

**EXPLORING THE NEXUS BETWEEN CROP DIVERSIFICATION AND HOUSEHOLD
WELFARE AMONG SMALL-SCALE MAIZE FARMERS IN BORABU SUB-COUNTY,
NYAMIRA 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

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this university or any other for the award of a degree.

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Recommendation

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DEDICATION

To my dear son, Tarique-Bailey Omwenga, my lovely parents, Wilfred Omwenga and Patricia Bosibori, and siblings Stanford, Jemimah, Ashley, and Precious.

This work is dedicated to each of you with deep appreciation and heartfelt gratitude. You have all played a significant role in shaping the person I am today, and I am forever grateful for that. I hope this work serves as a small token of my appreciation for your love, support, and guidance.

May the Almighty bless all of you abundantly.

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ABSTRACT

While rural transformation has dominated recent literature as a way of improving welfare through diversifying into non-farm sectors, improving productivity and resilience to shocks in small-scale agricultural production cannot be downplayed. This is especially so in a context characterized by repeated exposure to shocks, threatening many livelihoods in rural areas. Persistence of maize lethal necrosis disease (MLND) in Borabu sub-county is one such shock that has threatened the livelihoods of farmers in the region. Crop diversification is considered an effective risk management strategy and consumption smoothing strategy against climatic shocks in farm production. Using cross section data from Borabu Sub-county, the study assesses the barriers and success factors related to effective crop diversification and the effect of these on household welfare. A multi-stage sampling technique was used to select 385 households, and data were collected using semi-structured pre-tested questionnaires. Data were analyzed using SPSS and STATA data analytical software. Herfindahl index was used to measure the extent of crop diversification. A double hurdle model was used to explore factors influencing the extent of crop diversification, and the endogenous switching regression model was used to investigate the nexus between crop diversification and household welfare. The study found the average crop diversification index to be 0.15, and about 85.5% of the sampled farmers had values below the average (0.5), indicating a low diversification rate in the study area. Upon examining factors influencing the extent of crop diversification, the age of the household head, education level of the household head, marital status of the household head, size of land under farming, gender of household head, land tenure and type of labour available to a household, were identified as significant in influencing participation and extent of crop diversification. Using consumption expenditure as a proxy for household welfare results indicated that crop diversification contributes significantly to a household having better welfare and improving its food security status. Factors such as the age of the household head, income source, household head's primary occupation, marital status of household head and size of land farmed, were found to significantly influence a household's consumption expenditure. The study concludes that crop diversification positively impacts household welfare, as farmers that practiced diversification had better overall welfare. Therefore, this study recommends developing policies aimed at enhancing multiple cropping and modernizing it to take full advantage of what comes with the practice.

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LIST OF ABBREVIATIONS AND ACRONYMS

ATE	Average Treatment Effect
ATT	Average Treatment Effect on Treated
ATU	Average Treatment Effect on Untreated
ASL	Above Sea Level
AU	African Union
CDI	Crop diversification index
CIMMYT	International Maize and Wheat Improvement Centre
CSA	Climate Smart Agriculture
DHM	Double Hurdle Model
IV	Instrumental Variable
EAC	East African Community
ESR	Endogenous Switching Regression model
FAO	Food and Agriculture Organization of the United Nations
FAW	Fall Army Worm
Ha	Hectares
HI	Herfindahl Index
IPM	Integrated Pest Management
KALRO	Kenya Agricultural Livestock Research Organization
KNBS	Kenya National Bureau of Statistics
MI	Margalef's Index
MLND	Maize lethal necrosis disease
MoALF	Ministry of Agriculture, Livestock, and Fisheries
MCMV	Maize Chlorotic Mottle virus
MT	Metric Tonnes
NCIDP	Nyamira County Integrated Development Project
NGOs	Non-governmental organizations
NPPO	National Plant Protection Organization
SACCOs	Savings and Credit Cooperative Organisations
SAI	Sustainable Agriculture Intensification
SDG	Sustainable Development Goals

SSA	Sub-Saharan Africa
SLA	Sustainable Livelihood Approach
SME	Small and medium enterprises
SMV	Sugarcane Mosaic Virus
SPSS	Statistical Package for Social Sciences
TLU	Total Livestock Unit
USA	United States of America
WSMV	Wheat Streak Mosaic Virus

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Farmers' dependence on specific environmental conditions for crop production has made managing climatic risks and risks associated with pests and diseases an intrinsic and critical part of agriculture. According to BIRTHAL and HAZRANA (2019), farmers' frequent exposure to shocks is one of the major causes of low agricultural productivity, slow economic growth, and persistent poverty. In most parts of Kenya, maize is a major staple food crop and a source of income for the majority. About 90% of the Kenyan population depends on maize for food, labour, and income (NGALA & KILALO, 2018).

In Nyamira County, maize is mainly grown on small-scale farms in four Sub Counties: (Manga, Nyamira North, Nyamira South & Masaba North). Most of the time, it is produced on 0.25 to 0.75 acres in most sub-counties. However, in the Borabu Sub-County, the production is concentrated mainly on relatively bigger farms with a capacity of 4 to 20 Ha (NCIDP, 2018). Like other food crops, maize is grown twice a year in the entire region. The primary season is typically February to August, and the short rainy season is September to December. In 2013, the total acreage under maize in the entire county was 31,546 Ha, which gave a cumulative production of 44,780 MT of maize. By the end of the 2017 season, the total land under maize had marginally risen by 404 Ha, giving an output of 45,504 MT of maize. As of 2017, the total land area under maize remained relatively constant (NCIDP, 2018).

Despite the favorable weather conditions for farming in Nyamira County, the average production level of maize has remained low, with farmers recording as low as four 90kg bags per acre (NCIDP, 2018). The significant challenges that face maize production in the region are declining soil fertility and soil acidity, as well as impacts of climate change, including delayed onset and untimely cessations of rains, skewed rainfall distribution & intensity, occasional hailstorms, and the emergence of new pests and diseases such as Maize Lethal Necrotic Disease (MLND) and Fall Army Worm (FAW) (NCIDP, 2018).

In September 2011, the first maize lethal necrosis disease (MLND) case was reported in Kenya in Bomet County (Ngala & Kilalo, 2018). This disease was said to be caused by a combination of maize chlorotic mottle virus (MCMV) and sugarcane mosaic virus (SMV). The disease further spread to other counties, including but not limited to Nyamira, Narok, Naivasha,

Sotik, Embu, Meru, and Trans-Nzoia, with Trans-Nzoia and Narok counties considered the country's major food baskets and the others, self-sufficient, concerning maize production.

MLND seriously impacted maize production and grain yields in Eastern Africa (De Groot *et al.*, 2016; Marenja *et al.*, 2018). For instance, in 2012-2013, the estimated maize yield losses in Kenya due to MLND were reported as 23–100% in the affected counties in the country. In 2012, losses by MLND were estimated at US\$ 52 million, which increased to US\$180 million in 2013, equivalent to about a 0.5million tonnes (Isabirye & Rwomushana, 2016). MLND devastated the maize crop and the livelihoods of the affected counties' resource-poor farmers and other key actors in the maize seed/grain value chain, especially small and medium enterprise (SME) seed companies and processors. Demand for the seed of commercial maize varieties decreased when MLND was a major epidemic in the affected counties, with consequent sales losses for maize-based seed companies and carry-over of significant quantities of seed. Thus, besides resource-poor farmers, SME seed companies were affected by the intensity and spread of MLND in Eastern Africa (Boddupalli *et al.*, 2020).

Due to its multifaceted and complex nature, strong, coordinated, and synergistic efforts from multiple institutions were needed to effectively counter the incidence, spread, and adverse impacts of MLND. To counter the disease, farmers were encouraged to integrate cultural practices with insecticides and host resistance (Ngala & Kilalo, 2018). Through a multi-institutional strategy, the International Maize and Wheat Improvement Centre (CIMMYT) implemented a strategy focused on reducing the impact of the disease and protecting the environment. Among them were intensive germplasm screening and fast-tracked development and deployment of MLND-tolerant/ resistant maize hybrids in Africa-adapted genetic background, optimizing the diagnostic protocols for MLND-causing viruses, especially maize chlorotic mosaic virus(MCMV), and capacity building of relevant public and private sector institutions on MLND diagnostics and management, MLND monitoring and surveillance across SSA in collaboration with National Plant Protection Organization(NPPOs), partnership with the private seed sector for production and exchange of MLND pathogen free commercial maize seed and awareness creation among relevant stakeholders about MLND management, including engagement with policymakers (Boddupalli *et al.*, 2020).

Certified seeds, sanitation, quarantine, crop rotation with a non-maize crop, and resistant and tolerant maize varieties were the most effective ways of managing MLND (Kiruwa *et al.*,

2016). However, implementing some of these strategies among small-scale farmers was impossible in Borabu Sub-County, citing their cost implications and high incidences of poverty. For instance, due to the dense population in the region, most households own small parcels of land, necessitating them to practice intercropping.

Despite all the efforts put in place to combat the disease, most farmers in some parts of Borabu Sub-County are still dealing with the impacts of MLND and are, therefore, unable to produce maize. The disease's persistence over the years necessitated the government to encourage farmers to diversify away from maize production to improve the household food and nutrition status of farming households. Experts and the government expected that this strategy would help improve the living standards of farming households while offering various cropping alternatives to farmers instead of relying on a single crop, maize.

Among the crops farmers consider are orange sweet potatoes, beans, finger millet, cabbages, carrots, black nightshade, spider plants, passion fruits, pineapples, and eucalyptus trees. One of the advantages of growing more than one crop is that it allows farm households to mitigate the risks associated with crop-specific failure due to shocks such as MLND. The disease is still a significant threat to the maize crops in Eastern Africa, and the danger of its emergence in other regions in Sub-Saharan Africa (SSA) still looms (Isabirye & Rwomushana, 2016).

1.2 Statement of the problem

Exogenous trends and shocks are essential in pushing rural people towards a diversified livelihood strategy. However, diversification choices are firmly rooted in the microeconomic logic of farming households. Most people in Kenya depend on maize production for food, labour, and income. With unpredictable weather patterns and the emergence of new pests and diseases such as MLND that attack maize, farmers have long been advised to diversify away from the production of maize. Farmers in the Borabu sub-county have been planting maize for a long time, but ten years ago, the occurrence of MLND brought some changes to its production in the region. The disease resulted in crop losses of up to 100%, jeopardizing most maize farming households' economic and food security. The disease's persistence over the years necessitated the government to encourage farmers to plant crops other than maize. However, a few of the farmers in the region could diversify away from maize while others could not. This study, therefore, sought to find out why and how some households could diversify away from maize while others were not, thereby promoting crop diversification to mitigate risks associated with crop-specific failure.

1.3 Objectives of the study

1.3.1 General objective

To contribute towards improving households' welfare and food and nutrition security by promoting crop diversification to mitigate risks associated with crop-specific failure in Borabu sub-county.

1.3.2 Specific objectives

- i. To determine the extent of crop diversification by small-scale farmers of Borabu sub-county in response to the presence of MLND.
- ii. To determine factors influencing the extent of crop diversification by small-scale farmers of Borabu sub-county in light of the presence of MLND.
- iii. To investigate the nexus between crop diversification and household welfare among small-scale farmers in Borabu sub-county with a focus on the impact of MLND.

1.3.3 Research questions

- i. What is the current level of crop diversification among small-scale farmers in Borabu Sub-county?
- ii. How has the spread of MLND impacted small-scale farmers' decisions on crop diversification?
- iii. In what ways has MLND affected the relationship between crop diversification and household welfare in the region?

1.4 Justification of the study

Relying on a few low-risk crops or specializing in a few staple crops may intensify exposure to shocks and worsen food insecurity and poverty, especially in a context characterized by repeated exposure to shocks. Increasing crop diversification is the most promising solution for dealing with unstable weather conditions and market shocks and improving rural livelihoods. The reduction in maize yields associated with the emergence of new pests and diseases, such as MLND in the Borabu sub-county, has emphasized the need for maize farmers to diversify away from maize production. The government has promoted crop diversification to improve food security and minimize risks associated with heavy dependence on maize. In Kenya, where about half the population lives below the poverty line, most households in rural areas are small land holders. Crop diversification for such households is crucial in the face of the increasing vulnerability of agriculture to climatic changes and economic shocks. With the recent shocks and stressors,

especially to the maize production sector, specifically MLND, households are highly food insecure and at risk of falling into poverty. A shift from maize to other crops is a trend that experts hope can be replicated in the country to help diversify and thereby contribute to improved food security. The findings of this study may be relevant in understanding strategic household behaviour in the event of risks, and this information can be necessary for formulating integrated rural development policies. A study on crop diversification is of interest as it falls within the interests and focus of sustainable development goals (SDGs)1 and 2 of no poverty and zero hunger, respectively, one of Kenya's big four agendas of improving food and nutrition security, East African Community (EAC) agenda 2050 of attaining food security within the community as well as one of the African Union (AU) agenda 2063 goal of achieving a high standard of living, quality of life and well-being for all.

1.5 Scope and limitations of the study

This study was carried out in the Borabu Sub-County of Nyamira County. Cross-sectional data were used by taking only maize farmers operating on a small scale. The sample unit for this study was farmers above the age of 18 years who have at some point or at all times planted maize between 2011 and the time of the survey and operating on a small scale, that is, has a low asset base and operate on less than two hectares of cropland. The primary limitation to the generalization of results is that the findings of this study were only relevant to Borabu sub-county and may not necessarily reflect the exact situation for other regions that were affected by MLND. Another limitation of the study was recall bias. The study overcame this bias using a carefully constructed questionnaire to get accurate and complete information.

1.6 The operational definition of terms

Resilience: resilience is the capacity to absorb shocks and re-organize while the effects of a shock occur.

Crop diversification: Growing more than one crop on one piece of land by a farmer.

Small-scale farmers: Farmers with a low asset base operating in less than 2 hectares of cropland.

Coping mechanism: how households mitigate themselves from the threats of food shortage problems such as reduced frequency of food intake, selling of assets, working for food, and receiving food aid, among others.

Risk: the probability that exposure to a hazard will lead to negative consequences.

Shocks: refers to a risk that causes a “significant” negative welfare effect such as major income loss and production disruption.

Vulnerability: These characteristics or conditions increase a community's susceptibility to a hazard's impacts. They could be physical, social, economic, or environmental.

Mitigation: Actions meant to minimize possible impacts of an undesirable event

CHAPTER TWO

LITERATURE REVIEW

This chapter discusses the literature on crop diversification and household welfare in the face of maize lethal necrosis disease in Borabu sub-county. Also, it discusses various implemented interventions to deal with MLND, factors influencing the participation of farmers in crop diversification, the extent of diversification, and the shortcomings of the reviewed literature. In addition, the section discusses the theoretical and conceptual framework used in this study.

2.1 Overview of crop diversification

Crop diversification refers to the process of increasing the diversity of crops through the use of multiple crops. It is regarded as one sub-set of a large matrix of production options in the cropping sector. Crop diversification is achieved through various means, such as crop rotation, multiple cropping, or intercropping, compared to specialized farming to improve the productivity, stability, and delivery of ecosystem services (Garbach *et al.*, 2016). A more sustainable production system can be established by diversifying crops and increasing the variety of crops available (Meynard *et al.*, 2018), contributing to socioeconomic benefits (Feliciano, 2019).

From an economic point of view, diversification can be examined from two analytical viewpoints: First, as a problem of determining, given a set of prices, the optimal crop mixes on a production possibility frontier, and second, as a mechanism for incorporating risk aversion into a farmer's decision-making process in which crop specialization may lead to precarious income due to variance in output, production or price for a particular crop (van Zonneveld *et al.*, 2020). Diversification has two main properties; first, it expands the production possibility set or area allocation frontier for a farmer, thereby increasing income generation and employment creation. Second, it reduces the risk of having all of one's eggs in a basket with one crop only or a few crops with potentially high covariance risk (Makate *et al.*, 2016).

In agriculture, diversification is defined as reallocating some of a farm's productive resources, such as land, capital, labour, and equipment, into new farm activities (Boncinelli *et al.*, 2018). Crop diversification is usually viewed as a shift from traditionally grown, less profitable crops to newer, more profitable crops (Kankwamba *et al.*, 2018). It is also a strategy used to maximize the use of land, water, and other resources for the overall agricultural development in a country. It provides farmers with feasible options to grow different crops on their land. Therefore,

a farmer's decision to diversify is considered a significant economic decision that strongly affects the farmers' income level and food security.

The economic theory asserts that households diversify their economic activities to improve risk management capacity, smooth income streams ex-ante, and smooth consumption ex-post shocks. Consumption smoothing expresses a household's desire to have a stable and predictable consumption path in their lifetime. Although diversification is a common practice across different sectors (e.g., finance), the uniqueness of agricultural production, such as dependence on weather patterns, seasonality in demand for inputs, and heterogeneity in land quality, distinguishes diversification in agricultural production from other sectors (Arslan *et al.*, 2018). Incomplete credit and insurance markets or market failures, quasi-universal circumstances in developing countries, are among the primary conditions that lead to diversification in rural economies

Although diversity is often seen as equal to diversification, from an agronomic point of view, that is not the case. While the former deals with biological principles such as genetic diversity, the latter deals with agronomic principles such as crop rotation or mixed cropping that might lead to higher biodiversity and associated ecosystem services. Diversification is a process that involves diversifying a crop's diversity. Although it is claimed that it is the solution to many problems of today's intercropping, the process can also lead to the development of new ecosystems (Fischer *et al.*, 2020).

In this paper, we focused on crop diversification and defined it as a process that makes a simplified cropping system more diverse in time and space by adding additional crops (Recklin *et al.*, 2019). Diversification by agronomic measures, such as tillage, was not considered unless tested in combination with crop diversification. This analysis was restricted to crop diversification at the field level. In contrast to many studies, an agronomic perspective was taken on crop diversification as a basis for this review.

2.1.1 Benefits of crop diversification

Crop diversification is associated with several benefits. First, crop diversification can improve soil health and fertility through various mechanisms, such as nitrogen fixation, nutrient cycling and pest and disease pressure reduction. Diverse cropping systems can promote soil organic matter accumulation and nutrient availability, improving crop productivity and sustainability (French *et al.*, 2021). Growing various crops can help reduce the incidence and severity of pests and diseases. Crop rotation and intercropping can disrupt the life cycles of pests

and pathogens, decreasing their populations and minimizing the need for chemical inputs. Crop diversification can enhance resilience to climate change by reducing vulnerability to extreme weather events. Diversified cropping systems are more resilient to climate variability and yield higher than monoculture systems (Zakari *et al.*, 2022).

Growing a diverse range of crops can provide farmers with a more stable income stream. By diversifying their production, farmers can spread their risks and reduce dependence on a single crop, which can be susceptible to market fluctuations or crop failures (Zakari *et al.*, 2022). Crop diversification can contribute to ecosystem services such as pollination, soil erosion control and biodiversity conservation. Joshi (2005) found out that diversification is among the most ecologically viable, efficient, and practical strategies for minimizing uncertainties in agriculture, particularly among small-scale farmers. In addition, crop diversification enhances resilience and boosts farm spatial and biodiversity (Makate *et al.*, 2016). Lin (2011) indicates that soil fertility is improved through crop diversification. It also enhances pests and disease control, facilitates yield stability, and improves human nutritional diversity and health.

Crop diversification is also a dominant substitute for chemical use in soil fertility conservation and pest control. Diversified cropping systems are generally more agronomically stable and resilient due to decreased weed and insect, reduced requirement of nitrogen fertilizers (especially when leguminous crops are incorporated), reduced erosion due to cover crops use, increased and increased productivity (Lin, 2011; Makate *et al.*, 2016). Moreover, Makate *et al.* (2016) indicate that crop-diversified systems provide a conducive environment for beneficial insects, reducing pests and making the host crops less conspicuous for attack by pests. Crop diversification also contributes to local biodiversity, especially when growing indigenous crop varieties. Lin (2011) also indicates that proper management of soils helps maximize plants' water use, thereby improving overall crop yields. Crop diversification, therefore, contributes in one way or another to all three principles of climate-smart agriculture (CSA) through improving productivity, livelihood, resilience of agricultural systems, and reduction of carbon dioxide emissions.

This study, therefore, aimed to elucidate the current use of crop diversification in research and support a common approach to utilize its full potential. It was assumed that a common understanding of the diversification concept in the context of crop production was needed to enable the comparison of results and to enhance the empirical evidence of the effects of diversification as

a measure to make cropping systems more resilient and reduce negative impacts on the environment.

2.1.2 Levels of Diversification

According to Golleti (1999), agricultural diversification occurs at three levels: micro, regional and macro. Individual households diversify at the micro level to strengthen their income sources. This level involves horizontal diversification, an expansion towards new agricultural commodities, and vertical diversification into non-farm activities such as marketing, storage, and processing. At the regional level, regions undertake agricultural activities in which they have a comparative advantage. At the macro-level, diversification entails an organizational shift from agriculture into non-farm activities in rural or urban areas or in rural towns.

Diversification refers to the number of economic activities an economic unit is involved in and the distribution of those activities in the total economic unit (Kimenju & Tschirley, 2008). In this study, diversification was based on the micro-level (household), the individual smallholder maize farmer who practices diversification to enhance household welfare and improve food security.

2.2 Determinants and extent of crop diversification

Many empirical studies have attempted to assess farm diversification's relevance to food security and household welfare in many agricultural societies. Several scholars have studied crop diversification in many places such as India, China, Pakistan, and many African countries such as Nigeria, Malawi, Zambia, Ethiopia, Zimbabwe, and Kenya. While studying the status and determinants of crop diversification in Eastern India, Kumar and Sharma (2012) analyzed the age and education level of the household head, Agriculture as the main occupation, household size, credit access, farm assets, operated area, use of technology components, infrastructure, and caste. Three-stage and stratified sampling were used in this study, and 2885 farmers were studied. They used the Herfindahl Index to establish the extent of crop diversification and the Tobit regression model to analyze determinants of diversification towards vegetable cultivation in the study area. They established that the crop sector in the eastern region was moderately diversified. The study also showed that Education, household size, the value of productive assets, and the primary household head occupation significantly influenced diversification. Age and gender, however, did

not substantially affect farmers' decision to diversify in favour of vegetables. While seeking to recognize factors influencing the household decision to crop diversification in Ukhonul District, Manipur *et al.* (2017) adopted Heckman's two-stage model to evaluate the determinants of household diversification decision and its intensity. The results showed that the education level of the head of the household had a positive association with the level of crop diversification, which is similar to Kumar *et al.* (2012), and Shabzah *et al.* (2017). Other factors with positive influence are access to fertilizer, access to plough, availability of irrigation, regular exposure to farming information, distance to the nearest market, and farmer experience.

While studying trends, patterns, and determinants of crop diversification of smallholders in West Bengal, Mithiya *et al.* (2018) used secondary data from different districts. The Simpson Index (SI), which Aheibam (2017) also used, showed that every district in West Bengal and the whole state demonstrated higher crop diversification levels during the new millennium compared to the nineties. The factors analyzed include the level of literacy, the urban population percentage of the district, comparative earnings from high-value crops compared to cereals, regional market density, smallholders' percentage and area under high-yielding food grain varieties. Education, land size, distance from the market, and income from other sources had a significant influence. In addition, Huang *et al.* (2014) did a study on crop diversification in coping with extreme weather events in China and used multiple-stage sampling to obtain 3330 smallholder farmers. They determined that age had a negative effect on diversification, and aged farmers were less expected to adopt crop diversification compared to younger farmers. Young farmers also have less experience and are more likely to adopt crop diversification to avoid production risks. Young people are also more willing to try new things. These findings are in line with those of Aheibam *et al.* (2017), Dube *et al.* (2016), and Ojo *et al.* (2014). However, Huang noted that farmers with lower education levels are more vulnerable and likely to use crop diversification to mitigate the effects of extreme weather. In addition, Huang' found out that farmers with larger farms are more likely to diversify their crop types. A household with more land is expected to plant more crops since more arable land is available in extensive lands, enabling them to grow more crops.

While studying determinants of crop diversification in the mixed cropping zone of Punjab, Pakistan *et al.* (2017) used multiple-stage sampling to select 100 growers for the study. The Herfindahl index was applied to calculate the farmer's diversification level, which has been used by many other scholars such as Kumar *et al.* (2012), Ojo *et al.* (2014) and Kanyua *et al.* (2013).

Determinants of crop diversification were analyzed using the Tobit model, which was also used by Kumar *et al.* (2012), Ojo *et al.* (2014) and Kanyua *et al.* (2013). It was established that the level of education and farm size positively and significantly influence crop diversification. An educated farmer is more likely to understand the market condition and can act as a sound tackler of the impact of the uncertain event.

Similarly, ownership of farm machinery enhanced the levels of diversification in crop cultivation. The study, however, indicates a negative relationship between age and crop diversification. The reason could be that younger farmers are more innovative, risk-takers, and more robust in physical activities at the farm than older people. The study also revealed that self-owned operated farms were less diversified in crop production than other tenures, such as renter or shareholder. Sichoongwe (2014) also studied the determinants and extent of crop diversification among smallholder farmers in the Southern Province of Zambia. He analyzed gender, age, education level of the household head and household size, land holding size, number of fields or land plots, hired labour, tillage time, plough tillage, fertilizer quantity and distance from the market in 1,555 farmers. Determinants of crop diversification were analyzed using the Tobit regression model, while the extent of diversification was established using the Crop Diversification Index (CDI). Sichoongwe established that crop diversification by smallholder farmers was relatively low. In his study, size of land holding, quantity of fertilizer, distance to the market, tillage time and tillage (plough) were established to determine crop diversification significantly.

While studying factors influencing smallholder crop diversification among 479 smallholder farmers in Manicaland and Masvingo provinces of Zambia, Dude (2016) used the Herfindahl Index to estimate diversification. He used the Tobit regression model to evaluate factors associated with diversification. This study showed that male-headed households were slightly more diversified than female-headed households. Tobit regression model also revealed that education, number of livestock units, access to irrigation, membership of a farmers' group, access to markets, farming experience, farms of flat terrain, farmer-to-farmer extension, agro-ecological zone and household income were the most significant factors in crop diversification.

Ojo *et al.* (2013) also studied determinants of crop diversification among small-scale food crop farmers in North Central Nigeria. Multiple-stage sampling was used to obtain a sample of 300 respondents. Using the Herfindahl Index, their study revealed that North central Nigerian smallholders were less diversified. The study also showed that experience, extension contacts, and

land size positively influenced diversification. Age and income from other sources, however, had no influence. In another study on determinants of food crop diversity and profitability in southeastern Nigeria, Rahman and Chima (2015) used the Multivariate Tobit approach. Their analysis revealed that farm size is the most dominant determinant of diversity compared to profitability. Other factors that vary in their influence include proximity to the market and extension office, extension contact, training, agricultural credit, subsistence pressure and location. The study covered a total of 450 households.

Mesfin *et al.* (2011) studied patterns, trends, and determinants of crop diversification in Eastern Ethiopia among smallholder farmers and interviewed 167 farm households. A Tobit regression model was used to analyze covariates of crop diversification and its intensity. Among the determinants under scrutiny were farm size, age of the household head, household size, distance to the market, number of extension contacts, farm machinery (tractor and water pump), off/non-farm income, number of farm plots, access to market information, irrigation intensity and sex of the household. They used a modified Entropy Index to measure crop diversification. According to Ogotu and Obare (2015), farmers with more plots are more likely to diversify by growing different crops on each plot of land. It was also established that farmers were likely to diversify with access to market information, irrigation, and machinery ownership. The findings, however, established a negative relationship between the number of extension services contacts and diversification since extension service providers advocated for productivity and profitability, favoring specialization at the micro level and overlooking the role of diversification in risk minimization.

In another study on determinants of crop diversification in Ethiopia, Oromia region, Mussema *et al.* (2015) used Margalef's Index (MI) to analyze the determinants of crop diversification. The results suggest that asset ownership, soil quality, agricultural extension, and level of infrastructure development are significant drivers of crop diversification. A three-stage sampling model was used to arrive at 382 households. The results revealed that land size affected crop diversification decisions positively and significantly. Many plots also had a significant and positive impact on diversification. In the same way, Extension services, market information, and access to all-weather roads had positive and significant effects. Their findings on access to the market were in line with those of Aheibam *et al.* (2017).

In another study on factors influencing diversification and intensification of horticultural production by smallholder tea farmers in Gatanga District, Kenya, Kanyua *et al.* (2013) analyzed participation in diversified cash crop farming, occupation, age and education level of the household head, tools, credit, distance from the market, contract among others. Heckman's two-step model was used to analyze the determinants, and found that farm size and value of farm tools are the most significant in crop diversification. Aheibam *et al.* (2017) also used the Heckman two-stage model. It was also established that the amount of land owned by a farmer significantly affects the degree of diversification, with an increase in the farm size leading to a rise in the crop diversification index. From Kanyua's study, the amount of free land owned by the farmer significantly affected diversification to horticulture; however, other farmers with big lands had little crop diversity since more land had been allocated to tea. Gender was a significant factor in tea farmers' diversification into horticulture; male-headed households were more diversified than female-headed households. These findings were similar to those of Dube *et al.* (2016), which stated that male-headed households were more diversified. The household head's experience significantly affects the degree of diversification, possibly due to the effects of the learning curve.

Finally, Ogotu and Obare (2015) conducted a study on crop choice and adopting sustainable agricultural intensification practices on 532 randomly sampled smallholder households from Eastern and Western Kenya. They used the stochastic production function model and established that gender was important in adopting sustainable agricultural intensification (SAI) innovation and cropping choices. Female decision-makers were seen to practice more intercrop on their plots. Land size and number of plots also had a positive influence. Education, however, did not influence SAI practice and crop choice, while income from other sources had a negative impact. None of the above studies focused on smallholder farmers' diversification of food crops. This study, therefore, backs the knowledge gap on diversification of food crops by the smallholders.

2.3 Concept of Household Welfare

A welfare measure is a set of measures that allows the evaluation of living patterns within a population over time. Consumption expenditure, asset accumulation, and income are commonly used as proxies for household welfare. Researchers have debated income and consumption intensely, with a clear consensus on favoring consumption over income (Moratti & Natali, 2012). First, consumption seems to capture the standard of living better since individuals derive material

well-being from the actual consumption of goods and services rather than income. Consumption better reflects long-term income as it is not closely tied to short-term fluctuations; it smoothens over seasons and is less variable than income.

Income is more likely to be affected by seasonal patterns, resulting in an exaggeration of real income. Although collecting data on consumption is usually very time-consuming, the concept of consumption is usually more precise than the concept of income. Furthermore, it isn't very easy to accurately measure household income, especially for self-employed households and those working in informal sectors. Finally, income is likely a more sensitive issue for respondents than consumption. Those well-off are less likely to participate in the survey or respond, leading to an underestimation of income inequality among the population (Brewer & O'Dea, 2012).

Assets indices are also an alternative measure of welfare. Using asset-based wealth indices as an alternative metric has become increasingly prominent. It has been considered superior to consumption and income as wealth better reflects long-term welfare and is less volatile than income and consumption (Sherraden, 1990). It is suitable for analyzing multidimensional poverty and is less data-intensive, making it easier to calculate. These features, however, make the wealth index a specific indicator that cannot be comparable to conventional measures of economic status.

Different studies report that the asset index is a poor proxy for current household income or expenditure, even though it may reflect permanent income (Filmer & Pritchett, 1999). Some reasons for limiting asset-based indices are as follows: First, this index measures household wealth relative to other households in the sample but does not quantify the households' current levels of welfare or poverty. Secondly, it has been found to have an urban bias and limited discriminatory power at the lower end of the wealth distribution. Thirdly, differences in price levels and asset quality across regions are not considered in the asset-based approach (Filmer & Pritchett, 1999). Therefore, the wealth index cannot be used as a perfect substitute for income or consumption, which, among other considerations, remain the most common and accepted welfare measures

2.4 Maize Lethal Necrosis Disease

Maize lethal necrosis disease (MLND) is a devastating disease that affects maize, one of the world's most important food crops (Eunice *et al.*, 2021). The disease is caused by combining maize chlorotic mottle virus (MCMV) and sugarcane mosaic virus (SCMV). MLND was first reported in Kenya in 2011 and has since spread to other countries in East Africa, including Tanzania, Uganda, and Rwanda. It has also been reported in parts of Asia. Maize lethal disease is

caused by synergistic co-infection of maize chlorotic mottle virus (MCMV) (Machlomovirus, Tombusviridae) and a maize-infecting potyvirus such as maize dwarf mosaic virus (MDMV) or wheat streak mosaic virus (WSMV) or sugarcane mosaic virus (SCMV) (Wangai *et al.*, 2012). MCMV alone does not cause significant damage to maize plants, while SCMV can cause mild symptoms. However, when the two viruses infect the same plant, they interact, leading to a rapid and severe disease progression that ultimately results in plant death.

The exact mechanism of how the two viruses interact to cause MLND is not fully understood. Still, studies have shown that the viruses likely interact at the molecular level, potentially through the suppression of plant defenses and the modulation of gene expression. A study by Wangai *et al.* (2018) found that the viral synergism observed in MLND was associated with the upregulation of genes involved in plant defense responses. This suggests that the viruses may suppress these responses to facilitate infection.

Other studies have also shown that the spread of MLND is facilitated by insect vectors, such as thrips, which can transmit both MCMV and SCMV from infected to healthy plants. In addition, using infected seeds or plant material for planting has also been identified as a major source of MLND spread. The exact mechanism of viral synergism is not yet fully understood, but studies suggest that it involves the suppression of plant defenses and modulating gene expression. The co-infection leads to intensive to complete yield loss (Kiruwa *et al.*, 2016). Early infection can result in total yield losses, further compounded by the possible disappearance of symptoms during the growing season, making disease detection more difficult. MLND is a transboundary disease, and its spread, as well as that of other transboundary diseases, has increased significantly in recent years, which has affected the food and income security of millions of resource-poor farmers, especially in Sub-Saharan Africa, Asia, and Latin America (Boddupalli *et al.*, 2020)

2.4.1 Genesis of MLND and its distribution

MLND was first reported in the United States of America (USA), and symptoms such as chlorosis, mosaic, and necrosis were seen in infected plants, resulting in either plant-stunted growth or death (Niblett & Claflin, 1978; Uyemoto *et al.*, 1980). In Africa, the disease was reported in Rwanda, the Democratic Republic of Congo in 2014 (Adams *et al.*, 2014; Lukanda *et al.*, 2014), and in the border districts of Uganda (Asareca, 2013). MLND has spread to all the eastern African countries and most sub-Saharan countries, significantly affecting maize production (Lukanda *et al.*, 2014; Mahuku *et al.*, 2015; Manje *et al.*, 2015).

In Kenya, the disease was first reported in 2011 in Bomet County (Wangai *et al.*, 2012), with an estimated loss of maize valued at US\$ 67 M in 2012 (Prasanna, 2014). Since then, the disease has spread to other parts of the country, including the Central, Nyanza, Western, and Rift Valley (Miano, 2014; Wangai *et al.*, 2012). Many districts had reported an incidence of the disease by June 2012 (Adams *et al.*, 2012). Counties located south of the Great Rift Valley region (Kajiado, Bomet, Narok, and Baringo) recorded the highest incidences of MLND. Bomet county registered the highest disease symptom severity of 3.6, while Homabay registered the lowest at 1.6 on the 1-5 MLND symptom severity scale (Mwatuni *et al.*, 2020).

2.4.2 Actions against MLND

MLND is a major threat to food security in sub-Saharan Africa and other regions where maize is a staple crop. Efforts to control the spread of the disease have been ongoing since its first reported outbreak in Kenya in 2011. Due to its multifaceted and complex nature, strong, coordinated, and synergistic efforts from multiple institutions were needed to effectively counter the incidence, spread, and adverse impacts of MLND. One approach to managing MLND has been the development of resistant maize varieties. In Kenya, the International Maize and Wheat Improvement Center (CIMMYT) and the Kenyan Agricultural and Livestock Research Organization (KALRO) have collaborated to develop maize varieties resistant to MLND. These varieties have been distributed to farmers in MLND-affected regions, with positive results reported regarding reduced disease incidence and increased crop yields (Wangai *et al.*, 2019).

Another approach was using integrated pest management (IPM) strategies to control insect vectors that transmit the disease. In Kenya, researchers have been studying the effectiveness of using insecticides and other IPM techniques to control thrips, which are known to transmit both MCMV and SCMV. These efforts have shown promise in reducing thrips populations and slowing the spread of MLND (Wangai *et al.*, 2021). Farmers were urged to integrate cultural practices with insecticides and host resistance (Ngala & Kilalo, 2018). Through a multi-institutional strategy, the International Maize and Wheat Improvement Centre (CIMMYT) implemented a strategy focused on reducing the impact of the disease and protecting the environment.

Other approaches included intensive germplasm screening and fast-tracked development and deployment of MLND-tolerant/ resistant maize hybrids in Africa-adapted genetic background, optimizing the diagnostic protocols for MLND-causing viruses, especially MCMV, and capacity building of relevant public and private sector institutions on MLND diagnostics and management,

MLND monitoring and surveillance across SSA in collaboration with NPPOs, partnership with the private seed sector for production and exchange of MLND pathogen free commercial maize seed and awareness creation among relevant stakeholders about MLND management, including engagement with policymakers (Boddupalli *et al.*, 2020).

In addition to these approaches, there have been efforts to increase awareness of MLND among farmers and promote the best disease prevention and management practices. For example, the Food and Agriculture Organization of the United Nations (FAO) has worked with national governments and other organizations to provide training and education on MLND and promote disease-free planting material and other preventative measures (FAO, 2018). Using certified seeds, sanitation, quarantine, crop rotation with a non-maize crop, and resistant and tolerant maize varieties proved to be the most effective way to manage MLND (Kiruwa *et al.*, 2016). However, implementing some of these strategies was not possible in Borabu Sub-County, citing their cost implication and high incidences of poverty. For instance, due to the dense population in the region, most households own small parcels of land, necessitating them to practice intercropping. This, therefore, makes crop rotation as a way of dealing with MLND not ideal. Overall, these efforts represent important steps toward controlling the spread of MLND and safeguarding food security in affected regions.

2.5 The Case of Borabu Sub County

The choice of Borabu as a case for this study was motivated by the following reasons. First, Borabu is a sub-county facing many development challenges, including low agricultural productivity, food insecurity, and climate change. Increased weather (rainfall and temperature) variability negatively affects food production and consumption, making farm households net market buyers. In response to climatic variability, households in Borabu engage in ex-ante and ex-post consumption smoothing strategies. Second, the region has high farming diversity potential and rich agroecological diversity hotspots essential for improving food security and reducing the adverse effects of current and future climate change on livelihoods and food systems. Third, there are few off-farm income diversification options in the region, limiting the capacity of diversifying income away from agriculture as a strategy for poverty reduction.

Agriculture is the region's main economic activity, with most households farming maize. In the past few years, maize farmers in the area have seen a gradual shift in maize production, thereby contributing to increased poverty levels and high food insecurity. This sharp shift in the

production of maize was primarily related to the occurrence of MLND. The variations in production have given rise to price fluctuations that have negatively impacted the livelihood of small-scale farmers and consumers of maize more than any other cereal crop because of their sensitivity and vulnerability to disease.

In 2012, during the early stages of the occurrence of the disease, the annual production of maize in the region was 45,400 tonnes. In 2013, the production declined to 25,000 tonnes per annum, and the decline was witnessed in subsequent years. In 2017, the effect of MLND had taken root, and the annual production was at 14,580 tonnes (MoALF, Borabu sub-county). While the impact of MLND was taking place, Fall Army Worm (FAW) attacked the region in 2018, which led to 100% destruction of any maize crop left in 2017. Because of this, there was a maize deficit in the entire country, which led to a rise in the price of maize in 2017. In 2018, incidences of FAW destroyed maize, and hence, none was harvested (MoALF, Borabu sub-county). This paper, therefore, sought to understand whether MLND impacted the decision of farmers to diversify and, consequently, food security for households in Borabu sub-county. In particular, it was interesting to understand if food security or lack thereof was reduced due to the disease.

2.6 Theoretical Framework

Theories that can be used to discuss the concept of crop diversification include the crop diversification theory, the sustainable livelihood approach theory, and the social network theory. This study, however, draws its basis from the theory of crop diversification among smallholders by Rahm and Huffman (1984) and the Sustainable Livelihood Approach (SLA) theory by Ashley and Carney (1999).

2.6.1 Social Network Theory

This theory is based on the importance of social network peer effects in agricultural technology adoption and production decisions. Household production decisions such as crop choices and land allocation are likely to be influenced by the decisions of other households in the study area due to potential learning externality. The extent of crop diversification may be magnified through social interactions between farmers in the local neighborhood. Far households that operate in the same Agroecological conditions and face similar demographic, economic, and institutional characteristics are likely to adopt similar production systems (Asfau *et al.*, 2019; Lovo & Veronesi, 2019; Tesfaye & Tirivayi, 2020)

2.6.2 Crop diversification theory

The fundamental assumption of this theory is that a farmer's decision on whether to diversify is based on utility maximization (Rahm & Huffman 1984). The expression $U(W_{ij}, L_{ji})$ is a non-observable underlying utility function that ranks the preference of the i^{th} farmer for the j^{th} diversification process ($j=0,1$; where 0=no diversification and 1=diversification). Thus, the utility derived from crop diversification depends on W , a vector of farm and farmer-specific attributes of the diversifier, and L , a vector of attributes associated with crop diversification.

Although the utility function is unobserved, the relation between the utility derivable from the j^{th} diversification process is postulated to be a function of the vector of observed farm, farmer, and crop diversification-specific characteristics and a disturbance term that has a mean of zero, as shown in equation 1:

$$U_{ji} = a_j F_i(W_i L_i) + \varepsilon_{ji} \quad (1)$$

where: $j=0,1$; $i=1,2, 3\dots n$. Since the utilities U_{ij} are random, the i^{th} farmer will select the alternative $j=1$ if $U_{ij} > U_{0i}$ or the non-observable (latent) random variable $Y^* = U_{ij} - U_{0i} > 0$. The probability that Y_i equals one. That is, the probability that the farmer practices crop diversification is a function of the explanatory variables as shown in equations 2 to 6 below:

$$P_i = P_r(Y_i = 1) = P_r(U_{1i} > U_{0i}) \quad (2)$$

$$= P_r[a_1 F_i(W_i, L_i) + \varepsilon_{1i} > a_0 F_i(W_i, L_i) + \varepsilon_{0i}] \quad (3)$$

$$= P_r[\varepsilon_{1i} - \varepsilon_{0i} > F_i(W_i, L_i)(a_1 - a_0)] \quad (4)$$

$$= P_r(\mu_i > -F_i(W_i, L_i)\beta) \quad (5)$$

$$= F_i(X_i\beta) \quad (6)$$

where X is the $n \times k$ matrix of the explanatory variables, β is a $k \times 1$ vector of parameters to be estimated, the probability function μ_i is the random error term, and $F_i \cdot X_i\beta$ is the cumulative distribution function for U_i evaluated at $X_i\beta$. The probability that a farmer will diversify in crop production is a function of the vector of explanatory variables, unknown parameters, and the error term.

2.6.3 Sustainable Livelihoods Approach (SLA)

The SLA works intensively with people to find secure long-term income sources and become resilient to light shocks, making life hard to cope. Conceptually, "livelihoods" connote the means, activities, entitlements, and assets by which people make a living. The important feature of this livelihood definition is that it links assets and options people possess in practice to pursue alternative activities that generate the income level required for survival. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future while not undermining the natural resource base (Chambers & Conway, 1992).

SLA helps people to identify the strengths they already have and the assets they can build on to help support themselves. These strengths fall into five categories: Human assets like skills and knowledge; social assets like family and community groups; physical assets like decent housing or tools for work; public assets like the nearest community health center; and financial assets like wages, benefits, or savings.

This holistic, people-sensitive approach is the best way to help people help themselves by boosting self-worth, empowering people, inspiring friends and family, and strengthening communities.

2.7 Conceptual framework

The study is conceptualized as presented in figure 2.1. The framework links factors affecting crop diversification and how these interrelationships further affect the extent of diversification for a smallholder farmer. Socioeconomic, institutional, and climate-related factors, specifically MLND, are explanatory variables directly affecting the extent of crop diversification. There is a positive relationship between the dependent variables, the extent of diversification, and consumption expenditure, which was used as a proxy for household welfare. Smallholder farmers with a higher diversification index are more likely to have an enhanced ability to save, leading to enhanced resilience, livelihood, food security in the long run, and better overall welfare. On the other hand, smallholder farmers with a low diversification index are more likely to have reduced resilience in the face of climatic shocks, as well as livelihood and food insecurity in the long run.

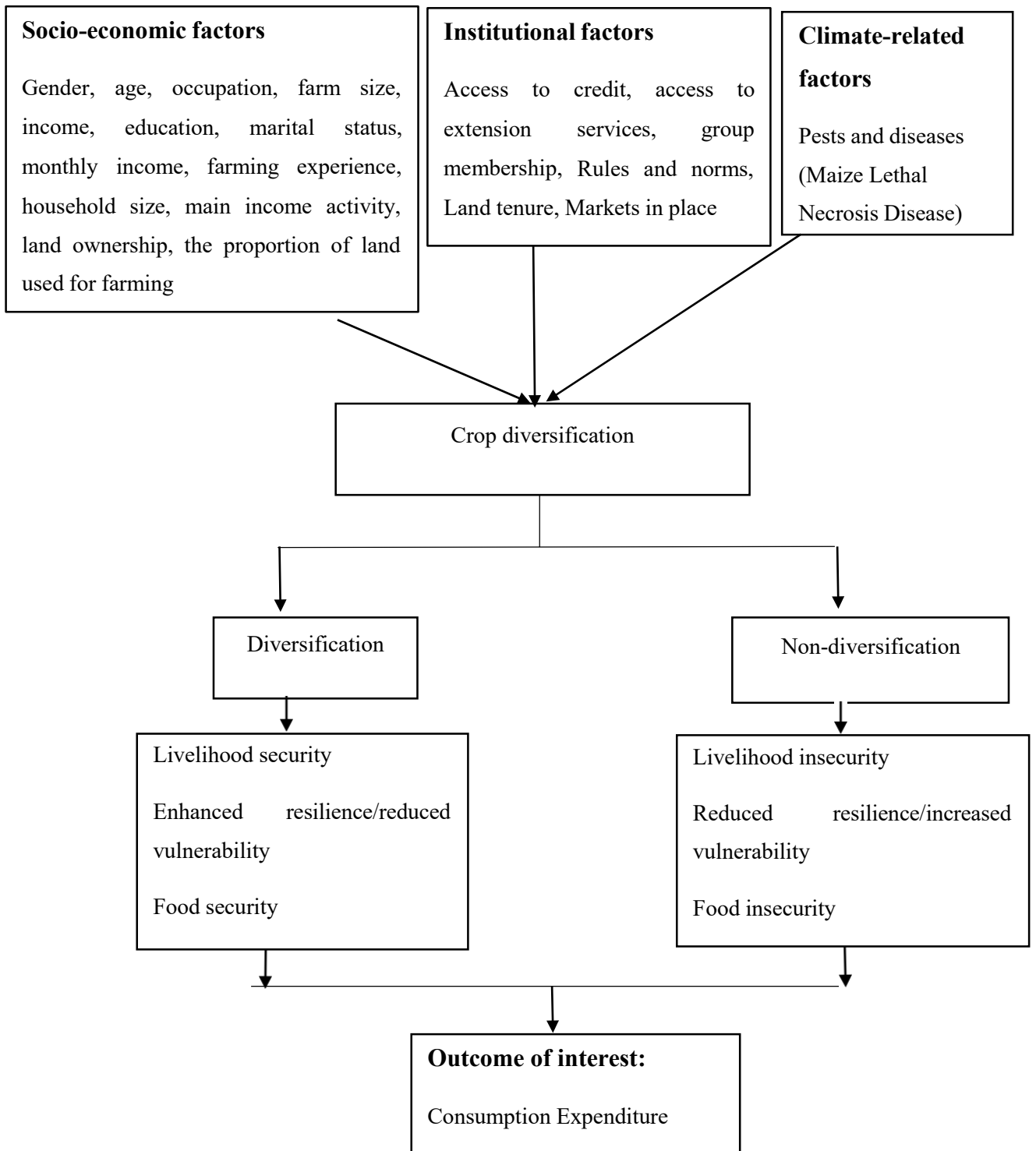


Figure 2.1: Conceptual Framework

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter discusses the methods and materials used in this study. It provides insight into the study areas, including a map, sampling procedures, data collection, and analytical frameworks.

3.1: Description of the Study Area

The study was conducted in Borabu sub-county in Nyamira county. The county borders Homabay county to the North, Kisii county to the west, Bomet county to the southeast, and Kericho County to the east. The sub-county occupies about 246.9 square kilometers with a total population of about 73,167 people and a population density of 296 persons per square kilometer. The number of households in the region is 19,468, with an average household size of 4 (KNBS, 2019). The sub-county is between the longitudes 340 45' and 350 00' east and latitudes 00 30' and 00 45' south (NCIDP, 2018). It is divided into four wards: Nyansiongo, Esise, Mekenene, and Kiabonyoru.

The area has a bimodal rainfall pattern that is well-distributed, reliable, and adequate for various crops. The long rains are experienced between December and June, and the short rains occur from July to November, with no distinct dry spell separating them. The annual rainfall ranges between 1200 to 2100 mm per annum, with the altitude ranging between 1250 meters and 2100 meters above sea level (ASL). The minimum night and maximum day temperatures are normally between 10.1 degrees Celsius and 28.7 degrees Celsius, respectively, resulting in an average normal temperature of 19.4 degrees Celsius, which is favorable for crop and livestock production (NCIDP, 2018).

The sub-county is endowed with red volcanic soils (Nitisols), which are deep, fertile, and well-drained, accounting for 75% of soils in the region, while the remaining 25% are those found in the valley bottoms and swampy areas, which are suitable for brick making (NCIDP, 2018) Small scale crop and livestock production is an important component of agricultural activity in the area with the majority of farmers engaging in the production of maize, beans, local vegetables, bananas, potatoes among others. Livestock production includes dairy cattle, goats, sheep, and chicken.

There is a total labor force of about 38,047 people, which accounts for 52% of the total population, with the majority being engaged in the agricultural sector. The Borabu sub-county was selected because it is one of the areas in Kenya affected by MLND. Secondly, despite the efforts

put in by the government to combat the disease being effective in other regions that were affected by the disease, there are still signs of the disease in the area, hence impeding the farmers' ability to produce maize. Figure 3.1 shows the study area map.

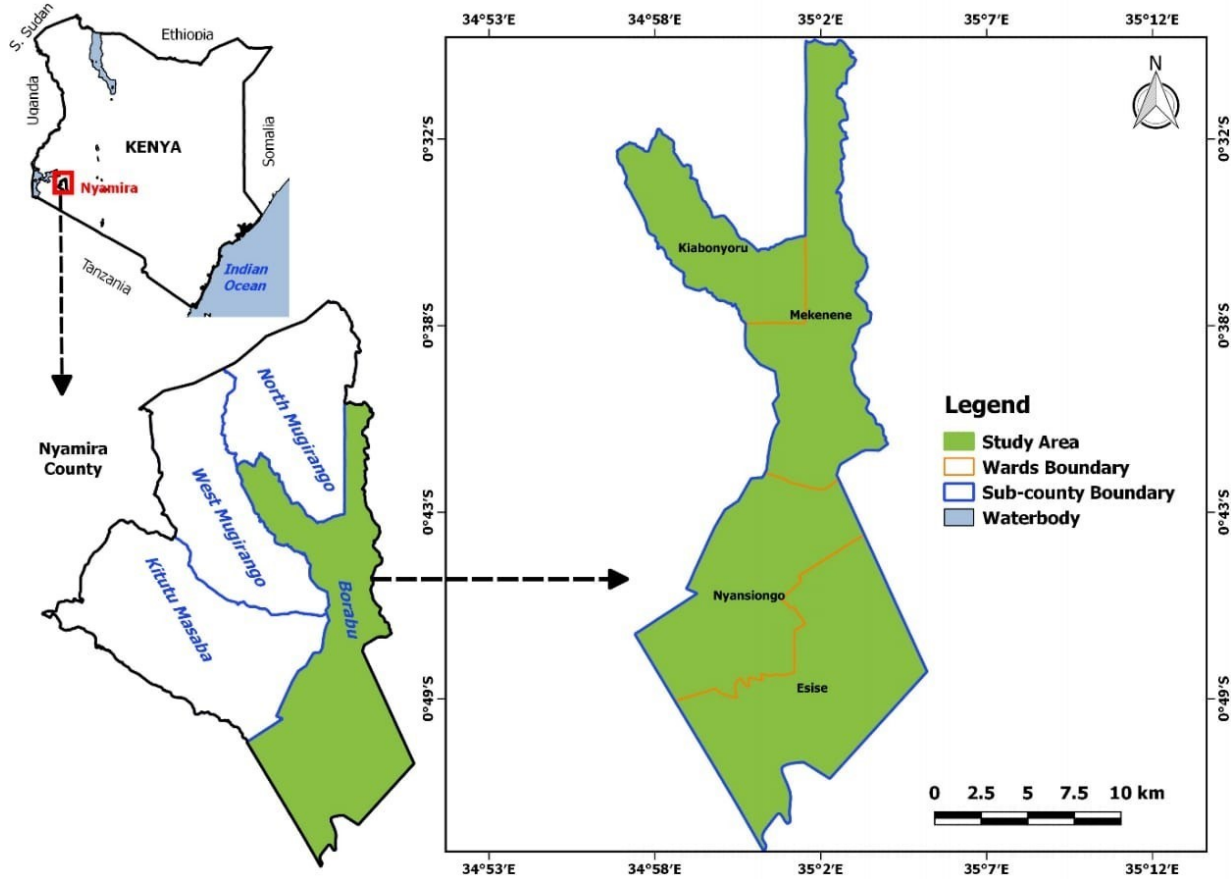


Figure 3.0.1: Map of Borabu Sub-County

Source: Egerton University Department of Geography

3.2 Sample Size Determination

Cochran's (1977) formula was used to determine the number of respondents needed for the study from each ward, as shown in equation 7 below:

$$n = \frac{pqZ^2}{e^2} \quad (7)$$

where n is the sample size to be determined, p is the sample proportion, $q=1-p$, Z =Confidence level($\alpha=0.05$), and e is the acceptable or allowable error since the population proportion is unknown, $p=0.5$, $q=1-0.5=0.5$, $Z=1.96$ and $e=0.05$.

$$n = \frac{(0.5)(0.5)(1.96)^2}{(0.05)^2} = 384.16 \approx 385$$

This resulted in a sample population of 385 respondents.

3.3 Sampling Procedure

This study used Multi-stage sampling procedures to select the appropriate sample size. In the first stage, the Borabu Sub-County was purposively selected as one of the areas affected by MLND. In the second stage, the four wards of Borabu sub-county (Nyansiongo, Esise, Kiabonyoru, and Mekenene) were purposively selected based on the severity of MLND in the wards. The farmers in the area were then stratified into four groups based on the ward where they were located. A source list of maize farmers in the four wards was acquired from MoALF, Borabu sub-county. From each of these four groups, the number of farmers was selected proportionate to the group size using a stratified random sampling procedure to select a total sample of 385 farmers.

Table 3.1: Sample Size Determination

Wards	Number of Maize farming households	Sample proportion	Sample Size
Nyansiongo	3000	0.20	79
Esise	2700	0.18	70
Mekenene	5000	0.34	131
Kiabonyoru	4000	0.27	105
Total	14700		385

3.4 Data Collection

Primary data was mainly used to generate the information required for the study. Data was collected through observations and interviews using a semi-structured questionnaire administered to smallholder farmers. Data collected included information on the land tenure system, farmer access to credit, training services, farm size, off-farm income, gender of the household head, age of the household head, education level of the household head, household size, extension services, group membership, and household financial savings.

3.5 Validity of the instrument

The questionnaire was pre-tested in 20 households in Masaba sub-county in Kisii county to verify whether the instrument logically measured its intended parameters, as described by

Taherdoost (2016). This step aimed to confirm that the questionnaire items were concise, complete, clear, comprehensive, well-organized, and unambiguous before deployment in the field.

3.5.1 Reliability of research instruments

According to Kothari (2008), reliability refers to the degree to which scores obtained with an instrument are consistent. Cronbach alpha coefficient was used to calculate the reliability coefficient. A coefficient of 0.7 was considered acceptable. In case this threshold was not achieved, the instrument was to be revised and pilot-tested until an acceptable score was achieved

3.6 Data Analysis

The Statistical Package for Social Sciences (SPSS) program entered data and generated descriptive statistics. Excel program was used to determine the crop diversification index for different farmers. STATA program was used to determine factors influencing the extent of diversification among farmers and the effect of crop diversification on household welfare. For the first objective, a CDI was calculated. For the second objective, a double-hurdle model was used to determine factors influencing the extent of crop diversification. In contrast, the Endogenous Switching Regression(ESR) model was used to assess crop diversification's effect on household welfare.

3.7 Analytical Framework

3.7.1 Determining the extent of crop diversification among small-scale farming households

A CDI was used to measure households' extent of crop diversification. This index is a measure that quantifies the degree of diversification in agricultural production. It provides insight into the variety of crops grown within a specific region or farm, indicating the level of agricultural diversity. The CDI considers factors such as the number of crops grown and the area cultivated for each crop. By considering these factors, the index provides a numerical value between 0 and 1 that reflects the level of crop diversification. The CDI is an index of concentration and directly relates to diversification. A zero value indicates specialization and a value greater than 0 signifies diversification across different levels.

A higher crop diversification index indicates a greater variety of cultivated crops, which can have several benefits. Calculating the CDI involves analyzing data on crop types and areas under cultivation. Different methods and formulas can be used depending on the specific objectives and context of the analysis. For this study, the index was calculated by assigning weights

to different crops based on their relative importance or economic value and summing up these weighted values. The CDI was obtained by subtracting the Herfindahl index (HI) from one.

The CDI index was calculated as shown in equations 8 to 10:

$$P_i = \frac{A_i}{\sum A_i} \quad (8)$$

where P_i = proportion of the i 'th crop, A = area under the i 'th crop, $\sum A_i$ = Total cropped area, and $i=1,2,3\dots n$.

$$H_i = \sum_i P_i^2 \quad \text{Herfindahl index} \quad (9)$$

$$CDI = 1 - \sum_i P_i^2 = 1 - HI \quad \text{Crop diversification index} \quad (10)$$

3.7.2 Determining factors influencing extent of crop diversification among small-scale households

A double hurdle model was used to determine factors influencing the extent of crop diversification among households. Since some farmers did not diversify, the dependent variable had a lot of zeroes, resulting in a corner-solution outcome. In such a situation, ordinary least square regression could not be used since its outcome generated inconsistent and biased parameter estimates (Wang & Leng, 2016). Also, the Tobit model can be used. Still, it is very restrictive, as it assumes the determinants of the probability of participation in crop diversification are similar to the extent of diversification (Ahmadzai, 2017). This may not be the case as different factors may influence participation in diversification and the extent of diversification. To overcome these restrictions, a double-hurdle model was used. The model was divided into two stages. The first stage is a selection model, which considers the participation decision. It utilized a probit model that allowed separate estimation of the probability of participation in crop diversification. At the same time, the second stage examined the farmer's decision concerning the extent of crop diversification. The results were categorized on an ordinal scale (Non-diversified, least diversified, moderately diversified, and highly diversified). An ordered probit model is a good tool for showing movement between the diversification groups. Following Greene (1997), the reduced form of the ordered probit model was given as shown in equation 11 below:

$$Y_{i1}^* = X_{i1}^* \beta + \mu_i \quad (11)$$

Where Y^* is the given state of diversification, the X_{ij} 's were the explanatory variables that determined the diversification level of a household. β 's were the parameters estimated, and μ_{ij} was the disturbance term.

The second phase of the double hurdle model was to examine the decision by the farmer concerning the extent of crop diversification, as shown in equations 12:

$$Y_{i2}^* = W_{i2}^* \alpha + V_i \text{ Extent decision} \quad (12)$$

$$Y_{i1}^* = X_{i1}^* \beta + \mu_i \text{ if } Y_{i1}^* > 0 \text{ and } Y_{i2}^* > 0 \quad (13)$$

$$Y_i = 0 \text{ otherwise} \quad (14)$$

where Y_{i2}^* is a latent variable describing the extent of crop diversification, and Y_i is the observed dependent variable (farmer's extent to diversify). W_i is a vector of variables explaining the extent of the decision, and V_i and μ_i are the respective error terms assumed to be independent.

The empirical model is represented as follows:

$$\begin{aligned} CDI = & \beta_0 + \beta_2 gnd + \beta_3 Age + \beta_4 edu + \beta_5 mrts + \beta_6 lnd + \beta_7 slnd + \beta_8 hhedu + \beta_8 loc \\ & + \beta_9 inc + \beta_{10} crplnd, peq (\beta_{11} lbr + \beta_2 gnd + \beta_3 edu + \beta_4 lnd + \beta_5 occ \\ & + \beta_6 inc + \beta_7 hhsz) + \mu \end{aligned} \quad (15)$$

3.7.2.1 Preliminary Diagnostics Assumptions of Variables Used in Econometric Analysis

Before data analysis, various tests such as Variance Inflation Factor (VIF) and Breusch-Pagan tests were conducted to test for Multicollinearity and Heteroskedasticity, respectively. The Multicollinearity test was done for both continuous and categorical variables using the VIF.

Testing for Multicollinearity

A Multicollinearity problem occurs when two or more predictor variables in the regression model have a perfect relationship (Yang & Wu, 2016). This may lead to a lack of statistical significance of individual predictor variables even though the overall model might be significant.

Heteroskedasticity Test

Heteroskedasticity occurs whenever the variance of the unobserved factors changes across different population segments (Williams, 2020). A graphical approach or relevance tests such as the Breusch-Pagan or the White tests can be used to detect the presence of heteroskedasticity. The Breusch-Pagan test only checks for the linear form of

heteroskedasticity. In contrast, the White test allows independent variables to have a non-linear and interactive effect on the error variance. Further, unlike the Breusch-Pagan test, the White test can detect a more general form of Heteroskedasticity (Wooldridge, 2004).

Table 3.2: Description of Variables Used in the Double-Hurdle Model

Variable		Description	Measurement	Apriori Assumption
CDI	Crop diversification Index	Non-Diversifiers=0, Least diversified=1, Moderately diversified=2, Highly diversified=3	Categorical	+/-
gnd	Gender	Gender of household head (male=1, female=0)	Binary	+/-
Age	Age	Age of household head in years 18-35=1, 36-49=2, 50-65=3, Above 65=4	Categorical	+/-
hhsz	Householdsize	Number of household members	Continuous	+
lnd	Land tenure	Land owned with title deed=1 Land Owned without title deed=2 Rented/Leased land=3	Categorical	+/-
slnd	Size of land	Size of land owned by a household in acres	Continuous	+/-
hheduc	Education	Primary=1, Secondary=2 Tertiary=3	Categorical	+/-
lbr	Labour	1=hired, 0=family	Categorical	+/-
hhinc	Household income	Average household income (both on-farm and off-farm)	Continuous	+/-
mrts	Marital status	1=Married, 2=single, 3=separated/divorced 4=widowed	Categorical	+/-
Occ	Occupation of household head	1= farmer, 2= Formal employment 3=Business/trader, 4=Informal employment	Categorical	+/-

3.7.3 Investigating the Nexus Between Crop Diversification and Household Welfare Among Small-Scale Households in Borabu Sub-County.

Endogenous Switching Regression Model Specification

The third objective of this study was to determine the effect of crop diversification on the household welfare of small-scale farmers of Borabu sub-county. Observable and non-observable factors determined farmers' decision to diversify or not diversify. A methodological challenge in this estimation is the sample selection problem since smallholder maize farmers may self-select themselves into diversification or have innate characteristics that correlate with household welfare. The decision by a smallholder farmer to engage in diversifying their enterprises is potentially an endogenous variable, and there is a need to account for and cater to this endogeneity as it may lead to inconsistent and biased estimates. The suspected endogeneity of crop diversification may result from a farmer's voluntary nature to diversify his crops. For instance, some smallholder farmers might decide to adopt crop diversification simply because they have certain characteristics that support farm diversification, which is to their advantage over others, in terms of diversification's benefit to farmers. If not accounted for, this type of selection bias may overstate or understate the actual effect of crop diversification on household welfare in the regression model.

On the other hand, smallholder farmers may fail to practice crop diversification simply because they are not privy to vital information on the benefit of diversifying into crops, or they lack certain characteristics that may support diversification. In such instances, when we fail to control for the potential endogeneity, the real benefits that come with adopting crop diversification may be underestimated. The study used the endogenous switching regression (ESR) model to control for the possible bias resulting from non-observable traits. This model corrected for both observable and non-observable biases that may have resulted from the non-random assignment of small-scale farmers into diversification, hence providing unbiased estimates of the impact of diversification on household welfare. Household financial savings were used as a proxy for household welfare.

Estimation of Average Treatment Effects

The endogenous switching regression model estimated crop diversification's average treatment effect (ATE) on the outcome variable, household welfare. The endogenous switching model was further used to examine the average treatment effect by comparing the expected outcomes of each alternative package of diversification. This model was used to compute the

average treatment effects of the treated (ATT), whereby the expected outcomes of diversification were compared. To estimate the impact of crop diversification, a counterfactual effect in a result that a farmer could have achieved had they picked a different diversification strategy from the one they did. According to Di Falco and Veronesi (2013), we compute the ATT in the actual and counterfactual scenarios as follows:

For actual diversifiers in the sample, the outcome estimation model was given as follows:

$$\begin{cases} E(Q_{h2}|H = 2) = J_h\alpha_2 + \sigma_2\lambda_2 \end{cases} \quad (16a)$$

$$\begin{cases} E(Q_{hg}|H = 2) = J_h\alpha_g + \sigma_g\lambda_g \end{cases} \quad (16b)$$

$$\begin{cases} E(Q_{h1}|H = 1) = J_h\alpha_1 + \sigma_1\lambda_1 \end{cases} \quad (17a)$$

$$\begin{cases} E(Q_{h3}|H = 3) = J_h\alpha_3 + \sigma_3\lambda_3 \end{cases} \quad (17b)$$

If users of a given diversification strategy had not chosen that specific strategy, the counterfactual was modeled as follows:

$$\begin{cases} E(Q_{h1}|H = 2) = J_h\alpha_1 + \sigma_1\lambda_2 \end{cases} \quad (18a)$$

$$\begin{cases} E(Q_{h3}|H = G) = J_h\alpha_1 + \sigma_1\lambda_G \end{cases} \quad (18b)$$

$$\begin{cases} E(Q_{h2}|H = 1) = J_2\alpha_2 + \sigma_2\lambda_1 \end{cases} \quad (19a)$$

$$\begin{cases} E(Q_{hg}|H = 3) = J_2\alpha_3 + \sigma_3\lambda_3 \end{cases} \quad (19b)$$

The above-estimated values help derive unbiased estimates of the average treatment effects on treated (ATT) and untreated (ATU). ATT is the difference between 16a and 18a or equation 16b and 18b, which is given as:

$$ATT = E(Q_{h2}|H = 2) - E(Q_{h1}|H = 2) = J_h(\alpha_2 - \alpha_1) + \lambda_h(\alpha_2 - \alpha_1) \quad (20)$$

The expected change in the mean outcome for a farmer who uses h diversification strategy is equal to the returns of a farmer who has not diversified their crop mix given by

$J_h(\alpha_2 - \alpha_1) + \lambda_h(\alpha_2 - \alpha_1)$, λ_h is the choice term capturing all potential effects of the differences in unobserved variables. On the other hand, ATU is given as the difference between equations 17a and 19a or equations 17b and 19b, resulting in equation 21 below:

$$ATU = E(Q_{h1}|H = 1) - E(Q_{h2}|H = 1) = J_h(\alpha_2 - \alpha_2) + \lambda_2(\alpha_2 - \alpha_2) \quad (21)$$

Tropical Livestock Units' Calculation

Tropical Livestock Units(TLUs) were used to standardize and compare different types and sizes of livestock across various regions and production systems. This study adopted the weights used by Jahnke (1982) as shown in table 3.3 below:

Table 3.3: Tropical Livestock Units(TLU) Weights

Animal Category	TLU weight
Cattle	1.0
Sheep and goats	0.13
Poultry	0.013
Donkey	0.7
Camel	1.25

Source: Jahnke (1982)

The number of each type of livestock was multiplied by its corresponding TLU weight. The calculated TLUs for every kind of livestock were then summed to obtain the total TLUs for each household.

Table3.4: Description of variables used in the ESR model

Variables	Type	Description	Exp. sign
Dependent Variable			
Household welfare		Consumption Expenditure as a proxy of welfare	+/-
Independent Variables			
Gender of household head	Dummy	1=Male, 0=Female	+/-
Age	Categorical	18-35=1, 36-49=2, 50-65=3, above 65=4	+/-
Household size	Continuous	Number of household members	+/-
Education	Categorical	Primary=1, Secondary=2, Tertiary=3	+/-
Marital status of head	Categorical	1=Married,2=Single,3=Widow/widower,4=Separated/Divorced,	+/-
Household income	Continuous	The average amount of monthly income in KSH	+/-
Tropical Livestock Unit (TLU)	Continuous	Calculated TLUs	+/-
Land tenure	Categorical	1= Land owned with title deed,2= Land owned without title deed, 4= Rented land/Leased land	+/-
Size of land	Continuous	Size of landholding in acres	+/-
Access to credit	Dummy	1=Access to credit, 0=No access to credit	+/-
Farm land	Continuous	Proportion of land under agriculture in acres	+/-
Occupation of household head	Continuous	1=farmer,2=government sector, 3=Unemployed 4=casual labour	+/-
Belonging to a social group	Dummy	1=yes, 0=No	+/-

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results and discussion of the data analysis. It is divided into sections according to the objectives of the study. The first section of this chapter presents the descriptive statistics of the household's socio-economic characteristics. The second section presents the distribution of farming households depending on their diversification levels. The third section presents an analysis of factors influencing crop diversification. The fourth section presents an analysis of the effect of crop diversification on household welfare.

4.1 Descriptive statistics

Most respondents were between 36 and 49 years old and 50 and 65 years old, accounting for 37.4% and 37.9% of the population, respectively. Younger farmers between 18 and 35 years old were about 19.2% of the sampled population while the older farmers above 65 accounted for 5.5%. On average, 56.6% of the sampled population were aged 50 or less, indicating that the study area population was predominantly young and active and, hence, could engage in agricultural production. Of the households involved in maize production, 34.3% were headed by women, while men headed 65.7%. Results in Table 4.1 confirm that men generally head most households. The majority of the household heads (48.3%) completed secondary education.

In comparison, 32% of the household heads had basic primary education, 3% had vocational training, and only about 8% attained a college training or university degree. Results in Table 4.1 indicated that most household heads were married (82%) while few were unmarried (18%). The primary occupation for most household heads was farming (73.8%). This implies that most household heads should prioritize farming activity since it sustains even those who do not wholly participate. Results in Table 4.1 indicate that only about 5.7% of the household heads are in the formal sector, while 94.3% are in the informal sector. The highest percentage of farmers (42.1%) owned land but had not acquired title deeds, while about 34.8% of the household heads who owned land had acquired title deeds, and 23.1% of the household heads leased or rented land for agricultural production. The average household size was 5.34 (Table 4.2), a bit higher than Kenya's average household size of 3.9 (KNBS, 2019). The total household size determines the available labor force utilized for farming and non-farming activities for the particular household. Likewise, household size determines the quantity of food consumed, influencing household farming decisions (Dimelu *et al.*, 2020).

Table 4.1: Household Characteristics of Small-Scale Farmers in Borabu Sub-County

Variable	Categories	Frequency	Percentage
Household head	Male-headed	253	65.7
	Female-headed	132	34.3
Marital status	Married	315	81.8
	Widowed	36	9.4
	Single	33	8.6
	Separated	1	0.3
Age (Years)	18 to 35	74	19.2
	36 to 49	144	37.4
	50 to 65	146	37.9
	Above 65	21	5.5
Education level	Informal Education	31	8.1
	Primary	126	32.7
	Secondary	186	48.3
	Tertiary	42	11.0
Primary Occupation	Informal Employment	363	94.3
	Formal Employment	22	5.7
Primary Income	Farming	301	78.2
	Formal Employment	16	4.2
	Informal Employment	65	16.9
	Pension	1	0.3
	Remittances	2	0.5
Type of land ownership	Owned with title deed	134	34.8
	Owned Without a title deed	162	42.1
	Leased/ Rented	89	23.1

Table 4.2: Household Characteristics of Continuous Variables

Variable	Mean	Standard Deviation
Household size	5.34	2.15
Size of land owned	1.78	6.16
Average Household Income	99256.41	119534.7

4.2 The Extent of Crop Diversification by Small-Scale Farmers of Borabu Sub-County

The crop diversification index (CDI) was used to measure the extent of crop diversification by households in Nyansiongo, Esise, Mekenene, and Kiabonyoru wards in the Borabu sub-county. The results in Table 4.3 show that the total number of farmers who did not diversify their crop mix was 250, with a CDI of zero (0) making up 64.94% of the total sample. These farmers produced maize, beans, or millet alone for an entire planting season. About 35.07% of the smallholder maize farmers diversified their crop mix at different levels with a CDI of 0.1 and 1. Those least/lowly diversified farmers, at a CDI of between 0.1 and 0.33, were 0.78%% of the total sample. These farmers majorly grew maize in the first season, and others produced beans in the second season, with very sparse production of other food crops along the range. The moderately diversified farmers, with a CDI of between 0.34 to 0.66, were 23.84% of the total sample, and they grew maize and beans in the first season and had a moderate distribution of the other food crops within the two cropping seasons. The highly diversified group had a CDI of 0.67 to 1, about 10.65% of the total sample. These were farmers with a good distribution of various food crops across the two cropping seasons. The mean CDI was 0.15, implying that the majority of smallholder farmers in Borabu sub-county were least diversified. The low diversification may be attributed to most farmers owning small parcels of land, and extreme diversification on such small pieces would be impractical. This finding is similar to the findings of Kurds-Kujawska *et al.* (2021) on crop diversification in small farms in Poland, which found that the intensity of crop diversification in small farms was low.

Table 4.3: Extent of Crop Diversification by Small-Scale Farmers in Borabu Sub-County

Category	Level of CDI	No of farmers	Percentage
Non-diversifiers	0	250	64.94
Low diversifiers	0.1-0.33	3	0.78
Moderate diversifiers	0.34-0.66	91	23.64

High diversifiers 0.67-1 41 10.65

Nyansiongo ward had the highest number of highly diversified farming households, with Kiabonyoru ward having the least number of highly diversified farms, as indicated by the results in Table 4.4. Most non-diversified farming households were from the Mekenene ward, accounting for 101 farming households. There was significant variation in diversification across the four wards, with farming households being distributed across the four diversification levels agreeing with the findings of Tamburini *et al.* (2020) on the impact of several agricultural diversification practices and multiple ecosystem services, who found that there is a significant variation in diversification in numerous ecosystems.

Table 4.4: Distribution of Crop Diversification by Ward

WARDS	CDI				Total
	High Diversifiers	Moderate Diversifiers	Low Diversifiers	Non Diversifiers	
Esise	11	25	2	40	78
% within CDI	26.8	27.5	66.7	16	20.3
Kiabonyoru	5	17	0	86	108
% within CDI	12.2	18.7	0	34.4	28.1
Mekenene	8	25	0	92	125
% within CDI	19.5	27.5	0	36.8	32.5
Nyansiongo	17	24	1	32	74
% within CDI	41.5	26.4	33.3	1.28	19.2
Total	41	91	3	250	385
% within CDI	100	100	100	100	100

Note: CDI = Crop Diversification Index, number of households, % represents the proportion of the households within CDI.

4.3 Factors Influencing Extent of Crop Diversification among Smallholder Farmers

This objective was analyzed using the Double Hurdle Model(DHM). The Crop Diversification Index was treated as the exogenous variable in both stages. The determinants of Participation in crop diversification and extent of crop diversification by smallholder maize farmers in Borabu sub-county were determined by considering the decision to participate in the

crop diversification (decision to practice diversification) regarded as the first hurdle and the extent of crop diversification (Extent decision) as the second hurdle.

4.3.1 Factors Influencing Farmers' Decision to Practice Diversification.

In this stage, the dependent variable for farmers' decision to participate in diversification was binary (1= participate, 0= Not to participate). Before this analysis, a VIF test was conducted to test for multicollinearity. The study obtained a mean VIF of 1.64, as seen in Appendix 4. According to Hair *et al.* (2011), the VIF should be below the standard cut-off threshold of ten or a more restrictive criterion of less than 5. Thus, the obtained VIF indicates an absence of a perfect relationship to the selected variables. In addition, heteroskedasticity was tested using the white test with a null hypothesis that residuals are homoscedastic. Then, from the results in Appendix 5, we fail to reject the null hypothesis at a 5% significance level and conclude that residuals are homoscedastic since the probability of χ^2 was 0.9504.

Results in Table 4.5 indicate factors influencing the decision to participate in crop diversification (first hurdle). The results showed that the household head's marital status, the income source of the household head, the main source of household income, the gender of the household head, the type of labour available to a household, and the size of land farmed significantly influenced a farmer's decision to participate in crop diversification. Farm labor services in Borabu sub-county are either hired or family. Results in Table 4.5 indicate that family labour has a negative effect on participation in crop diversification. Family labour is typically limited in quantity and skills. Since crop diversification often requires more labour for managing different crops with varying needs, family labour may not be sufficient to meet these demands. Households with limited family labour tend to focus on fewer crops to maximize efficiency and minimize labour overload. When relying on family labour, shifting focus to new crops comes with a higher opportunity cost, as family members may need to dedicate their time to tasks that might not guarantee immediate returns.

On the other hand, households with hired labor can delegate work across different crops without significantly altering the labor availability for each. Hired labor often leads to a more specialized and focused approach in crop production, as workers may have specific skills or tasks (Brousseau *et al.*, 2021). On the other hand, hired workers may lack a personal stake in the farm's success, potentially leading to less attention to diverse crops or a focus on more profitable ones. In contrast, family labor encourages various crops to meet diverse household needs. The negative

relationship between the type of labor and diversification aligns with the findings of Asante *et al.* (2017), who found that the type of labor (hired) negatively affects crop diversification.

Results in Table 4.5 indicate that the size of land farmed had a negative association with the decision to participate in crop diversification. The average farm size for Borabu sub-county is 1.78 acres. Small landholders have limited space, forcing them to prioritize the most profitable or essential crops to maximize returns on their small plots. Diversifying into other crops may reduce the area available for the primary crop, potentially lowering overall productivity and income. Small farmers may lack the economies of scale needed to manage a variety of crops efficiently. With limited land, they cannot benefit from cost reductions that larger farmers may achieve by spreading fixed costs across many crops. This makes diversification less feasible for smallholders. A study by Kurdys-Kujawska *et al.* (2021) on crop diversification in small farms in Poland found that the intensity of crop diversification in small farms was low. Due to the small farm sizes in Borabu sub-county, farmers are less likely to participate in crop diversification. Farmers with larger farms are more inclined to engage in crop diversification because larger farms may have the resources and capacity to manage multiple crops more efficiently (Mzyece & Ng'ombe, 2020). Economies of scale can lead to cost advantages in production, distribution, and marketing, making diversification financially viable for larger operations. On the other hand, crop diversification is often considered a risk management strategy. Larger farms with more extensive land holdings may find it easier to allocate specific portions of their land to different crops, thereby spreading the risk associated with fluctuations in market prices, weather conditions, or pests.

With crop farming as the primary occupation, household heads were less likely to participate in crop diversification (Table 4.5). This negative association might be because these farmers rely more on their traditional farming practices and may be hesitant to shift to diversified cropping patterns, which they may perceive as riskier. Diversifying into unfamiliar crops can increase yield variability, pests, diseases, and market uncertainty risks. These households may stick to well-known crops and have historically provided reliable income rather than experimenting with new crops. If farming is the primary income source, households are more likely to concentrate on a few high-value or staple crops that are guaranteed to bring consistent returns. These crops often have well-established markets or government support, for example, subsidies or price guarantees, reducing the incentive to diversify. These findings contradict the findings of Feliciano (2019), who established that farming, as the household head's primary

occupation, was positively and significantly associated with participation in crop diversification in different world regions.

Being married positively influences a farmer's decision to participate in crop diversification. This could be explained by the fact that in married households, decision-making is often shared between spouses, which can lead to a more balanced approach to risk-taking. With more people involved in decision-making, there may be a greater willingness to diversify crops to spread risk across different types of produce rather than relying solely on one crop for income. Married couples can pool financial resources, skills, and knowledge, making it easier to invest in crop diversification. These findings align with the findings of Emmanuel Inoni *et al.* (2021), who found a positive association between married household heads and the decision to participate in crop diversification.

Being male negatively affected crop diversification decisions, suggesting that female farmers are more likely to diversify. Men are often associated with cash crops and large-scale, single-crop (monoculture) farming in many agricultural societies. At the same time, women are typically more involved in subsistence farming and food crops for household consumption. Women may diversify their crops to ensure a varied diet for their families and reduce the risk of food insecurity. At the same time, men may focus on maximizing profit from a single, high-revenue crop. Men may also prefer to invest in more profitable cash crops like maize, sugarcane, or coffee, which may require specialization rather than diversification. A study by Abdulai and Baba (2021) showed that women tend to be more risk-averse than men, especially in rural farming contexts. Diversifying crops is a strategy to mitigate risks like crop failure, price volatility, and climate variability. Women may diversify to spread out these risks, ensuring that at least one crop will succeed, even if others fail. Conversely, men might be more willing to take risks associated with specializing in one or two profitable crops, betting on higher returns.

Table 4.5: Factors Influencing Decision of a Farmer to Participate in Crop Diversification

CDI	Coefficient	Std. Error	P> Z
Married	1.34***	0.40	0.00
Land tenure			
Owned with title deed	-0.52	0.45	0.26
Owned without title deed	-0.50	0.39	0.20
Rented Land	-6.23	282.60	0.98
Education Level			
Primary	0.22	0.61	0.72
Secondary	0.05	0.34	0.89
Tertiary	-0.19	0.38	0.62
Occupation			
Farming	-0.18	0.68	0.79
Government Sector	-0.07	0.71	0.92
Business	-0.13	0.80	0.87
Main Source of Income			
Farm Income	-1.18***	0.35	0.00
Formal Income	-1.50	0.92	0.10
Group Membership	-0.30	0.24	0.21
Access to remittances	0.06	0.27	0.81
Male	-0.55*	0.28	0.05
Family Labour	-0.72**	0.29	0.02
Size of land farmed	-0.13***	0.03	0.00

LR Chi² (19)- 132.67 Prob> Chi²-0.00 Pseudo R²- 0.42

Log Likelihood- 93.18

Legend * P<.1; ** P<.05;***P<0.01

4.3.2 Extent of crop diversification

The second stage used the truncated normal regression model to determine the extent of farmer participation in crop diversification. In this stage, the crop diversification index measured the extent of diversification.

Household heads between the ages of 36 and 49 and those above 65 years had a positive and significant influence on the extent of crop diversification, implying that for each unit increase in the age of the household head, the level of diversification is expected to increase by 19.73%, holding other variables constant. These farmers had a marginally significant positive effect on crop diversification. This could imply that farmers in this age group may be more stable, leading to better socioeconomic outcomes. Older individuals might benefit from accumulated wealth or social security, thus improving their CDI. The positive association between age and crop diversification implies that as individuals age, there is a slight increase in crop diversification across high, moderate, and low levels. This observation is in contrast with the findings of Fisher and Qaim (2012) but in line with Akinwekomi *et al.* (2017) and Kankwamba *et al.* (2018). An explanation for this might be that older farmers are more receptive to new agricultural practices and are less risk-averse than younger farmers (Akpan *et al.*, 2015; Ayuya, 2010).

The household head's education level had a negative but significant effect on the extent of crop diversification at a 5% significance level. Holding other variables constant, for each unit increase in education level, for example, from primary to secondary or from secondary to college/university, the extent of crop diversification would decline by 2.54%. This implies that as education levels rise, there is a slight decline in the extent of crop diversification across high, moderate, and low diversification levels (Kumar *et al.*, 2012). The plausible explanation for these findings could be that educated farmers can explore more to identify available income-generating sources to support the income from on-farm activities, increasing household welfare levels (Ghafoor *et al.*, 2010).

There is a significant positive association between the marital status of a household head and the extent of crop diversification. Married household heads have a positive and statistically significant effect on crop diversification. Results indicate that being married affects crop diversification by a 23% increase. Marriage may provide financial and emotional stability, thus improving CDI. Separated household heads had a higher positive coefficient than other subcategories, with significant results. Being separated had a 69.41% increase in the extent of crop

diversification. Separated people might face social and economic disruptions but eventually achieve independence, which leads to a stronger CDI, likely through remarrying or other stabilizing factors. Farmers in the widowed category had a marginally significant effect with a small positive impact (14.79%) on CDI. Widows may face initial hardship, but some may receive support that eventually helps improve their economic status. Marriages create an opportunity to increase the support base in managing the household farm. According to Baba and Abdulai (2020), marriage imposes more burden on household heads as more mouths are to be fed. The obligation to provide for the family makes households try several enterprises to make sure the family meets its responsibility of taking care of the entire family. These findings are similar to the findings of Baba and Abdulai (2020), who established that the marital status of the household head affected crop diversification positively since marriages create an opportunity to increase the support base in managing the household farm. The obligation to provide for a family makes households try several enterprises to ensure the family meets its responsibility of taking care of the entire family.

Land tenure had a significant negative relationship with the extent of crop diversification. Owning land with a title deed is negatively associated with CDI, with members having title deeds' extent of crop diversification declining by 32.3%. Although secure ownership might be expected to boost crop diversification, the cost of maintaining such land or legal issues could weigh negatively on economic benefits. Farmers who owned lands without title deeds had a slightly negative effect (29%) on crop diversification compared to those with a title deed. Uncertainty regarding ownership may create insecurity, limiting investment and productivity. Renting land had the most significant negative effect (41%) in this category, implying that tenants who rent land may face uncertainty regarding land access and high rent costs, limiting their economic potential and reducing CDI. Secure land tenure gives farmers the confidence and incentives to invest in long-term agricultural practices such as crop diversification (Akugre *et al.*, 2021). When farmers have formal and informal rights to the land they cultivate, they are more likely to invest in improving soil fertility, adopting new cropping systems, and exploring diversified options. Insecure tenure, conversely, may discourage farmers from taking such risks.

Land tenure arrangements may sometimes contribute to land fragmentation, particularly in small landholdings. Fragmented land ownership can limit the scope of crop diversification as smaller plots may not provide sufficient space or resources to experiment with diverse crops effectively. These findings align with the findings of Madsen *et al.* (2021), who established that

secure land tenure, such as formal ownership or long-term leases, gives farmers the confidence to make long-term investments in their land. This can lead to a greater willingness to experiment with different crops and invest in diverse cropping systems.

The type of labour available to a household significantly negatively affected crop diversification. Relying on the use of family labour declined the extent of crop diversification by 14.06%. Family labour is typically limited in quantity and skills. Since crop diversification often requires more labour for managing different crops with varying needs, family labour may not be sufficient to meet these demands. Households with limited family labour are more likely to focus on fewer crops to maximize efficiency and minimize labour overload. When relying on family labour, shifting focus to new crops comes with a higher opportunity cost, as family members may need to dedicate their time to tasks that might not guarantee immediate returns. On the other hand, households with hired labor can delegate work across different crops without significantly altering the labor availability for each. Hired labor often leads to a more specialized and focused approach in crop production, as workers may have specific skills or tasks (Brosseau *et al.*, 2021).

On the other hand, hired workers may lack a personal stake in the farm's success, potentially leading to less attention to diverse crops or a focus on more profitable ones. In contrast, family labor encourages various crops to meet diverse household needs. The negative relationship between the type of labor and diversification aligns with the findings of Asante *et al.* (2017), who found that the type of labor (hired) negatively affects crop diversification.

Table 4.6: Factors Affecting Extent of Crop Diversification

CDI	Coefficient	Std. Error	P> t
Marital Status			
Married	0.23***	0.07	0.00
Separated	0.69**	0.32	0.03
Widowed	0.14*	0.08	0.07
Land tenure			
Land Owned with title deed	-0.32***	0.74	0.00
Land Owned without title deed	-0.29***	0.07	0.00
Rented Land	-0.41***	0.08	0.00
Education			
Primary	0.002	0.08	0.98
Secondary	0.01	0.06	0.86
Tertiary	-0.03**	0.06	0.66
Occupation			
Farming	-0.03	0.09	0.72
Government Sector	-0.01	0.10	0.89
Business sector	0.13	0.13	0.31
Main Income Source			
Farm Income	0.02	0.31	0.94
Formal Income	-0.02	0.32	0.96
Business Income	0.35	0.33	0.29
Casual Income	0.25	0.32	0.46
Group Membership	0.04	0.04	0.28
Access to Remittances	-0.02	0.04	0.68
Age			
Age 18-35	-0.10	0.09	0.25
Age 36-49	0.10*	0.06	0.09
Age 50-65	omitted		

Above 65years	0.20**	0.10	0.05
Gender	-0.04	0.04	0.36
Family Labour	-0.14***	0.05	0.01
Cons	0.58	0.36	0.11
Number of observations=385 Prob>F = 0.000 R.Squared=0.34 Adj. R.Squared=0.29			

Legend: * p<.1; ** p<.05; *** p<.01

4.4 Investigating the Nexus Between Crop Diversification and Household Welfare

Tests of Endogeneity

The Durbin score test is used to detect endogeneity in a regression model. The null hypothesis (H_0) is that there is no correlation between the independent variables and the error term, indicating endogeneity. In this case, the test statistic is 16.90 with a p-value of 0, suggesting that the null hypothesis (H_0 : the variables are exogenous) is strongly rejected. This implies that the variables are endogenous. The Wu-Hausman test is another endogeneity test specifically designed for instrumental variable estimation. The null hypothesis (H_0) also states that the variables are exogenous. A significant F-statistic ($F = 17.04$) with a p-value of 0.00 indicates that the difference between OLS and IV estimates is statistically significant, again leading to the rejection of the null hypothesis of exogeneity. This further confirms that the variables are endogenous (Table 4.7).

Table 4.7: Tests of Endogeneity

H0: Variables are exogenous	
Durbin (score) $\text{Chi}^2(1)$	= 16.90 (p = 0.00)
Wu-Hausman $F(1,371)$	= 17.04 (p = 0.00)

Tests of Over-Identifying Restrictions

The over-identifying restrictions tests were used to establish if the instruments were uncorrelated with the error term, if the equation was incorrectly defined, and if one or more of the exogenous variables left out of the equation should have been included. The Sargan and Basman tests are often used in the context of instrumental variable (IV) regression models to assess the validity of instruments, specifically whether the instruments are uncorrelated with the error term. Both tests are implemented to check for over-identifying restrictions, which means having more instruments than the number of endogenous regressors. The Sargan test checks the over-identifying restrictions in IV models, where there are more instruments than endogenous variables. The test statistic follows a Chi-square distribution with degrees of freedom equal to the number of over-identifying restrictions (in this case, 5). A high p-value (here, $p = 0.61$) indicates that the null hypothesis cannot be rejected, meaning there is no evidence that the instruments are invalid. The instruments appear exogenous, as their correlation with the error term is statistically insignificant. The Basman test is an alternative to the Sargan test for testing over-identifying restrictions in IV models. It is based on the same null hypothesis (the instruments are valid). The test statistic also follows a Chi-square distribution with degrees of freedom equal to the number of over-identifying restrictions (5). Similar to the Sargan test, a p-value of 0.64 indicates that the null hypothesis is not rejected, confirming that the instruments are valid (Table 4.8).

Table 4.8: Tests of OverIdentifying Restrictions

Ho: Instruments are valid	
Sargan (score) $\text{Chi}^2(5)$	= 3.56 (p = 0.61)
Basman $\text{Chi}^2(5)$	= 3.42 (p = 0.64)

The correlation coefficients ρ_0 and ρ_1 indicate the correlation between the unobserved factors affecting the decision to diversify and household consumption expenditure. (Table 4.9). The positive and significant ρ_0 suggests that households with unobserved characteristics that make them more likely to diversify also tend to have higher welfare.

Since ρ_2 is positive and significantly different from zero, the model suggests that smallholder maize farmers who practiced crop diversification experienced better overall welfare than a random individual from the sample would have experienced. The likelihood ratio test for the independence of the equations shows that the decision to diversify and the welfare outcomes are significantly related, justifying the use of the Endogenous Switching Regression model.

The size of the farm owned by household heads significantly and negatively affected their consumption expenditure at a 1% significance level. Holding all other factors constant, if households increase farm size by 1 unit, it will lead to a decline in consumption expenditure by 13%. This implies that households with larger farm sizes have a lower consumption expenditure and better welfare than farmers with smaller farm sizes. Households with larger farmlands can get more produce and diversify more than households with small farm sizes. Mesfin *et al.* (2011) found that the ability to cultivate larger areas allows farmers to cultivate a greater range of crops that can ensure that the household has enough food to avert food insecurity. This finding agrees with Aidoo *et al.* (2013), who maintained that the odds ratio of being food secure increases with an increase in the area under cultivation, and findings by Feliciano (2019), who established a significant association between land size and household welfare.

The gender of the household head had opposite effects depending on diversification. Being male has a negative impact on consumption expenditure for diversifiers, while for non-diversifiers, it is positive. This could indicate that women in diversifying households are more involved in managing diverse crops, leading to better welfare outcomes. In contrast, non-diversifying households may still benefit from traditional male-led income-generating activities. Men are often associated with cash crops and large-scale, single-crop (monoculture) farming in many agricultural societies. At the same time, women are typically more involved in subsistence farming and food crops for household consumption. Women may diversify their crops to ensure a varied diet for their families and reduce the risk of food insecurity. At the same time, men may focus on maximizing profit from a single, high-revenue crop. Men may also prefer to invest in more profitable cash crops like maize, sugarcane, or coffee, which may require specialization rather than diversification. A study by Abdulai and Baba (2021) showed that women tend to be more risk-averse than men, especially in rural farming contexts. Diversifying crops is a strategy to mitigate risks like crop failure, price volatility, and climate variability.

Younger household heads (18-35 years) who do not diversify their crops experience lower consumption expenditure compared to elderly farmers. Consumption expenditure for older farmers of between the ages of 36-49 years increases by 20.4% while those above 65 years increases by 30.8%. This could be due to a lack of resources or experience in farming, indicating that younger households may benefit from crop diversification to improve their welfare, for diversifiers and non-diversifiers in the age group of 36 to 49 years see an increase in consumption expenditure. However, the effect is stronger for diversifiers, highlighting the benefits of crop diversification for middle-aged households, likely due to more experience and better resource management. According to Brown *et al.* (2019) elderly households benefit significantly in terms of welfare from crop diversification. The large positive coefficient for diversifiers implies that older households, perhaps with more experience and established land ownership, see the greatest welfare gains from diversification.

Dependence on farm income as the primary source of income has an inverse relationship with household welfare. For every 1-unit increase in reliance on farm income, expenditure decreases by 0.99 units. This could reflect the vulnerability of farm-dependent households to fluctuations in agricultural productivity, market prices, or external factors like climate change. Farming income is often volatile due to these factors. Farm-dependent households may face more economic instability, as agriculture can be seasonal, weather-dependent, and sensitive to market shifts. This instability could negatively affect household welfare, income security, or overall economic growth. A heavy reliance on farming as the primary income source might imply a lack of diversification (Dessie *et al.*, 2019). This heavy reliance on agriculture could make households more vulnerable to income shocks when farm production or prices drop. This could mean that even though diversification provides income stability, overall farm income may still not be enough to significantly increase welfare, especially if diversification strategies are not well optimized.

Households whose primary occupation is farming significantly negatively affect consumption expenditure for non-diversifiers. These households tend to have lower consumption expenditures. For every unit that increases in dependence on agriculture as the primary occupation and income, consumption expenditure decreases by 0.57 units. Households relying on farming may face income volatility due to seasonality, crop yields, weather conditions, and fluctuating agricultural market prices. This instability could result in reduced or cautious consumption spending, as farming households may need to save or spend less during periods of low income. In many cases, farming

households may have lower disposable income levels due to smaller profits or higher production costs, especially in rural or subsistence agriculture settings. This can limit their ability to spend on goods and services, thus lowering their consumption expenditure.

Being married positively impacts consumption expenditure for crop diversifiers. The significant positive coefficient implies that married households engaged in crop diversification experience higher welfare. Being married is associated with higher consumption expenditure. Results in Table 4.9 indicate that households where the household head is married experience an increase in consumption expenditure by 0.89 units. Married households are often associated with larger family sizes, which may increase overall consumption needs (Baba & Abdulai, 2021). For example, a married couple may have children, resulting in higher spending on food, education, healthcare, and housing. In many cases, marriage might involve pooling financial resources (from both spouses), which increases the household's disposable income and enables higher consumption expenditure. Being married might also provide more economic and emotional stability, allowing households to spend more confidently, even on non-essential items or investments in long-term consumption like housing or education.

Table 4.9: Results of ESR model for the Nexus Between Crop Diversification and Household Welfare

Variable	Crop Diversification Index		Consumption Expenditure			
	Coefficient	Std. Error	Diversifiers		Non-Diversifiers	
			Coefficient	Std. Error	Coefficient	Std. Error
Married	0.89**	0.43	0.22	0.51	0.28	0.20
Single	-0.50	0.53	-0.37	0.63	-0.40	0.25
Farming	-0.03	0.39	-0.04	0.39	-0.57**	0.24
Govt Sector	0.13	0.40	0.17	0.37	-0.59**	0.26
Farm Income	-0.99***	0.27	-0.55	0.42	-0.12	0.19
Age 18-35	-0.78*	0.46	-1.47***	0.53	-0.44	0.31
Age 36-49	0.76**	0.37	2.04***	0.56	0.90***	0.19
Above 65	1.32**	0.55	3.08***	0.77	1.25***	0.34
Gender	-0.44*	0.25	0.50*	0.29	-0.10	0.13
Family Labour	-0.40	0.28	0.35	0.28	-0.01	0.17
Farmland	-0.13***	0.03				
Owned with title deed	0.17	0.28				
Owned without title deed	0.08	0.24				
Primary	-0.14	0.45				
Secondary	0.16	0.28				
Tertiary	0.01	0.29				

_Cons	-0.32	0.64	8.32***	0.83	11.45***	0.34
/lns0	-0.03	0.04				
/lns1	-0.18	0.19				
/r0	1.38***	0.28				
/r1	0.78	0.53				
Sigma0	0.97	0.04				
Sigma1	0.83	0.16				
rho0	0.88	0.06				
rho1	0.65	0.30				

LR test of Indep. eqns.: $\text{Chi}^2(2)=16.29$ Prob > $\text{Chi}^2=0.0003$

Legend: * p<.1; ** p<.05; *** p<.01

Average treatment-effects estimation

Table 4.10 indicates the summarized results of the average mean treatment effects on household welfare among farmers, with household consumption expenditure used as a proxy for household welfare. In determining the mean treatment effects of these farmers, diversifiers were considered the treatment group, whereas non-diversifiers were considered the control group. In addition, hypothetical counterfactual estimations for both diversifiers and non-diversifiers were estimated. Cells (a) and (d) indicate actual mean values of consumption expenditure for diversifiers and non-diversifiers, respectively. At the same time, (b) indicates the value for counterfactual expected consumption expenditure estimates for crop diversifiers, while (c) indicates the counterfactual expected estimates for crop non-diversifiers.

For diversifiers, the ATT, which is the effect of diversification on diversified farmers, was 11.1049. The ATU, the hypothetical impact if diversifiers had not diversified, is 10.1386. The difference between these values is the ATE, which is 0.9663, indicating that diversification had a positive and significant effect on diversifiers. For non-diversifiers, the ATT, which was the effect of diversification if these had diversified, was 11.5118. The ATU, the actual outcome of non-diversifiers without diversification is 12.7955. The difference here is -1.2837, showing that if non-diversifiers had diversified, their outcomes would have been worse by this value. BH1 represents the difference in outcomes for diversifiers versus non-diversifiers under the actual status quo (not diversifying). A value of -0.4069 suggests that non-diversifiers would perform slightly worse than diversifiers if both had chosen not to diversify. BH2 represents the difference if both groups had diversified. The -2.6569 suggests non-diversifiers would have done much worse under diversification than diversifiers. The overall heterogeneity effect of 2.25 shows the total variation between the diversifying and non-diversifying groups, indicating that the effect of diversification differs significantly between them. Diversification positively impacts the welfare of those who diversify (0.9663), while non-diversifiers experience negative impacts if they have diversified (-1.2837).

Table 4.10: Results of Average Treatment Effects

Sub-sample	Diversification status		Average Treatment Effects (ATE)
	Diversify (ATT)	Not to Diversify (ATU)	
Diversifiers	(a) 11.1049	(b) 10.1386	0.9663***
Non-diversifiers	(c) 11.5118	(d) 12.7955	-1.2837
Heterogeneity Effects	BH1 = -0.4069	BH2 = -2.6569	2.25

***represents 1% significance level

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- i. Findings from Borabu sub-county highlight the low level of crop diversification among farmers, as indicated by the Crop Diversification Index (CDI). With an average CDI of 0.15, significantly below the threshold of 0.5, it is clear that diversification is not a prevalent practice in the region. This suggests a reliance on limited crop types, which may increase vulnerability to market fluctuations, climate change, and other risks.
- ii. The Double Hurdle model provided valuable insights into the barriers and success factors related to effective crop diversification among small-scale farmers in Borabu sub-county. The first hurdle revealed that key determinants of a farmer's likelihood to diversify included the marital status of a household head, main income source of the household head, gender of the household head, size of land farmed and type of labour available to a household. In the second hurdle, factors such as the age of the household head, education level of the household head, marital status, land tenure and type of labour available to a household played significant roles in shaping the extent of crop diversification.
- iii. The Endogenous Switching Regression Model was used to investigate the nexus between crop diversification and household welfare, with consumption expenditure used as a proxy for household welfare. The model indicated a strong positive relationship between crop diversification and household welfare. This implies that crop diversification significantly improves household welfare in Borabu sub-county. Marital status, occupation and main source of income significantly influenced consumption expenditure by diversifiers. On the other hand, age of the household head, size of land farmed, income source significantly influenced consumption expenditure for non-diversifiers.

5.2 Recommendations

- i. Different areas may differ in the comparative advantage in terms of the agroecology for the production of crops. In such a case, households may thus be better off specializing in a particular enterprise, with adequate diversification within that enterprise for resilience, then accessing other food products from the markets. To encourage diversification, extension

advice should be targeted towards improving knowledge on climate change in the region and dissemination of information on the available strategies households can utilize to mitigate climatic shocks like pests and diseases, in this case, MLND.

- ii. The study identifies gender of the household head as a key determinant of diversification decisions. Male-headed households were more diversified and had better overall welfare compared to female-headed households. Study findings suggest that female-headed households are more vulnerable and policies that aim to empower women in the study area would be beneficial. Such policies could be in the form of special financial products specifically meant for women in order to enable them access credit easily. Intervention programs by development partners that target women have been shown to be highly effective elsewhere in improving household welfare and should be advocated for in the study region.
- iii. Adapting to changing climate is critical for small-scale farmers. Diversification of livelihoods is a key strategy of strengthening the adaptive capacity and resilience of vulnerable rural communities. Encouraging crop diversification through targeted policies, extension services and access to diverse markets could enhance agricultural resilience and sustainability in Borabu sub-county and ultimately impacting the welfare and food security status of households in the region.

5.2 Areas of further research

- i. Investigate how market accessibility, infrastructure, and value chains can influence crop diversification and its effect on household welfare, particularly in rural settings.
- ii. Explore the impact of climate variability and resilience strategies on crop diversification and household welfare, examining how climate-smart practices enhance both income and food security.
- iii. A long-term analysis could help understand how sustained crop diversification affects household welfare and food security over time, capturing trends and causal relationships more effectively.
- iv. Investigating the effects of government policies or agricultural programs such as subsidies, extension services or input provision on promoting crop diversification and its role in enhancing household welfare.

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APPENDICES

Appendix A: Questionnaire

Introduction and Consent for respondent

Dear Sir/Madam,

I am researching on behalf of Valerie Kerubo who is a student of Agricultural and Applied Economics at Egerton University. This study intends to find out factors that affect crop diversification as well as how crop diversification has affected household welfare in Borabu Sub-County. Your response to the questions will be used to assess the current position and help formulate policies that will be geared towards mitigating risks associated with crop-specific failure as well as promoting crop diversification. The information obtained will be used only for the study. Your responses will be confidential and your participation is voluntary. Thank you for your cooperation.

Please tick where applicable

SECTION A: Biodata of the respondent

Date	
Name of enumerator	
Ward	
Respondent's phone number	
Respondent's name(Optional)	

SECTION B: Household Profile

Household head characteristics	Coding	Response
Relationship of the respondent to the household head	1=Self 2= Spouse 3=Son4=Daughter 5=Parent6= Adopted/ fostered child 7= Friend of the head8=Other(Specify)	
Gender of household head	1= male 0= female	
Marital status	1=Married 2=Single 3=Widow/ widower 4= Separated 5=Divorced 6=Other	

Age of household head	1= Under 18 Years 2= 18-35 years 3= 36-49 years 4=50-65 years 5=Above 65 years	
Highest education level of household head	1=None 2=Informal Education 3=Completed Primary 4=Completed Secondary 5=Vocational Training 6=College/ University	
The main occupation of the household head	1=farmer 2=government sector 3=private sector 4=self-employed 5=unemployed 6=other (specify)	
The main source of income	1= Farming (livestock, crops) 2= Formal employment 3= Informal employment such as casual labor 4= Business/ Trade 5= Remittances 6= Pension 7= Social Protection such as Inua Jamii	
Type of residence	Wall-1=mud2=wood3=bricks4=stones Roof-1=grass2=iron sheet	

	Floor-1=earth2=cemented3=tiled	
Household size	Males Adults: Children: Females Adults:Children: Total household size.....	

SECTION C: Land ownership details

C.1 Do you own land? (1=Yes 0=No)

If yes, complete the table for tenure systems employed

Total size	Rented in	Rented out	Owned with title deed	Owned without a title deed	Communal
Acres					

C.2 What proportion of land in acres is used for farming?

C.3 Type of Labour used

Family labour

Hired labour

SECTION D: HOUSEHOLD RESILIENCE

Adaptive Capacity	
D1: Ability of household head to read and write	1=yes, 0=no
D2: highest level of formal education of the household head?	
D3: Age of household member with the highest level of education?	
D4: Number of household members who have at least a diploma	
D5: Main source of household income in the past 12 months	
D6: Other sources of household income	
D7: Income variation in the last 6 months	

D8: Number of household members who have lost jobs in the last 1 year	
D9: Number of different crops grown during the last season	
D10: Perception of the capacity to keep up in the future, in the face of shocks	
Belonging to a social group	
D11: Are you a member of any social group?	1=Yes 0=No
D12: What kind of group are you in	1=farmergroup2=multi-purpose group 3=youth group4=savings group5=community based organization6=others (specify
D13: For how long have you been in the group	Number in years
D14: What was the purpose of joining the group	1=trainings,2=market access,3=financial services,4=input Access,5=access to information,6=other (specify

CODES: D2	D3	D6	D7	D10
1=Primary 2=Secondary 3=Tertiary	1=4-20 years 2=21-37 years 3=3-64 years 4=Above 64years	1=Agriculture 2=Family business other than agriculture 3=Government wage and salary 4= Private sector wage and salary 5=Transfers and social assistance 6= Other (specify)	1=Increased 2=Remained the same 3=Decreased	1=Most likely 2=Likely 3=Indifferent 4=Less likely

ASSETS	
D15: Durable assets owned (Give number)	
D16: Size of land owned (owned, leased, or used) in hectares	
D17: Livestock owned (Give the corresponding number)	
D18: How much [crop] did the household harvest/ do they expect to harvest during the last/ current crop season in kilograms	
D19: Use of input (Seeds, Fertilizer, pesticides/herbicides)	

CODE: D15	D17	D18	D19
1=Car 2=Bicycle 3=Gas/electric cooker 4=Mobile 5=Plough 6=Machete 7=Tractor	1=Cows/ calves 2=Sheep, goat 3=Chicken 4=Donkeys	1=Maize 2=Millet. 3=Sorghum 4=Beans 5= Sweet potatoes 6= others(specify)	1=Yes 2=No

SOCIAL SAFETY NETS	
D20: The total amount of loan(s) received in the last 12 months by the members of the household (In KSH)	
D21: The total amount of formal transfers received in the last 12 months by the members of the household?	
D22: The total amount of informal transfers) received in the last 12 months by the members of the household.	
D23: Who can the members of the household rely on in case of need?	
D24: Which of these associations do the household members depend much on when in need	
SAVINGS AND/OR CREDIT SCHEMES	

D25: Do you have any form of savings and/or credit scheme? 1=Yes, 0=No	
D26(b): If yes, approximately how much can you gather in a month? (In KSHs)	
D27: Did you acquire any credit while you were experiencing MLND? 1=YES, 0=NO	
D28: If yes, have you used these savings and/or credit to cover losses associated with MLND? If no, why?	
D29: Do you have insurance against crop disease shocks? 1=Yes, 0=No	
D29(b): If yes, has insuring against crop diseases proved useful? 1=Yes, 0=No If no, why?	

CODES: D23	D24	D25	D26
1= relief food 2=cash assistance 3= livestock 4=safety net programs 5=pension schemes	1=cash 2=remittances 3=food or grain gift 3= seed gift 4= free use of animals	1=farmer groups, 2=women support groups, 3=youth groups, 4=business associations, unions 5=Relatives/friends/family members	1=Farmer groups 2=Women support groups 3=Youth groups 4=Business associations 5=Unions 6=Relatives

SECTION E: Household Consumption Expenditure

E1: Non-durable goods

E11	Food Expenditure	Value of purchases
	Fruits and Vegetables	

	Legumes and nuts	
	Dairy products (yogurt, ice cream, butter, cheese, milk powder, etc.)	
	Cereals (wheat, millet, sorghum, rice, maize, etc.)	
	Bread and flour	
	Meat, fish, eggs	
	Fats and oils	
	Spices and confectionaries(sweets, candy	
	Non-alcoholic drinks	
	Alcoholic drinks	
	Tobacco products (cigarettes)	
E12	Clothing	
	Bedding attire	
	Men's clothes and shoes	
	Women's clothes and shoes	
	Children's clothes and shoes	
	Toiletries and cosmetic products	
E13	Housing and energy expenditures	
	Charcoal	
	Paraffin	
	Firewood	
	Electricity	
	Batteries	
	Monthly rent paid	
	Maintenance costs for owned house	

E.2 Durable goods

Items	Value in Kshs
Electronic appliances	
Furniture	
Personal vehicle	

Farm machinery	
----------------	--

E.3 Services

Items		Value in ksh
E.31	Healthcare	
	Hospital bills	
	Medicine	
	Traditional medical services	
E.32	Education	
	School fees	
	School attire	
	Stationery and books	
	Accommodation(boarding)	
E.33	Transport and communication	
	Maintenance for a personal vehicle	
	Car fuel	
	Public transport	
	Airtime	
E.34	Entertainment	
	Parties	
	Program subscriptions(TV)	
E.35	Others	
	Insurance	
	Gift and donations	
	Church offerings	

SECTION F: Coping Strategies

Coping Strategy	In the past 30 days, were there days (and if so how many) when your household had to use any of the following strategies to cope with food shortage or lack of money to buy it?
------------------------	---

	Insert frequency= number of days value, 0-7
Relied on less preferred and or less expensive food?	
Borrowed food, or relied on help from a friend or relative?	
Reduced the number of meals eaten per day	
Reduced portion size of meals	
Give available food to vulnerable members of the family only	
Traveling long distances to look for food/ vegetables	
Migrating in search of income	
Exchange labor for food	
Getting food on credit	
Sought food aid from the government and other organizations	
Alternative income e.g Off-farm employment	
Use of savings	

SECTION G: CROP INFORMATION

Type of crop	Area planted (Acres)	Income generated (KSHS)	Cost of Labor (KSHS)	Cost of seeds and fertilizers	Cost of pesticides and/ herbicides
Maize					
Beans					
Millet					
Sweet Potatoes					
Kales					
Cabbages					
Local vegetables					
Others(Specify)					

Appendix B: Copy of Research Ethical Clearance

EGERTON



UNIVERSITY

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EGERTON UNIVERSITY INSTITUTIONAL SCIENTIFIC AND ETHICS REVIEW COMMITTEE

EU/RE/DIR/009

Approval No. EUISERC/APP/231/2023

11th April, 2023

Omwenga Kerubo Valerie
Egerton University
P.O.Box 536-20115
Telephone: +254790430482
E-mail: kerubovalerie@gmail.com

Dear Valerie,

**RE: ETHICAL APPROVAL: EXPLORING THE NEXUS BETWEEN CROP
DIVERSIFICATION AND HOUSEHOLD WELFARE AMONG SMALL SCALE MAIZE
FARMERS IN BORABU SUB-COUNTY, NYAMIRA COUNTY.**

This is to inform you that *Egerton University Institutional Scientific and Ethics Review Committee* has reviewed and approved your above research proposal. Your application approval number is *EUISERC/APP/231/2023*. The approval period is *11th March, 2023 –12th April, 2024*

This approval is subject to compliance with the following requirements;

- i. Only approved documents including (informed consents, study instruments, MTA) will be used.
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by *Egerton University Institutional Scientific and Ethics Review Committee*.
- iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to *Egerton University Institutional Scientific and Ethics Review Committee* within 72 hours of notification.
- iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to *Egerton University Institutional Scientific and Ethics Review Committee* within 72 hours.
- v. Clearance for Material Transfer of biological specimens must be obtained from relevant institutions.
- vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.

"Transforming Lives through Quality Education"

vii. Submission of an executive summary report within 90 days upon completion of the study to *Egerton University Institutional Scientific and Ethics Review Committee*.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) <https://oris.nacosti.go.ke> and also obtain other clearances needed.

Yours sincerely,



Prof. Raphael M. Ngunjiri
**CHAIRMAN, EGERTON UNIVERSITY INSTITUTIONAL SCIENTIFIC AND ETHICS
REVIEW CTTEE**

RMN/BK

Appendix D: Results of Multicollinearity test using VIF

Variable	VIF	1/VIF
Sources of income	2.02	0.4954
The household head's main source of income	1.94	0.5164
Gender of household head	1.70	0.5874
Education of household head	1.53	0.6519
occupation of household head	1.48	0.6734
Marital status of household head	1.48	0.6776
Number of household members	1.44	0.6960
Amount of Labour	1.43	0.6985
Land tenure	1.23	0.8099
Group membership	1.14	0.8756
Age of household head	1.10	0.9132
Herd size	1.07	0.9318
Locational dummy	1.07	0.9323
Size of land owned in acres	1.06	0.9398
Credit access	1.06	0.9440
Mean VIF	1.64	

Note: VIF refers to Variance Inflation Factor

Appendix E: Results of Heteroscedasticity test using the White Test

Source	chi²	df	p
Heteroskedasticity	156.81	184	0.9277
Skewness	12.83	18	0.8018
Kurtosis	1.32	1	0.2503
Total	170.96	203	0.9504

Note: Chi²=Chi-Square; df= degrees of Freedom and P-Value= Significance level.

Appendix F: Results of Double-Hurdle Regression Model Stata Output-First-Hurdle Results

Ordered probit regression

Number of obs = 384

LR chi2(19) = 132.67

Prob > chi2 = 0.0000

Pseudo R2 = 0.4159

Log likelihood = -93.182779

CDI1	Coefficient	Std. err.	z	P> z	[95% conf. interval]	
married	1.342029	.3954433	3.39	0.001	.5669749	2.117084
owned_with_titled	-.5096005	.4476885	-1.14	0.255	-1.387054	.3678529
owned_without_titled	-.4998115	.3901105	-1.28	0.200	-1.264414	.2647909
Rented_Land	-6.228437	282.6072	-0.02	0.982	-560.1284	547.6716
Leased	0 (omitted)					
primary	.2167267	.6114504	0.35	0.723	-.9816941	1.415148
Secondary	.0484471	.3357588	0.14	0.885	-.6096281	.7065222
Tertiary	-.1883972	.375376	-0.50	0.616	-.9241208	.5473263
farmer	-.1811863	.6773977	-0.27	0.789	-1.508861	1.146489
unemployed	0 (omitted)					
govtsector	-.0690294	.7128783	-0.10	0.923	-1.466245	1.328186
business	-.1316242	.7956882	-0.17	0.869	-1.691144	1.427896
farm_income	-1.177515	.3453221	-3.41	0.001	-1.854334	-.5006962
formal_inc	-1.498678	.9224153	-1.62	0.104	-3.306579	.3092224
group_membership	-.3044046	.2412586	-1.26	0.207	-.7772628	.1684536
access_remittances	.0640101	.2679081	0.24	0.811	-.4610801	.5891004
age36_49	.359331	.2430102	1.48	0.139	-.1169602	.8356222
age50_65	-.5043724	.4045827	-1.25	0.213	-1.29734	.2885952
above65years	0 (omitted)					
male	-.5450225	.2803501	-1.94	0.052	-1.094499	.0044535
family_labour	-.7151563	.2927733	-2.44	0.015	-1.288981	-.1413311
acreslandfarming	-.1253833	.0341336	-3.67	0.000	-.1922839	-.0584826
/cut1	-1.274854	.8167497			-2.875654	.3259462

Note: 53 observations completely determined. Standard errors questionable.

. estimates table, star(.1 .05 .01)

Variable	Active
CDI1	
married	1.3420295***
owned_with_~	-.50960051
owned_without_titl~d	-.49981152
Rented_Land	-6.228437
Leased	(omitted)
primary	.21672674
Secondary	.04844707
Tertiary	-.18839723
farmer	-.18118626
unemployed	(omitted)
govtsector	-.06902936
business	-.13162415
farm_income	-1.1775151***
formal_inc	-1.4986783
group_memb~p	-.3044046
access_rem~s	.06401014
age36_49	.35933101
age50_65	-.50437239
above65years	(omitted)
male	-.5450225*
family_lab~r	-.7151563**
acreslandf~g	-.12538328***
/cut1	-1.2748537

Legend: * p<.1; ** p<.05; *** p<.01

**APPENDIX G: Results of Double-Hurdle Regression model STATA Output- Second Hurdle
Results**

Source	SS	df	MS	Number of obs	=	385
Model	16.0344235	24	.668100978	F(24, 360)	=	7.56
Residual	31.820122	360	.088389228	Prob > F	=	0.0000
				R-squared	=	0.3351
				Adj R-squared	=	0.2907
Total	47.8545455	384	.124621212	Root MSE	=	.2973

CDI1	Coefficient	Std. err.	t	P> t	[95% conf. interval]
married	.2337117	.0656898	3.56	0.000	.1045278 .3628956
separated	.6941464	.3185924	2.18	0.030	.0676104 1.320682
widowed	.147978	.0806331	1.84	0.067	-.0105931 .3065491
owned_with_titled	-.3226469	.0741623	-4.35	0.000	-.4684926 -.1768012
owned_without_titled	-.2876963	.0695246	-4.14	0.000	-.4244218 -.1509709
Rented_Land	-.411264	.0783507	-5.25	0.000	-.5653467 -.2571814
primary	.0022128	.0800898	0.03	0.978	-.1552898 .1597153
Secondary	.0096158	.0555091	0.17	0.863	-.099547 .1187785
Tertiary	-.0253919	.0575363	-0.44	0.659	-.1385413 .0877575
farmer	-.0330485	.0914186	-0.36	0.718	-.2128302 .1467331
govtsector	-.0142222	.0996436	-0.14	0.887	-.2101789 .1817345
business	.1313241	.1299995	1.01	0.313	-.1243298 .386978
farm_income	.0232227	.3146616	0.07	0.941	-.5955831 .6420285
formal_inc	-.0176981	.318993	-0.06	0.956	-.6450218 .6096257
business_inc	.3493674	.3266055	1.07	0.285	-.292927 .9916617
casual_inc	.2376061	.3199916	0.74	0.458	-.3916815 .8668938
group_membership	-.040991	.0381925	-1.07	0.284	-.1160995 .0341174
credit_access	0 (omitted)				
access_remittances	-.0162663	.0392225	-0.41	0.679	-.0934003 .0608676
age18_35years	-.1002399	.0875806	-1.14	0.253	-.2724738 .0719939
age36_49	.1016838	.0601024	1.69	0.092	-.0165121 .2198797
age50_65	0 (omitted)				
above65years	.197251	.1001335	1.97	0.050	.0003309 .3941712
male	-.0376711	.0409222	-0.92	0.358	-.1181477 .0428056
family_labour	-.140621	.0509599	-2.76	0.006	-.2408375 -.0404045
Log_Consumption_Exp	-.0252505	.0175955	-1.44	0.152	-.0598534 .0093523
_cons	.5793142	.3613798	1.60	0.110	-.1313664 1.289995

. estimates table, star(.1 .05 .01)

Variable	Active
married	.23371171***
separated	.69414643**
widowed	.14797801*
owned_with_~	-.32264688***
o~out_titl~d	-.28769633***
Rented_Land	-.41126401***
primary	.00221277
Secondary	.00961575
Tertiary	-.02539193
farmer	-.03304855
govtsector	-.01422218
business	.1313241
farm_income	.02322273
formal_inc	-.01769808
business_inc	.34936735
casual_inc	.23760612
group_memb~p	-.040991
credit_acc~s	(omitted)
access_rem~s	-.01626634
age18_35ye~s	-.10023994
age36_49	.10168382*
age50_65	(omitted)
above65years	.19725105**
male	-.03767108
family_lab~r	-.14062098***
Log_Consum~p	-.02525052
_cons	.57931419

Legend: * p<.1; ** p<.05; *** p<.01

Appendix H: Results of Endogenous Switching Regression Model Stata Output for Objective Three

Endogenous switching regression model Number of obs = 385
Wald chi2(11) = 54.18
Log likelihood = -589.72688 Prob > chi2 = 0.0000

	Coefficient	Std. err.	z	P> z	[95% conf. interval]	
Log_Consumption_Exp0						
married	.2778784	.2010568	1.38	0.167	-.1161858	.6719426
single	-.3956231	.2486608	-1.59	0.112	-.8829894	.0917432
farmer	-.5684092	.2436418	-2.33	0.020	-1.045938	-.09088
govtsector	-.590652	.2589215	-2.28	0.023	-1.098129	-.0831751
casuallabour	-.4087626	.3706404	-1.10	0.270	-1.135204	.3176792
farm_income	-.1186036	.1930368	-0.61	0.539	-.4969487	.2597415
age18_35years	-.4419259	.3059755	-1.44	0.149	-1.041627	.157775
age36_49	.9026566	.1881517	4.80	0.000	.5338861	1.271427
above65years	1.246747	.3371875	3.70	0.000	.5858721	1.907623
male	-.1049836	.1333892	-0.79	0.431	-.3664217	.1564544
family_labour	-.0051643	.1706359	-0.03	0.976	-.3396045	.329276
_cons	11.44663	.3412138	33.55	0.000	10.77787	12.1154
Log_Consumption_Exp1						
married	.2227484	.5106777	0.44	0.663	-.7781614	1.223658
single	-.3685782	.6303257	-0.58	0.559	-1.603994	.8668374
farmer	-.0401474	.3861893	-0.10	0.917	-.7970646	.7167697
govtsector	.1719524	.365896	0.47	0.638	-.5451906	.8890954
farm_income	-.5456086	.4246218	-1.28	0.199	-1.377852	.2866348
age18_35years	-1.467813	.532963	-2.75	0.006	-2.512402	-.4232248
age36_49	2.041807	.5581115	3.66	0.000	.9479282	3.135685
above65years	3.081701	.7741812	3.98	0.000	1.564334	4.599069
male	.4975892	.2681256	1.86	0.063	-.0279274	1.023106
family_labour	.3508566	.277642	1.26	0.206	-.1933118	.895025
_cons	8.324593	.8280484	10.05	0.000	6.701648	9.947538
select						
married	.8862767	.4311425	2.06	0.040	.0412529	1.7313
single	-.4987631	.5293073	-0.94	0.346	-1.536186	.5386602
owned_with_titleddeed	.1653635	.2790734	0.59	0.553	-.3816103	.7123374
owned_without_titleddeed	.0756002	.2350324	0.32	0.748	-.3850549	.5362554
primary	-.1389227	.4457725	-0.31	0.755	-1.012621	.7347753
Secondary	.162742	.2804947	0.58	0.562	-.3870174	.7125014
Tertiary	.0075906	.2906976	0.03	0.979	-.5621662	.5773475
farmer	-.0337092	.3890302	-0.09	0.931	-.7961943	.7287759
govtsector	.128255	.4012732	0.32	0.749	-.658226	.914736
farm_income	-.9857125	.2712689	-3.63	0.000	-1.51739	-.4540353
age18_35years	-.7801953	.4556767	-1.71	0.087	-1.673305	.1129146
age36_49	.7562307	.3693588	2.05	0.041	.0323007	1.480161
above65years	1.323857	.5455054	2.43	0.015	.2546856	2.393027
male	-.435864	.2457515	-1.77	0.076	-.9175282	.0458001
family_labour	-.3978986	.2803781	-1.42	0.156	-.9474295	.1516324
acreslandfarming	-.1327548	.0275508	-4.82	0.000	-.1867534	-.0787563
_cons	-.3209504	.6356552	-0.50	0.614	-1.566812	.9249109
/lns0	-.026043	.044807	-0.58	0.561	-.1138631	.0617771
/lns1	-.1809142	.1888596	-0.96	0.338	-.5510722	.1892439
/r0	1.375911	.2803367	4.91	0.000	.8264616	1.925361
/r1	.7811919	.5267392	1.48	0.138	-.2511979	1.813582
sigma0	.9742932	.0436552		.0923001	1.063725	
sigma1	.834507	.1576047		.5763315	1.200336	
rho0	.8800324	.063228		.6785714	.9583568	
rho1	.6533903	.3018643		-.2460444	.9481946	

LR test of indep. eqns. : chi2(2) = 16.29 Prob > chi2 = 0.0003

. estimates table, star(.1 .05 .01)

Variable	Active
Log_Consumption_p0	
married	.2778784
single	-.39562308
farmer	-.56840916**
govtsector	-.59065201**
casuallabour	-.40876258
farm_income	-.11860358
age18_35years	-.44192592
age36_49	.90265663***
above65years	1.2467475***
male	-.10498364
family_labour	-.00516428
_cons	11.446633***
Log_Consumption_p1	
married	.22274839
single	-.36857819
farmer	-.04014745
govtsector	.17195238
farm_income	-.5456086
age18_35years	-1.4678132***
age36_49	2.0418067***
above65years	3.0817014***
male	.49758921*
family_labour	.35085659

Variable	Obs	Mean	Std. dev.	Min	Max
Log_Consum~11	56	11.10494	.5640669	8.815672	12.14827
Log_Consum~00	56	12.79546	.4447772	11.54176	13.79574
Log_Consum~10	329	10.13859	.7467499	7.718877	12.06375
Log_Consum~01	329	11.51176	.359692	10.22748	12.46329

Appendix I: Snapshot of publication Abstract Page

Exploring The Nexus Between Crop Diversification and Household Welfare, in Borabu Sub-County, Kenya

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Abstract

Following the effects of climate change, there has been a resurgence of interest in promoting crop diversification as a climate-smart agricultural practice in Sub-Saharan Africa to improve food security, increase income, and reduce vulnerability to external shocks. This practice is considered an effective risk management strategy and consumption smoothing strategy in a context characterized by repeated exposure to shocks. Agricultural production in Kenya is mainly dependent on rain-fed cultivation, with maize as the principal staple food crop. However, staple crops face major challenges and therefore, a diversification from over-reliance on staples will be important as part of progress toward achieving food security. The Kenyan government has, for a long time, been promoting crop diversification to improve household welfare and minimize risks associated with heavy dependence on maize. A decline in maize yields associated with the emergence of new pests and diseases, such as maize lethal necrosis disease (MLND) in Borabu sub-county, emphasized the need for maize farmers to diversify away from maize production. Although this strategy is in use, there is no clear evidence of the impact it has on the livelihoods of vulnerable households. Thus, the study sought to find out the nexus between crop diversification and household welfare among small-scale farming households in Borabu sub-county. Multi-stage sampling procedure was used to select a representative sample size of 385 small-scale farmers. Primary data was collected using observations and interviews with the help of a semi-structured questionnaire. The data were analyzed using the STATA computer program. This paper adopted the Endogenous Switching Regression Model to determine the nexus between crop diversification and household welfare, with household welfare being proxied by household financial savings. The findings indicate that smallholder maize farmers who practiced crop diversification experienced an enhanced ability to save than a random individual would have experienced.

Keywords: Crop diversification, household welfare, Maize Lethal Necrosis Disease, Endogenous Switching Regression Model.

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