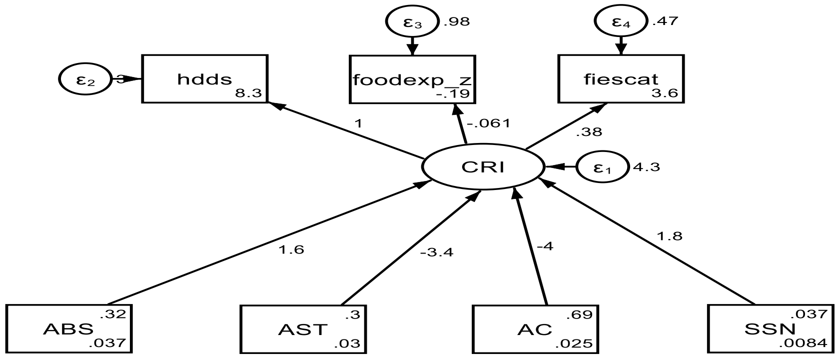

Figure 0.2: Resilience Path Diagram Estimated by Structural Equation Model

The study disaggregated the resilience index by gender of the household head and presented results in Figure 0.3. The results show that different households have different spreads of resilience scores. Further, the results indicate that female-headed households had their resilience score spread on the upper part of the histogram, while male-headed households appeared to be more spread on the lower part of the histogram. This result seems to imply that female-headed households are more resilient compared to male-headed households.

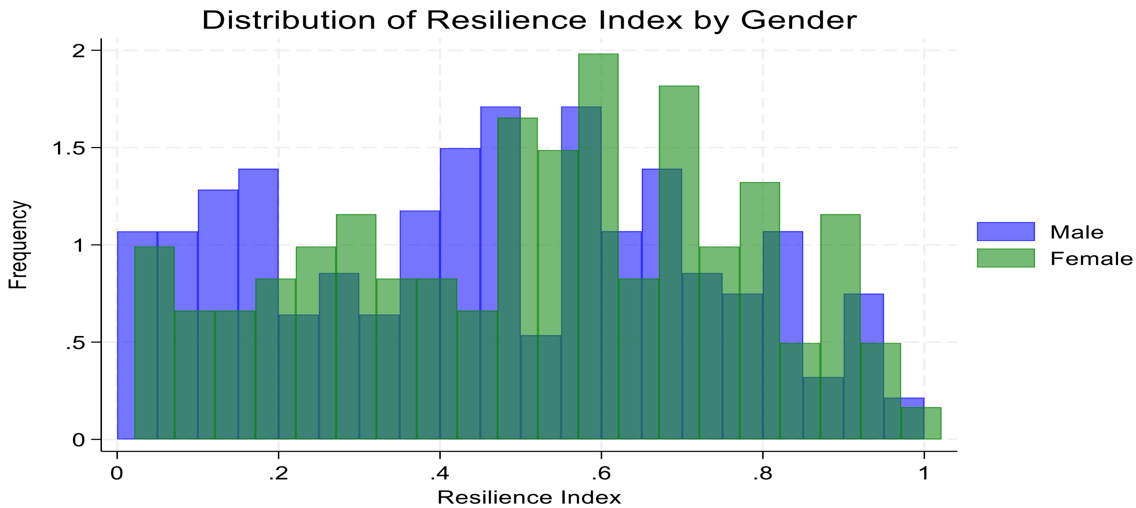

Figure 0.3: Distribution of Climate Resilience Index by Gender of the Household Head

Further confirmation with the t-test, as shown in Table 0.7, indicates that, on average, male-headed households were less resilient by 0.061 compared to female-headed households. The difference was statistically significant at 5% level, as shown by the *p*-value of 0.0467. The finding upholds the argument by Diiro *et al*. (2018) that a good number of agricultural empowerment programs in the study area target women, and this increases adoption of good agricultural techniques among female-headed households, which translates to an improved level of resilience to agroweather shocks

Table 0.7: T-test comparing climate resilience index by gender of household head

Gender	Observation	Mean	Std. dev	t-test
Female	121	0.517	0.2525	1.9975 **
Male	187	0.456	0.2643	
p-value				0.0467

Note: ***, **, * indicates Significant at 1%, 5% and 10% significance level, respectively

Source: Survey Data, 2024

The distribution of all resilience pillars in comparison to the overall climate resilience index is important in indicating how each pillar relates to the overall resilience index. The distribution of access to basic services, assets, and social safety nets is negatively skewed, as shown in Figure 0.4. However, the distribution of adaptive capacity is positively skewed. The overall resilience index has a normal distribution. The distribution suggests that there is a higher probability of increasing the resilience capacity of households in the study area by providing access to basic services, assets, and social safety nets. Notably, the low variation and contribution in social safety nets could be attributed to higher disparities in the amount of formal and informal transfers received by households in the study area. On the other hand, there is higher variation in adaptive capacity relative to access to basic services and assets, implying higher levels of disparity in household resilience. The skewed distributions of resilience pillars suggest the need to improve the resilience capacity of agro-pastoralists in the study area.

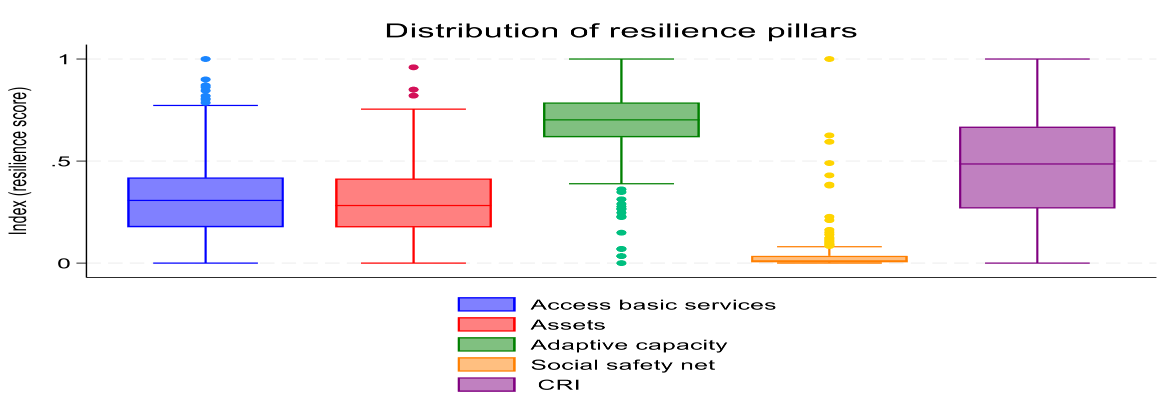

Figure 0.4: Distribution of Resilience Pillars

Moreover, the link between CRI and food security indicators was presented in the MIMIC model. CRI indicated a negative and significant association with standardized food expenditure but a positive and significant correlation with FIES. Table 0.8 indicates that an increase in CRI by a standard deviation increases the Food Insecurity Experience Scale (FIES) by 0.4 but reduces standardized Food Expenditure by 0.1 standard deviations. The findings imply that when CRI increases, food expenditure reduces while the level of food insecurity increases among agro-pastoralist households. The results may be attributed to agro-pastoralists' households with a higher climate resilience index spending less to meet the demand for food within the last seven days. This finding is at odds with Tefere *et al.* (2025), who noted that an increase in household resilience capacity reduces food insecurity in Ethiopia, but contradicts Tofu *et al.* (2023) results, where agro-pastoralists with a higher resilience index were spending more to meet the demand for food.

Table 0.8: MIMIC Model of CRI: Coefficients of Structural and Measurement Components (n=308)

Structural component	**Standardized estimation**	**Significant level**
Access to basic services (ABS)	1.643 **	0.026
Asset (AST)	-3.422 ***	0.000
Adaptive capacity (AC)	-4.034 ***	0.000
Social Safety Net (SSN)	1.824	0.234
Measurement Component		
Food Insecurity Experience Scale (FIES)	0.379 ***	0.000
Standardized Food Expenditure (SFE)	-0.061**	0.030
Household Dietary Diversity Score (HDDS)	1	
The goodness of the model fit statistic		
χ^2	26.650	
p- value	0.001	
RMSEA	0.087	
CMIN/DF	3.0	

CFI	0.916
TLI	0.843

Note: ***, **, * indicates Significant at 1%, 5% and 10% significance level, respectively

Source: Survey Data, 2024

5.3.3 Empirical Results

The estimation of the robustness of the determinants of household resilience to climate variability is presented in Table 0.9. The Kleibergen underidentification statistic χ^2 (11) = 0.2139) is not statistically significant, implying that the study fails to reject the null hypothesis that the instruments are uncorrelated with the endogenous regressors. Further, Hansen's over-identification test indicates a failure to reject the null hypothesis of correct overidentified restrictions (χ^2 (10) = 0.3896). Additionally, Kleibergen's F-statistic was 11.187, which was slightly below 11.93, which implies that the instruments are moderately strong. This indicates that the instruments: perception and awareness are valid and uncorrelated with the error term. The finding is consistent with Wuepper *et al.* (2018), where perception was a crucial instrument, and their position was that knowledge is significant to shape a person's behavior, particularly in countries that are developing, where formal learning plays a limited role. Durbin-Wu-Hausman χ^2 test affirmed the endogeneity effect of climate variability adaptation packages on agro-pastoralists' resilience - a p-value of 0.0470. Further, the significance of the Hausman test implies there is endogeneity, which implies the instrumental variable model fitted the data well. To check the robustness of the results, Two-Stage Least Squares (2SLS) regression was estimated. The Hansen over-identification test results affirmed that all instruments are valid with a *p*-value of 0.4404. Durbin-Wu-Hausman test confirmed the presence of endogeneity since the *p*-value was 0.0939.

Table 0.9: Estimation of The Determinants of Resilience

	IV Regression Results			**Two-Stage Least Squares Estimation**		
Climate Resilience Index (CRI)	**Coefficient.**	**Robust St. Err.**	**p-value**	**Coefficient**	**Robust St. Err.**	**p-value**

Endogenous variables						
Risk	0.218	0.073	0.003 ***	0.218	0.073	0.003 ***
Diversification	0.332	0.078	0.000 ***	0.332	0.078	0.000 ***
Livestock	0.019	0.045	0.669	0.019	0.045	0.669
Exogenous variables						
Age of the household head	0.000	0.000	0.317	0.000	0.000	0.317
Age squared of the household head	0.000	0.000	0.994	0.000	0.000	0.994
Household size	0.014	0.007	0.035 **	0.014	0.007	0.035 **
Gender of household head	-0.013	0.016	0.430	-0.013	0.016	0.430
Education of the household head	0.011	0.005	0.015 **	0.011	0.005	0.015 **
The education stock of the household	-0.001	0.004	0.752	-0.001	0.004	0.752
Received agroweather information	0.062	0.035	0.080 *	0.062	0.035	0.080 *
Constant	-0.032	0.044	0.471	-0.032	0.044	0.471
Centered R^2 =			0.7518			0.7518
Uncentered R^2 =			0.9436			0.9436
Root MSE =			0.1298			0.1298

Wald $\chi^2(9)$ =96.50, Prob > χ^2= 0.0000; ***, **, * indicates Significant at 1%, 5% and 10% significance level, respectively

Source: Survey Data, 2024

The study assessed the novelty and robustness of using instrumental variable regression by estimating two outcomes: The first used the International Panel of Climate Change livelihood vulnerability index (LVI-IPCC), and the second was with the RIMA-II climate resilience index (RIMA-II CRI), as in Table 0.10. From the results, both models indicated significant effects of socio-economic variables. However, the RIMA-II CRI plus IV regression explained 75.2% of the variation in resilience outcome (Centered R^2=0.7518) relative to 13.77% (Centered R^2=0.1377) for LVI-IPCC. Additionally, RIMA-II CRI using IV had a smaller root mean squared error of 0.1298 compared to LVI-IPCC, which had 0.4814. This implies that RIMA-II CRI, together with IV regression, determines resilience outcome more accurately and with lower variance. Durbin-Wu-Hausman χ^2 test for RIMA-II CRI together with IV had a p-value of 0.0470 while LVI-IPCC produced a p-value of 0.7134, further asserting the use of RIMA-II with IV to estimate the effects of adaptation strategies on resilience to climate variability.

Table 0.10: Comparison of RIMA-II CRI and LVI Results Using Instrumental Variable Regression

	RIMA-II CRI + IV Results			LVI-IPCC + IV Results		
Climate Resilience Index (CRI)	**Coefficient.**	**Robust St. Err.**	**p-value**	**Coefficient**	**Robust St. Err.**	**p-value**
Endogenous variables						
Risk	0.218	0.073	0.003 ***	0.026	0.291	0.928
Diversification	0.332	0.078	0.000 ***	-0.110	0.272	0.685
Livestock	0.019	0.045	0.669	-0.001	0.166	0.995
Exogenous variables						
Age of the household head	0.000	0.000	0.317	-0.017	0.003	0.000 ***

Age squared of the household head	0.000	0.000	0.994	0.000	0.000	0.486
Household size	0.014	0.007	0.035 **	-0.053	0.023	0.022 **
Gender of household head	-0.013	0.016	0.430	-0.018	0.060	0.760
Education of the household head	0.011	0.005	0.015 **	0.041	0.018	0.021 **
The education stock of the household	-0.001	0.004	0.752	0.006	0.016	0.701
Received agroweather information	0.062	0.035	0.080 *	-0.037	0.137	0.790
Constant	-0.032	0.044	0.471	0.016	0.171	0.926
Centered R^2 =		0.7518			0.1377	
Uncentered R^2 =		0.9436			0.6123	
Root MSE =		0.1298			0.4814	

Note: ***, **, * indicates Significant at 1%, 5% and 10% significance level, respectively

Source: Survey Data, 2024

From the study results, it was found that the endogenous and exogenous variables had varying effects on agro-pastoralists’ resilience, as provided in Table 0.11.

Farm risk reduction practices positively and significantly influenced agro-pastoralists' resilience to climate variability. Adoption of farm risk reduction practices was associated with agro-pastoralists' increased resilience to agroweather shocks. Farm risk reduction practices such as planting drought-tolerant crop varieties, harvesting rainwater, and the use of forage are crucial to enhancing the adaptive potential of agro-pastoralists. Using the strategies improves adaptive levels when exposed to agroweather shocks. Enhanced adaptive capacity increased the resilience levels of the households. The finding is in line with Matewos (2020), who indicated that failure to use small-scale irrigation, harvest rainwater, and use of improved fodder reduces the adaptive capacity of households and communities.

Table 0.11: Two-Stage Least Squares Estimation (An Endogeneity Effect) Instrumental Variables 2SLS Regression

RI	Coef.	Robust St. Err.	*p*-value
Endogenous variables			
Risk	0.219	0.072	0.002 ***
Diversification	0.324	0.079	0.000 ***
Livestock	0.012	0.044	0.790
Exogenous variables			
Age of the household head	0.001	0.001	0.320
Age squared of the household head	-0.000	0.000	0.982
Household size	0.014	0.007	0.028 **
Gender of household head	-0.013	0.016	0.415
Education of the household head	0.011	0.005	0.018 **
The education stock of the household	-0.001	0.004	0.777
Received agroweather information	0.059	0.034	0.087 *
Constant	-0.026	0.043	0.543
Number of observations		308	
Centered R^2		0.7511	
Uncentered R^2		0.9444	
Root MSE		0.1273	

Wald $\chi^2(9)$ =96.60, Prob > χ^2= 0.0000; ***, **, * indicate Significant at 1%, 5% and 10% significance level, respectively

Source: Survey Data, 2024

Diversification practices positively influenced the CRI of households. Agro-pastoralists who adopted diversification practices were more resilient to agroweather shocks. The results could be attributed to the diversification practices' ability to produce desired agricultural yields. Taking up diversification practices may reduce agricultural production uncertainties by building resilient production systems against extreme agroweather shocks. Further, the adoption of diversification practices may reduce the vulnerability of production systems to extreme climate events and, in the process, enhance the resilience of the households. A similar finding was reported by Tesso *et al.* (2012) that increased farm production improves a household's resilience to shocks.

Adult equivalent household size increased agro-pastoralists' resilience. Households with many adults were more resilient compared with those with fewer adults. The results could be attributed to farm risk reduction and labor-intensive diversification practices. Therefore, households with large family sizes may adopt practices that will improve adaptive levels and enhance resilience. Further, large households may diversify their sources of income relative to smaller households and become more resilient to agro-weather shocks. The finding contradicts Kasie *et al.* (2017), who reported a negative correlation between household size and resilience.

The instrumental variable regression results indicated that climate resilience was positively and significantly associated with the years of education of the household head. In other words, the higher the years of education of the household head, the more resilient the household would be. Households with highly educated heads were more knowledgeable and had improved decision-making capabilities regarding climate shocks. Additionally, a higher level of education of a household head increases access to better employment opportunities to expand the income portfolio. A higher income portfolio implies more income and increased access to investment opportunities such as drought-tolerant and early maturing seeds and irrigation facilities, which could improve resilience to agroweather shocks. The finding contradicts Asiimwe *et al.* (2020) results, which found a negative influence of education level on household resilience.

Receiving agroweather information was positively related and statistically significant to resilience to agroweather shocks. This implies that, as agro-pastoralists continue to access agro-weather information, their level of resilience increases as well. Agroweather information provides agro-pastoralists with accurate and timely information about weather forecasts, which assists in better decision-making when faced with agroweather shocks. Further access to agroweather information provides an opportunity for knowledge exchange, and this equips agro-pastoralists with ideas on better practices that may improve their level of resilience. Finally, agroweather information helps agro-pastoralists to utilize and optimize the resources available, which translates to increased agricultural production that offsets the unanticipated household consumption disruptions.

5.4 Conclusion

The study's findings reveal that access to basic services, particularly transport infrastructure, crop markets, and health facilities, plays a fundamental role in building resilience. The study shows that both agricultural and non-agricultural assets contribute equally to household resilience, suggesting the importance of a diversified asset base. Education levels and diverse income sources emerged as critical components of adaptive capacity, while both formal and informal transfers proved essential in strengthening social safety nets. This showed that the multidimensionality of resilience can be reduced into an index that is suitable for targeting purposes. Further, the findings suggest that prioritizing and strengthening access to social safety nets, particularly through enhanced financial credit services and formal transfer systems, would enable agro-pastoralists to invest in essential agricultural inputs and services, thereby improving their capacity to withstand climate shocks. Second, the results emphasize the need for comprehensive education and information dissemination programs, focusing particularly on agricultural practices and climate adaptation strategies.

The study's findings also point to the importance of an integrated approach to resilience building. Rather than focusing on isolated interventions, policies should address multiple resilience pillars simultaneously. This could include improving basic infrastructure while also supporting asset accumulation and diversification strategies. Furthermore, the strong relationship between adaptation strategies and resilience suggests that policies should actively promote and support the adoption of diverse farm risk reduction practices. Additionally, programs should be developed to enhance access to financial services, improve educational opportunities, strengthen information systems for weather forecasting, and support diversification of both agricultural and non-agricultural activities. Finally, efforts focused on building resilience require a multi-faceted approach that addresses both immediate needs and long-term capacity building. Success in implementing these recommendations will require coordinated efforts among various stakeholders, including government agencies, financial institutions, development partners, and local communities. Through such coordinated action, it is possible to significantly enhance the resilience of agro-pastoral communities to climate variability and associated shocks.

CHAPTER SIX

DETERMINANTS OF THE EFFECT OF ADAPTATION STRATEGIES ON FOOD SECURITY AMONG AGRO-PASTORALISTS IN LAIKIPIA WEST SUB-COUNTY

Abstract

This study investigated the determinants of the effectiveness of adaptation strategies among 308 households in Laikipia West to address agro-pastoralist vulnerability to climate shocks and enhance food security in arid Kenya. Using factor analysis to categorize strategies, the Rasch-validated Food Insecurity Experience Scale (FIES; reliability 0.83) to measure insecurity, and generalized ordered probit modelling to assess impacts, the study results show that while household characteristics (size, education, and livestock) and agroweather information access are significant, a multi-component adaptation package—integrating risk reduction, cultural, sustainable, and traditional practices—is a crucial positive determinant of improved food security. The results imply that implementing combined adaptation strategies enhances their effectiveness, highlighting the importance of policy interventions that promote locally relevant approaches to improve food security.

6.1 Introduction

Agricultural production plays a significant role in food security globally. However, climate variability and change pose major and growing threats to agricultural systems and food security (Intergovernmental Panel on Climate Change (IPCC), 2014). The global climate model lists sub-Saharan Africa (SSA) among the regions that will be most affected by climate change, with a decline in agricultural productivity for major crops of up to 20%, high poverty levels, and food insecurity incidences, especially in rural areas (Arslan *et al*., 2014). Food insecurity remains a critical economic and social problem in SSA today. According to FAO (2015), a quarter of the sub-Saharan African population could not attain the required dietary energy in 2014-2015. Further, between 2015 and 2016, about 22.7% of the people in SSA were undernourished, which was an increase from the previous year’s 21% (FAO, 2017). An additional report from FAO on food security showed that there was an upsurge in the percentage of severely food-insecure people in the area. The increase in food insecurity and malnutrition is attributed to extreme climate conditions that affect agricultural production.

Most studies on climate variability and change have focused on the impact on food availability owing to its direct effect on agricultural food production. However, according to FAO *et al.* (2018) and IPCC (2022), climate variability negatively affects all four dimensions of food security: access, utilization, stability, and availability. Food availability is negatively impacted through changes in livestock and crop productivity due to changes in rainfall patterns, increased incidence of pests and diseases, e.g., desert locust, increase in temperature, and extreme droughts and floods (Nicholson, 2017). Food utilization is directly affected by food quality deterioration because of high levels of mycotoxins in food and livestock feeds, reduced dietary diversity, and food safety, and indirectly through effects on health. Gitau *et al.* (2018) noted that food stability and access are affected by high incidence and intensity of climate extreme events, which lead to local price volatility and disruptions in transport systems.

Climate variability and change affect crops and livestock production in SSA, particularly in areas that are prone to drought, and over 70% of farmers rely on rainfall, threatening their livelihoods and food security (Ignaciuk *et al.*, 2021). Hence, there is a need to adopt adaptation strategies that can abate the adverse effects of climate change. According to Samuel and Sylvia (2019), adaptation strategies against the effects of climate variability and change have the potential to improve agricultural productivity amidst those effects, thereby enhancing livelihoods and improving food security. However, most farmers in developing countries downplay the significance of the adaptation strategies due to cost implications. For example, in South Africa, Ncube *et al.* (2016) it was found that high poverty levels hindered households in rural areas from embracing adaptation strategies to climate change.

To address climate variability and change in agriculture, smallholder farmers can adopt strategies such as introducing improved crop varieties, diversifying crops and incomes, harvesting rainwater, and improving weather forecasting, as noted by Kabubo-Mariara and Mulwa (2019) and Shisanya and Mafongoya (2016). A study by Di Falco *et al.* (2011) in Ethiopia found that households employing these adaptation strategies had significantly better food production than those that did not. This highlights the importance of climate adaptation for food security. However, as Ali and Erenstein (2017) observed, farmers differ in their approach—some rely on a single method while others use multiple strategies, leading to varying levels of food security even among those who adapt.

Giannini *et al.* (2017) reported that in Mali, climate variability increased food insecurity among subsistence farmers. However, households that diversified their livelihoods beyond subsistence farming were found to be more food secure. Similarly, Douxchamps *et al.* (2016) highlighted those strategies such as the use of fertilizers, soil and water conservation, crop diversification, and improved crop varieties contributed to enhanced food security in Ghana, Senegal, and Burkina Faso. Rahman *et al*. (2022) also found that adaptive strategies—such as changing fishing locations, using fish-finder tools, altering fishing gear, and adjusting fishing schedules- significantly improved food security among fish farmers in Indonesia. Similarly, Amare and Simane (2018) observed that farmers who adopted adaptation strategies reported higher food security levels. Collectively, these studies underscore the critical role of adaptation in enhancing food security.

For smallholder food crop farmers, adopting adaptation strategies aligned with sustainable agricultural practices is vital for achieving self-sustaining food security at both household and national levels (Tilman *et al.*, 2011; Waha *et al.*, 2018). Hassan *et al.* (2018) emphasized that practices such as mulching and the use of organic fertilizers are significantly associated with improved household food security, particularly in terms of per capita annual food expenditure. The study also noted the heightened vulnerability of African agricultural systems to climate variability compared with other regions. Adverse conditions, such as famine, heat stress, and flooding, have further reduced agricultural and livestock yields, thereby exacerbating poverty, hunger, and a decline in living standards.

Agriculture remains the backbone of Kenya’s economy, contributing approximately 33% to the gross domestic product (GDP), accounting for 60% of employment and 65% of exports (World Bank, 2018). Nevertheless, climate variability and change pose a serious threat to food security by negatively affecting farm productivity, soil moisture, and rainfall patterns. This situation is particularly dire given that most of Kenya’s population resides in rural areas and depends heavily on rain-fed agriculture for their livelihoods. Only approximately 16% of Kenya’s land receives sufficient and reliable rainfall for crop farming. The remaining 84% comprises arid and semi-arid lands (ASALs), which receive an average annual rainfall of 400 mm (Kalele *et al.*, 2021). Consequently, smallholder farmers in these regions have become increasingly diversified into off-farm employment to cope with these challenges.

According to Karienye and Macharia (2021), the effects of climate variability in Kenya are most evident through frequent and prolonged droughts, floods, environmental disasters, and the resurgence of pests and diseases. These events have led to a significant decline in agricultural productivity, threatening livelihoods and deepening food insecurity. In the ASAL regions, severe climate variability has particularly hindered crop production, leading to shortages of food, pasture, and other agricultural resources. In response, farmers have adopted various adaptation strategies, including planting drought-tolerant and early-maturing crop varieties, practicing crop rotation and diversification, engaging in income diversification, altering sowing times, constructing trenches and ditches, and implementing agroforestry practices (Franklin *et al.,* 2021; Kogo *et al.,* 2020). These strategies have reduced the vulnerability of farmers to the impacts of climate variability. Therefore, farmers who adopt such adaptation strategies tend to be more food secure compared to those who do not.

Given that a large proportion of Kenya's rural population depends on agriculture for their livelihood, adapting to climate variability is essential for building resilience in the agricultural sector and ensuring food security. Di Falco *et al*. (2012) noted that adaptation significantly reduces vulnerability to climate variability, as the extent to which agricultural productivity is affected depends largely on a household's adaptive capacity (Ochieng *et al.*, 2017). Conversely, failure to adapt can have devastating consequences for the economy, rural livelihoods, and food security due to its adverse impact on agricultural production.

Numerous studies have investigated the effects of climate change and adaptation strategies on food security (Ali & Erenstein, 2017; Amare & Simane, 2018; Di Falco *et al.,* 2011; Gebre *et al.*, 2023; Kabubo-Mariara & Mulwa, 2019; Karienye & Macharia, 2021). However, except for Karienye and Macharia (2021) and Ndiritu and Muricho (2021), few studies have specifically examined the impact of climate adaptation on food security in Kenya's arid and semi-arid regions. Moreover, most existing studies have assessed the effects of adaptation by categorizing farming households into adopters and non-adopters of individual strategies, without considering the use of adaptation strategies as integrated packages or bundles (Kabubo-Mariara & Mulwa, 2019; Ndiritu & Muricho, 2021). Additionally, aside from Gebre *et al.* (2023), who employed the Household Food Insecurity Access Prevalence indicator—a categorical and ordered measure—many studies have simply classified households as either food secure or food insecure. Such a binary classification fails to capture the full severity of food poverty and obscures more extreme cases of food insecurity.

To address these gaps, the present study employs the Household Food Insecurity Experience Scale (FIES), a categorical and ordered measure that captures the severity of food insecurity over the past 12 months. Furthermore, adaptation strategies were analyzed as bundles or packages, simplifying the analysis and facilitating clearer conclusions regarding the effectiveness of specific strategy combinations.

6.2 Methodology

6.2.1 Study Area, Research Design, Sampling Procedure, Sample Size Determination

The research was carried out in arid and semi-arid areas of Laikipia West sub-county (refer to section 3.2.1). The research design was a cross-sectional quantitative research design as detailed in (section 3.2.2). The sampling procedure was a multi-stage sampling technique, and respondents were chosen using simple random sampling as discussed in (Section 3.2.3). The sample size was determined using Yamane's (1967) method and distributed proportionally across the five wards as outlined in (section 3.2.4).

6.2.2 Data Collection and Analysis

Data were collected, cleaned, coded, and analyzed using the R program version 4.4.1 and Stata version 18.

6.2.2 Measuring Household Food Security

This study measured household food insecurity using self-reported food security data that were scored on FIES. The Food Insecurity Experience Scale (FIES) has been validated to estimate individual or household food security in developing countries (BPS, 2018). FIES is a food security measurement based on individual lived experience (FAO, 2017). The FIES survey module measures the prevalence and severity of a household's food insecurity. According to Broussard and Tandon (2016), FIES questions follow an order of severity where households are categorized by their level of severity of food insecurity. Households were categorized into four food security levels, based on their FIES responses, where 1 represented household that were food secure. With regards to food Insecurity, 2, 3, and 4 represented households who were mildly, moderately, and severely food insecure, respectively.

6.2.3 Analytical Framework

Factor analysis (FA) was applied to categorize the adaptation strategies. According to Otitoju (2013), FA is a multivariate statistical technique that can reduce large sets of identified variables to a small number of controllable dimensions known as factors. To select the underlying categories, the Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity were utilized to assess sampling adequacy and correlation of variables, respectively.

The FIES statistical model was assessed, and a scale was constructed using a single-parameter logistic measurement (Rasch) model (Engelhard, 2013). The Rasch model hypothesizes that an item and a respondent's position can be located on a similar dimensional scale. Further, the model suggests that the logarithm of odds for the respondent *y* saying "yes" to item *i* is a linear function of the difference between the severity of item *i* and the severity of food insecurity status reported by respondent *y* (Cafiero *et al.*, 2018). The response provided by respondent *y* for item *i*, as 1 for "yes" and 0 otherwise, is given as:

$$\Pr(M_{yi} = 1) = \frac{e^{(c_y - d_i(\ )}}{1 + e^{(c_y - d_i)}} \leftrightarrow \ln\left(\frac{p}{1-p}\right) = c_y - d_i \quad (6.1)$$

where $d_i$and c_y Are the positions of the item and the respondent on a similar scale, respectively?

The dependent variable is food security, which is ordinal in nature, implying that there exists relative ordering. In such an event, an ordered probit model is relevant for estimating the effects of adaptation strategies on household food (in)security. Furthermore, the estimation allows for predicting the effects of a change in any of the explanatory variables on the categorical dependent variable (Cameron & Trivedi, 2009). The ordered probit model assumes that there exists a cut-off between the ordinal outcomes, but the distance between them is not exact. Therefore, considering the food security categories and following Pfarr *et al.* (2010), y^* is the underlying latent food security status. Thus, if *y* is an ordered categorical outcome, an ordered probit model is presented as follows:

$$Pr[\, y \leq j|x] = F\left(y_j - x'\beta\right) \qquad \forall j = 1,2,\ldots..J \quad (6.2)$$

where y_j and β represent unknown threshold parameters and coefficients, respectively, and *j* is a vector of distinct ordered categories. *F* denotes a cumulative standard normal distribution. The vector of *x* covariates determines the discrete outcome categories.

Introducing a latent variable y^* into equation (6.2) results in *y*=*j*, if and only if:

$$y_{j-1} \leq y^* = x^{'}\beta + \mu < y_j \tag{6.3}$$

The threshold divides the linear slopes into *J* categories. *u* is the unobserved disturbance term; *u* and *x* influence the latent variable. From equation 6.3, *u* assumes a mean of zero and *x* a constant variance. Therefore, the probability that a household's self-reported food security would be in one of the four categories is given as:

$$\Pr[y \leq j \mid x] = F(y_j - x^{'}\beta) - F(y_{j-1} - x^{'}\beta) \tag{6.4}$$

Nevertheless, the standard ordered probit model (specified in equations 6.2 through to 6.4) is built on the parallel-lines assumption (Pfarr *et al.*, 2010). The assumption states that the parameter estimates are constant between the categories. This implies that the parallel-lines assumption ignores the possibility of heterogeneity of some of the covariate variables. According to Pfarr *et al.* (2010), the generalized ordered probit model assumes that threshold parameters depend on covariates and is represented as:

$$y_j = y_j{}^{\sim} + x'\delta_j \tag{6.5}$$

where δ_j is the coefficient of threshold covariates. On considering the ordered nature of food security categories and incorporating the adaptation strategies packages as explanatory variables. Taking the threshold equation 6.5 into 6.4 leads to a cumulative probability of the generalized ordered probit model, which is given as:

$$Pr[y \leq j|x] = F\left(y_j{}^{\sim} + x'\delta_j - x'\beta\right) = F\left(y_{j-1}{}^{\sim} - x'\beta_j\right) \quad \forall j = 1, \dots J \tag{6.6}$$

6.2.3.1 Food Insecurity Experience Scale Survey Model (FIES-SM)

The FIES-SM is comprised of eight questions meant to evaluate the sufficiency of an individual's (or a household's) access to food. The question's focal point is on respondents' conduct and experience when there is a challenge in attaining their basic food requirement during the last 12 months, as shown in Table 0.1.

Table 0.1: Food Insecurity Experience Scale Questions

Now I would like to ask you some questions about food consumption. During the last 12 months, there was a time when:	
Food Insecurity Experience Scale Questions	**Response**
You or others in your household worried about not having enough food to eat because of a lack of money, water, crops, and livestock resources?	1=Yes,0=No 98=Don't know 99=Refused
Still thinking about the last 12 months, was there a time when you or others in your household were unable to eat healthy and nutritious food because of a lack of money, water, crops, and livestock resources?	1=Yes,0=No 98=Don't know 99=Refused
Was there a time when you or others in your household ate only a few kinds of foods because of a lack of money, water, crops, and livestock resources?	1=Yes,0=No 98=Don't know 99=Refused
Was there a time when you or others in your household had to skip a meal because there was not enough money, water, crops, or livestock resources?	1=Yes,0=No 98=Don't know 99=Refused
Still thinking about the last 12 months, was there a time when you or others in your household ate less than you thought you should because of a lack of money, water, crops, and livestock resources?	1=Yes,0=No 98=Don't know 99=Refused
Was there a time when your household ran out of food because of a lack of money, water, crops, and livestock resources?	1=Yes,0=No 98=Don't know 99=Refused
Was there a time when you or others in your household were hungry but did not eat because there was not enough money, water, crops, or livestock resources?	1=Yes,0=No 98=Don't know 99=Refused
Was there a time when you or others in your household went without eating for a whole day because of a lack of money, water, crops, and livestock resources?	1=Yes,0=No 98=Don't know 99=Refused

Sources: Ballard *et al.* 2013; Hendricks 2015

6.2.3.2 Description of Variables

The description of variables used in econometric estimation and their measures are provided in

Table **0.2**. The choice of the variables was informed by other empirical literature on the related study subject.

Table 0.2: Description of Variables for Generalized Ordered Probit Model

Variable	Description	Measurement
Dependent Variables		
FIES categories	1=Food secure, 2=Mildly food insecure, 3=Moderately food insecure, 4=Severely food insecure	Discrete
Independent Variables		
Gender	Gender of household head	Dummy, 1= Male, 0= Female
Household size	Household size (Consumption equivalent)	Continuous
Farming experience	Household head farming experience in years	Continuous
Age	Age of household head in years	Continuous
Age squared	Age squared of the household head in years	Continuous
Head's education	Household head's education (years of schooling)	Continuous
Education stock	Household education stock in years	Continuous
Wealth index	3 quantiles of wealth index (rich, middle, poor)	Categorical
Farm size	Farm land holding	Continuous
TLU	Tropical Livestock Unit	Continuous
Credit access	Household access to credit (didn't need credit, received the amount needed,	Categorical

	didn't receive the amount needed, needed and didn't receive completely)	
Off-farm income	Household off-farm income	Continuous
AS package combinations	Septuplicate AS package combinations	Dummy, 1= Yes, 0= No

6.3 Results and Discussion

6.3.1 Descriptive Results for FIES Items Responses

The descriptive results for FIES items responses are presented in Table 0.3. The severity of food insecurity, indicated by items (response to FIES questions), rose while the percentage of affirmative responses decreased. The item severity parameter ranged from -3.88 to 4.39, which implies that items with lower severity parameters would affirm response with a lower degree of food insecurity relative to items with higher severity parameters (Gulliford *et al.*, 2005). Except for items 4 (skipped meal) and 5 (Ate less), all the remaining severity responses performed as expected. Approximately 14.29% of all respondents reported going the whole day without food, whereas 76.62% reported worrying that they would not have enough food. The proportion of respondents who reported having skipped meals was 46.43%, whereas 47.40% reported that they ate less than they thought they should. This was inconsistent with the expected performance of the items as supported by their severity parameter. However, this did not pose any challenge to results interpretation.

The study used a single-parameter Logistic measurement statistical model (Rasch) to assess the psychometric properties of FIES. Table 0.3 presents the results for infit and outfit statistics. The infit statistics were between 0.7 and 1.3, implying that the items were acceptable for adequate Rasch modeling (Jubayer *et al.*, 2023). The items "whole day" and "worried" had the highest infit values. Likewise, items "skipped" and "healthy" reported the lowest infit values. The finding implies that items "whole day" and "worried" are weakly associated with food insecurity, whereas items "skipped" and "healthy" indicate that the responses are more predictable than expected. Turning to outfit statistics, items "healthy" and "whole day" had the highest outfit values. Since the items had good fits, high outfits do not imply any violation of Rasch assumptions (Sahyoun *et al.*, 2014). The Rasch reliability of FIES to the Rasch model (in column eight) was 0.83, which was good, and according to Wambogo *et al.* (2018), a Rasch reliability value of ≥0.7 is valid for the analysis. The study further calculated the residual correlation matrix for each pair of the FIES items (shown in APPENDIX III). The results indicate that the residual correlation matrix for each pair of FIES items was not significantly high (≥0.4), further confirming that the responses were appropriate for analysis.

Table 0.3: FIES Item Responses, Statistics, Standard Errors, and Rasch Reliability

Item	Proportion of affirmative responses	Severity	SE_Severity	Infit	SE_Infit	Outfit	Rasch Relia bility
WORRIED	76.62	-3.88	0.38	1.04	0.23	0.66	0.83
HEALTHY	73.70	-3.10	0.32	0.80	0.21	11.85	
ATEFEW	70.78	-2.45	0.29	0.89	0.20	1.63	
SKIPPED	46.43	0.51	0.21	0.76	0.12	0.54	
ATELESS	47.40	0.40	0.21	0.90	0.13	1.30	
RANOUT	34.74	1.71	0.21	0.99	0.11	0.69	
HUNGRY	27.92	2.42	0.22	0.95	0.12	1.83	
WHOLEDAY	14.29	4.39	0.34	1.07	0.25	9.70	

Note: Rasch reliability is overall for the FIES module

Source: Survey Data, 2024

The study categorized food security by the gender of the household head and presented results in

Table 0.4. Approximately 32.09% and 25.62% of female and male-headed households were food secure, respectively. The finding implies that women are more likely to go into agropastoralism to cater to immediate family needs and are likely to focus on increasing agricultural production (Doss & Raney, 2011). The lower percentage of male-headed households relative to female-headed households could be attributed to male-headed households focusing on agropastoralism for cash generation. Similarly, about 25.62% and 23.53% of male and female-headed households were mildly food insecure, respectively. About 25.13% of female-headed

households are moderately food insecure compared to 25.62% of male-headed households. Finally, approximately 23.14% and 19.25% of male and female-headed households were severely food insecure, respectively. However, food insecurity did not differ significantly due to the gender of the household head, as shown by *p*-values of 0.634.

Table 0.4: Proportions of Household Food Security by Gender of Household Head

FIES Categories	Female	Male	χ^2	Total
Food Secure	32.09 (60)	25.62 (31)	1.71	29.55 (91)
Mildly Food Insecure	23.53 (44)	25.62 (31)		24.35 (75)
Moderately Food Insecure	25.13 (47)	25.62 (31)		25.32 (78)
Severely Food Insecure	19.25 (36)	23.14 (28)		20.78 (64)

Note: figures in parentheses represent frequencies; χ^2 is for the entire FIES categories.

Source: Survey Data, 2024

Different combinations of adaptation strategy packages obtained from Table 3.5 are presented in Table 0.5. AS packages can be adopted in a wide range of different combinations, and these may vary in terms of their effect on households' food security (Branca *et al*., 2011). From the given combinations, understanding which combination best contributes to food security is important for policy development.

The results presented in Table 0.5 indicate that 10 out of 11 combinations were actively used by agro-pastoralists. A few agro-pastoralists (3.57%) did not use any combination. About 2.92% of agro-pastoralists used the combination $R_0C_0S_1F_1L_0D_1T_0$. This combination comprises sustainable agricultural, farm management, and diversification practices only. Approximately, 3.25% opted for combination $R_1C_1S_1F_1L_1D_1T_1$ that had all combinations of adaptation strategy packages; risk reduction, cultural farm, sustainable agricultural, farm management, livestock management, diversification, and traditional practices, while 3.90% used combination $R_1C_1S_1F_1L_0D_0T_0$ that contained farm risk reduction, cultural farm, sustainable agricultural, and farm management practices only. Further, 4.55% of agro-pastoralists used combinations $R_1C_0S_1F_1L_1D_1T_0$ and $R_1C_1S_1F_1L_1D_0T_1$, respectively. Combination $R_1C_0S_1F_1L_1D_1T_0$ consists of farm risk reduction, sustainable agricultural, farm and livestock management, and diversification practices only, while $R_1C_1S_1F_1L_1D_0T_1$ comprises farm risk reduction, cultural farm, sustainable agricultural, farm and livestock management, and traditional practices.

Approximately 6.48% used the combination $R_1C_1S_1F_0L_0D_0T_0$ that had farm risk reduction, cultural farm, and sustainable agricultural practices only. Approximately, 12.34% of agro-pastoralists employed a combination $R_1C_1S_1F_1L_0D_1T_0$ that contained farm risk reduction, cultural farm, sustainable agricultural, farm management, and diversification practices only. 18.50% of agro-pastoralists approximately used a combination $R_1C_1S_1F_0L_1D_0T_0$ that contained farm risk reduction, cultural farm, sustainable agricultural, and livestock management practices. The proportion of agro-pastoralists that applied combination $R_1C_1S_1F_1L_1D_0T_0$ was 19.16%. The combination consists of farm risk reduction practices, cultural farming, sustainable agricultural, and farm and livestock management practices only. The largest share of agro-pastoralists, 20.78% used the combination $R_1C_1S_1F_1L_1D_1T_0$ that contained farm risk reduction, cultural farm, sustainable agricultural, farm, and livestock management and diversification practices only. This indicates how attaining food production among agro-pastoralists is important despite the challenges of agroweather shocks. Similar results were reported by Wekesa *et al.* (2018), who noted that several smallholder farmers adopt many strategies to increase food production. Further, Table 28 shows that all agro-pastoralists who used various combinations adopted a package with at least sustainable agricultural practices. This observation indicates the need for many agro-pastoralists to increase agricultural production for food generation in the study area.

Table 0.5: Specification of Climate Adaptation Strategy Packages to Form the Combinations

Choice(j)	**Binary septuplicate**	**R=Risk practices**		**C=Cultural practices**		**S=Sustainable practices**		**F=Farm practices**		**L=Livestock practices**		**D=Diversification practices**		**T=Traditional practices**		**Frequency**	**Percentage**
		R_0	**R_1**	**C_0**	**C_1**	**S_0**	**S_1**	**F_0**	**F_1**	**L_0**	**L_1**	**D_0**	**D_1**	**T_0**	**T_1**		
1	$R_0C_0S_0F_0L_0D_0T_0$	✓		✓		✓		✓		✓		✓		✓		11.00	3.57
2	$R_1C_1S_1F_0L_1D_0T_0$		✓		✓		✓	✓			✓	✓		✓		57.00	18.50
3	$R_1C_1S_1F_1L_1D_0T_0$		✓		✓		✓		✓		✓	✓		✓		59.00	19.16
4	$R_1C_1S_1F_1L_0D_1T_0$		✓		✓		✓		✓	✓			✓	✓		38.00	12.34
5	$R_0C_0S_1F_1L_0D_1T_0$	✓		✓			✓		✓	✓			✓	✓		9.00	2.92
6	$R_1C_1S_1F_0L_0D_0T_0$		✓		✓		✓	✓		✓		✓		✓		20.00	6.48
7	$R_1C_1S_1F_1L_0D_0T_0$		✓		✓		✓		✓	✓		✓		✓		12.00	3.90
8	$R_1C_1S_1F_1L_1D_1T_0$		✓		✓		✓		✓		✓		✓	✓		64.00	20.78
9	$R_1C_0S_1F_1L_1D_1T_0$		✓	✓			✓		✓		✓		✓	✓		14.00	4.55
10	$R_1C_1S_1F_1L_1D_0T_1$		✓		✓		✓		✓		✓	✓			✓	14.00	4.55
11	$R_1C_1S_1F_1L_1D_1T_1$		✓		✓		✓		✓		✓		✓		✓	10.00	3.25
Total																**308.00**	**100.00**

Note: The binary septuplicate represents the possible combinations. Each element in the septuplicate is a binary variable for AS packages combination: Risk reduction practices (R), Cultural farm practices (C), Sustainable agricultural practices (S), Farm management practices (F), Livestock management practices (L), Diversification practices (D), and Traditional practices (T). Subscript 1 = use and 0 = otherwise.

Source: Survey Data, 2024

6.3.2 Empirical Estimation Results

6.3.2.1 Model Diagnostic Results

First, a standard ordered probit model was fit (APPENDIX IV). The results indicate five statistically significant variables (consumption equivalent household size, household education stock, tropical livestock unit, receiving agroweather information, and $R_1C_1S_1F_0L_0D_0T_0$, which comprised risk reduction, cultural farm, and sustainable agricultural practices only).

Second, the autofit procedure was applied after constrained and unconstrained variables were identified to test the parallel lines assumption. The null hypothesis of equal coefficients is rejected for variables farming experience of household head (p= 0.01159), age squared of household head (p= 0.00986), and off-farm Income (p= 0.01069) for the model (APPENDIX V) since the p-values are less than 0.05. Specification test for the model with constraints (χ^2= 59.22; p=0.1285) is insignificant, implying that the generalized ordered probit model does not violate the parallel lines assumption.

6.3.2.2 Econometric Results

The model's statistic, likelihood ratio χ^2= 204.95; p= 0.000 is significant, suggesting that the generalized ordered probit model fits the data well. Appendix VI presents result for generalized ordered probit estimates. Seven variables significantly associated with agro-pastoralists' food (in)security. Interestingly, the level of significance of the variables was similar across food security categories except for the farming experience of the household head and off-farm income. The results suggest that different factors influence household food security. However, the direction of their partial influence is different, implying differences in determinant effects on household food security.

In Appendix VI, coefficients of tropical livestock unit and receiving agroweather information are significant at 1% significance level throughout the three food security categories. Farming experience of the household head is significant at 5% level for the food secure category. The coefficient for consumption equivalent household size is significant at 10% across the three food security categories, while off-farm income is significant at 5% but only for the moderately food insecure. Lastly, household education stock and $R_1C_1S_1F_0L_0D_0T_0$ (comprising risk reduction, cultural farm practices, sustainable agriculture, and traditional practices but excluding farm management, livestock, and diversification) were significant at 5% level throughout the three food security categories.

The marginal effects from the generalized ordered probit model are presented in Table 0.6. The coefficients of the generalized ordered probit regression show the direction of association of regressors on regressand variables. Therefore, the estimation of marginal effects indicates the magnitude of the changes in the regressand variable. From the marginal effects in Table 6.6, the consumption equivalent household size is negative and significant at 10% for food security. Farming experience of the household head is negative and significant at 1% for food secure, while positive and significant at 5% for mildly food insecure. Household education stock is positive and significant at 5% for both food secure and mildly food insecure, but negative and significant at 1% for moderately food insecure. Whereas the tropical livestock unit is positive and significant at 1% and 5% for both food secure and mildly food insecure, respectively, it is negative and significant at 5% level for moderately food insecure. Receiving agroweather information is highly significant throughout the three food insecurity categories; however, it shows a positive effect for both food secure and mildly food insecure, but a positive effect for moderately food insecure. Off-farm income is negative and significant at 1% level but only for a moderately food-insecure status. Finally, $R_1C_1S_1F_0L_0D_0T_0$, which consists of risk reduction, cultural farm, and sustainable agricultural practices only, is positive and significant at 1% level for food secure and mildly food insecure statuses, it is negative and significant at 5% level for moderately food-insecure.

Table 0.6: Marginal Effects from The Generalized Ordered Probit Food Insecurity Experience Scale Categories

FIES_Category	Food Secure		Mildly Food Insecure		Moderately Food Insecure	
Variable	**dy/dx Coef.**	**Std. Err.**	**dy/dx Coef.**	**Std. Err.**	**dy/dx Coef.**	**Std. Err.**
Consumption equivalent household size	-0.021 *	0.012	-0.004	0.002	0.005	0.003
Farming experience of the household	-0.015 ***	0.005	0.013 **	0.006	0.006	0.005
The education stock of the household	0.012 **	0.006	0.002 **	0.001	-0.003 *	0.002
Tropical livestock unit	0.025 ***	0.008	0.004 **	0.002	-0.006 **	0.002
Received agroweather information	-0.382 ***	0.024	-0.065 ***	0.012	0.088 ***	0.023
Off-farm income	0.031	0.042	0.008	0.046	-0.142 ***	0.048
$R_1C_1S_1F_0L_0D_0T_0$	0.181 ***	0.067	0.031 ***	0.012	-0.042 **	0.019

Note: ***, **, * indicates Significant at 1%, 5% and 10% probability level, respectively; Marginal effects (dy/dx)

Source: SurveyData, 2024

Consumption equivalent household size was negative and significant at the 10% level with food-secure agropastoral households. In other words, an increase in the household size reduces the likelihood of the household becoming food secure by 2.1% relative to being severely food insecure. This suggests that large household size increases the probability of food insecurity. The large-sized households probably represent a significant burden of feeding household members due to the large food requirement. Additionally, large family size may likely comprise nonproductive members that burden active ones and therefore make it difficult to ensure food security (Gemecha *et al*., 2016). A Large family size is more likely to create a dependency burden due to the sharing of available limited resources and contributing more to consumption than production (Dube *et al.*,2018). This result contradicts the finding reported by Amwata *et al.* (2016) that large family size among the agropastoral system increases food security due to a large labor force used in production.

The farming experience of the household head was negative and significant at 1% level for food secure, but positive and significant at 5% level for mildly food insecure. This finding appears to suggest that a unit increase in farming experience of the household head reduces the probability of the household becoming food secure by 1.5% while it increases the likelihood of the household becoming mildly food insecure by 1.3% compared to severely food insecure, respectively. The finding suggests the diminishing contribution of farming experience to household food security. An increase in farming experience of agro-pastoralists may probably imply more reliance on traditional agricultural methods of farming, which are less productive. Further, more farming experience suggests old age, which is likely to imply reduced labor available for agricultural activities due to participation in other income-generating activities that require minimal labor, which in exchange exposes the household to food insecurity.

Household education stock was significant throughout the three categories of food security. However, the magnitudes of the influence for food secure and mildly food insecure were 0.012 and 0.002, respectively, while -0.003 for moderately food insecure. This finding suggests that a higher level of household education stock increases the likelihood of a household falling in the categories of food secure and mildly food insecure by 1.2% and 2% respectively, but at the same time reduces the probability of becoming moderately food insecure by 3% relative to severely food insecure. A higher education stock reflects household endowment with human capital. An increase in human capital suggests that members of the household are well informed about the significance of achieving a better food security status. The finding is concurrent with Kolog *et al*. (2023), who argued that educated members are knowledgeable and more exposed to the food needs of their households.

Tropical livestock unit is significantly and positively associated with food security at 1% level, positively associated with mildly food insecure at 5% level, and negatively associated with moderately food insecure at 5% level. This finding highlight that a unit increase in tropical livestock unit increased the probability of becoming food secure and mildly food insecure by 2.5% and 4% respectively, while at the same time reducing the likelihood of falling into the status of moderately food insecure by 6%. A higher tropical livestock unit reflects endowment with wealth among agro-pastoralists. An increase in TLU is more likely to improve food security through direct access to livestock products. Further, the sale of livestock and livestock products provides income that can be used to buy food. Likewise, manure from livestock can be used as organic fertilizer to increase crop production. The result corroborates Dube *et al.* (2018) 's finding that large TLU improves food security and income from livestock production.

Receiving agroweather information was highly significant across the three categories of food security. The magnitude of the coefficient estimates was -0.382 for food secure, -0.065 for mildly food insecure, and 0.088 for moderately food insecure. This can be interpreted that a unit increase in receiving agroweather information reduces the likelihood of becoming food secure and mildly food insecure by 38.2% and 6.5% while increasing the probability of being moderately food insecure by 8.8% relative to severely food insecure, respectively. This finding could be attributed to agro-pastoralists having limited resources, such as finances to implement necessary agricultural practices. Further, some of the information may require inputs that may not be available to the households. Agro-pastoralists, upon receiving agroweather information, may more likely delay various agricultural activities that may temporarily reduce available food.

Off-farm income was negative and significant at 1% level, with moderately food insecure. The interpretation of this finding is that a unit increase in off-farm income reduced the likelihood of a household being moderately food insecure by 14.2% relative to being severely food insecure. The finding suggests that off-farm income increases the probability of agro-pastoralists falling into better categories of food security. In a different way, off-farm income is more likely to be used by the household to acquire food through direct purchases. To further add on, off-farm income can be used by households to purchase inputs required for agricultural production, which in turn leads to higher food production. This finding is consistent with studies done by Mustafa (2014) and Ahmad *et al.* (2016) in Pakistan.

Finally, combination $R_1C_1S_1F_0L_0D_0T_0$ (comprising risk reduction, cultural farm practices, and sustainable agriculture but excluding traditional practices, farm management, livestock, and diversification) was positive and significant at 1% levels for food secure and mildly food insecure. At the same time, it was negative and significant at 5% level with moderately food insecure. The finding appears to imply that adopting $R_1C_1S_1F_0L_0D_0T_0$ (comprising risk reduction, cultural farm practices, sustainable agriculture, and traditional practices but excluding farm management, livestock, and diversification) is associated with 18.1% higher probability of agropastoral households becoming food secure, and 3.1% higher probability of a household being mildly food insecure, albeit it reduces the likelihood of households being moderately food insecure by 4.2% in relation to severely food insecure, respectively. This finding reflects the significance of $R_1C_1S_1F_0L_0D_0T_0$ (which comprises risk reduction, cultural farm practices, sustainable agriculture, and traditional practices but excluding farm management, livestock, and diversification) in mitigating the effects of agroweather shocks on agricultural production. This could also be explained by the possibility that the more households mitigate agroweather shocks, the higher the likelihood of producing more food, which in turn translates to increased food security. The indirect role of $R_1C_1S_1F_0L_0D_0T_0$ (comprising risk reduction, cultural farm practices, sustainable agriculture, and traditional practices but excluding farm management, livestock, and diversification) in improving soil organic matter content and moisture leads to desirable soil properties that are necessary for soil fertility improvement, which enhances agricultural production and, in turn leads to improved food security status of the agro-pastoralists household. In addition, the use of $R_1C_1S_1F_0L_0D_0T_0$ (comprising risk reduction, cultural farm practices, sustainable agriculture, and traditional practices but excluding farm management, livestock, and diversification) is more likely to enhance the resilience of food-insecure households to agricultural shocks to improve their food security status. These results are in line with the study results reported by Asare-Nuamah *et al.* (2020) in Ghana.

6.4 Conclusion

The study estimates the effect of adaptation strategy combinations on the food security of agro-pastoralists. From the results, consumption equivalent household size, farming experience of household head, receiving agroweather information reduced the probability that the household will be food secure, while education stock of the household, tropical livestock unit, and $R_1C_1S_1F_0L_0D_0T_0$ (comprising risk reduction, cultural farm practices, sustainable agricultural practices) increased the likelihood of the household becoming food secure. Farming experience of household head, education stock of household, tropical livestock unit, and $R_1C_1S_1F_0L_0D_0T_0$ (comprising risk reduction, cultural farm practices, and sustainable agriculture only) had a positive association with mild food insecurity. Findings further indicate that the education stock of household, tropical livestock unit, off-farm income, and $R_1C_1S_1F_0L_0D_0T_0$ (comprising risk reduction, cultural farm practices, sustainable agriculture only) covariates were significant and negative, while receiving agroweather information was positive and significant to the probability of being moderately food insecure.

These findings imply that adaptation strategies, when used in combination, enhance the food security of Agro-pastoralists. The study recommends that policy interventions aimed at improving households' food security in agro-pastoral areas should support adoption models such as $R_1C_1S_1F_0L_0D_0T_0$ (comprising risk reduction, cultural farm practices, and sustainable agriculture only) that improve household food security levels. Also, agro-pastoralists should be well sensitized on the need to invest in education, which enables them to make informed decisions when experiencing agro-weather shocks.

CHAPTER SEVEN

GENERAL DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

7.1 Introduction

This chapter provides a summary of the entire study. It provides a general discussion of each objective's key findings and gives a conclusion. Lastly, it gives recommendations drawn from the findings and provides areas for further research.

7.2 General Discussion

To achieve the United Nations' sustainable development agenda, adaptation practices, resilience of agricultural systems, and food security are important concepts. However, the concepts are affected to a greater extent by agroweather shocks, more so in arid and semi-arid lands that are occupied by agro-pastoralists who entirely depend on agriculture as their main source of livelihood. To enhance survival, development partners, government, and agro-pastoralists have developed practices in agriculture that would ensure survival amid agroweather shocks and increase agricultural production. The common mitigations to increasing agricultural production are the use of climate adaptation strategies. The adoption of strategies is significant to improving agricultural yields and enhancing the resilience of agro-pastoralists to the devastating effects of agroweather shocks. To this end, studies have focused on determining the implications of adaptation strategies on livelihood outcomes such as poverty reduction, income, food security, and resilience. Further, there has been much focus on the potential of mitigating climate change and variability through the adoption of strategies. This study determined socioeconomic and institutional factors that influence intensity and choice of adaptation strategies, which are largely missing in the literature within the context of the study area. In addition, the study focused on determining the effects of adaptation strategy packages on household resilience, which most of the empirical studies have not addressed. Finally, the study also focused on determinants of the effect of adaptation strategy package combinations on agro-pastoralist household food security.

First, results indicate that drought was the highly observed agroweather shock at 89.29%. However, a few 2.27% reported flood incidences in the area. In response, 21 adaptation strategies were actively in use by agro-pastoralists. After clustering of the practices by factor analysis (FA), seven factors were extracted, which include farm risk reduction, cultural farm, sustainable agricultural, farm management, livestock management, diversification, and traditional practices.

Most agro-pastoralists used farm risk reduction practices at 78.25% while the least adopted factor was traditional practices at 6.82%. The factors that influenced the intensity and choice differed across agropastoral households. Intensity of adoption of adaptation packages was analyzed through a Poisson regression model, which was positively influenced by household dependency ratio, gender of the household head, household education stock in years, wealth index for the rich and middle, and the number of agricultural groups the household belonged to. Age squared of the household head, interaction of gender and farming experience of household head, log of years of education of household head, and households that needed and didn't receive credit completely significantly reduced the intensity of use of the packages. The choice of adaptation packages was analyzed by a Multivariate probit model and the marginal effects reported. The results indicate that the wealth index for rich and middle households, the number of agricultural group households belonging to, and households that did not need credit positively influenced the choice. Likewise, the choice was negatively influenced by the log of years of education of household head, farm size, tropical livestock unit, interaction of group membership and number of groups belonging, and households that didn't receive the amount needed. Further, age and age squared of household head, interaction of age and age squared, household dependency ratio, household education stock, group membership, and distance to extension agents' office had both positive and negative influences on the choice of the packages.

Secondly, assets, adaptive capacity, and social safety nets had positive effects and loadings on the first resilience component. Access to basic services had a positive influence on the second component, indicating the highest contribution to the resilience index. To establish effect, endogenous variables such as farm risk reduction and diversification practices positively and significantly influence resilience to climate variability and change. Exogenous variables like adult equivalent household size, education of household head, and receiving agroweather information increased the resilience of agro-pastoralists. Food security was measured by the food insecurity experience scale (FIES). Rasch model results indicate that the item severity parameter ranged from -3.88 to 4.39. The infit statistics were between 0.7 and 1.3, implying that the items were acceptable for adequate Rasch modeling. The Rasch reliability value was 0.83, and residual correlation was not significantly high; this further confirmed that the responses were appropriate for analysis. The estimation of the marginal effect from the generalized ordered probit model indicates that consumption equivalent household size reduces the likelihood of a household becoming food secure. Farming experience of household head reduced the likelihood of the household becoming food secure while increasing the probability of becoming mildly food insecure. The education stock of households increases the likelihood of becoming food secure and mildly food insecure, while it reduces the likelihood of becoming moderately food insecure. Tropical livestock unit increased the probability of becoming food secure and mildly food insecure but reduced the likelihood of becoming moderately food insecure. Receiving agroweather information reduces the chances of being food secure and mildly food insecure, while it increases the likelihood of becoming moderately food insecure. Off-farm income reduced the probability of a household becoming moderately food insecure. $R_1C_1S_1F_0L_0D_0T_0$ combination increased the probability of a household becoming food secure and mildly food insecure, while it reduced the likelihood of a household becoming moderately food insecure.

7. 3 Conclusions

i. The study established that drought was the highly reported agroweather shock. Further adaptation of strategies was still low, with farm risk reduction being the most dominant, perhaps to increase agricultural production among agro-pastoralists. The traditional practices are the least adopted.

ii. Most agro-pastoralists adopted strategies with at least four practices. The household socio-economic and institutional covariates, such as household dependency ratio, education stock, wealth index, and number of agricultural associations, increased the intensity and choice of Adaptation Strategy packages. Farm size, tropical livestock unit, group membership, and distance to extension agents' office only influenced the choice of Adaptation Strategy packages. All the Adaptation Strategy packages are adopted as complements.

iii. The probability of becoming more resilient was positively associated with farm risk reduction practices, diversification practices, adult equivalent household size, number of years of education of household size, and receiving agroweather information. The findings affirm the likelihood of adaptation packages increasing resilience to agroweather shocks.

iv. Adaptation Strategy packages have the potential to alleviate food insecurity among agro-pastoralists if used in combination and to a great extent. Therefore, the enhanced use of these strategies can help improve food security in ASAL areas.

7.4 Policy Recommendations

i. Climate adaptation strategies should aim at improving agro-pastoralists' resilience to shocks by promoting the use of AS package combinations. Climate variability and change discourses should encourage the use of combinations of AS packages instead of focusing on isolated adoption of each strategy. This may provide an opportunity for agro-pastoralists to exploit the complementarities of AS packages. Agricultural policy should increase awareness about the significance of using multiple AS packages by enhancing the quality of public extension. Additionally, public extension should formulate extension information that promotes knowledge of AS packages. Agricultural training ought to be geared towards helping agro-pastoralists become more knowledgeable in identifying and use of AS package combinations that can guarantee higher agricultural output when adopted jointly.

ii. Several adaptation strategies have been developed on a generalized basis and therefore may be unsuccessful in some agro-ecological areas due to differences in agro-weather-related effects. A better knowledge of local vulnerability is critical in developing context-appropriate strategies that will mitigate adverse agroweather shocks. Agricultural policy should provide area-specific strategies. Further, such information should be made available depending on the agro-ecological zones.

7.5 Areas of Further Research

The aim of the study was to provide an understanding of dominant adaptation strategies, factors associated with intensity and choice, and the effects of strategies on resilience and food security of agro-pastoralists. While the findings have provided reasonable understandings and key policy implications, further research should capture the effect of the adoption and dis-adoption of AS packages and combinations on food security and resilience. Secondly, the results presented only provide conjecture of barriers and don’t go on to really measure such barriers. Future research should focus on ex-ante simulations of a structural model in which behavior can be elicited. Additionally, future studies should attempt to use panel data to track and account for dynamic changes over time.

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APPENDICES

Appendix I: Questionnaire

EFFECTS OF CLIMATE VARIABILITY ADAPTATION STRATEGIES ON KENYAN AGRO-PASTORALISTS' RESILIENCE AND FOOD SECURITY: A CASE OF LAIKIPIA WEST SUB-COUNTY

Dear Sir/Madam,

My name is **Cyrille Awuonda,** a postgraduate student at Egerton University, Njoro Campus. In partial fulfillment of the requirement for the Master of Science in Agricultural and Applied Economics, I am conducting research on the **effects of climate variability adaptation strategies on agro-pastoralists' resilience and food security in Laikipia-West sub-county, Kenya**. I would like to kindly request your assistance to provide information by answering the questions provided in the questionnaire below. Your views are considered very significant to this study. Please note that your participation is **voluntary** and that any information given will be treated with utmost **respect** and **confidentiality** and will be used precisely for the purpose of this study.

Are you willing to take part in the survey?

1= Yes, 0=No (stop the interview and move to the next household)

SECTION A: GENERAL INFORMATION

Name of Enumerator	Sub-County	Ward	Sub-location	Location	Village	Household ID	Date of Interview	Questionnaire number
A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**

A.10. Are you the one who makes production decisions within the household?

1=Yes, 0=No, (if yes, continue to A.12. If no, proceed to A.11.)

A.11. If no, who made production decisions within the household between January 2023 to January 2024?

1=Household head, 2=Spouse, 3=Son/daughter, 4=Parent, 5=Son/daughter-in-law, 6=Grandson/granddaughter,7=Other relative, 8=Hired worker, 9=Other, specify……………,

A.12. Name of the respondent………?

SECTION B: HOUSEHOLD INFORMATION

1.0. Members of Household (People living in the household over the last six months) ………………….?

1.0.1 Member Code	**1.0.2** Are you the Household head? **1=Yes 0=No**	**1.0.3** Gender: 1=Male 0=Female	**1.0.4** Relationship to the household head **CODE 1**	**1.0.5** Age (Complete years)	**1.0.6** Primary occupation **CODE 2**	**1.0.7** Number of years of schooling
1						
2						
3						
4						
5						
6						
7						
8						
9						

CODE 1: 1=Household head, 2=Spouse, 3=Son/daughter, 4=Parent, 5=Son/daughter-in-law, 6=Grandson/granddaughter, 7=Other relative, 8=Hired worker, 9=Other, specify, **CODE 2:** 1=Farming (crop+ livestock) 2=Salaried employment,3=Self-employed off-fam,4=Casual laborer on-farm 5=Casual laborer off-farm 6=School/college 7=Non-school

SECTION C: LAND OWNERSHIP

C.1 Does the household have access to land **1=Yes** **0=No**	**C.2** What is the size of the household's total land owned…(Acres)	**C.3** What is the type of Land ownership? **CODE 1**	**C.4** Acres of land used for crop and livestock farming from January 2023 to January 2024……?	**C.5** What is the distance of the Household's owned land farm to the homestead… Km	**C.6** Who in the household owns the land? **CODE 2**	**C.7** Did your household rent land between January 2023 to January 2024 **1=Yes** **0=No**	**C.8** Acres of Land rented between January 2023 to January 2024 …?	**C.9** What is the distance from the household's rented farmland to the homestead… Km

CODE1: 1=Freehold without certificate/title, 2= Freehold with certificate/title **CODE 2**: 1=Household head, 2=Spouse, 3=Head and Spouse Jointly, 4=Others (Specify)

SECTION D: LIVESTOCK AND ASSET OWNERSHIP

D.1. Does the household have any livestock **1=Yes** **0=No**	**D.2.**How long have you been involved in livestock farming……	**D.3.**What have you observed in terms of livestock production within the last 10 years? **CODE 1**

CODE 1: 1=Improved, 2=Declined, 3=Remained same

Animal/Asset ID	Animal /Asset type	Does the household own […] 1=Yes 0=No	Number owned	If you were to sell the assets, how much would you sell them for?
1	**Indigenous cattle**			
2	**Dairy cows**			
3	**Goats**			
4	**Sheep**			
5	**Pigs**			
6	**Rabbits**			
7	**Camels**			
8	**Poultry**			
9	**Donkeys**			
10	**Car**			
11	**Bicycle**			
12	**Mobile phone**			
13	**Plough/Ox-plough**			
14	**Jembe**			

SECTION E: FARM CHARACTERISTICS

E.1. What is the nature of the landscape of the household-owned land? **CODE 1**	**E.2.**What proportion of the household-owned land is steep, medium steep, flat…?	**E.3.**What proportion of land owned by the household that is flat, steep, and medium steep is prone to severe soil erosion conditions ……?	**E.4.**How has the soil fertility on your household farm-owned land changed over the past 5 years? **CODE 2**	**E.5.**Has the Household rented any land? **CODE 3**	**E.6.**How would you describe the condition of the household's rented Land at the time of lease? **CODE 4**	**E.7.**What soil erosion management practices did the household implement to control soil erosion? **CODE 5**	**E.8.**What proportion of households old rented land is steep, medium steep, or flat?	**E.9.**What proportion of households' rented land that is flat, steep, and medium steep is prone to the severity of soil erosion …...?	**E.10.**How has the soil fertility on your farm's rented land changed within the past 1 year, i.e., January 2023 to January 2024 **CODE 2**

CODE 1: 1=Flat, 2=Medium steep, 3=Steep, 4=None (proceed to **E5),**

CODE 2: 1= Poor, 2= Medium, 3=Fertile,

CODE 3: 1=Yes, 0=No (**If Yes, continue. If No, proceed to Section 1.1),**

CODE 4: 1=Low fertility, 2=Fertile, 3=Prone to erosion (If 3, proceed to E7), 4=No erosion

CODE 5: 1=Terraces, 2=Gabions, 3=Mulching, 4=cover cropping,5=Bench Terraces, 6=Fanya Juu Terraces, 7=Fanya Chini Terraces, 8=Contour Bands, 9=others (Specify)

SECTION F: CROP ACTIVITY

1.1 Did the household plant any crop between January 2023 to January 2024 during the short and long cropping seasons?

1=Yes, 0=No. If yes, continue. If No, proceed to Section 1.1.5

1.1.1 Crop ID	**1.1.2** Crop type	**1.1.3** Did the household produce (**Crop type**) **CODE 1**	**1.1.4** How much did the household harvest/expect to harvest during the last/current cropping season (January 2023 to January 2024), **Kg**	**1.1.5** How long have you been involved in crop farming……	**1.1.6** What have you observed in terms of crop production within the last 10 years? **CODE 2**
1	Maize				
2	Beans				
3	Sorghum				
4	Wheat				
5	Irish potatoes				
6	Vegetables				
7	0thers (Specify)				

CODE 1: 1=Yes,0=No**, CODE 2:** 1=Improved, 2=Declined, 3=No change

SECTION F: CLIMATE CHANGE AND ADAPTATION STRATEGIES

2.1 Have you observed any changes in agro-weather conditions in the past 10 years?
1= Yes, 0= No. If yes, continue. If No, proceed to Section 4.1

3.1 What changes have you observed with regard to agro-weather conditions?

3.1.1 Observed shock	**3.1.2** Have you observed changes with regard to agro-weather patterns in the last 5 years? **CODE 1**	**3.1.3** What was the level of severity of the climate shock? **CODE 2**	**3.1.4** What was the household experience of the shock? **CODE 3**	**3.1.5** How did the shock affect agricultural activities? **CODE 4**
		Lev_sev	**Exp_shc**	**Aff_agr**
Increased Droughts				
High-intense Drought				
Too many floods				
High levels of crop pests and diseases				
High levels of livestock parasites and diseases				
Hail storm				

CODE 1: 1=Yes, 0=No. **If yes, continue. If No, proceed to Section 4.1**

CODE 2: 1= Less severe, 2=Moderate, 3= Severe, 4= Very severe

CODE 3: 1= Increased, 2=Constant, 3=Decreased, 4= Others (Specify)

CODE 4: 1=No effect, 2= Reduced, 3= Increased

4.1 Has the household experienced agro-pastoralist conflict in the past 5 years because of agro-weather conditions?

1=Yes, 0=No

5.1 Household awareness level and information access

5.1.1 Is the household aware of adaptation strategies to changes in agro-weather patterns? 1=Yes 0=No	**5.1.2** What does the household know about the occurrence of agro-weather patterns……..?	**5.1.3** Why have you not done anything about the agro-weather patterns? **CODE 1**	**5.1.4** Are you aware of agro-weather information services (i.e., service on weather forecasts, agro-weather advisories)? 1=Yes 0=No	**5.1.5** Did you receive agro-weather information during the period between January 2023 and January 2024? 1=Yes 0=No	**5.1.6** What was the source of agro-weather information? **CODE 2**	**5.1.7** What was the channel through which agro-weather information was received? **CODE 3**	**5.1.8** Did you use the agro-weather information? 1=Yes 0=No

Awr_lev	Knw-lev	Bar_adpt	Agrwthr_inf	Agrwthr_infrcd	Scr_agrwthr	Chnl_agrwthr	Us_agrwthr

CODE 1: 1= Lack of information, 2=Shortage of money, 3= Shortage of labor,4= Shortage of land,5=Slow technological adoption 6=Others (specify)

CODE 2: 1=Agricultural Extension Officer, 2=Government Agency (Kenya Metrological Department), 3=Farmer organizations/Cooperatives, 4=NGO,5=Other Farmers, 6=Research organization,6=Others (Specify)

CODE 3: 1= Radio, 2=Television, 3=Mobile phone platforms, 4=Internet platforms, 5=field days, 6=farm visits, 7=Farmer field schools, 8=Others (specify)

6.1 In response to the observed agro-weather pattern changes, what have you done to cope with them?

6.1.1 Crop Strategies	**6.1.2** Has your household had to (adaptation strategy) **CODE 1**	**6.1.3**. Livestock strategies	**6.1.4** Has your household had to (adaptation strategy) **CODE 2**	**6.1.5** Water Strategies	**6.1.6** Has your household had to (adaptation strategy) **CODE 3**	**6.1.7** Who decided on the use of the strategy? **CODE 4**
Change planting dates		Use crop residue as animal feed.		Harvest rainwater		
Use organic manure		Supplement feeds		Dig borehole		
Use inorganic fertilizer		improve fodder		Dig Water pans		
Plant early		Improve livestock breeds		Construct a retention ditch.		
Plant drought-tolerant varieties		Sell Livestock		Others (specify)		
Intercrop		Diversify livestock types				
Do crop rotation		Make hay				
Plant early maturing crops		Do Fodder cropping				
Plant agro-forestry trees		Others (Specify)				
Herbicides						
Pesticides						
Do soil conservation						
Minimum tillage						
Do Irrigation						
Others (specify)						

CODE 1: 1=Yes, 0=No; **CODE 2**: 1=Yes, 0=No; **CODE 3**: 1=Yes, 0=No.

CODE 4: 1=Household head, 2=Spouse, 3= Jointly, 4=Others (Specify)

SECTION G: INSTITUTIONAL INFORMATION

7.1 Did the household need any financial assistance/or credit between January 2023 and January 2024?

1=Yes, 0=No. If Yes, continue; if No, proceed to Question 7.1.7

7.1.1 Did the household receive financial assistance/ or credit needed? **1=Yes 0=No**	**7.1.2** Did the household receive the amount of cash/credit needed? **1=Yes 0=No**	**7.1.3** What was the source of the credit? **CODE 1**	**7.1.4** Type of credit received **CODE 2**	**7.1.5** Amount of Cash/In-Kind received	**7.1.6** Main purpose for which credit was used….?	**7.1.7** If no in **7.1,** provide reasons **CODE 3**	**7.1.8** What is the distance to the nearest credit offering facility………….?	**7.1.9** Who in the household received the credit? **CODE 4**
		Crd_sorc	**Crd_typ**	**Crd_Amnt**	**Crd_purp**	**Crd_no**	**Crd_dist**	

CODE 1: 1= Farmer groups/CHAMAS, 2=Farmer Cooperatives, 3=Microfinance Institutions, 4=Commercial banks, 5=Informal lenders, 6=SACCO, 7=Digital Platforms (Hustler fund, Fuliza, Mshwari, Tala), 8=Women Enterprise Fund, 9=Youth Enterprise Fund, 10=Uwezo Fund, 11=Others (Specify); **CODE 2: 1**=Cash, 2=Inputs, 3=Both.

CODE 3: 1=No collaterals, 2=Insufficient return, 3=Crop failure and unfavorable climate, 4=Others (Specify)

CODE 4: 1=Household head, 2=Spouse, 3=Head and Spouse Jointly, 4=Others (Specify)

8.1 Has the household received any extension messages/contact on adapting to agro-weather patterns due to climate variability?

1=Yes, 0=No

9.1 Did the household receive any extension messages/contact on adapting to agro-weather patterns due to climate variability between January 2023 to January 2024?

1=Yes, 0=No: If Yes, continue; if No proceed to Question 10.1

9.1.1 In what areas did the household receive extension messages on adapting to agro-weather patterns between January 2023 to January 2024…...? **CODE 1**	**9.1.2** If the extension message was on agro-weather adaptation information, who was the provider between January 2023 to January 2024? **CODE 2**	**9.1.3** How many times did the household receive extension services on adapting to agro-weather patterns between January 2023 to January 2024…...?	**9.1.4** During what time did you receive extension services/contact? **CODE 3**	**9.1.5** What is the distance to the agricultural extension provider………? Km
Ext_msg	**Ext_prvdr**	**Ext_freq**	**Ext_tim**	**Ext_dst**

CODE 1: 1=Crop production, 2=Livestock production, 3=Agricultural marketing (crop and livestock), 4=Crop management, 5=Livestock Management,

6=Agro-weather adaptation information, 7=Others (specify)

CODE 2: 1=Fellow farmer, 2=Farmer groups, 3=Government officers, 4=NGOs, 5=Community based organizations (CBOs), 6=Research organizations, 7=Private individual/firm, 8=Farmer's training center, 9=Others (Specify)

CODE 3: 1=During severe climate events, 2=During onset of extreme climate events, 3=During crop growth period,4=Others (Specify)

10.1 Did any member of the household receive/participate in any training on adapting to agro-weather patterns from January 2023 to January 2024?

1=Yes 0=No, If Yes, continue, No proceed to Question 11.1

10.1.1 How many members of the household have received training on adaptation to agro-weather patterns between January 2023 to January 2024…...?	**10.1.2** How many training sessions related to adaptation to agro-weather patterns did the household members receive between January 2023 to January 2024……?	**1.1.3** When did the household receive the training? **CODE 1**
Membr_rectrn	**Trn_sessn**	**Tim_trn**

CODE 1: 1= Within the last 6 Months,2=6months to 1 year

11.1 Has any household member been a member of a group or association?

1=Yes, 0=No.

12.1 Has any household member been a member of a group or association between January 2023 to January 2024?

1=Yes, 0=No. If Yes, continue; No, proceed to Question 13.1

12.1.1 How many household member(s) belong to a group or association between January 2023 to January 2024 **CODE 1**	**12.1.2** How many group(s) does the **11.1.1** belong to…?	**12.1.3** What kind of group(s) or association does the household member(s) belong? **CODE 2**	**12.1.4** Do the group(s) engage in adaptation to agro-weather patterns? **CODE 3**	**12.1.5** What kind of adaptation to agro-weather patterns do the household member(s) discuss? **CODE 4**
GRP_mbr	**Grp_nbr**	**Grp_typ**		**Adpt_agrwthr**

CODE 1: 1=Household head, 2=Spouse, 3=Any other member, **CODE 2:** 1=Agricultural/livestock, 2=Savings and credit, 3=Trade and business, 4=Religious, 5=Self-help group, 6=Civic or charitable group,7=Environmental group (Water, forest, tree planting), 8=Others (Specify); **CODE 3:** 1=Yes, 0=No **If Yes continue, No proceed to Question 12.1**; **CODE 4**: 1=crop adaptation to agro-weather pattern, 2=Livestock adaptation to agro-weather patterns, 3=water adaptation to agro-weather, 4= All,

SECTION H: FOOD SECURITY

Food Insecurity Experience Scale (FIES) (12-month recall. Period)

13.1 Now I would like to ask you some questions about food consumption. During the last 12 months, was there a time when:

You or others in your household worried about not having enough food to eat because of a lack of money, water, crops, and livestock resources?	1	1=Yes 0=No 98=Don't know 99=Refused
Still thinking about the last 12 months, was there a time when you or others in your household were unable to eat healthy and nutritious food because of a lack of money, water, crops, and livestock resources?	2	1=Yes 0=No 98= Don't know 99=Refused
Was there a time when you or others in your household ate only a few kinds of foods because of a lack of money, water, crops, and livestock resources?	3	1=Yes 0=No 98= Don't know 99=Refused
Was there a time when you or others in your household had to skip a meal because there was not enough money, water, crops, or livestock resources?	4	1=Yes 0=No 98= Don't know 99=Refused
Still thinking about the last 12 months, was there a time when you or others in your household ate less than you thought you should because of a lack of money, water, crops, and livestock resources?	5	1=Yes 0=No 98= Don't know 99=Refused
Was there a time when your household ran out of food because of a lack of money, water, crops, and livestock resources?	6	1=Yes 0=No 98= Don't know 99=Refused
Was there a time when you or others in your household were hungry but did not eat because there was not enough money, water, crops, or livestock resources?	7	1=Yes 0=No 98= Don't know 99=Refused
Was there a time when you or others in your household went without eating for a whole day because of a lack of money, water, crops, and livestock resources?	8	1=Yes 0=No 98= Don't know 99=Refused

SECTION I: RESILIENCE

Income and Food Access

1	What percentage of your monthly total income do you spend on food purchases……….?	
2	How much money did your household spend on food consumed during the past 7 days……………...?	
3	How much money did your household spend on food consumed in the past 7 days using credit (because of inability to cover the cost)?	

4	If the household were to buy what it produces, how much would the household spend on food consumed in the past 7 days?	
5	How much money would the household have spent if it were to buy food that it received through assistance/gifts in the past 7 days?	
6	How many meals does your household eat in a day?	**CODE 1**
7	During the last 7 days, have you been faced with a situation wherein you did not have enough food to feed the household? • Maize/Sorghum • Legumes • Vegetables • Roots and Tubers • Eggs • Meat • Milk • Fruits • Sugar • Oil & Fats	**CODE 2**

CODE 1: 1=One, 2=Two, 3=Three, 4=Four, 5=Other (Specify)

CODE 2: 1=Yes,0=No

Assets

1	How many agricultural assets do the members of the household own?	**CODE 1**
2	Do the members of the household use it? • **Seeds** • **herbicides** • **Pesticides** • **Fertilizers** • **Organic manure**	**CODE 2**
3	What is the total area of agricultural land that the household uses in crop and livestock farming acres?	
4	How many livestock did the household own between January 2023 to January 2024?	**CODE 3**
5	How much did the household harvest / do they expect during the last/current crop season in kilograms? [kg] • Maize • Sorghum • Beans	

CODE 1: 1=Car, 2=Bicycle, 3=Mobile, 4=Plough, 5=Jembe, 6=Tractor

CODE 2: 1=Yes, 0=No

CODE 3: 1=indigenous, 2=Dairy cows, 3=Sheep, 4=Pigs, 5=Camels, 6=Poultry, 7=Donkey

NOTE: Although Asset is a requirement in the RIMA II framework questionnaire, this has been captured in earlier sections.

Access to Basic Services

1	What is the main source of drinking water for members of the household?	**CODE 1**
2	What is the main type of toilet facility used by members of the household?	**CODE 2**
3	Do you have access to electricity in the household for lighting?	
4	How far (one way) is the household dwelling from the closest accessible/ functioning [SERVICE] in minutes? • Water source • Primary school • Public hospital/health facility • Livestock market • Agricultural/crops market • Public means of transport • County headquarters • Sub-county headquarters	

CODE 1: 1=Piped water connection, 2=Public tabs/standpipes, 3= Tube wells, 4=Boreholes, 5=Protected Dug wells, 6=Protected Spring, 7=Rainwater collection

CODE 2: 1=Pour flush, 2=Ventilated Improved Pit (VIP) latrine, 3=Pit latrine with slap, 4=Composting Toilets

CODE 3: 1=Yes, 0=No

Social Safety Nets

1	**1a** Did the household need a loan between January 2023 to January 2024? 1b Did you get the amount of the loan applied for? **1c** What is the total amount of loan received between January 2023 to January 2024 by the members of the household?	**1=Yes, 0=N0** **If Yes, continue to 1c; if No, proceed to 2**
2	What is the total amount of formal transfers (relief food, cash assistance, livestock, safety net programs, pension schemes, etc.) received between January 2023 to January 2024 by the members of the household?	
3	What is the total amount of informal transfers (cash, remittances, food or grain gift, seed gift, free use of animals, etc.) received between January 2023 to January 2024 by members of the household?	
4	How many [NETWORKS] can the members of the household rely on in case of need? • Associations (farmers groups, women support groups, youth groups, business associations, unions, etc.) • Relatives/friends/family members	

Adaptive Capacity

1	Did the head of the household attend school?	**1=Yes, 0=No**
2	How many years did the household head attend school?	
3	How many years has the household member with the highest level of education attended school?	
4	How many years on average have the household members of working age attended school?	
5	Between January 2023 to January 2024, was [SOURCE] a source of household income? • Agriculture (Crop & Livestock) • Family business (other than agriculture) • Government wage and salary • Private sector wage and salary • Transfers and social assistance	**CODE 1**

6	What is considered the main income source of the household?	
7	How many different crops have the household members grown during the last season?	

CODE 1; 1=Yes, 0=No

NOTE: Although Adaptive capacity is a requirement in the RIMA II framework questionnaire, this has been captured in earlier sections.

SECTION J: HOUSEHOLD INCOME

Main source of Household income between January 2023 to January 2024? **CODE 1**	How much income did the household receive between January 2023 to January 2024? **CODE 2**	Other sources of income for the household between January 2023 to January 2024? **CODE 1**	How much income did the household receive from the other sources of income between January 2023 to January 2024? **CODE 2**
Incm_src	**Amnt_incm**	**Othr_incsrc**	**Amt_othinsrc**

CODE 1; 1= Farming (Crops &Livestock),2=Business Person, 3=Casual off-farm income,4=Casual non-farm income ,5=Salaried, 6=Others (Specify)

CODE 2; 1=< Kes 4000,2=Kes 4001-8,000, 3=Kes 8,001-12,000,4=Above Kes 12,001 (**Kenya Poverty Report 2021**

Appendix II: Indicators of agro-pastoralists' resilience

Pillars	Sub-pillar Indicator and description of the observed indicator
Assets	
Agricultural assets index	
Farm Size	Acres of land for agricultural use
TLU	Tropical Livestock Unit
Agricultural Wealth Index	3 quantiles of the agricultural wealth index
Agricultural Input Use	Household use of agricultural inputs
Crop Harvest	Total Crop Harvest by the household in Kg
Non-Agricultural assets index	
Cars owned	Number of cars owned by the household
Bicycles owned	Number of bicycles owned by the household
Mobile phones owned	Number of mobile phones owned by the household
Access to Basic Services	
Minutes closest water source	Minutes to the main source of household drinking water
Minutes closest primary school	Minutes to the nearest primary school
Minutes closest public hospital	Minutes to the closest public hospital
Minutes closest livestock market	Minutes to the closest livestock market
Minutes closest crop market	Minutes to the closest crop market
Minutes closest public transport	Minutes to the nearest public transport system
Social Safety Nets	
Loan received	Total amount of loan received
Informal transfer	Total amount received from informal transfers
Formal transfer	Total amount received from formal transfers
Social networks	The number of social network household depend on.
Adaptive Capacity	
Education	Household head's education level
Education of the household head	Number of years of education of the household head
Education of household members	Number of years of education of the household member with the highest education level
Average education	Average number of years of education of household members working.
Income portfolio	Household income portfolio
Source of income	Main source of income for the household
Crop type	Different types of crops grown by households

Appendix III: Indicators of food security

Food indicator	Measurement
Food Expenditure	
Cash	Amount in cash spent to purchase food
Credit	Amount in cash that would have been spent to purchase food consumed on credit
Own production	Amount in cash that would have been spent to purchase food consumed from own production
Assistance/gift	Amount in cash that would have been spent to purchase food received as assistance or gifts
Household Dietary Diversity Score	
Cereals	If household consumed any cereal =1, 0= Otherwise
Legumes	If household consumed any legume =1, 0= Otherwise
Vegetables	If household consumed any vegetable =1, 0= Otherwise
Roots & Tubers	If household consumed any root & tuber =1, 0= Otherwise
Eggs	If household consumed eggs =1, 0= Otherwise
Meat	If household consumed any meat & meat products =1, 0= Otherwise
Milk	If household consumed any milk & milk products =1, 0= Otherwise
Fruits	If household consumed any fruit =1, 0= Otherwise
Sugar	If household consumed sugar =1, 0= Otherwise
Oil & Fats	If household consumed oil & fats =1, 0= Otherwise
Household Food Insecurity Experience Scale	
Worried about not having enough food to eat	If household was worried=1, 0= Otherwise
Unable to eat healthy and nutritious food	If the household was unable to access healthy and nutritious food =1, 0=Otherwise
Ate a few kinds of food	If households ate few kinds of food = 1, 0=Otherwise
Skipped meal	If household skipped meal = 1, 0=Otherwise
Ate less than they should have eaten	If household ate less than what they should eat=1, 0=Otherwise
Ran out of food	If the household ran out of food, 1 = 0=Otherwise
Hungry but did not eat.	If the household was hungry and did not eat=1, 0=Otherwise
Stayed without eating for a whole day	If the household stayed without eating for a whole day, 0=Otherwise

Appendix IV: Negative binomial model

Negative binomial regression — Number of obs = 308; LR chi2(15) = 106.49; Prob > chi2 = 0.0000; Pseudo R2 = 0.0981

Dispersion: **mean**

Log likelihood = **-489.44549**

Factor_Count	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
HHsize	.0875624	.0322771	2.71	0.007	.0243004	.1508244
1.Gender	-.0142199	.0636826	-0.22	0.823	-.1390354	.1105957
FarmExprnce	.0162175	.0082378	1.97	0.049	.0000716	.0323634
Age	-.0116407	.0064632	-1.80	0.072	-.0243084	.0010269
log_Educ	.1263351	.070842	1.78	0.075	-.0125127	.2651829
Wealth_index						
2	.010993	.0713032	0.15	0.877	-.1287587	.1507448
3	-.1899955	.1057822	-1.80	0.072	-.3973248	.0173338
Farmsize	.0040049	.0173886	0.23	0.818	-.0300761	.0380859
TLU	-.0000514	.0134802	-0.00	0.997	-.0264721	.0263693
Credit						
2	.0512869	.0799761	0.64	0.521	-.1054635	.2080372
3	.054623	.0887213	0.62	0.538	-.1192676	.2285136
4	-.2214336	.1108492	-2.00	0.046	-.438694	-.0041731
1.AccessTrain	-.0121387	.0671656	-0.18	0.857	-.1437809	.1195034
GrpMbrshp_NumberGrpInteraction	.007703	.0288175	0.27	0.789	-.0487782	.0641842
DistnceExtns	.0018252	.0059629	0.31	0.760	-.0098619	.0135122
_cons	.9804001	.2798628	3.50	0.000	.4318791	1.528921
/lnalpha	-21.03155	.			.	.
alpha	7.35e-10	.			.	.

LR test of alpha=0: chibar2(01) = **0.00** Prob >= chibar2 = **1.000**

.

. **estat ic**

Akaike's information criterion and Bayesian information criterion

Model	N	ll(null)	ll(model)	df	AIC	BIC
.	308	-542.6883	-489.4455	16	1010.891	1070.573

Note: BIC uses N = number of observations. See **[R] IC note**.

Appendix V: Multivariate Probit results

Variable	Risk Coef.	Cultural Coef.	Sustainable Coef.	Farm Coef.	Livestock Coef.	Diversification Coef.	Traditional Coef.
Adult Equivalent household size	-0.109(0.081)	0.049(0.072)	0.011(0.071)	0.049(0.077)	0.109(0.074)	0.050(0.083)	0.034 (0.121)
Age of household head	-0.008(0.016)	0.022(0.017)	0.001(0.015)	0.037(0.017) **	-0.004(0.015)	-0.050(0.016) ***	0.053(0.027) **
Age squared of the household head	-0.000(0.000)	-0.001(0.000) **	0.000(0.000)	0.000(0.000)	-0.001(0.000) *	-0.000(0.000)	0.001(0.000) **
Age and age-squared interaction	0.000(0.000)	0.000(0.000)	-0.000(0.000)	-0.000(0.000)	0.000(0.000) **	0.000(0.000)	-0.000(0.000) ***
Dependency Ratio	0.260(0.261)	-0.259(0.263)	-0.527(0.241) **	0.581(0.257) **	-0.309(0.251)	0.048(0.259)	1.390(0.380) ***
Gender of household head (male)	0.069(0.168)	-0.198(0.166)	-0.298(0.165) *	-0.057(0.162)	0.048(0.160)	-0.172(0.163)	-0.126(0.269)
Log of Years of education of household head	-0.078(0.156)	-0.012(0.139)	-0.103(0.138)	-0.431(0.131) ***	-0.441(0.138) ***	0.162(0.132)	-0.216(0.201)
Education stock of the household in years	0.004(0.038)	0.041(0.036)	0.018(0.036)	0.069(0.035) **	0.054(0.035)	0.096(0.038) **	-0.217(0.066) ***
Wealth Index dummy							
3. Rich	-0.112(0.243)	0.330(0.249)	-0.031(0.246)	0.058(0.245)	0.488(0.243) **	-0.155(0.233)	0.477(0.408)
4. Middle	0.181(0.238)	0.247(0.232)	0.018(0.234)	0.193(0.229)	0.374(0.223) *	-0.283(0.226)	0.181(0.397)
Farm size	0.023(0.052)	-0.057(0.047)	-0.003(0.044)	0.026(0.045)	-0.058(0.046)	-0.115(0.048) **	0.068(0.061)
Tropical Livestock Unit	0.039(0.068)	-0.171(0.064) ***	0.029(0.066)	-0.078(0.065)	-0.136(0.065) **	0.031(0.064)	0.166(0.101)
Institutional Characteristics							
Annual Access to training	-0.004(0.186)	0.108(0.183)	-0.018(0.176)	-0.124(0.178)	-0.029(0.190)	0.220(0.180)	-0.133(0.287)
Group membership	-0.045(0.267)	-0.029(0.274)	0.525(0.266) **	0.083(0.273)	0.142(0.269)	-0.150(0.297)	-0.950(0.481) **
Group membership and the number of group households belong interaction	-0.020(0.070)	0.036(0.084)	0.044(0.082)	0.094(0.074)	-0.015(0.072)	-0.151(0.081) **	0.156(0.116)
The number of groups a household belongs to	0.260(0.126) **	0.191(0.114) *	-0.071(0.111)	0.391(0.116) ***	0.466(0.111) ***	0.427(0.113) ***	0.419(0.192) **
Credit Access dummy							
3. Did not need credit	0.210(0.192)	0.250(0.188)	0.154(0.185)	0.324(0.184) *	0.048(0.187)	0.163(0.188)	0.166(0.284)
4. Didn't receive the amount needed	0.219(0.222)	-0.059(0.214)	0.139(0.208)	-0.194(0.210)	0.039(0.197)	0.223(0.206)	-0.889(0.501) *
Distance to extension agents' office	-0.012(0.047)	-0.031(0.043)	-0.002(0.043)	0.004(0.045)	-0.002(0.048)	0.136(0.044) ***	-0.239(0.080) ***
Constant	0.797(0.792)	-0.073(0.796)	0.133(0.788)	-2.340(0.824) ***	-0.510(0.844)	0.007(0.778)	-1.935(1.543)
Rho2	0.221 ***						
Rho3	0.400 ***	0.213 ***					
Rho4	0.246 ***	0.139 **	0.139 **				
Rho5	0.371 ***	0.260 ***	0.216 ***	0.344 ***			
Rho6	0.049	0.065	0.004	0.000	0.008		
Rho7	-0.013	-0.014	-0.014	0.046	-0.057	-0.076	
Observations					308		
Log Likelihood					-979.432		
Wald χ^2 (133)					544.11		
Prob > χ^2					0.0000		

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho32 = rho42 = rho52 = rho62 = rho72 = rho43 = rho53 = rho63 = rho73 = rho54 = rho64 = rho74 = rho65 = rho75 = rho76 = 0: χ^2 ((21) = 149.358 Prob > χ^2 (= 0.000)

Appendix VI: Rasch Model Pearson Residual Correlation

ITEM	WORRIED	HEALTHY	ATEFEW	SKIPPED	ATELESS	RANOUT	HUNGRY	WHOLEDAY
WORRIED	1.000	0.294	-0.113	-0.253	-0.289	-0.151	-0.174	-0.092
HEALTHY	0.294	1.000	0.236	-0.258	-0.318	-0.146	-0.295	-0.146
ATEFEW	-0.113	0.236	1.000	-0.296	-0.185	-0.199	-0.197	-0.137
SKIPPED	-0.253	-0.258	-0.296	1.000	0.031	-0.222	-0.029	-0.096
ATELESS	-0.289	-0.318	-0.185	0.031	1.000	-0.171	-0.187	-0.033
RANOUT	-0.151	-0.147	-0.199	-0.222	-0.171	1.000	-0.178	-0.104
HUNGRY	-0.174	-0.294	-0.197	-0.029	-0.187	-0.178	1.000	-0.089
WHOLEDAY	-0.092	-0.146	-0.137	-0.096	-0.033	-0.104	-0.089	1.000

APPENDIX VII: Standard ordered probit model

```
Ordered probit regression                               Number of obs =    290
                                                        Wald chi2(27) = 200.85
                                                        Prob > chi2   = 0.0000
Log pseudolikelihood = -308.13024                       Pseudo R2     = 0.2288
```

FIES_category	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
1.Gender	-.0807936	.1504223	-0.54	0.591	-.375616	.2140288
Hsize	.0970387	.0561708	1.73	0.084	-.013054	.2071314
FarmExprnce	.0088844	.0158907	0.56	0.576	-.0222609	.0400297
Age	-.0626527	.0473159	-1.32	0.185	-.1553902	.0300849
Age_squared	.0006447	.0004348	1.48	0.138	-.0002076	.001497
Educ_HHd	-.0526036	.0353712	-1.49	0.137	-.1219299	.0167226
Educations_Stock	-.0547717	.0249653	-2.19	0.028	-.1037027	-.0058407
Wealth_index						
2	-.2782567	.2000881	-1.39	0.164	-.6704222	.1139089
3	-.2894867	.406198	-0.71	0.476	-1.08562	.5066467
FarmSize	-.0976377	.0614457	-1.59	0.112	-.218069	.0227936
TLU	-.1044893	.0400356	-2.61	0.009	-.1829576	-.0260209
1.GrpMbrshp	.30083	.2554881	1.18	0.239	-.1999175	.8015776
AcceCrdt						
2	.0276355	.2176655	0.13	0.899	-.398981	.4542519
3	.1062373	.2004287	0.53	0.596	-.2865957	.4990703
4	.0716859	.4385304	0.16	0.870	-.7878178	.9311896
Recv_AgroInfo	1.738914	.1563007	11.13	0.000	1.43257	2.045258
1.Off_farmIncome	.0568048	.141674	0.40	0.688	-.2208711	.3344808
R0C0S0F0L0D0T0	.6333042	.4567778	1.39	0.166	-.2619639	1.528572
R1C1S1F0L1D0T0	.3697766	.2525624	1.46	0.143	-.1252367	.8647899
R1C1S1F1L1D0T0	-.0043041	.2454999	-0.02	0.986	-.4854751	.476867
R1C1S1F1L0D1T0	.0829148	.2585286	0.32	0.748	-.4237918	.5896215
R0C0S1F1L0D1T0	.0008204	.3307347	0.00	0.998	-.6474077	.6490484
R1C1S1F0L0D0T0	-.6393398	.3091792	-2.07	0.039	-1.24532	-.0333598
R1C1S1F1L0D0T0	.0118567	.3680374	0.03	0.974	-.7094834	.7331968
R1C0S1F1L1D1T0	-.1652431	.3406116	-0.49	0.628	-.8328295	.5023434
R1C1S1F1L1D0T1	.3658741	.3519969	1.04	0.299	-.3240272	1.055775
R1C1S1F1L1D1T1	.4663333	.4484177	1.04	0.298	-.4125492	1.345216
/cut1	-1.860848	1.263252			-4.336776	.6150799
/cut2	-.8719029	1.258331			-3.338187	1.594381
/cut3	.2214439	1.252541			-2.233492	2.67638

Appendix VIII: Constrained variables for the model

```
Testing parallel lines assumption using the .05 level of significance...

Step  1:  Constraints for parallel lines imposed for 3.Wealth_index (P Value = 0.8893)
Step  2:  Constraints for parallel lines imposed for 2.Wealth_index (P Value = 0.9741)
Step  3:  Constraints for parallel lines imposed for Hsize (P Value = 0.9320)
Step  4:  Constraints for parallel lines imposed for Recv_AgroInfo (P Value = 0.8946)
Step  5:  Constraints for parallel lines imposed for R1C1S1F1L1D1T1 (P Value = 0.7381)
Step  6:  Constraints for parallel lines imposed for TLU (P Value = 0.7340)
Step  7:  Constraints for parallel lines imposed for 2.AcceCrdt (P Value = 0.6024)
Step  8:  Constraints for parallel lines imposed for 4.AcceCrdt (P Value = 0.3854)
Step  9:  Constraints for parallel lines imposed for Educ_HHd (P Value = 0.5011)
Step  10: Constraints for parallel lines imposed for Educations_Stock (P Value = 0.3564)
Step  11: Constraints for parallel lines imposed for 3.AcceCrdt (P Value = 0.4279)
Step  12: Constraints for parallel lines imposed for 1.GrpMbrshp (P Value = 0.4212)
Step  13: Constraints for parallel lines imposed for R1C1S1F1L1D0T0 (P Value = 0.3060)
Step  14: Constraints for parallel lines imposed for Age (P Value = 0.3137)
Step  15: Constraints for parallel lines imposed for FarmSize (P Value = 0.3120)
Step  16: Constraints for parallel lines imposed for R0C0S1F1L0D1T0 (P Value = 0.2424)
Step  17: Constraints for parallel lines imposed for R1C1S1F1L1D0T1 (P Value = 0.2001)
Step  18: Constraints for parallel lines imposed for 1.Gender (P Value = 0.2454)
Step  19: Constraints for parallel lines imposed for R0C0S0F0L0D0T0 (P Value = 0.1634)
Step  20: Constraints for parallel lines imposed for R1C1S1F1L0D1T0 (P Value = 0.1379)
Step  21: Constraints for parallel lines imposed for R1C0S1F1L1D1T0 (P Value = 0.0822)
Step  22: Constraints for parallel lines imposed for R1C1S1F1L0D0T0 (P Value = 0.0628)
Step  23: Constraints for parallel lines imposed for R1C1S1F0L1D0T0 (P Value = 0.0752)
Step  24: Constraints for parallel lines imposed for R1C1S1F0L0D0T0 (P Value = 0.1018)
Step  25: Constraints for parallel lines are not imposed for
          FarmExprnce (P Value = 0.01159)
          Age_squared (P Value = 0.00986)
          1.Off_farmIncome (P Value = 0.01069)
```

```
Wald test of parallel lines assumption for the final model:

 ( 1)  [1]2.Wealth_index - [2]2.Wealth_index = 0
 ( 2)  [1]3.Wealth_index - [2]3.Wealth_index = 0
 ( 3)  [1]1.Gender - [2]1.Gender = 0
 ( 4)  [1]1.GrpMbrshp - [2]1.GrpMbrshp = 0
 ( 5)  [1]2.AcceCrdt - [2]2.AcceCrdt = 0
 ( 6)  [1]3.AcceCrdt - [2]3.AcceCrdt = 0
 ( 7)  [1]4.AcceCrdt - [2]4.AcceCrdt = 0
 ( 8)  [1]Hsize - [2]Hsize = 0
 ( 9)  [1]Recv_AgroInfo - [2]Recv_AgroInfo = 0
 (10)  [1]R1C1S1F1L1D1T1 - [2]R1C1S1F1L1D1T1 = 0
 (11)  [1]TLU - [2]TLU = 0
 (12)  [1]Educ_HHd - [2]Educ_HHd = 0
 (13)  [1]Educations_Stock - [2]Educations_Stock = 0
 (14)  [1]R1C1S1F1L1D0T0 - [2]R1C1S1F1L1D0T0 = 0
 (15)  [1]Age - [2]Age = 0
 (16)  [1]FarmSize - [2]FarmSize = 0
 (17)  [1]R0C0S1F1L0D1T0 - [2]R0C0S1F1L0D1T0 = 0
 (18)  [1]R1C1S1F1L1D0T1 - [2]R1C1S1F1L1D0T1 = 0
 (19)  [1]R0C0S0F0L0D0T0 - [2]R0C0S0F0L0D0T0 = 0
 (20)  [1]R1C1S1F1L0D1T0 - [2]R1C1S1F1L0D1T0 = 0
 (21)  [1]R1C0S1F1L1D1T0 - [2]R1C0S1F1L1D1T0 = 0
 (22)  [1]R1C1S1F1L0D0T0 - [2]R1C1S1F1L0D0T0 = 0
 (23)  [1]R1C1S1F0L1D0T0 - [2]R1C1S1F0L1D0T0 = 0
 (24)  [1]R1C1S1F0L0D0T0 - [2]R1C1S1F0L0D0T0 = 0
 (25)  [1]2.Wealth_index - [3]2.Wealth_index = 0
 (26)  [1]3.Wealth_index - [3]3.Wealth_index = 0
 (27)  [1]1.Gender - [3]1.Gender = 0
 (28)  [1]1.GrpMbrshp - [3]1.GrpMbrshp = 0
 (29)  [1]2.AcceCrdt - [3]2.AcceCrdt = 0
```

```
 (30)  [1]3.AcceCrdt - [3]3.AcceCrdt = 0
 (31)  [1]4.AcceCrdt - [3]4.AcceCrdt = 0
 (32)  [1]Hsize - [3]Hsize = 0
 (33)  [1]Recv_AgroInfo - [3]Recv_AgroInfo = 0
 (34)  [1]R1C1S1F1L1D1T1 - [3]R1C1S1F1L1D1T1 = 0
 (35)  [1]TLU - [3]TLU = 0
 (36)  [1]Educ_HHd - [3]Educ_HHd = 0
 (37)  [1]Educations_Stock - [3]Educations_Stock = 0
 (38)  [1]R1C1S1F1L1D0T0 - [3]R1C1S1F1L1D0T0 = 0
 (39)  [1]Age - [3]Age = 0
 (40)  [1]FarmSize - [3]FarmSize = 0
 (41)  [1]R0C0S1F1L0D1T0 - [3]R0C0S1F1L0D1T0 = 0
 (42)  [1]R1C1S1F1L1D0T1 - [3]R1C1S1F1L1D0T1 = 0
 (43)  [1]R0C0S0F0L0D0T0 - [3]R0C0S0F0L0D0T0 = 0
 (44)  [1]R1C1S1F1L0D1T0 - [3]R1C1S1F1L0D1T0 = 0
 (45)  [1]R1C0S1F1L1D1T0 - [3]R1C0S1F1L1D1T0 = 0
 (46)  [1]R1C1S1F1L0D0T0 - [3]R1C1S1F1L0D0T0 = 0
 (47)  [1]R1C1S1F0L1D0T0 - [3]R1C1S1F0L1D0T0 = 0
 (48)  [1]R1C1S1F0L0D0T0 - [3]R1C1S1F0L0D0T0 = 0

           chi2( 48) =   59.22
         Prob > chi2 =    0.1285

An insignificant test statistic indicates that the final model
does not violate the proportional odds/ parallel lines assumption
```

Appendix IX: Generalized ordered probit model estimates for household food security

FIES_category	Food Secure		Mildly Food Insecure		Moderately Food Insecure	
Variable	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
Gender of household head (Male)	-0.060	0.148	-0.060	0.148	-0.060	0.148
Consumption equivalent household size	0.095 *	0.057	0.095 *	0.057	0.095 *	0.057
Farming experience of the household	0.067 **	0.026	0.005	0.021	-0.023	0.022
Age of household head	-0.048	0.050	-0.048	0.050	-0.048	0.050
Age squared of the household head	0.000	0.000	0.001	0.000	0.001	0.000
Education of the household head	-0.053	0.036	-0.053	0.036	-0.053	0.036
The education stock of the household	-0.058 **	0.026	-0.058 **	0.026	-0.058 **	0.026
Wealth index (Rich)						
2. Middle	-0.282	0.210	-0.282	0.210	-0.282	0.210
3. Poor	-0.349	0.456	-0.349	0.456	-0.349	0.456
Farm size	-0.098	0.062	-0.098	0.062	-0.098	0.062
Tropical livestock unit	-0.114 ***	0.038	-0.114 ***	0.038	-0.114 ***	0.038
Membership in rural agric. institution	0.251	0.259	0.251	0.259	0.251	0.259
Access to credit (Didn't need credit)						
2. Received Amount Needed	-0.026	0.225	-0.026	0.225	-0.026	0.225
3. Didn't receive the amount needed	0.078	0.212	0.078	0.212	0.078	0.212
4. Needed and didn't receive completely	0.087	0.448	0.087	0.448	0.087	0.448
Received agroweather information	1.782 ***	0.166	1.782 ***	0.166	1.782 ***	0.166
Off-farm income	-0.158	0.197	-0.172	0.180	0.488 **	0.213
$R_0C_0S_0F_0L_0D_0T_0$	0.567	0.434	0.567	0.434	0.567	0.434
$R_1C_1S_1F_0L_1D_0T_0$	0.322	0.235	0.322	0.235	0.322	0.235
$R_1C_1S_1F_1L_1D_0T_0$	-0.055	0.227	-0.055	0.227	-0.055	0.227
$R_1C_1S_1F_1L_0D_1T_0$	0.039	0.254	0.039	0.254	0.039	0.254
$R_0C_0S_1F_1L_0D_1T_0$	-0.011	0.445	-0.011	0.445	-0.011	0.445
$R_1C_1S_1F_0L_0D_0T_0$	-0.729 **	0.325	-0.729 **	0.325	-0.729 **	0.325
$R_1C_1S_1F_1L_0D_0T_0$	0.041	0.363	0.041	0.363	0.041	0.363
$R_1C_0S_1F_1L_1D_1T_0$	-0.294	0.380	-0.294	0.380	-0.294	0.380
$R_1C_1S_1F_1L_1D_0T_1$	0.351	0.377	0.351	0.377	0.351	0.377
$R_1C_1S_1F_1L_1D_1T_1$	0.499	0.443	0.499	0.443	0.499	0.443
Constant	1.468	1.288	0.646	1.278	-0.463	1.283

Observations = 308; LR χ^2 (33) = 204.95, p=0.000

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Appendix X: Research Permit

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