GENDER FOOD INSECURITY PERCEPTIONS AND EFFECT OF SUSTAINABLE AGRICULTURAL INTENSIFICATION PRACTICES ON HOUSEHOLD VULNERABILITY TO POVERTY IN WESTERN AND EASTERN KENYA

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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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DEDICATION

This work is dedicated to my father, Vincent Lutomia Kweyu, my caring mother, Dorothy Ometo Lutomia, my brother Victor Mayabi, and my sisters, Sorophineh, Trizah, and Cornelia.

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ABSTRACT

While number of studies focusing on the effect of technology adoption on alleviating rural poverty is increasing, much remains unclear about effects of shocks and Sustainable Agricultural Intensification Practices (SAIPs) on household vulnerability to poverty. Furthermore, most literature focuses on household food security without adequately capturing determinants of gender perceptions of food insecurity. Therefore, the study estimated the effects of shocks and SAIPs on household vulnerability to poverty and analysed determinants of differences in gender food insecurity perceptions. Three waves of panel data collected by the Adoption Pathways (AP) project in 2011, 2013, and 2015 from 613 households in Bungoma and Siaya counties in western Kenya and Meru, Tharaka Nithi and Embu counties in eastern Kenya were used. The fixed effects (FE) and generalized random effects (RE) ordered probit models were used for inferential data analyses. Descriptive results showed that while 33% and 28% of female respondents indicated that their households were food secure and severely food insecure across panels, about 30% and 26% of male respondents perceived their household as food secure and severely food insecure respectively. Additionally, 61% of the households were vulnerable to poverty across the panels. The generalized RE ordered probit estimates showed that whereas education level of household head and participation in rural institutions were negatively and positively associated, respectively, with female perceptions of household food insecurity, they were insignificant with respect to male perceptions of household food security. The FE results show that household size, dependency ratio, sickness, drought, and large increase in food and input prices were positively associated with household vulnerability to poverty. In contrast, education stock, SAIPs, and off-farm income reduced vulnerability. These results provide evidence that shocks exacerbate household poverty, while SAIPs improves household resilience and reduced vulnerability to poverty. Therefore, policy interventions should aim to increase the adaptive capacity of smallholder farmers against shocks through adoption of multiple SAIPs. In addition, gender policy should focus on strengthening gender capacities in household and farm and off-farm activities in order to improve the contribution of men and women in safeguarding food security. Future research should focus on establishing the cause-effect relationships among SAIPs adoption and multi-dimensional food security and vulnerability to poverty.

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LIST OF ABBREVIATIONS AND ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
AP	Adoption Pathways
CIMMYT	International Maize and Wheat Improvement Centre
FAO	Food and Agriculture Organization
FE	Fixed Effects
HFIAS	Household Food Insecurity Access Scale
GDP	Gross Domestic Product
KALRO	Kenya Agricultural & Livestock Research Organization
OECD	Organisation for Economic Co-operation and Development
PCA	Principal Component Analysis
POLS	Pooled Ordinary least squares
RE	Random Effects
SIMLESA	Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa
SSA	Sub-Saharan Africa

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Agriculture is an important economic sector in Sub-Saharan Africa (SSA), accounting for an average of 15% of the region's total GDP (OECD/FAO, 2016). The critical role of agriculture in SSA economies is further underscored by its contribution to employment and food security. According to OECD/FAO (2016), nearly 65% of SSA's labour force is employed in agricultural sector. The wages earned from agricultural labour form a bulk of rural households' incomes. Furthermore, the importance of the sector in the region is underscored the comprehensive agricultural programs that have been implemented over the years. The programs are premised on recognition that increased agricultural production contributes to access and availability of food to both farming and non-farming households.

Smallholder farmers dominate agricultural production in SSA. OECD/FAO (2016) report estimates that 80% of farms in the region are smallholder, directly employing about 175 million people. It is against this background that smallholder agriculture is regarded as being crucial to economic development and food security. Food security is the ability of households to have access to sufficient, nutritious, and preferred food items throughout the year. On the other hand, poverty is widely defined as individual or household deficiency in terms of consumption, income and asset holding. (World Bank Institute, 2005). The definitions show that food security and poverty are intertwined phenomena, that is, they occur concurrently.

Despite the crucial role played by the agricultural sector, smallholder farmers in SSA are food insecure, poor, and marginalized. According to Atamanov *et al*. (2018), about 42.3% of people in SSA were poor in 2018 compared to about 41% in 2017. Bussolo *et al*. (2011) note that poverty in SSA is higher in rural areas, implying that the most food insecure and poor households are smallholder farmers. Poverty and food insecurity are widespread in the region based on a variety of world development indicators. For instance, according to Asenso-Okyere and Jemaneh (2012), majority of smallholder farmers in SSA live on less than two dollars per day. Additionally, farm income and agricultural wages do not adequately meet household food consumption needs.

Food insecurity is furthermore undermined by the subsistence nature of smallholder agriculture. Additionally, agricultural productivity is undermined by production uncertainties, including climate change-related stresses, as well as high input and low output prices.

Furthermore, smallholder farming households have low adaptive capacity to both idiosyncratic and covariate shocks, and their exposure to such shocks makes them more vulnerable to food insecurity and poverty. The occurrence of the shocks does not only cause or increase the severity of poverty and food insecurity, but increases non-poor household vulnerable to poverty.

Shocks are important events that explain vulnerability of most households to poverty. Idiosyncratic shocks are occurrences that cause serious hardship on individuals or households, while covariate shocks cause substantive negative effect on groups of households in a community, region, or country (Rahman *et al*., 2013). Examples of idiosyncratic shocks are health problems (sickness and death), loss of employment, and crop failure. Covariate shocks include drought, flooding, financial upheavals, and changes in food and input prices among others. The effect of such shocks may be instant or persist over time. For instance, climate change has increased drought frequency and unpredictable rainfall patterns. Climate vagaries adversely affects smallholder agriculture both in the short-term and long-run (Notenbaert *et al*., 2013), pushing rural households further into poverty and food insecurity. Agricultural production is also affected by low input consumption (Vanlauwe *et al*., 2014). This results in low agricultural productivity, causing a slowdown in household efforts in reducing food insecurity and poverty.

The importance of agriculture in Kenya is reflected in various agricultural programs and policies. Despite public and private efforts to strengthen the agricultural sector, poverty in Kenya remains high. Additionally, poverty in Kenya is disproportionately distributed. According to Njonjo (2013), the prevalence of poverty in rural and urban areas stood at 51% and 33%, respectively by 2009. The number of poor people in the country declined to about 36% between 2015 and 2016 down from about 46.8% in 2006 (World Bank, 2018a). The World Bank (2018a) notes that despite the decline, poverty in Kenya remains relatively high in comparison to its lower middle-income counterparts. The overarching concern is that over 60% of the poor people live in rural areas and are mostly dependent on agriculture as the primary source of their livelihoods (Radeny *et al*., 2012).

The slow progress towards revitalization of smallholder agriculture's role in alleviation of food insecurity and poverty is constrained by, among many other factors, climate change. Smallholder agriculture in Kenya is largely rain-fed and, therefore, adversely affected by extreme weather and climatic conditions such as prolonged drought and unpredictable rainfall patterns (Munyua & Wagara, 2015). The effect of such events on agricultural production devastates rural households that have low coping capacity as a result of economic and social disadvantages. Notably, household consumption and poverty are worsened as a result of household exposure to extreme climate conditions. Agricultural production in Kenya is further undermined by low use of agricultural technology such as improved seed, fertilizer and irrigation (AGRA, 2014).

In recognizing the need to enhance food security and reduce poverty in Kenya and East and Southern Africa at large, governments and international agricultural research institutions have partnered to spearhead technological innovation for pro-poor growth. One such collaboration was the SIMLESA project. The SIMLESA project was established in 2010 by CIMMYT with the aim of contributing to the alleviation of poverty and food insecurity by promoting uptake of Sustainable Agricultural Intensification Practices (SAIPs) by smallholder maize farmers (CIMMYT, 2016). The SAIPs are technologies and practices that improve agricultural productivity while minimizing degradation of environmental resources (FAO, 2011). The SAIPs include crop diversification, inorganic fertilizer and manure application, improved crop varieties, and soil and water conservation practices. These practices can generate productivity and environment gains (FAO, 2011), resulting in reduction of food insecurity and poverty in the region.

Understanding gender differences in food insecurity perceptions and the impact of covariate and idiosyncratic shocks on household risk of becoming poor should be the starting point for the implementation of food security and poverty reduction interventions. This is because gender inequality and shocks slow down the contribution of agriculture to reduction of food insecurity and poverty. Consequently, many studies have attempted to assess shocks and poverty nexus in Kenya and beyond and the potential role of Sustainable Agricultural Intensification Practices (SAIPs) in poverty reduction. Whereas these studies are important in providing an understanding of the role of SAIPs adoption in poverty reduction, majority of them provide ex-post impact assessment of SAIPs on poverty, which ignores poverty dynamics over time. Furthermore, few studies consider gendered perceptions of household food security, which play a crucial role in driving strategies that secure household livelihood strategies and welfare.

1.2 Statement of the Problem

The importance of agriculture in contributing to food security and rural livelihoods is well documented. Despite central role played by agriculture in rural livelihoods, most smallholder farmers in Kenya are poor. The adverse effects of shocks further exacerbate smallholder farming household vulnerability to poverty. Notwithstanding attempts to understand household poverty dynamics, most empirical studies are cross-sectional and focus on ex-post poverty analysis, thereby ignoring how poverty fluctuates and perpetuates itself over time. Also, limited attention is given to understanding gender perceptions of household food poverty and identification of households that are likely to suffer welfare losses as a result of natural, health-related, and economic shocks. The limited understanding of household vulnerability to poverty and gendered perceptions of household food insecurity makes the identification of appropriate responses to poverty and food insecurity reduction difficult. Hence, the study sought to provide an understanding of the effects of the SAIPs on household vulnerability to poverty. Additionally, the study established factors that explain differences in household food insecurity perceptions between men and women.

1.3 Objectives of the Study

1.3.1 General Objective

To contribute towards improved food security and poverty reduction through dissemination and adoption of sustainable agricultural intensification practices.

1.3.2 Specific Objectives

i. To establish factors that influence differences in gender perceptions of household food insecurity across time and space.

ii. To determine effects of shocks and sustainable agricultural intensification practices on household vulnerability to poverty across time and space.

1.4 Research Questions

i. Which are the factors that influence differences in gender perceptions of household food insecurity across time and space and how?

ii. How do shocks and adoption of sustainable agricultural intensification practices affect household vulnerability to poverty over time and space?

1.5 Justification of the Study

The interventions intended to help rural households to overcome food security problem need to recognize the differentiated gender roles. The objective of development interventions need to be cognisant of that men are constrained differently, which impacts on their perceptions of household food insecurity and the strategies they undertake to overcome the challenge. Therefore, profiling the demographic, economic, institutional, and social characteristics and factors that underline the differences in gender food security perceptions is important in the design of gender responsive interventions that are intended to improve food security. This can only be achieved by using gender-disaggregated data. Information generated from gender-disaggregated analysis of food security perceptions can be used to create and raise policy awareness on the relevant gender-based issues that need to be addressed to through promotion of livelihood strategies that empower men and women to overcome food poverty.

Furthermore, farming households are disproportionately affected by adverse effects of idiosyncratic and covariate shocks. Smallholder farmers are also low consumers of commercial inputs and the most affected by climate variability. Therefore, the goal of poverty reduction can be achieved by, among many other measures, targeting the vulnerable households who are mostly rural farming households. Alleviating the adverse effects of climate variability and increasing smallholder farmer access to low-cost inputs should be the focus of agricultural policy that aims at enhancing the contribution of the sector to poverty reduction. Improving the contribution of agriculture to poverty alleviation can be achieved through the adoption of SAIPs. SAIPs are less costly and have a positive impact on crop productivity. Also, SAIPs are likely to ameliorate the effects of extensive soil mining, leading to enhanced soil health. It is, therefore, important to understand smallholder farming household vulnerability to poverty and food insecurity and the factors that condition their vulnerability when formulating and implementing intervention measures. Hence, the study sought to generate additional knowledge to inform policy on the link between household vulnerability to idiosyncratic and covariate shocks and poverty.

1.6 Scope and Limitation of the Study

The study covered only five counties in Kenya, three in the eastern region (Embu, Meru and Tharaka Nithi) and two in the western region (Bungoma and Siaya). The study used data that were collected by the Adoption Pathway (AP) project and, as a result, it majorly focused on maize-legume production systems. Furthermore, the study only used three panels of data.

1.7 Definition of Terms

Consumption expenditure: Total household monetary expenses on food, durable and non-food items, and utilities.

Food security: The ability of households to have access to sufficient, nutritious, and preferred food items throughout the year.

Household: Persons living together and share a common provision of food or other basic needs.

Poverty: Household deficiency in terms of consumption, income and asset holding.

Shock: An event that causes or triggers a decline in household or individual wellbeing.

Smallholder Farmer: A farmer owning less than five acres of land on which subsistence crops and one or two commercial crops are produced, and the household members provide a larger fraction of farm labour.

Sustainable Agricultural Intensification: Increasing agricultural production from a unit area of land while reducing degradation of environmental resources.

Vulnerability to Poverty: The risk of households becoming poor in the future.

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CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The chapter reviews past and recent empirical literature. First, it reviews literature on the impact of household-specific and locational-level shocks on household vulnerability to poverty. Literature on gender perceptions of household food insecurity is also provided. The chapter also reviews past and recent studies that focused on the potential impact of SAIPs adoption on household vulnerability to poverty. Furthermore, it provides a theoretical model on which the study is based. The chapter concludes by conceptualizing the relationship between factors influencing household vulnerability to poverty and gender food security perceptions.

2.2 Shocks and Household Vulnerability to Poverty

Households in developing countries have low access to risk management options, and the existing options are weak and informal. Individuals and households are, therefore, partially or not fully protected from the effects of shocks. As a result, Heltberg and Lund (2009) mapped and quantified health-related, economic, agricultural and natural shocks with the view of establishing their impact on rural and urban households' welfare in Pakistan. They ran a logistic regression model and demonstrated that agricultural, economic and health-related shocks significantly impacted on households' food and non-food expenditure. The authors noted that these shocks perpetuated poverty and caused destitution to both rural and urban poor households.

Günther and Harttgen (2009) studied the implication of shocks on household consumption in Madagascar and found that households were disproportionately affected by shocks. The chances of rural households falling into poverty were higher than for those in urban areas. The effect of idiosyncratic shocks was more devastating to urban household compared to covariate shocks and explained more of household consumption volatility in cities and rural areas. However, the study made strong assumption in estimating consumption expenditure. The study made an assumption that the consumption error term captured the impact of covariate and idiosyncratic shocks. This assumption made it difficult to draw precise conclusion about the impact of the shocks on consumption.

Death is not only loss of human capital, but it is also an economically costly shock. Grimm (2010), informed by mixed empirical results on the effect of sickness and death on household welfare, investigated effects of the death of a household member on household consumption in Indonesia. The specific shocks considered included death of child, adult man, adult woman, and elderly person. Using fixed-effects (FE) specification of analysing three waves of panel data, the author found that death of household members, except death of adult women, had significant and positive effect on consumption. The death of adult man, child, and elderly person increased consumption by between three to five percentage points. The authors attributed an increase in consumption to a reduction in household size, implying few mouths to feed. On the other hand, the effect of covariate shock on household consumption was not statistically significant.

Similar to the study conducted by Günther and Harttgen (2009) and Grimm (2010), Porter (2012) estimated the impact of adverse events on consumption expenditure of Ethiopian rural households. The results from ordinary least square, FE, and Generalized Method of Moments showed that illness and death had a positive impact on consumption. On the other hand, extreme variations in rainfall severely depressed households' consumption, thereby making them vulnerable to poverty. However, the study did not directly address household vulnerability to ex-ante poverty which the current study is investigating.

The findings by Porter (2012) were further confirmed by Calvo and Dercon (2013) in their study of individual and aggregate poverty in Ethiopia. The latter estimated the impact of rainfall distribution, illness and market shocks on household consumption using random-effects (RE) specification. The results indicated that whereas other shocks did not have systematic negative effects on household consumption, serious illness significantly reduced household consumption. Furthermore, the study found that rainfall variability increased households' vulnerability to poverty despite households reporting increases in consumption in the same periods.

The preceding studies used RE and FE to estimate the association between vulnerability to poverty and shocks (Grimm, 2010; Calvo & Dercon, 2013). However, these models suffer from critical empirical shortcomings. The RE specification does not adequately deal with the fundamental differences among individual units and does not allow for observed and unobserved heterogeneity. The FE specification does not allow estimation of the effects of time-invariant factors (Hsiao, 2007). This study used time fixed effects model which allows varying intercepts across time (Wooldridge, 2010).

In a household-level vulnerability study conducted in Turkana, Kenya, Opiyo *et al*. (2014) found that climatic shocks had varied implication on the risk of household becoming poor. The authors observed that household exposure to drought events had devastating impacts on household livelihood which escalated food insecurity and risk of poverty. In another study, Povel (2015) predicted the association between adverse events and household vulnerability to poverty in Vietnam and Thailand using tobit regression. The study results indicated that drought, floods, and crop pests as well as livestock diseases increased household vulnerability to poverty in the two countries. Agricultural shocks in the previous year resulted in income shortfalls which increased households' vulnerability to poverty in the subsequent year. However, while sickness and raise in input prices had an insignificant impact on vulnerability to poverty in Thailand, Vietnamese households relatively suffered income losses as a result of the two shocks.

Using primary panel data drawn from three waves of surveys in Vidarbha, India, Gaurav (2015) found evidence that household exposure to idiosyncratic and covariate shocks increases vulnerability to poverty. The study found a negative relationship between covariate shocks and household consumption, suggesting greater vulnerability to food poverty. Whereas household income losses increased vulnerability to poverty, health-related shocks were positively and significantly related to household consumption. However, the data used to measure health shocks were limited to the extent that they did not capture the incidence of illness and its implication on income. Therefore, the impact of the health-related shocks could have probably been underestimated. The current study considered the incidence and income losses associated with household illness in analysing the effect of illness on household vulnerability to poverty.

Khan *et al*. (2015) reported that sickness and death caused severe economic consequences which had ripple effects on Bangladesh households' future consumption. Serious illness and death caused substantial reduction of income which had a detrimental impact on household future consumption. The shocks contributed to increased risk of poverty traps for the poorest urban population. These results were further supported by the findings of Knight *et al*. (2015) in South Africa. Knight *et al*. (2015) found that health-related shocks experienced in previous year significantly increased household vulnerability to future poverty. However, relative to the impact of health-related risks, self-reported price increases and job loss had moderate to severe impacts on likelihood of poverty at household level.

Despite contribution of above-reviewed studies to the growing literature on vulnerability to poverty in the global south, they are not devoid of methodological shortcomings. Studies by Günther and Harttgen (2009), Heltberg and Lund (2009), Porter (2012), Povel (2015) and Knight *et al*. (2015) used cross-section data that do not have a time dimension. This limited precise observation of inter-temporal changes in consumptions caused by the shocks. Hence, the current study used three waves of panel data so as to give a dynamic perspective of the impact of the shocks on household vulnerability to poverty. Panel data are critical in measuring and estimating vulnerability to poverty because it captures the dynamic changes in the effects of different types of shocks on consumption expenditure.

2.3 Gender and Food Security

Understanding men and women perceptions of household food insecurity is one of the starting points for policy interventions designed to address food poverty. Consequently, Demeke *et al*. (2011) used three rounds of panel data to measure the effects of farmer perception of rainfall variability on household food security status in Ethiopia. Employing RE, instrumental variable (IV) and multinomial logistic model specification, the authors found households' and gender perception of rainfall variability to be negative and significantly associated with vulnerability to food poverty. Furthermore, the study found a negative and significant association between household size and food insecurity. Livestock endowment and food security had a positive and significant relationship. However, the study used absolute numbers of individuals in a household which overlooks the effect of household composition on food security status. In this current study, adult equivalent household size is the proxy for household composition because it produces efficient estimates of the impact of household composition on food insecurity and vulnerability.

Hadley *et al*. (2011) used two rounds of panel data to explore how food price spikes affected household food security in Ethiopia. Predictive effects of explanatory variables were estimated using multiple linear regression model. The study found that the current food insecurity status among urban households significantly predicted household food security. Food price spikes were positively associated with household food insecurity. Food poverty was more severe among female-headed rural and urban households. Additionally, the study found that social capital reduced food insecurity. Kumar and Quisumbing (2013) analysed the association between food price spikes in Ethiopia and found that households headed by women were more prone to price-induced food insecurity. However, studies by Hadley *et al*. (2011) and Kumar and Quisumbing (2013) did not look at the gender-specific effects beyond household headship. This study used gender-disaggregated data that do not confound gender. Gender-disaggregated data provide complete understanding of the food insecurity situation within households regardless of headship status.

Kassie *et al*. (2014) used ordered probit exogenous switching regression to estimate the relationship between food insecurity and household headship in Kenya. The study found that female-headed households were more likely to be food deprived than male-headed households. The number of female-headed households suffering from food insecurity was twice the number of male-headed households. Approximately fifty-eight percent of male-headed households fell into break-even and food secure categories as compared to forty-tree percent of female-headed households. They attributed the disparities in food security status to gender-specific factors that disadvantaged women. Despite the contribution of the study to the understanding of gender differences in food security perceptions, it is cross-sectional, meaning it does not disentangle dynamism of individual perceptions of food security. Thus, the current study filled this gap by using panel data that allow observation of changes in household food insecurity over time.

Tibesigwa *et al*. (2015) assessed determinants of food security in South Africa and revealed that male-headed households were more food secure than female-headed households. However, Tibesigwa *et al*. (2015) did not assess the ex-ante possibilities that current food security status can have an effect on household food security probabilities in the future. This implies that the studies did not identify non-poor households that were at risk of becoming poor. At the same time, the studies could not identify the vulnerability of the already poor households. The current study overcame this shortcoming by providing an ex-ante assessment of household food insecurity in a panel data setup.

In summary, the aforementioned studies indicated that apart from household headship, both demographic and exogenous factors have either negative or positive effect on food insecurity. Household participation in savings groups, the level of household income, social capital and networks, and farm size are negatively associated with food insecurity (Demeke *et al*., 2011; Hadley *et al*., 2011). On the other hand, agricultural-related and economic shocks are positively related to household vulnerability to food insecurity (Kumar & Quisumbing, 2013; Tibesigwa *et al*., 2015). This study built on the evidence provided by these past studies to examine the association between gender-specific, household, and exogenous factors and household food insecurity.

2.4 SAIPs Adoption and Vulnerability to Poverty

SAIPs are cited as important in increasing the resilience of smallholder production systems to the adverse effects of climate change. Thorlakson and Neufeldt (2012) studied the effect of agroforestry as a mitigation strategy for vulnerability to climate change in Western

Kenya. The study found that farmers who adopted agroforestry were able to cope with shocks and stresses related to climate change. Adoption of agroforestry increased households' food secure months by two to three months as compared to the non-adopting households. Agroforestry had a positive causal effect on agricultural productivity, which improved food availability, household wealth, and income diversity. However, the study relied on a sample size of 119 farmers which is relatively inadequate to reveal variations across households. The current study used a large sample size of panel data to capture variability in the effects of technology adoption on vulnerability to poverty.

In an ex-post study, Kassie *et al*. (2011) evaluated the poverty impact of improved groundnut technology in Uganda and found that its adoption significantly translated into reduced severity of poverty. The results by Kassie *et al.* (2011) confirmed earlier findings by Becerril and Abdulai (2010) who evaluated poverty-reducing effect of hybrid maize. They found that hybrid maize led to poverty reduction by thirty-eight percent. The studies concluded that adoption of improved crop varieties is a crucial pathway out of poverty for smallholder farmers. However, the two studies in Uganda and Mexico used PSM which, despite dealing with selection problem, makes a strong uncofoundedness assumption. Although not testable, PSM does not adjust for the differences in a set of covariates when comparing the treatment effects. The current study differed from these two previous studies by using time fixed effects to estimate the association between SAIPs and vulnerability to poverty.

Asfaw *et al*. (2012) and Amare *et al*. (2012) analysed effect of maize-pigeon pea intensification on household welfare in Tanzania and Ethiopia. The findings revealed that adoption of maize-pigeon pea intercrop tended to have a positive and significant effect on poverty reduction. Overall, adopters' had higher consumption per capita than non-adopters. These results were further reemphasized by Khonje *et al*. (2015) who found that adoption hybrid maize seed increased production and productivity, and reduced rural poverty in Zambia. However, these studies used cross-sectional data which failed to capture the distributional impact of technology adoption. The current study used three waves of panel data to overcome this problem. Furthermore, the previous studies in Ethiopia and Tanzania did not capture the poverty-vulnerability linkage and the poverty reducing potential of SAIPs, which this study attempted to establish.

Adgo *et al*. (2013), using a sample size of 60 farm households, investigated the potential long-term contribution of Soil and Water Conservation (SWC) practices to crop production and productivity, profitability as well as socioeconomic well-being of rural households in Anjene watershed region in Ethiopia. The authors found that SWC practices had an enormous potential of contributing to the improvement of rural livelihoods. Adoption of terraces and grass strips contributed to increased maize productivity, which, in turn, led to improved farm income and poverty reduction. However, the study relied on small sample size, which fails to distil the variations in variables and between households. This made it problematic to disentangle the different relationships that are critical in measuring the potential of SWC practices on poverty eradication. The current study attempted to overcome this weakness by using a considerably larger sample size.

To address the shortcomings of using cross-sectional data in measuring welfare impacts of technology adoption, Bezu *et al*. (2014) and Mathenge *et al*. (2014) analysed the impact of SAIPs on poverty in Malawi and Kenya, respectively. The results of these two studies showed that adoption of hybrid maize varieties had the potential of improving per capita household income, which would translate into poverty reduction. Relative to non-adopting households, adopters' income increased significantly which had positive effects on poverty reduction. However, these studies concentrated on the welfare impact of isolated technologies without considering the possibility that farmers may adopt multiple technologies over time. Consequently, this current study investigated the potential impact of multiple SAIPs on household vulnerability to poverty.

Zereyesus *et al*. (2017) sought to establish the implication of off-farm income on household vulnerability to food insecurity. The study found that off-farm income lowered the likelihood of future poverty. The study concluded by confirming that there exists a positive association between current food insecurity and vulnerability to future food insecurity. However, the study did not disaggregate the effects of different types of off-farm activities on the household vulnerability to food poverty.

2.5 Theoretical Framework

A rural farming household is a basic unit of production and consumption. Household exposure to idiosyncratic and covariate shocks makes it vulnerable to food insecurity and poverty. Therefore, it is assumed that a household puts in place ex-ante strategies in order to reduce its probability of being food insecure or poor in the future. Since vulnerability can be defined as expected poverty, a household tends to make ex-ante decisions that improve its future welfare. In this context, a household seeks to smooth its future consumption as a result of its exposure to shocks. Ex-ante strategies that are pursued are expected to place the household at and/or above a certain level of consumption that does not make it vulnerable to poverty and food insecurity. Therefore, a household's decision to adopt SAIPs as one of the ex-ante strategies for mitigating food insecurity and consumption effects of shocks can be explained based on random utility theory (Barbera *et al*., 1998; Caviglia-Harris, 2003).

A household chooses to invest in SAIPs if the practices allow it to maximize expected utility from consumption. It implies that a farmer allocates resources to SAIPs that contribute to the maximization of consumption (Caviglia-Harris, 2003). A household would adopt SAIPs if the difference between the utility derived from adopting the SAIPs exceeds expected utility of not adopting. This can be expressed as:

$$AD_{it} = U_{it}(CA) - EU_{it}(C_{it}) > 0 \quad (2.1)$$

where AD_{it} denotes adoption of a bundle of SAIPS , U_{it} donates utility, CA is consumption with adoption of SAIPs and $EU_{it}(C_{it})$ is the expected utility of consumption (C_{it}) without adoption for household i in time t. A household would not be considered vulnerable when consumption with adoption of SAIPs (CA) is greater than expected utility without adoption (C_{it}) and, therefore, the decision to invest in SAIPs.

2.6 Conceptual Framework

Idiosyncratic and covariate shocks represent risks to poor rural farming households (Günther & Harttgen, 2009). Vulnerability to these shocks contributes to household's failure to secure its future wellbeing. The decision to adopt a set of SAIPs is assumed to be aimed at reducing household's vulnerability to food insecurity and poverty. Adoption of SAIPs directly and indirectly influences per capita consumption of the households (Günther & Harttgen, 2009). The intensity of SAIPs adoption can be hypothesized to depend on the degree of exposure and vulnerability of the household to shocks. The adoption of SAIPs in response to shocks can be termed as both an adaptation and mitigation strategy. However, the level of sensitivity to shocks is determined by demographic characteristics of the household. Since adoption of SAIPs is ex-ante in nature, it is expected to have a positive influence on the household's level of future consumption.

Vulnerability in the context of this study is the probability that a household will fall into poverty in the future (Hoddinott & Quisumbing, 2003). Thus, household vulnerability to poverty (V_{ht}) at time t is the probability that its level of per capita consumption (C_{ht+1}) will fall below the consumption poverty threshold, Z, thus:

$$V_{ht} = \Pr(C_{ht+1} < Z) \quad (2.2)$$

Following Hoddinott & Quisumbing (2003) the outcome of interest (C_h), which is the expected per capita consumption for household h, can be postulated to be influenced by, among many other factors, covariate and idiosyncratic shocks, adoption of a bundle of SAIPs and household demographic characteristics as:

$$\Delta C_{htv} = \alpha + \lambda_i S(i)_{tv} + \beta_i S(i)_{htv} + \gamma AD_{ht} + \delta X_{htv} + \varepsilon_{htv} \quad (2.3)$$

where ΔC_{htv} is the change in total consumption per capita of household h, in time t and location v, $S(i)_{tv}$ and $S(i)_{htv}$ are covariate and idiosyncratic shocks respectively, AD_{ht} is an indicator for SAIPs adoption as defined in (2.1), X_{htv} is a vector of household demographic characteristics, $\lambda, \beta, \gamma,$ and δ are vector parameters to be estimated and ε_{htv} is the error term.

SAIPs are conceptualized to have vulnerability reducing effects. It is assumed that a household attempts to cushion itself from the effect of shocks by adopting SAIPs. The adoption of a set of SAIPs by households helps reduce vulnerability to poverty directly through increased production and productivity. Increased production directly raises income and consumption expenditure. Secondly, SAIPs adoption represents technological change that can have an indirect poverty-reducing effect, which rewards both poor and non-poor farmers. Increased farm income as a result of increased yields translates into increased purchases of food and non-food commodities. Figure 1 presents a conceptual framework illustrating causal explanation of how adoption of SAIPs impacts on household vulnerability to poverty, that is, SAIPs impact pathways on household welfare.

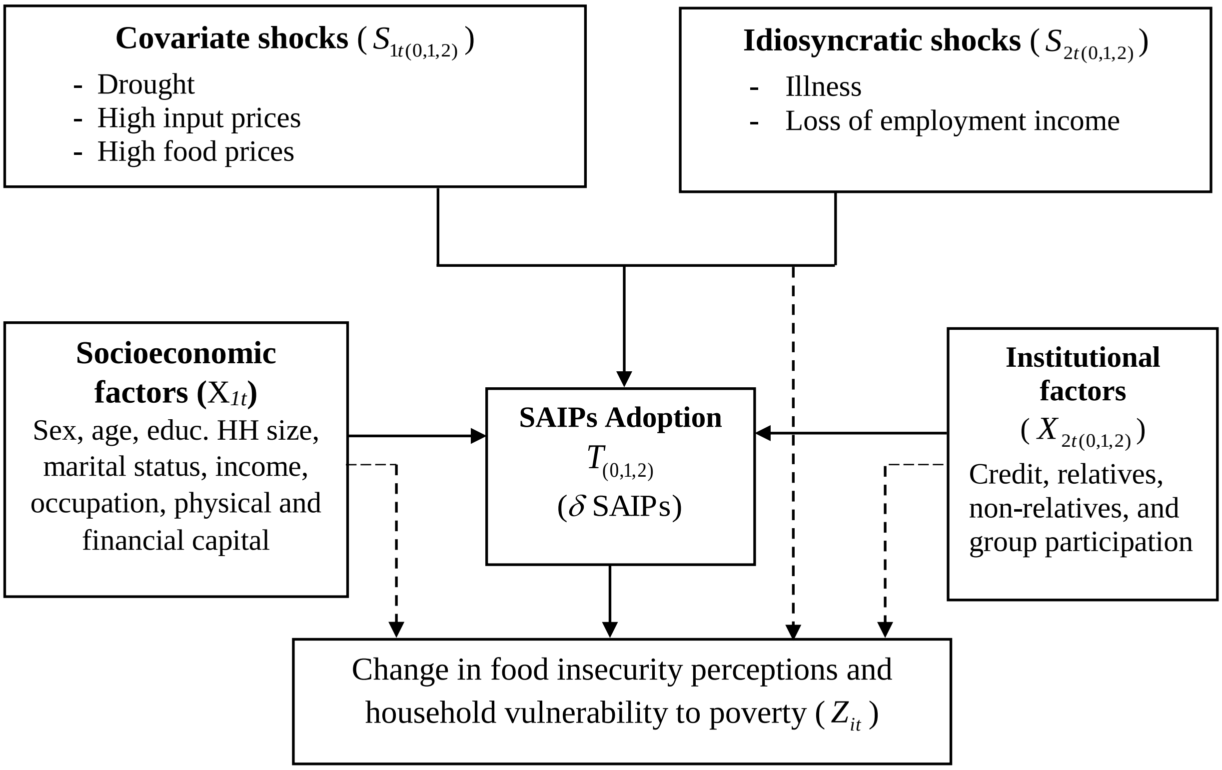

Figure 1: Conceptual framework

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CHAPTER THREE

DETERMINANTS OF DIFFERENCES IN GENDER PERCEPTIONS OF HOUSEHOLD FOOD INSECURITY

Abstract

Although food security literature abounds, there is little focus on understanding determinants of gender perceptions of food insecurity. This study identified determinants of gender differences in household food insecurity perceptions. The study used two waves of gender disaggregated panel data collected from 535 households in western and eastern regions of Kenya in 2013 and 2015. Descriptive results showed that while more male (25%) than female (22%) respondents perceived their households as food secure in 2013, more female (46%) than male (41%) reported that their households were food secure in 2015. According to female respondents, 30%, 37%, and 12% of the households were severely, moderately, and mildly food insecure in 2013. Additionally, in 2015, about 12%, 16%, and 27% of female respondents perceived their households as mildly, moderately, and severely food insecure respectively. In contrast, 16%, 33%, 22% of male respondents reported that households were mildly, moderately, and severely food insecure in 2013 respectively. According to male respondents, household that were mildly, moderately, and severely food insecure in 2015 were 14%, 20%, and 24% respectively. Results from generalized RE ordered probit model indicated that gender, age, and education of household head, dependency ratio, participation in rural institutions, access to credit, and off-farm income explained the gender differences in household food insecurity perceptions. The results suggest that intra-household dynamics may constrain household food insecurity alleviation efforts or impact gender contribution towards addressing the problem. Policy interventions should strengthen diverse gender roles in rural livelihood in order to contribute to improved food security.

3.1 Introduction

Food insecurity remains one of the most significant social and economic challenges in Sub-Saharan Africa (SSA) in the twenty-first century. The number of undernourished people, and prevalence of food insecurity increased between 2015 and 2016 despite the region having achieved significant progress in the alleviation of food insecurity since 2000 (FAO, 2017). About 22.7% of the people in SSA were undernourished between 2015 and 2016 up from about 21% in 2014 (FAO, 2017). Furthermore, the FAO food security report indicates that there was an increase in proportion of severely food insecure people in the region. The rise in food insecurity and undernourishment is attributed to adverse climate conditions which severely affected agricultural production. In addition, FAO attributes food security problems to conflicts and difficult global environment.

The FAO report echoes importance of improvements in the agricultural sector in accelerating the momentum of sustained poverty and food insecurity reduction in SSA. Nevertheless, this would remain elusive if persistent gender inequality in the region is not addressed. According to the World Bank (2014) and Diiro *et al*. (2018), women constitute a significant proportion of SSA's farmers and contribute most of the agricultural labour. However, the slow progress towards gender equality in the region implies that women face challenges in access to land, productive assets, credit, extension services, and input and output markets, which constrain agricultural productivity (World Bank, 2014; Mukasa & Salami, 2016; Debela, 2017). In addition, women are adversely affected and vulnerable to conflicts and poverty. These challenges prevent women from exploiting the existing and emerging agricultural and non-agricultural opportunities. These affect households and communities by exacerbating poverty, food insecurity, vulnerability and gender inequality.

In Kenya, women form the largest share of farmers and their engagement in agriculture plays vital role in rural economies, food security and nutrition (Owoo *et al*., 2015; USAID, 2017; Diiro *et al*., 2018). However, gender inequality, culture and less access to employment, land, and education undermine the contribution of women to agricultural and non-agricultural activities. For instance, less than 5% of land in Kenya is owned by women farmers, which is attributed to cultural factors that favour men in terms of land inheritance (Young, 2012). Further, Githinji *et al*. (2014) observe that women in Kenya have fewer land tenure rights and own small plots, forcing them to engage in less valuable farm enterprises. These occur despite empirical evidence suggesting that women empowerment in agricultural decision-making and land ownership yields significant improvements in agricultural productivity (Diiro *et al*., 2018). The social and economic factor that undermines women's participation in agriculture results in poverty, which, according to Yushi *et al*. (2013), is the root cause of food insecurity. These result in gender disparities in food security between female-headed and male-headed households.

Furthermore, Kenya has witnessed unprecedented social changes which are continuously restructuring and shaping gender roles. This indicates that further women empowerment and reduction in gender inequality would enhance the role of women in ensuring food security. Concurrent with the social changes is the shift in gender roles in ownership of productive resources and involvement in decision-making. In particular, agricultural decision-making is increasingly becoming a joint affair between men and women. Notably, the number of female-headed households are on the rise. This has been caused by the increasing focus of international development policy on role of female gender in sustainable social and economic development (Hanjra *et al*., 2013). The continued implementation of policies targeted at improving gender equality is making significant progress in reducing gender disparities in livelihood outcomes.

Gender mainstreaming into agriculture and other economic activities has attracted the focus of empirical research. For instance, Sharaunga *et al*. (2016) focused on the relationship between gender and food (in)security in Kenya and South Africa, respectively. Other studies have also focused on gender mainstreaming in land ownership and agricultural productivity (Owoo *et al*., 2015), collective action and agriculture (Fischer & Qaim, 2012), poverty (Milazzo & Van de Walle, 2015), agricultural production (Diiro *et al*., 2018), and asset ownership (Doss *et al*., 2014). Although these studies provide an understanding of gender disparities in terms of multiple outcomes, the results may be misconstrued to mean that female-headed households are worse-off or subordinated. In addition, the studies use household headship in distinguishing the gender-specific and welfare outcomes. However, headship is an inadequate indicator of gender-differentiated impacts and outcomes for it reduces gender to male or female sexes. Lastly, these studies relied on cross-sectional data which provides a snapshot of the outcomes of interest instead of dynamic outcomes.

Therefore, this chapter addresses the abovementioned shortcomings in recent literature. First, gender perceptions of household food security are captured by self-reported responses measured on Household Food Insecurity Access Scale (HFIAS). The study disentangles determinants of gender perceptions of household security. Second, this study enriches the existing literature on gender disparities in livelihood outcomes using gender-disaggregated data which allows for analysis of intra-household dynamics as reflected in relative positions of women and men within rural households. Lastly, this study uses two waves of panel data to understand how women and male perceptions of household food security changes over time.

Several past and recent studies have examined household food security. For instance, Sraboni *et al*. (2014) examined empowerment-food security nexus in Bangladesh and found that women empowerment in agriculture improved household food and nutritional security. In a related study, Diiro *et al*. (2018) reported that women empowerment in agriculture resulted in increased maize productivity in western Kenya. In another study in western

Kenya, Owoo and Boakye-Yiadom (2015) reported that female farmers with land title deeds produced significantly higher maize output than farmers without title deeds. Sraboni *et al*. (2014), Diiro *et al*. (2018), and Owoo and Boakye-Yiadom (2015) noted that women empowerment in agricultural production and income expenditure decisions, and ownership and utilization of resources increased agricultural productivity which translated into improved food and nutritional security.

Mason *et al*. (2015) used household gender-disaggregated household data variables to analyse gendered food security statuses. There were markedly significant gendered differences in food security and livelihoods. The number of poor and vulnerable households headed by women was higher that the number of poor and vulnerable households headed by men. The study identified female ownership of livestock as an important pathway for reducing gender disparities in food consumption. The findings by Mason *et al*. were reiterated by Kassie *et al*. (2015) who indicated that Malawian households headed by women were disproportionately more food insecure than households headed by men, which they attributed to differences in ownership of productive assets. However, Kassie *et al*. (2015) observed that food security gap which was higher among female-headed households would be reduces if females were equally endowed with productive resources as men.

Tibesigwa and Vesser (2016) analysed gender food security disparities among rural and urban South African households and established that rural households headed by women were more likely to be food insecure compared to their urban counterparts. They attributed this finding to high dependency on agriculture. In a related study, Etana and Tolossa (2017) explored the unemployment-food insecurity nexus in Ethiopia and found that unemployment of household head exacerbated food insecurity among urban households. Households headed by unemployed persons were relatively more food insecure. The authors noted that the quality of the job was also a determinant of the likelihood of food insecurity. The findings by Tibesigwa and Vesser (2016) and Etana and Tolossa (2017) appear to suggest that employment or employment type are important determinants of gender disparities in food security.

Gendered differences in household food insecurity have also been viewed in climate change lenses with studies indicating that households headed by females are more vulnerable to climate change compared to male-headed households. This is revealed by Chandra *et al*. (2017) in a study conducted in the Philippines. Chandra *et al*. (2017) established that men and women were affected differently by climate change. Exposure to climate change disproportionately disadvantaged women as a result of its effect on agricultural yields. Reduced agricultural yields increased food insecurity which was more disastrous to female-headed households. Similar results were reported by Agidew and Singh (2018) in a study conducted in Ethiopia. However, in contrast to other studies herein, Agidew and Singh (2018) found that household headship and land redistribution had no significant effect on food security.

Besides gender inequality in resource ownership and vulnerability to climate change, other studies have identified demographic and economic characteristics as important determinants of food security. Kakota *et al*. (2015) showed income and household size as significant determinants of Malawian households' vulnerability to food poverty. In addition, access to climate information reduced household vulnerability to food insecurity. In another study, Omotayo *et al*. (2018) identified education status, age, marital status and poverty as factors that underlined food security in western Nigeria. Tiwasing *et al*. (2018) found that education reduced vulnerability to poverty among Pakistanis households. An important observation made by Tiwasing *et al*. (2018) is that sale of food crops worsened household food insecurity. Furthermore, Tiwasing *et al*. (2018) results indicated that agricultural technology, farm size, and livestock ownership improved the probability of household food security. However, dependency ratio and household size reduced the likelihood of food security.

In conclusion, there exist gender disparities in food security. However, with exception of Mason *et al*. (2015), the selected studies used household headship variables which give an incomplete picture of the intra-household roles of women and men. The household headships variable does not allow measurement of the social and economic realities that reflect the lives of men and women. Second, the studies classified households as food secure and food insecure. Such classification does not adequately capture the severity of food poverty, thereby limiting the identification of severe cases of food insecurity. Furthermore, the studies relied on cross-sectional data which fails to capture the dynamic nature of food security. Hence, this study used panel gender-disaggregated data in identifying determinants of gender perceptions of household food (in)security. Panel gender-disaggregated data allow measurement of the dynamic nature of food security and accounts for intra-household social and economic realities. This study used the HFIAS which disentangles the severity of food insecurity.

3.2 Methodology

3.2.1 Study Area

This study used data from the Adoption Pathways (AP) project that was conducted in five counties in Kenya; three counties in eastern region (Embu, Meru, and Tharaka Nithi) and two counties in western region (Bungoma and Siaya). The choice of the regions was based on the agro-ecological conditions, as well as the relatively diverse maize-legume production systems. However, the five counties are characterized by adverse climate change related-shocks that threaten maize-legume productions systems. The exact locations of the five counties are as shown in Figure 2.

Bungoma is one of the four counties in the former Western Province. Bungoma is located on the southern slopes of Mt. Elgon and covers an area of 3,032 km^2. It is one of the Kenyan counties bordering Uganda to the west. According to the last official population and housing census of 2009, Bungoma had 1, 375,000 million people. The average population density is about 454/km^2. The county's headcount poverty index stands at 47%. Agriculture is the main economic activity and source of livelihood for the county's population. In addition, agriculture supplies raw materials to the county's agro-processors. The county receives an annual rainfall of over 1800 mm per annum and its temperatures ranges between 15°C and 32°C (County Government of Bungoma, 2017). Bungoma has about 711,662 acres of arable land of which 504,137 acres are under food crops and about 200,000 acres under cash crops.

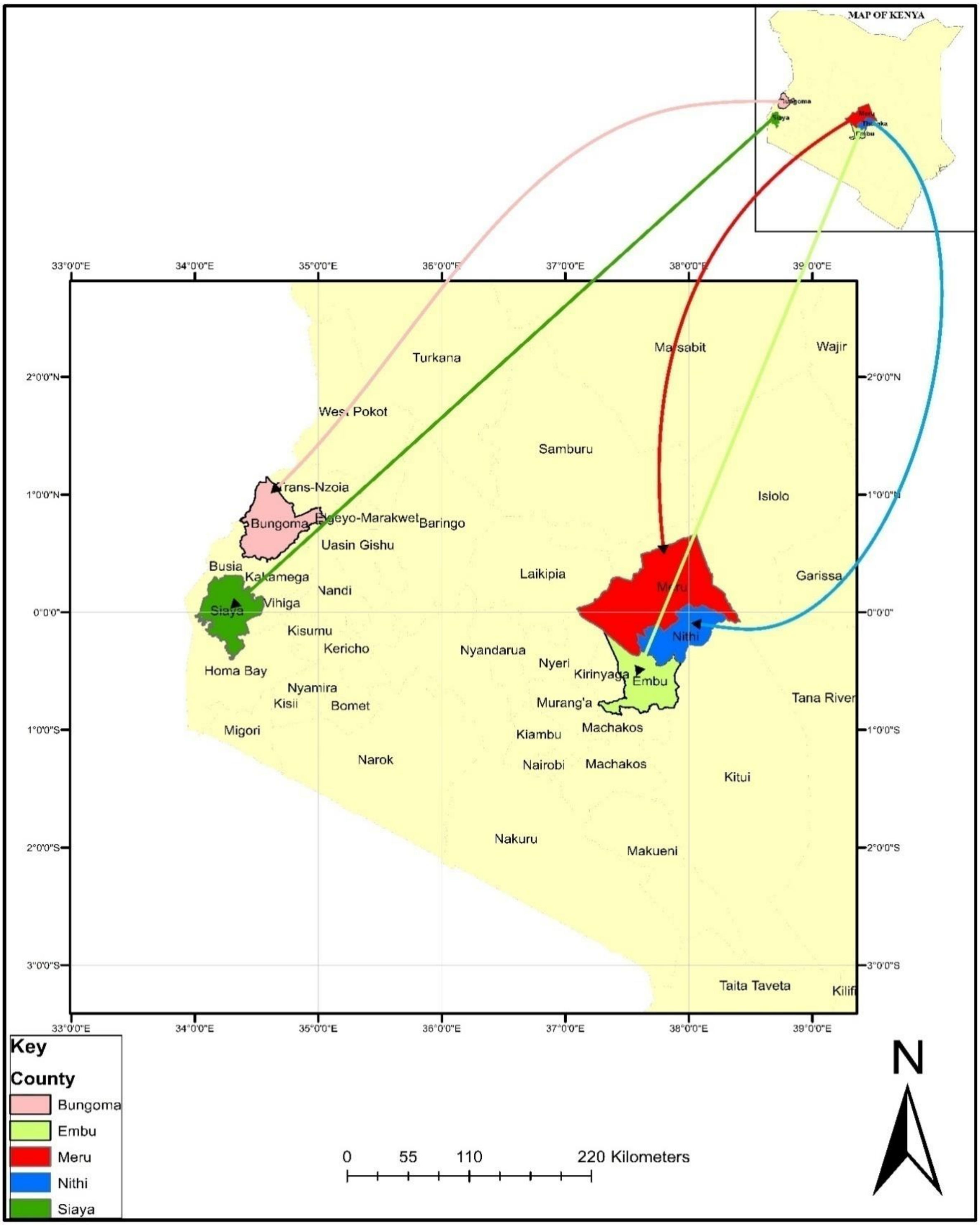

Figure 2: Map of the study areas

Source: Virtual Kenya and Google Earth Pro. (2017)

Siaya County borders Busia and Kisumu to the north and east, respectively. It also borders Vihiga and Kakamega to the north-east and Lake Victoria to the west. The national population and housing census of 2009 put Siaya's population at 842,304 people with an average population density of 332/km^2. Nearly 38% of Siaya's population is poor. Agriculture is the dominant economic activity and is largely subsistence. The major food crops produced in the county include maize, sorghum, millet, cassava, sweet potato, and groundnut. Sugarcane and rice are the major cash crops. Lake Victoria is an important fishing resource that also supports thousands of households in the county. Siaya receives an annual precipitation ranging between 1,140 mm and 1,400 mm with temperatures varying between 15°C and 30°C (County Government of Siaya, 2017).

Tharaka Nithi covers an area of about 2,662 km^2 (Tharaka Nithi County Government, 2017). It borders Meru County to the north, Kirinyaga and Nyeri counties to the west, and Kitui County to the southwest. It also borders Embu County to the southeast. According to the last official national population and housing census of 2009, Tharaka Nithi had 356,000 people consisting 88,000 households, with a population density of about 138/km^2. The headcount poverty index in the county is 41%. Agriculture is the primary economic activity, with both subsistence and commercial crop and dairy subsectors being the most dominant (Tharaka Nithi County Government, 2017). The main food crops include maize, beans, green grams, vegetables, pigeon pea, potatoes, millet, and sorghum. Cash crops include tea, coffee, and potato. The county receives an annual rainfall ranging between 200 mm and 800 mm with temperatures of between 14°C and 30°C (Tharaka Nithi County Government, 2017).

Embu County borders Tharaka Nithi County to the North and, Kirinyaga, Machakos and Kitui to the South, West and East, respectively. It is 2,818 km^2 in size, with a population of about 516,212 people of which 35% live below the poverty line (Embu County Government, 2017). The average population density is about 183/km^2. The annual amount of rainfall varies from 640 mm to 1495 mm with minimum and maximum temperatures of 12°C and 30°C, respectively. The county is dominantly agricultural with the main food crops being maize, beans, banana, potato, sorghum, and cowpea. Industrial crops produced in the county include tea and coffee. The common types of livestock in the Embu County include cattle, goats, sheep, and poultry.

Meru is one of the most densely populated counties in the eastern region. According to the last official national population and housing census of 2009, Meru County had 1,356,000 people. The county had 320,616 households with an average population density of 200/km^2. About 31% of the county's population is poor. The county borders Laikipia, Nyeri, Tharaka Nithi, Garissa, and Isiolo to the west, southwest, south, northeast, and north respectively (County Government of Meru, 2017). The annual amount of rainfall ranges between 500mm and 2600mm with minimum and maximum temperatures of 16°C and 23°C respectively. Agriculture is the mainstay economic activity in the county. The major crop grown in the county include maize, beans, bananas, tea, and coffee.

3.2.2 Research Design

The study applied quantitative research design to statistically answer the research questions. The quantitative research design was appropriate because the study determined statistical relationships between sociodemographic, economic, and institutional factor and household food security and vulnerability to poverty. Using project data, the study generalized food security and poverty concepts and investigated the causal relationships in a panel data design. The quantitative research design was appropriate because the study was an exploration of vulnerability phenomenon, which is largely understudied in adoption literature.

3.2.3 Sampling Design

The AP project used multi-stage sampling technique. The counties were purposively selected based on the agro-ecological zone and their maize-legume production potential. Sub-counties, locations, sub-locations, and villages were then randomly selected. In the third stage, households were randomly selected from the chosen villages. The target population were smallholder grain-legume farmers in eastern and western Kenya. The study used AP project's gender disaggregated panel dataset that were collected during the second and third waves of the AP project in 2013 and 2014 respectively. A total of 535 and 495 households were surveyed in 2013 and 2015 respectively. The panels are geographically diverse and representative of the rural maize-legume farming systems.

3.2.4 Data Collection

The data were collected by CIMMYT and local partners in Kenya, which included Egerton University, KALRO, and Ministry of Agriculture. The 2011 baseline data was conducted in collaboration with KARI, currently KALRO and Ministry of Agriculture. The midline and the end-line surveys were conducted by CIMMYT in collaboration with Egerton University, KALRO, and Ministry of Agriculture. The gender surveys used semi-structured questionnaire that captured information about men and women membership in rural institutions, social capital and networking, financial capital (credit and savings), household asset ownership, and gender perceptions of household food insecurity.

3.2.5 Analytical Framework

The first objective was to establish factors that explain differences in gender perception of household food security. The perceptions were measured on Household Food

Insecurity Access Scale (HFIAS). The HFIAS is preferred over other food security scales based on its ability of not only assessing prevalence of food insecurity across regions but also measuring changes in household food insecurity over time (Coates *et al*., 2007). The HFIAS consists of two types of questions; occurrence and frequency of occurrence (Coates *et al*., 2007). The occurrence question is split into nine questions that capture household experience of food insecurity. Each occurrence question has a corresponding frequency of occurrence question, which captures frequency of household food (in)security situations.

Households were categorized into four groups; food secure (1), mildly food insecure (2), moderately food insecure (3), and severely food insecure (4) based on their scores on the HFIAS. Households that have access to food that meets the adopted definition of household food security are classified as food secure. Households with less uncertainty or severe experience of food insecurity are categorized as mildly food insecure. Moderately food insecure households have reduced food portions, skip meals, and have monotonous diets (Ville *et al*., 2019). Households that go entire day without food and some members often sleep without eating are classified as severely food insecure. The causal effects of the explanatory variables on gender perceptions of household food security were estimated using random effects generalized ordered probit model.

The outcome variable is ordinal, implying that there exists relative ordering of food security. In this circumstance, an ordered probit model is appropriate for estimating the determinants of gender perceptions of household food (in)security. The ordered probit model assumes that there exist cut-offs between the ordinal outcomes, but the distance between them is not exact. Hence, following Pfarr *et al*. (2010), consider four observed categories of self-reported food security status with y^* as the underlying latent food security status. Thus, letting y be the ordered categorical outcome, a cross-section ordered probit model is written as:

$$\Pr[y \le j \mid x] = F(\kappa_j - x'\beta) \qquad j = 1, ..., J \tag{3.1}$$

where κ_j and β are unknown threshold parameters and coefficients respectively, and J is a vector of distinct ordered categories. The function F denotes a cumulative standard normal distribution. The discrete outcomes are explained by a vector of x covariates. Introducing the latent variable y^* into equation 3.1 results in:

$$y = j \quad \text{if and only if } \kappa_{j-1} \le y^* = x'\beta + u < \kappa_j \tag{3.2}$$

The interpretation of the threshold is that it divides the linear slopes into J categories. u is the unobserved disturbance term that, together with observable factors x, influences the latent variable. The ordered model as specified in equation 3.2 assumes a zero mean and a constant variance. Therefore, the probability that the respondent's self-reported food security status would be one out of the possible four is given as:

$$\Pr[y \leq j \mid x] = F(\kappa_j - x'\beta) - F(\kappa_{j-1} - x'\beta) \tag{3.3}$$

However, according to Pfarr *et al*. (2010), the standard ordered probit model (specified in equation 3.1 through 3.3) is anchored on parallel-lines assumption. The assumption is that the parameter estimates are constant between the categories. This implies that the parallel-lines assumption ignores the possibility of heterogeneity of some of the independent variables. Generalized ordered probit is appropriate when the parallel-lines assumption is violated. According to Pfarr *et al*. (2010), the generalized ordered probit model assumes that the threshold parameters depend on covariates and is written as:

$$\kappa_j = \tilde{\kappa}_j + x'\gamma_j \tag{3.4}$$

where γ_j are the coefficients of threshold covariates. Including the threshold equation 3.4 into equation 3.3 leads to a cumulative probability of generalized ordered probit model which is given as:

$$\Pr[y \leq j \mid x] = F(\tilde{\kappa}_j + x'\gamma - x'\beta) = F(\tilde{\kappa}_{j-1} - x'\beta_j) \qquad j = 1, ..., J \tag{3.5}$$

Equation 3.6 estimates J-1binary probit models which allow further estimation of $x'\beta_j$ for each distinct category j. Thus, "the generalized ordered probit model accounts for parameter heterogeneity" (Pfarr *et al*., 2010, p. 5).

Turning to the nature of the data used in this study, random effects (RE) generalized ordered probit model would be appropriate for fitting the determinants of gendered differences in household food security perceptions. Let the ordinal variable of household food security take the values $\text{j} = 1, ..., \text{J}$. The RE generalized ordered probit model is specified as:

$$\begin{aligned}
&\Pr(Y_{it} = 1 \mid x_{it}, \alpha_i) = F(-x'_{it}\beta_1 - \alpha_i) \\
&\Pr(Y_{it} = j \mid x_{it}, \alpha_i) = F(-x'_{it}\beta_1 - \alpha_i) - F(-x'_{it}\beta_{y-1} - \alpha_i) \qquad j = 2, ..., J-1 \\
&\Pr(Y_{it} = \text{J} \mid x_{it}, \alpha_i) = 1 - F(-x'_{it}\beta_{J-1} - \alpha_i)
\end{aligned} \tag{3.6}$$

The outcome variable in equation 3.6 is gender self-reported perceptions of household food security. In addition, compared to the standard cross-section generalized ordered probit model, RE generalized ordered probit model "outcome probabilities are conditional on the individual effects (α)" (Pfarr *et al.*, 2010, p. 5). Furthermore, the model assumes a zero mean and a constant variance.

3.2.6 Description of Variables

The descriptions of variables that were used in econometric estimations are provided in Table 1. The choice of variables was informed by economic theory and empirical literature. In addition, the description involves the measurement of each variable and the prior expectation of the direction of the relationship between explanatory variables and dependent variables.

Table 1: Description of variables for gender perceptions of household food insecurity

Variable	Description	Measurement	Expected sign
Dependent Variable			
FSP	Perception of food insecurity (1, 2,…., 4)	Discrete	
Independent Variables			
Gender	Gender of HH head (0=Female, 1=Male)	Binary	±
Age	Age of household head	Continuous	-
Hsz	Adult equivalent household size	Continuous	+
Marital status	Marital status of household head (1=Married, 0 otherwise)	Binary	-
Occup	Primary occupation(1=Agric. 2=non-agric.)	Binary	+
Dpratio	Household dependency ratio	Continuous	+
Educ1	Household education stock	Continuous	-
Income	Household off-farm income (Kshs)	Continuous	-
Savings	Total annual household savings (KES)	Continuous	-
Crt	Total credit received by household (KES)	Continuous	-
Assvalue	Total asset value (KES)	Continuous	-
Tlu	Tropical livestock unit	Continuous	-
Relatives	Number of relative living within and outside the village	Count	±
Nonrelatives	Number of non-relatives living within and outside the village	Count	-
PartInst	Participation in rural institutions	Continuous	-
Region	Region of residence (1=Western, 2=Eastern)	Binary	±

3.3 Results and Discussion

3.3.1 Descriptive Results

The gender perceptions of household food security across time are presented in Table 2. The results show that approximately 22% and 25% of female and male respondents perceived their households as food secure in 2013, respectively. The proportion of households that were food secure increased to 46% and 41% in 2015 as perceived by female and male respondents, respectively. Approximately 12%, 37%, and 30% of the female respondents perceived their households to be mildly, moderately, and severely food insecure in 2013, respectively. The proportion of female respondents who perceived their households as mildly, moderately, and severely food insecure in 2015 dropped to about 12%, 16%, and 27%, respectively. Turning to male perceptions, approximately 16%, 33%, and 26% of the male respondents perceived their households as mildly, moderately, and severely food insecure in 2013. Like their female counterparts, the proportions of males who perceived their households as mildly, moderately, and severely food insecure reduced to 14%, 20%, and 24%, respectively. Nonetheless, food insecurity perceptions did not differ significantly depending on the gender of the respondent.

Table 2: Proportions of female and male perceptions of household food security by year

	2013			2015		
	Female	Male	χ	Female	Male	χ
Food Secure	22.27	24.78	3.62	45.87	41.73	1.95
Mildly Food Insecure	12.25	15.85		11.97	13.67	
Moderately Food Insecure	35.63	33.14		15.67	20.14	
Severely Food Insecure	29.84	26.22		26.50	24.46	

Table 3 presents descriptive statistics of continuous household characteristics. The average ages of household heads in 2013 and 2015 were 52 and 53 years, respectively. Household heads had averagely 8 years of education across the two panels. This indicates that household heads had at least primary level education. The average household stock of education was 36 years across the two years. The overall household size in adult equivalent terms was 5 members. Additionally, the household dependency ratio remained at 1 across the years. The tropical livestock units reduced from an average of 1.4 in 2013 to 1.34 in 2015. Lastly, households earned approximately KES 84,384 in 2013 and KES 83,559 in 2015 as off-farm income per annum.

Table 3: Descriptive statistics of continuous household characteristics

Variable	2013 (N=535)		2015(N=495)		Overall (N=1030)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age of household head	52.13	13.85	54.26	13.73	52.94	13.84
Education of household head	8.23	3.64	8.23	3.83	8.23	3.71
Household education stock	35.80	19.74	35.58	18.96	35.71	19.44
Adult equivalent household size	5.05	2.31	4.76	2.11	4.93	2.24
Dependency ratio	1.00	0.95	0.97	0.94	0.99	0.94
Tropical livestock units	1.40	1.46	0.68	1.34	1.12	1.46
Off-farm income (KES)	84385	139853	83559	154751	84071	145650

The results in Table 4 shows that female and male respondents saved approximately KES 17,513 and KES 22,112 per annum, respectively. The difference in savings between female and male respondents was significantly different at 5%. The average amount of credit for females was KES 11,299 compared to approximately KES 13,787 for their male counterparts. The difference in access to credit by gender was insignificant. The female level of participation in rural institutions (0.15) was significantly lower than males' levels of participation (0.17). The average number of relatives and non-relatives as indicated in Table 6.

Table 4: Descriptive statistics of continuous variables disaggregated by gender

Variables	Female (800)		Male (486)		
	Mean	Std. Dev.	Mean	Std. Dev.	*t*-value
Savings	17513	39621	22112	41963	-1.974**
Credit	11299	35980	13787	39647	-1.156
Participation in rural institutions	0.15	0.12	0.17	0.11	-2.929***
Number of relatives	11.89	17.61	15.18	22.76	-2.902***
Number of non-relatives	15.61	29.82	20.98	46.17	-2.533**

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

Figure 3 presents results on household head by gender, marital status, and occupation of the respondents by year of study. Approximately 87% and 13% of the households were male and female-headed in 2013, respectively. The proportions of households that were male and female-headed in 2015 were 80% and 20%, respectively. Turning to marital status, about 88% and 81% of the respondents were married in 2013 and 2015, respectively. A majority of the respondents, (73% in 2013 and 82% in 2015), had farming as their main occupation. However, about 26% and 18% of the respondents indicated that their main occupations were off-farm activities in 2013 and 2015, respectively.

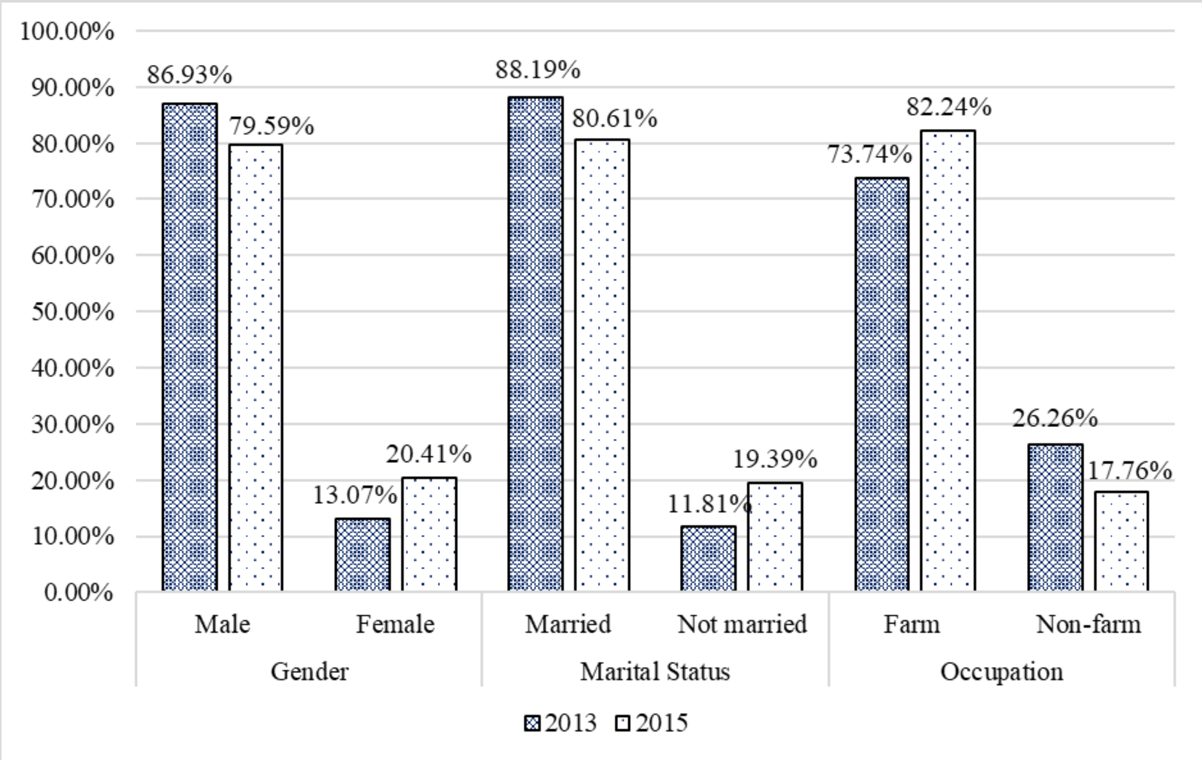

Figure 3: Proportions of the gender of household head, marital status, and occupation by year

3.3.2 Empirical Results

3.3.2.1 Model Diagnostics

First, standard RE ordered probit model for male equation was fit (Appendix 6). The results show five significant variables (age of household head, household stock of education, dependency ratio, asset value, and location). Appendix 7 shows results from the standard RE ordered probit model for the female equation. The results show nine significant variables (education of household head, household stock of education, adult equivalent household size, dependency ratio, number of relatives, group participation, asset value, credit, and location).

Second, constrained and unconstrained variables were identified for purposes of testing parallel-lines assumption. This was performed by applying the autofit procedure. The null hypotheses of equal coefficients are rejected for the variables adult equivalent household size and log of off-farm income for the male model (Appendix 8) and variables adult equivalent household size, participation in rural institutions, and log of asset value for the female model (Appendix 9). Specification test of male full model with constraints (global χ^2 = 36.48; p= 0.268) is insignificant, suggesting that RE generalized ordered probit model does not violate the parallel-lines assumption. The female model's specification test also suggests that the parallel-lines assumption is not violated (global χ^2 = 26.82; p= 0.633).

3.3.2.2 Econometric Results

The model's statistics, Wald χ^2 = 80.24; p=0.000 for male and Wald χ^2 111.93; p=0.000 for female, are significant meaning that the RE generalized ordered probit model fits data well. Table 5 and Table 6 present RE generalized ordered probit estimates of male and female perceptions of household food security, respectively. Six and ten variables were significantly associated with male and female perceptions of household food (in)security, respectively. However, the levels of significance of variables differed across food security categories and gender equations. These results can be construed to imply that different factors influence male and female perceptions of household food security. In addition, as presented in Table 5 and Table 6, adult equivalent household size and value of household assets are highly significant for all food security categories. However, the magnitude of their partial effects is different, suggesting differences in determinants influencing gender perception of household food security.

In Table 5, coefficients of age of household head, household education stock, adult equivalent household size, and region are significant at 1% significance level throughout the three food insecurity categories. Gender of household head is slightly significant throughout male model's food security categories. The coefficient for the log of the value of household assets is significant at 5% across the three food security categories, while the log of off-farm income is significant at 1% but only for severe food insecurity. In Table 6, education of household head, household stock of education, adult equivalent household size, and log of credit are significant at 1% level throughout the food insecurity categories. Dependency ratio and region are significant at 5% level while number of relatives and log of off-farm income are slightly significant across all food security categories. Whereas the log of the value of household assets is significant at 5% for mild food insecurity, it is significant at 1% level for moderate and severe food insecurity statuses. Lastly, participation in rural institutions was significant at 1% level but only for mildly and moderately food insecure statuses.

Table 5: RE generalized ordered probit estimates of male perceptions of household food security

	Mildly FI		Moderately FI		Severely FI	
Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age of household head	0.015***	0.006	0.015***	0.006	0.015***	0.006
Education of household head	0.004	0.026	0.004	0.026	0.004	0.026
Household education stock	-0.030***	0.008	-0.030***	0.008	-0.030***	0.008
Adult equivalent household size	0.402***	0.075	0.388***	0.072	0.281***	0.068
Dependency ratio	-0.056	0.074	-0.056	0.074	-0.056	0.074
Gender of HH head (0=Female, 1=Male)	0.601*	0.362	0.601*	0.362	0.601*	0.362
Marital status (1=Married, 2=Not married)	-0.142	0.243	-0.142	0.243	-0.142	0.243
Primary occupation(1=Agric. 2=non-agric.)	-0.002	0.040	-0.002	0.040	-0.002	0.040
Number of relatives	-0.001	0.003	-0.001	0.003	-0.001	0.003
Number of non-relatives	-0.002	0.001	-0.002	0.001	-0.002	0.001
Participation in rural institutions	-0.372	0.569	-0.372	0.569	-0.372	0.569
Log of value of household assets	-0.112**	0.048	-0.112**	0.048	-0.112**	0.048
Tropical livestock unit	-0.049	0.045	-0.049	0.045	-0.049	0.045
Log of savings	-0.016	0.015	-0.016	0.015	-0.016	0.015
Log of credit	0.010	0.013	0.010	0.013	0.010	0.013
Log of off-farm income	0.006	0.016	-0.014	0.016	-0.054***	0.018
Location (1=Western, 2=Eastern)	-0.460***	0.149	-0.460***	0.149	-0.460***	0.149

Observations = 486; Wald χ^2 = 80.24, p=0.000 Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 6: RE generalized ordered probit estimates of female perceptions of household food security

	Mildly FI		Moderately FI		Severely FI	
Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age of household head	0.001	0.004	0.001	0.004	0.001	0.004
Education of household head	-0.053***	0.020	-0.053***	0.020	-0.053***	0.020
Household education stock	-0.016***	0.006	-0.016***	0.006	-0.016***	0.006
Adult equivalent household size	0.220***	0.050	0.214***	0.049	0.145***	0.048
Dependency ratio	0.136**	0.067	0.136**	0.067	0.136**	0.067
Gender of HH head (0=Female, 1=Male)	-0.174	0.215	-0.174	0.215	-0.174	0.215
Marital status (1=Married, 2=Not married)	0.013	0.242	0.013	0.242	0.013	0.242
Primary occupation(1=Agric. 2=non-agric.)	0.042	0.033	0.042	0.033	0.042	0.033
Number of relatives	-0.008*	0.005	-0.008	0.005*	-0.008*	0.005
Number of non-relatives	0.003	0.003	0.003	0.003	0.003	0.003
Participation in rural institutions	2.154***	0.520	1.413***	0.506	0.483	0.563
Log of value of household assets	-0.090**	0.042	-0.183***	0.041	-0.126***	0.042
Tropical livestock unit	-0.035	0.036	-0.035	0.036	-0.035	0.036
Log of savings	-0.009	0.012	-0.009	0.012	-0.009	0.012
Log of credit	0.030***	0.011	0.030***	0.011	0.030***	0.011
Log of off-farm income	-0.020*	0.012	-0.020*	0.012	-0.020*	0.012
Location (1=Western, 2=Eastern)	-0.253**	0.117	-0.253**	0.117	-0.253**	0.117

Observations = 800; Wald χ^2 = 111.93, p=0.000

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

Age of the household head was positively associated with the male respondents' perception of household food security. In particular, an increase in the age of household member increased the possibility of male respondents perceiving households as mildly, moderately, and severely food insecure. This suggests the diminishing contribution of household heads to household food security or welfare as they age. Age possibly reduced the productive potential of household heads to stimulate the capacity of households to overcome food insecurity. An increase in age above a given level may have reduced economic contribution of individuals to welfare improvements. This result is similar to studies by Yahaya *et al*. (2018) and Oluwatayo and Ojo (2019) who found that the age of the household was important in explaining food insecurity in north-western Ghana and Nigeria, respectively.

The direction of the relationship between education level of household head and female perception of household food security was negative and statistically significant. This finding suggests that education reduces the likelihood of female respondents perceiving households as food insecure. Higher levels of education possibly enhanced knowledge and innovativeness of household heads which gave them opportunity to access productive resources. In turn, access to productive resources allowed households to directly and indirectly improve household food security. This finding is concurrent with Fiaz *et al*. (2016) who argued that improving food security requires educated farmers who are ready to update their knowledge in prosperous agriculture.

Household education stock was negatively associated with the likelihood of male and female respondents perceiving households as severely, moderately, and mildly food insecure. However, the magnitude of the effect of the household stock of educations for the male equations was -0.030 which is almost twice the magnitude of female equations (-0.016). This finding suggests that household stock of education influences gendered perceptions of household food security. Higher level of education reduced chances of male and female respondents perceiving households as severely, moderately, and mildly food insecure. In other words, respondents were likely to report higher status of food security with each additional year of the household stock of education. A higher stock of education implies that household members are more knowledgeable and aware of the importance of securing a higher food security status. In addition, households with a higher stock of education are possibly more productive and efficient, which could directly benefit households in terms of improved food security. Zhou *et al*. (2017) and Mutisya *et al*. (2016) reported similar results in studies conducted in Pakistan and Kenya, respectively.

The adult equivalent household size was positive and significant throughout the food security categories for male and female responses. This implies that large household size increases the likelihood of food insecurity. A large household size in adult equivalent terms made it more likely that male and female respondents would perceive households to be more food insecure than their current food insecurity statuses. These results suggest that the larger the household size, the higher the probability of food insecurity. The large food requirement by large-sized households may represent an important burden of feeding household members. This result agrees with findings reported by Mensah *et al*. (2013), Mango *et al*. (2014) and Tiwasing *et al*. (2018) in Ghana, Zimbabwe, and Thailand respectively.

Dependency ratio was positively associated with female respondents' perceptions of household food security. The interpretation of this finding is a higher dependency is associated with a high probability of female respondents perceiving households as mildly, moderately, or severely food insecure. In other words, dependency ratio reduces the chances of females perceiving households as food secure or increases chances of households being in lower levels of food security. Rising dependency ratio possibly negated household labour productivity growth, thereby increasing the burden on economically active household members. These may have made provision of adequate and quality food difficult as a result of the negative effect of dependency on consumption.

Gender of household head was positive and statistically significant in determining male respondents' perceptions of household food security. Relative to households headed by females, male-headed households were perceived to be more likely to remain in their current food security status or be in a lower food security status. This finding suggests that female household heads provide a critical buffer against food consumption shortfalls, allowing households to be food secure. The finding also suggests that households with female heads give more priority to improving food security. The finding could also be attributed to female-headed households being the de facto type of headship. These could have given women autonomy in decision-making, resulting in positive food security outcomes.

Kinship ties as proxied by the number of relatives was negatively and significantly associated with female perception of household security. The number of relatives reduced the likelihood of female respondents perceiving households as mildly, moderately, or severely food insecure. Put differently, female respondents with a high number of relatives living within and outside the village were at a higher chance of perceiving household to be in a higher food security status. This finding implies that kinship ties offer distinct mutual social relationships that support women by helping them starve the likelihood of severe food insecurity. Supposedly, women received food such as cereals and grocery from relatives which positively influenced their perception of household food security. This result reemphasizes Cox and Fafchamps (2008) position that extended families offer support to households during hardship times, enabling such households to sustain their consumption.

The log of the value of household assets was negative and significantly associated three categories food insecurity for male and female equations. The coefficient estimates of the log value of household assets were -0.112 for the male equations and ranged from -0.090 to -0.183 for the female equations. This can be interpreted that assets are more important in determining female perceptions of household food security as compared to male perceptions of household food security by magnitude. Assets are important resources for smoothing household food consumption by preventing periodic food shortages. The negative direction of the relationship between asset ownership and household food insecurity perceptions could be attributed to the ease of converting assets directly into cash and then exchanging cash for food. The households may have been able to employ the assets as economic capital over the years, which generated income that was used to acquire food. This result supports earlier findings by Guo (2011) and Reincke *et al*. (2018) who established a positive association between asset ownership and food security. The higher magnitudes of log of value of household assets for women food security equations affirm earlier conclusion by Kassie *et al*. (2015) that endowment of women with productive resources would substantially reduce gender food security gaps.

Contrary to what was expected, female perceptions of household food security were positively influenced by the amount of credit received. An increase in the amount of credit received over the two years increased the likelihood of female respondents perceiving households as food insecure. This is could be attributed to the burden of servicing the credit. Credit repayment could have, to a large extent, deviated income from food consumption. The positive relationship could also be explained by investment choices by households that may have resulted in poor returns or credit advances were insufficient to sustain investments. These could have negatively affected female respondents' perceptions of the role of credit in household food security. Similar results were reported by Ngema *et al*. (2018) in a study in a local municipality in South Africa. They explained that households possibly relied on informal credit, which attract exorbitant rates. However, in a study in western Nigeria, Ibrahim *et al*. (2016) found that an increase in access to credit reduced chances of households being moderately food insecure.

The log of off-farm income was negatively associated with female perceptions of households as mildly, moderately, and severely food insecure, but only significantly associated with male perceptions of households as severely food insecure. In other words, off-farm income reduced likelihood of female respondents perceiving households as mildly, moderately, and severely food insecure. Instead, off-farm income increased the chances of households being in higher categories of food security. This finding is a reflection of the importance of off-farm income in enabling households to procure food directly through purchases. This could also be explained by the possibility that households with diverse off-farm sources can invest in agricultural production through the acquisition of farming technologies which, in turn, translates into increased food production. The direct role of off-farm income in food acquisition together with its agricultural productivity effect possibly sustained food security for the already food secure households. In addition, it possibly enabled food insecure households to improve their food security statuses over the years. This finding is in line with study results reported by Mishra *et al*. (2015) in Bangladesh, Ibrahim *et al*. (2016) in Nigeria, and Ahmed *et al*. (2017) in Pakistan.

Unexpectedly, the effect of women participation in rural institutions was positively associated with female respondents' perceptions of household as mildly and moderately food insecure. The finding appears to imply that the level of women participation in rural groups increases the probability of female respondents perceiving households as mildly and moderately food insecure. This could be attributed to the possibility that group membership may not have adequately resulted in expected benefits. Second, participation in more rural groups could have negatively impacted on women allocation of time to productive economic activities that may have substantially affected food availability to households. These results are in contradiction to finding by Sseguya *et al*. (2018) who reported a strong positive association between group membership and food security in rural South Africa and Uganda, respectively.

Finally, location characteristic was negatively associated with male and female perceptions of household food (in)security. The magnitude of regions' influence on food security perceptions for male equations (-0.460) was almost 1.8 times larger than the females' coefficients (-0.253) in absolute terms. Compared to male and female respondents Bungoma and Siaya, female and male respondents in eastern counties (Meru, Tharaka Nithi, and Embu) were less likely to perceive the households as mildly, moderately, and severely food insecure. This finding reflects regional differences in food security. This can be attributed to interrelated and complex issues such as social, economic, environmental, and political factors. The variation of these factors over time and space, possibly, directly and indirectly, affected household participation in productive activities which explained differences in perceptions of household food security.

3.4 Conclusion

The understanding of gender differences in food security perceptions is the first step towards designing and implementing interventions targeted at alleviating chronic food insecurity. While food security issues concern every household member, individuals may differ in ways they perceive food security because of their role and status in households. Additionally, while some household members may have fewer meals in a day, others may have sufficient food, thereby influencing their perceptions of household food security status. Gender is one of the important factors that define roles of household members and their perceptions of household food security. Consequently, analysing gender-differentiated food security perceptions is critical to uncovering of underlying factors that explain differences in individual perceptions of household food security.

The study analysed factors that determine gender differences in household food security perceptions. First, RE generalized ordered probit model showed that male and female respondents in the eastern region were less likely to perceive households as food insecure relative to their counterparts in the western region. Second, the study found that household size, household stock of education, the value of household assets, off-farm and location characteristics significantly influenced both male and female perceptions of household food security. Whereas household size in adult equivalent terms positively influenced both male and female respondents' food insecurity perceptions, household stock of education, the value of household assets and location characteristic were negatively associated their perceptions. The education level of household head and dependency ratio were negatively and positively associated female perceptions of food security, respectively. On the other hand, age and gender of household head were positively correlated with male perception of household food security. Number of relative had a negative relationship, while participation in rural institutions had a positive relationship with female perceptions of food insecurity. The varying number and magnitude of statistically significant variables in RE generalized ordered probit model indicate differences in factors that influence male and female perceptions of household food security. Therefore, policy emphasis should be directed to strengthening women and men participation in programs that promote food security through gender mainstreaming in farm and off-farm economic activities.

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CHAPTER FOUR

EFFECT OF SHOCKS AND SUSTAINABLE AGRICULTURAL INTENSIFICATION PRACTICES ON HOUSEHOLD VULNERABILITY TO POVERTY

Abstract

Smallholder farmers in Kenya are resource poor and are disproportionately affected by climatic and economic shocks. Nonetheless, literature that empirically link shocks and household vulnerability to poverty in Kenya is limited. Additionally, the effect of sustainable agricultural intensification practices (SAIPs) on household vulnerability to poverty in Kenya has not been adequately studied. This study used three waves of household level panel data collected from 613 households in western and eastern Kenya to estimate effects of shocks and SAIPs on household vulnerability to poverty. Descriptive results showed that nearly 61% of the households were vulnerable to poverty across the panels. More households (66%) in western than in eastern (56%) were vulnerable to poverty. Results from FE and RE ordered probit model indicated adult equivalent household size, dependency ratio, drought, high input and food prices, and sickness of household members increased household vulnerability to poverty. In contrast, household education stock and SAIPs decreased the probability of households becoming poor. In conclusion, SAIPs have a potential of increasing the resilience of smallholder agricultural production systems to adverse effects of climate change, thereby contributing to poverty and vulnerability reduction. Therefore, agricultural policy should focus on encouraging multiple adoption and continued use of SAIPs by strengthening rural institutional programs such extension services and trainings.

4.1 Introduction

Kenya has recorded rapid economic growth in recent decades. For instance, GDP grew by 5.7% and 5.8% in 2015 and 2016 compared to regional averages of 1.5% and 3.8% respectively (KNBS, 2017). Despite rapid economic growth, poverty rates in the country are high relative to other lower middle-income countries. About 36% of an estimated population of 52 million people in Kenya is poor. With about 74% of the Kenyan population living in the rural areas (World Bank, 2018b), it implies that a substantial proportion of the rural population is poor. According to IFAD (2017) estimates, about 70% of the rural poor in Kenya live in high agricultural potential areas. These statistics indicate that poverty is largely a rural and agricultural problem.

The rainfall-dependent agriculture and low adaptive capacity of agricultural systems make rural households poor and vulnerable to devastating effects of extreme climatic conditions (Shiferaw *et al*., 2014; Simotwo *et al*., 2018). The resulting low agricultural productivity leads to reduced farm income, worsening poverty situation. For example, the country has experienced two prolonged droughts since 2010. In 2010 and 2011, drought subjected about 4 million people to food insecurity and severe poverty (IFAD, 2017). The recent prolonged droughts in 2016-2017 and 2017-2018 jeopardized progress towards reducing rural poverty. The increasing frequency and intensity of droughts, punctuated by erratic rainfall, impacts on both crop and livestock production, thereby increasing household vulnerability to poverty. Additionally, weather variability and extreme climatic events have increased prevalence of crop pests and diseases. The outbreak of maize lethal necrosis disease in 2011 and the recent infestation of maize by fall army-worm have threatened maize production, which is an important food and commercial crop (Osunga *et al*., 2017; KALRO, 2017). Consequently, climate change-related shock are important covariate shocks that negatively impact the already weak agricultural sector, thereby exacerbating rural poverty.

Rural households are resource-poor and have inadequate access to formal financial and insurance intermediation (Demirgüç-Kunt *et al*., 2014), making it impossible to overcome the negative consequences of idiosyncratic shocks like sickness and death household member, loss of livestock, and crop failure. The pre-existing poor socioeconomic conditions imply that occurrence of idiosyncratic shocks translates into increased household vulnerability to poverty. The long-term consequence may be reduced households' resilience to poverty. The inability of households to insulate their welfare against the effects of idiosyncratic shocks increases risk of future poverty, which makes ex-post poverty alleviation strategies less effective.

Besides the effect of climate-related factors on agriculture, food production in the country is also hampered low use improved agricultural practices by smallholder farmers. For instance, despite recent fertilizer subsidies, input prices have remained relatively high, resulting in low utilization rates by smallholder farmers. Thus, the decline in maize production to 37.1 million bags in 2016 down from 42.5 million bags in 2015 is not only attributed to extreme climatic conditions, crop pests and diseases, but also to high input prices (KNBS, 2017). The low use of inputs, punctuated by unsustainable land use practices, restricts smallholder farmer options for increasing agricultural productivity (Schroeder *et al*., 2013; Aura, 2016). Additionally, smallholder farmers lack adequate knowledge on available sustainable technologies, leading to low adoption rates (Danda *et al*., 2015). Lastly, the high variability in agricultural output prices constrains productive investment in agriculture. For instance, fluctuation of maize output prices is a major disincentive to investment in maize production despite the fertilizer subsidy.

The effect of the increasing incidences of extreme climatic conditions does not only result in short-term economic losses, but also long-term and multi-prolonged impact on rural livelihoods (FAO, 2018b). The isolated or simultaneous occurrence of extreme climatic events coupled with socioeconomic challenges may cause long-term inability of rural households to sustain their welfare. This perpetuates and increases poverty. Specifically, extreme climatic events lead to increased household vulnerability to poverty. This implies that the occurrence of climate-related shocks may increase the severity of poverty or cause non-poor households to fall into poverty in the long-run.

Therefore, alleviating rural poverty by reducing household vulnerability to poverty require interventions that enable smallholder farmers to mitigate impacts of extreme climatic events on agriculture. The interventions should sustainably enhance the resilience of agricultural systems against climate-related changes. In realization of this, the SIMLESA project was rolled out to create awareness, disseminate, and encourage uptake of Sustainable Agricultural Intensification practices (SAIPs). The objective of the SIMLESA project was not only to contribute to increased agricultural productivity, but also building resilience of smallholder agriculture to the devastating effects of climate change. In doing so, the project aimed at safeguarding rural livelihoods and welfare through sustainable agriculture.

Consequently, considerable empirical attention has been directed to investigating the impact of SAIPs as a result of their continued adoption. Studies examining effect of SAIPs on poverty reduction in Kenya and East and Southern Africa are increasingly becoming innumerable. For instance, studies by Muyanga *et al*. (2013) and Kostandini *et al*. (2013) have investigated the link between SAIPs adoption and rural poverty reduction. These studies illustrate how SAIPs enable households to adjust to climatic shocks as they seek increase maize and legume production. However, these studies are ex-post, ignoring that SAIPs adoption is an ex-ante strategy for reducing or minimizing the undesirable consequences of climatic shocks (Shiferaw *et al*., 2014). For instance, farmers may adopt SAIPs such as drought-tolerant maize varieties and soil and water conservations practices to reduce or insulate households against income or consumption losses as a result of drought and floods. Ex-post analysis of household poverty may not discern the effect of SAIPs on household vulnerability to poverty.

Furthermore, most studies focus on impact of isolated SAIPs which overlooks the differential impacts of different combinations of the practices. Moreover, a limited number of published research studies have investigated the dynamic effect of covariate and idiosyncratic shocks on ex-ante poverty. Lastly, the studies used cross-section data which do not uncover the dynamic impact of SAIPs on household transition into and out of poverty. Hence, this study estimated the effect of SAIPs on household vulnerability to ex-ante poverty using three waves of panel data from western and eastern regions in Kenya. The understanding of ex-ante impact of SAIPs is crucial to reinforcing the ability of smallholder farmers to overcoming the effects of covariate and idiosyncratic shocks and preventing them falling into poverty.

Numerous studies have investigated the effect of shocks on poverty and vulnerability to poverty. For instance, Shehu and Sidique (2015) analysed the effect of shocks on household consumption in Nigeria and found that most climatic and household-specific shocks insignificantly affected household consumption expenditure. However, price shocks significantly impacted on household expenditure. In another cross-sectional study, Mahanta and Das (2017), applying vulnerability as expected poverty approach, found that exposure floods increased the chances of households becoming poor. They also reported that the likelihood of future poverty was higher among female-headed, the elderly, and low among educated households. On the other hand, Hill and Porter (2017) found that prolonged drought and increase in food prices significantly increased household vulnerability to poverty.

Furthermore, Skoufias and Vinha (2013) found that climatic shocks (rainfall and increase in temperatures) caused variability in Mexican household consumption. However, they noted that the level of consumption variability differed across space and time and depended on household ability to insure against the shocks. Similarly, Watete *et al*. (2016), using stage-of-progress method, analysed poverty dynamics in northern Kenya between 1993 and 2013 and reported that drought and diseases caused loss of livestock, which increased pastoral poverty and risk of households falling into poverty.

The evidence generated from above review indicate that shocks are important in explaining household vulnerability to poverty. However, there are inherent shortcomings from the reviewed literature. Shehu and Sidique (2015) and Mahanta and Das (2017) used large cross-sectional data which seldom allows estimation of temporal vulnerability and the differential impact of different sources of vulnerability. Second, studies that used panel data (Skoufias & Vinha, 2013; Watete *et al*., 2016; Hill & Porter, 2017) focused on the isolated effect of either covariate or idiosyncratic shocks which does not allow measuring of the relative importance and effect of various shocks on variability of household consumption. The current study addressed the mentioned shortcomings by using panel data and recognized the relative importance of various shocks as sources of vulnerability.

The number of studies investigating impact of ex-ante climate change adaptation strategies is increasing. This underscores the importance of SAIPs as ex-ante risk managing strategies that have the potential of reducing the impact of climatic shocks a priori (Shiferaw *et al.,* 2014). Dhrifi (2014) showed that technological innovations are essential pro-poor growth strategies that make agricultural production responsive, dynamic and competitive. Dhrifi (2014) estimated the contribution and impact of technological innovations on poverty and economic growth of 32 SSA countries from 1990-2011. Results indicated that irrigation and mechanization had poverty-reducing effect at an aggregate level. The findings suggest that reducing overreliance on rainfed agriculture through irrigation can result in agriculture resilience to extreme climatic events. Despite its empirical contribution, the study used aggregated data to measure technological innovation effect on poverty. Hence, household welfare effects of technological innovation were not adequately demystified, which this study addressed by focusing on effect of SAIPs on household vulnerability to poverty.

In another study, Magrini and Vagani (2016) evaluated the impact of improved seed and inorganic fertilizer adoption on household vulnerability to poverty in Tanzania. The study measured vulnerability as expected poverty and determined the impact of technology on household vulnerability to poverty using propensity score matching. Adopters recorded a higher levels of welfare in terms of consumption compared to non-adopters. Whereas adoption of improved seed reduced household vulnerability to poverty, inorganic fertilizer had insignificant influence in vulnerability. These findings suggest that technology adoption potentially ameliorate the long-term consequences of extreme climate change. Nonetheless, rather than focusing on the effect of agricultural technology per se, the study disentangled the long-term sensitivity of household consumption to climatic shocks and the role of SAIPs adoption in ameliorating the negative effect of the shocks.

Besides exploring input intensification effect of climatic events, Bozzola *et al*. (2016) tested the hypothesis of whether or not input intensification potentially aggravated smallholder farmer vulnerability to poverty in Kenya. The study established that a larger land allocation to hybrid maize positively impacted on the expected crop income. However, the study reported that intensification of maize production had no statistically significant impact on the variance and skewness of crop income. The authors argued that although effective, the use of hybrid seed was inadequate in reducing long-term crop income shortfalls, which they attributed to multiple market failures. The insignificant association between the use of hybrid maize seed and the downside risk may have resulted from the study's focus on isolated farm intensification practices. The study did not consider that smallholder farmers may adopt multiple practices in order to shield crop production systems against the effects of extreme climate events. This study addressed this weakness by estimating the impact of combinations of SAIPs on household vulnerability to poverty.

Di Falco and Veronesi (2018) quantified impact of adoption of SAIPs as climate change adaptation strategies on downside risk in Ethiopia. They used skewness of yields as a metric of downside risk exposure. The study reported that the ex-ante change in crop varieties as well as soil and water conservation practices in response to rainfall variability and changes in temperature decreased the risk of crop failure. The authors discerned a significant difference in the level of risk exposure between adopters and non-adopters. This suggests that adoption makes adopters more resilient to extreme climatic events. However, the study utilized cross-sectional data which do not allow analysis of the dynamic impact of ex-ante adaptation strategies. Hence, the study used three waves of panel data to estimate the impact of SAIPs on household vulnerability to poverty.

In a cross-country analysis, Niles and Salerno (2018) illustrated the effect of climatic shocks on food poverty. Results from a multilevel model indicated that adequate adaptive strategies such as fertilizer and pesticide use, veterinary medicine and livestock ownership significantly reduced the effect of climatic shocks on food poverty. In particular, the authors explained that fertilizer as a yield improving strategy provides a greater base of agricultural production not only through an increase in crop yields but also provides crop residues utilized as livestock feed and soil and water conservation practice. This reduced ex-ante poverty. However, the authors asked whether households experienced climatic shocks without further details on the proportion of the main food crop and income loss as a result of climatic shocks. This may have masked the impact of the magnitude of the effect of shocks on household food poverty. This study overcame this limitation by using actual consumption data and capturing the magnitude of the effect of shocks on crop yields and household income.

4.2 Methodology

4.2.1 Sampling Design

The target population was smallholder grain-legume farmers in eastern and western Kenya. The study used Adoption Pathways (AP) project's panel dataset. Three surveys were conducted in Bungoma, Siaya, Embu, Tharaka, and Meru counties in 2011 (baseline), 2013 (midline) and 2015 (end-line). The first wave data was collected from 613 farm households. The second wave covered a total of 535 households while the last wave collected data from 495 households. Table 4.1 presents the sample sizes per county per wave and the corresponding attrition rate. The study sample size was determined using proportionate to size sampling approach as propounded by Groebner and Shannon (2005). Proportionate to size sampling approach is given by the following formula in equation 4.1

$$n = \frac{(pqz^2)}{d^2} \tag{4.1}$$

where n is the sample size, $z = 1.96$, p is the proportion of the population interest which is set 0.7 based on previous studies on adoptions rates (Ouma & De Groote, 2011), d is the significance level which is set at 3.628% to eliminate potential sample bias and q is a weighted variable that is computed at $1 - p$. Using equation 4.1 the resulting study sample size was 535.

$$\frac{0.7 * 0.3(1.96)^2}{(0.03628)^2} = 613$$

Table 7: Sample size

	Panel				
	2011	2013		2015	
Region/county	N	N	Attrition (%)	N	Attrition (%)
Western					
Bungoma	150	137	8.60	120	20.00
Siaya	149	143	4.02	142	4.70
Eastern					
Embu	111	93	16.22	85	23.42
Tharaka Nithi	101	81	19.80	81	19.80
Meru	102	81	20.59	67	34.31
Total	**613**	**535**	**12.72**	**495**	**19.25**

4.2.2 Data Collection

The data were collected by CIMMYT and local partners in Kenya, which included Egerton University, KALRO, and Ministry of Agriculture. The 2011 baseline data was conducted in collaboration with KARI, currently KALRO and Ministry of Agriculture. The midline and the end-line surveys were conducted by CIMMYT in collaboration with Egerton University, KALRO, and Ministry of Agriculture. The panels are geographically diverse and representative of the rural maize-legume farming systems. Three waves of the survey, 2011, 2013 and 2015, are available and provide detailed information on household demographic characteristics, consumption expenditure, location, income, Sustainable Intensification Practices (SAIPs), agricultural output, decision making, credit and other institutional information.

4.2.3 Analytical Framework

The second objective was to determine effects shocks and adoption of sustainable agricultural intensification technologies (SAIPs) on household vulnerability to poverty. Household consumption expenditure was used as an indicator of poverty. The analysis of vulnerability to poverty involved predicting the probability of households falling below a specified consumption threshold. The objective was analysed using fixed effects model. The choice of the model was made after a series of diagnostic tests.

4.2.3.1 Measuring household vulnerability to poverty

There are several approaches to measuring vulnerability to poverty. However, approaches proposed by Chaudhuri *et al*. (2002) are the commonly used in vulnerability analysis (Imai *et al*., 2011; Echevin, 2013; Nguyen *et al*., 2013; Hill & Porter, 2017). The most repeatedly used approach is vulnerability as expected poverty (VEP). The other two approaches are vulnerability as low expected utility (VEU) and vulnerability as uninsured exposure to risk (VER) (Chaudhuri *et al*., 2002). This study adopted VEP. Although, VEU and VEP are suitable for constructing vulnerability probabilities at individual or household levels VEP is preferred because the expected poverty is easily interpretable than VEU and VER (Ward, 2016).

Like in empirical poverty analysis, the determination of vulnerability threshold is the starting point in measuring household vulnerability to poverty. This makes expected poverty to be the likelihood of a household falling below a given vulnerability line. It also implies that, as suggested by Adger (2006), the Foster-Greer-Thorbecke poverty measure (Foster *et al*., 1984) can be used to measure vulnerability to poverty. Equation 4.2 is a general form equation for vulnerability to poverty as a headcount measure.

$$V_\alpha = \frac{1}{n}\left[\sum_{i=1}^{q}(W_0 - W_i / W_0)^\alpha\right] \tag{4.2}$$

where V_α denotes vulnerability to poverty, W_0 is the vulnerability threshold below which a household is considered vulnerable, W_i is household i vulnerability probability, n is the total sample size, q is the number of households above vulnerability threshold and α is the sensitivity parameter. Where $\alpha = 0$ is headcount vulnerability, $\alpha = 1$ is vulnerability gap, and $\alpha = 2$ severity of vulnerability.

The interest of the current study is headcount vulnerability. Recent studies (Imai *et al*., 2010; Adepoju *et al*., 2011; Sricharoen, 2011, Echevin, 2013) used 0.5 as a vulnerability threshold in classifying households as vulnerable and non-vulnerable. The 0.5 threshold is equated to a poverty line and represents 50/50 chances of a household falling into poverty. A vulnerability threshold at 0.5 implies that household on the threshold are considered vulnerable, and indicates the possibility that some households are at risk of becoming poor when hit by shocks despite being above the vulnerability line (Ward, 2016). Thus, the study adopted a vulnerability threshold of 0.5.

Following Chaudhuri *et al*. (2002), the probability of household i falling into poverty in time $t+1$ is given as:

$$V_{it} = pr(C_{h,t+1} \leq Z) \tag{4.3}$$

where V_{it} is the vulnerability of household i at time t, $C_{i,t+1}$ is household's level of consumption for household i at time t, and z is the per capita consumption expenditure requirement defined as the poverty line at time t.

Considering the outcomes of interest (C_h), which is the expected consumption per capita for household h, it can be conceptualized to be influenced by, among many other factors, SAIPs, covariate and idiosyncratic shocks and household socioeconomic characteristics. Equation 4.4 is the household consumption function.

$$\Delta C_{htv} = \alpha + \lambda_i S(i)_{tv} + \beta_i S(i)_{htv} + \beta_j A_{htv} + \delta X_{htv} + \varepsilon_{htv} \tag{4.4}$$

where ΔC_{htv} is change in total consumption per capita of household h, in time t and location v, $S(i)_{tv}$, $S(i)_{htv}$ and A_{htv} are covariate and idiosyncratic shocks, and SAIPs adoption respectively, X_{htv} is a vector of household socioeconomic characteristics, $\lambda, \beta, \gamma,$ and δ are vector parameters to be estimated, and ε_{htv} is the error term. The variance in consumption was determined by:

$$\sigma^2_{\varepsilon_i} = X\theta_i \tag{4.5}$$

where θ is also a vector parameter. The expected log consumption and its variance were estimated as follows:

$$\mathrm{E}[\mathrm{In}C_i \big| X] = X_i\hat{\beta} \tag{4.6}$$

$$\mathrm{E}[\mathrm{In}C_i \big| X] = X_i\hat{\theta} \tag{4.7}$$

Following Imai e*t al*. (2011), the study assumed that the $\mathrm{In}C_i$ is normally distributed and, therefore, the likelihood that household i will become poor is given by:

$$\mathrm{V\hat{E}P_i} = \hat{v} = \mathrm{\hat{P}r}(\mathrm{In}C_i < \mathrm{Inz} \big| X_{i,}) = \Phi\left\{\frac{\mathrm{In\ z}\text{ - }X_i\hat{\beta}}{\sqrt{X_i\Phi}}\right\} \tag{4.8}$$

where $\Phi(.)$ denotes the cumulative density of standard normal.

The probabilities of households becoming poor were generated using feasible generalized least squares (FGLS). The natural logarithm of household consumption (aggregation of annual food and non-food expenditure) was the outcome variable in the panel GLS model. The first step involved estimation of equation 4.6 which yielded consistent estimates of the predictors of consumption and non-independent residuals to account for unexplained variance in consumption. The second step involved fitting another regression that estimates the effect predictors used in step one on the squared variance of consumption as specified in equation 4.7. Lastly, the predicted probability values in step two were weighted with square roots to account for OLS inefficiencies in the estimation of 4.8. The generated probabilities from the GLS regression became the outcome variable in the second econometric procedure.

Equation 4.8 yields the probabilities of individual households being poor in 2011, 2013 or 2015. The estimated probabilities ($\mathrm{V\hat{E}P}$) are bound between 0 and 1. Household vulnerability to poverty increases from 0 to 1, with household closer to 0 being less vulnerable while those closer to 1 being severely vulnerable to poverty. The determinants of $\mathrm{V\hat{E}P}$ estimated in equations 4.2 through 4.7 were analysed as follows:

$$\mathrm{V\hat{E}P}_{it} = X_{it}\beta + \varepsilon_{it} \tag{4.9}$$

where $\mathrm{V\hat{E}P}$ is vulnerability as expected poverty, X is a vector of explanatory variables with coefficient β and ε_{it} is an error term.

Fixed effects (FE) was used to fit equation 4.9. The FE model is based on the expectation that the average value of the outcome variable, y_{it}, changes across time but not cross-sectionally. In this case, y_{it} is household vulnerability to poverty. The FE model is written as follows:

$$y_{it} = \alpha + \beta x_{it} + \lambda_t + v_{it} \tag{4.10}$$

where α is intercept term, β is a vector of parameters to be estimated for the corresponding predictor variables, x_{it} is a vector of predictor variables, λ_t is a time-varying intercept and v_{it} is disturbance term. λ_{it} captures all the predictor variables that influence the outcome variable across time, but constant cross-sectionally. The disturbance term varies over time and entities.

The spells approach was used to cross-validate the vulnerability probabilities obtained from VEP. According to Bayudan-Dacuycuy and Lim (2014), spells approach involves counting the number of times a household falls below a predetermined poverty threshold. Similar to VEP, per capita adult equivalent consumption expenditure was used to determine the poverty threshold. The first category consisted of households that remained non-poor between 2011 and 2015. They were referred to as always non-poor. A household that fall into poverty once across the three panels was categorized as "once poor", while a household that fall into poverty twice cross the three panels was classified as "twice poor". The once poor and the twice poor categories are referred to as transitory poor. The fourth category was composed of households that remained poor from 2011 to 2015. They were classified as "always poor".

The transient poor enter and exit poverty due to covariate and idiosyncratic shocks. The always poor lack economic and social capacity to exit poverty. Together, the always poor and the transient poor were classified as the vulnerable households, while the always non-poor are non-vulnerable to poverty. The RE ordered probit model as given in equations 3.1 through 3.3 in chapter five was used to cross-validate FE estimates of the effect of shocks and SAIPs on household vulnerability to poverty because of non-violation of parallel lines assumption.

4.2.3.2 Sustainable Agricultural Intensification Practices Index

In the real-world of technology adoption, it is expected that farmers evaluate individual practices or technologies. Hence, it follows that the adoption of a combination of SAIPs is multiple criteria that farmers consider when evaluating the practices. Therefore, the evaluation is usually correlated, not independent. This implies that adoption decision is calculated repeatedly, and there is a high possibility of correlation among practices. To cope with the correlation effect, the Principal Component Analysis (PCA) technique was used to create standardized linear components of the eighteen SAIPs combinations that contain same information as the original SAIPs. Equation 4.11 represents a set of correlated SAIPs that have to be reduced to an independent set of linear combinations that are presented in equation 4.12.

$$X = X_1, ..., X_m \tag{4.11}$$

$$W = W_1, ..., W_k \tag{4.12}$$

The W independent principal components in equation 4.11 replace the X combination by satisfying two conditions; $K \le m$ and $W^T = C^* X^T$, where X^T is the transpose of original vector X and C is the coefficient matrix for the orthogonal transformation.

In the context of this study, PCA is used in reducing the number of SAIPs combination from m to K. This is essential in simplifying the process of identifying and selecting SAIPs. In addition, PCA is used to eliminate correlations between different SAIPs, resulting in a more accurate selection. The selection of K uncorrelated principal component is arrived at by first calculating the covariance matrix of a summation of the eighteen SAIPs combinations. Second, eigenvalues and eigenvectors of the summation of the SAIPs combination are calculated. Using the calculated eigenvectors and eigenvalues, the K independent principal components, $Y = (Y_1, ..., Y_K)\,(K \le m)$, are obtained by retaining principal components with eigenvalues of greater or equal to 1. The original evaluation function, $Q(q_1, ..., q_m)$ is then transformed into another function that is based on the independent principal components $Y(Y_1,..., Y_K)$ by integrating the SAIPs weight values.

Following Kaiser criterion, component loadings with eigenvalues equal or higher than 1 were retained. To obtain practices that mostly defined each component, a threshold value of rotated component loadings of 0.45 was selected. Although the rule of thumb dictates that minimum loading from the matrix of rotates components should be 0.5, the 0.45 threshold was informed by the need to increase the variation in the generated indices using the reduced combinations of SAIPs.

4.2.3.3 Clusters of Sustainable Agricultural Intensification Practices

The selection of SAIPs combinations was based on the number of farm-level adaptation strategies recommended by SIMLESA and Adoption Pathways projects. SAIPs were broadly categorized as crop diversification (intercropping, rotation and improved crop varieties), fertilizers and chemicals (organic and inorganic), other chemical inputs, and composting and soil and water conservation practices. These practices were disproportionately adopted across the three-wave panels, with six practices being commonly adopted. These include improved maize and legume varieties, fertilizer, manure, minimum tillage, crop rotation and intercropping. The highest number of practices adopted by farmers was five practices across the panels.

The selection of all possible combinations was based on the understanding that crop production involves propagation of planting material. Hence, seed variety was the base SAIP. As expected, farmers who adopted more than one SAIP had different combinations. Eighteen possible combinations were, therefore, constructed with the least SAIPs combination being adoption of improved maize variety and maximum number of practices in a single combination being five. Hence, the construction of the possible SAIPs combinations met two selection criteria. The possible combination had to have maize variety as the base technology. Second, the selected SAIPs had to represent either a qualitative or quantitative aspect of adoption as an adaptation strategy as postulated by Naumann *et al.* (2014). The eighteen SAIPs combinations adopted by smallholder farmers in the study region are presented in Appendix 2.

4.2.3.4 Derivation of Adoption Indices

Possible combinations of the six practices were identified through PCA analysis (Appendix 3). Each component contained a number of combinations that were adopted by farmers as ex-ante strategies for increasing the resilience of maize-legume production systems against the effect of extreme climate events. Each combination of SAIPs from each principal component was assigned a score of 1.0 when adopted by individual farmers and 0.0 for non-adoption. This allowed the derivation of adoption index values for combinations that mostly defined each component. The SAIPs adoption index was constructed considering the minimum and maximum values from the summation of the scores for each combination. The normalization of each SAIPs index score was calculated as follows:

$$SIndex_i = \frac{\sum_{i=1}^{N} t}{N} \tag{4.13}$$

where $SIndex_i$ is the index value for SAIPs combinations from i^{th} principal component, t is the number of SAIPs combinations adopted by individual farmer from the i^{th}

principal component and N is the total number of SAIPs combinations contained in the i^{th} principal component.

Following Naumann *et al*. (2014), normalization of the SAIPs index for each possible combination was necessary in ensuring that all combinations had an identical range of values from 0 and 1. The normalization of the SAIPs combination indices was also necessary in allowing direct comparison of results among different households. This normalization avoided possible bias by assigning equal weightage to each of the selected SAIPs from each principal component. The expectation is that the impact SAIPs on ameliorating the effect of extreme climate events on maize-legume systems would vary with SAIPs packages adopted by individual farmers.

4.2.4 Description of Variables

The descriptions of variables used in econometric estimations are provided in Table 8. The choice of variables was informed by empirical literature. In addition, the description involves the measurement of each variable and the expected influence of independent variables on dependent variables.

Table 8: Description of variables for household vulnerability to poverty

Variable	Description	Measurement	Expected sign
Dependent Variable			
VEP	Vulnerability to poverty	Continuous	
VULCAT	Vulnerability categories (1=Not poor, 2=Once poor, 3=Twice poor, 4=Always poor)	Discrete	
Independent Variables			
Gender	Gender of the household head (1=Male, 0 Otherwise)	Binary	-
Hsz	Household size	Continuous	+
Dpratio	Household dependency ratio	Continuous	+
Educ	Household education stock	Continuous	-
Educ1	Household education stock	Continuous	-
Income	Household off-farm income (Kshs)	Continuous	-
Assvalue	Total asset value (KES)	Continuous	-
Tlu	Tropical livestock unit	Continuous	-
Relatives	Number of relative living within and outside the village	Count	-
PartInst	Household participation in rural institution (Index)	Continuous	-
Inputprice	% loss crop and income due to large increase in input prices	Continuous	+
Fudprices	% loss in income due to large increase in food prices	Continuous	+
Illness	% loss of income due to illness of family members	Continuous	+
Drought	% loss in food crop to drought	Continuous	+
Region	Region of residence (1=Western, 2=Eastern)	Binary	±

4.3 Results and Discussion

4.3.1 Descriptive Results

4.3.1.1 Poverty and vulnerability status

Figure 4 presents the ex-post poverty of the sampled households across the three panels. The difference between proportions of non-poor and poor households was statistically significant ($\chi^2 = 55.58$; p=0.000). The head count poverty was 64% in 2011 before increasing to 73% in 2013 and dropping to 50% in 2015. The results indicate dynamic nature of poverty and suggests that poverty fluctuates over time. Nonetheless, the results in Figure 1 only shows households that were poor without indicating their vulnerability. It is also evident that household transited into and out of poverty across the panels.

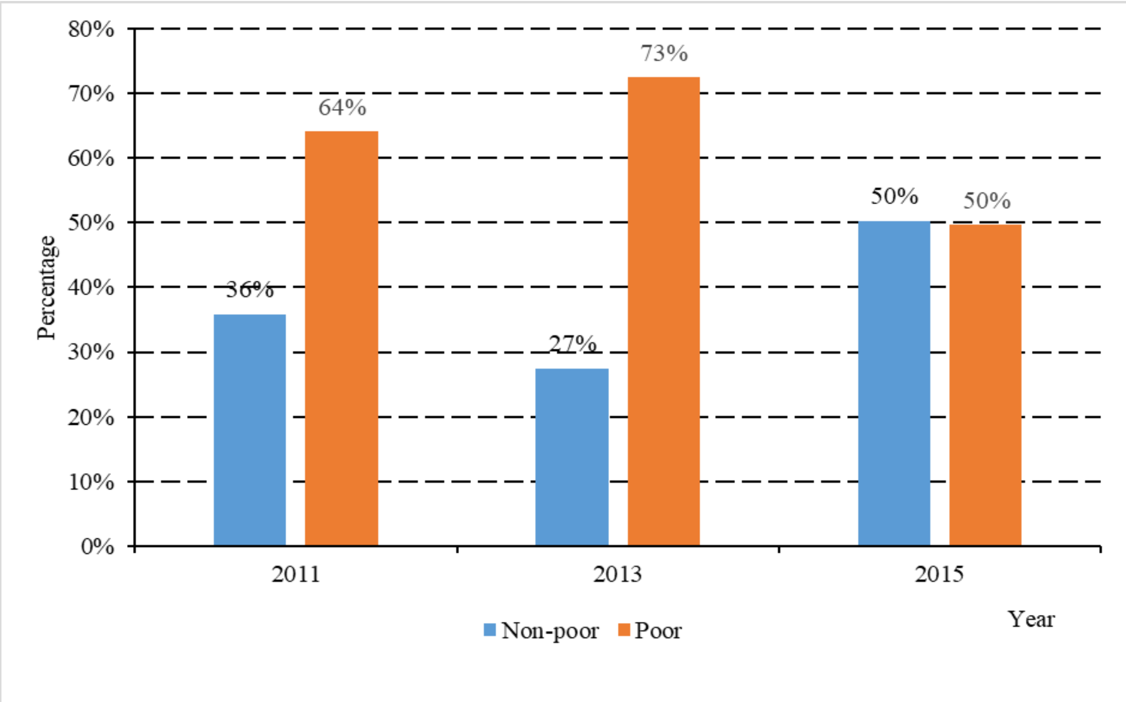

Figure 4: Poverty status across time

The study profiled households into vulnerability statuses to address the shortcoming of ex-post poverty analysis. Table 9 presents transition matrix of the probabilities of households moving into and out of poverty between 2011 and 2015. The rows in Table 9 reflect the initial poverty probabilities in 2011, while columns indicate final poverty probabilities in 2015. However, the results are interpreted with caution. Each year, nearly half (48%) of non-poor households remained non-poor in the next year, while 52% became poor. While non-poor households had 52% chance of becoming poor in each year, poor households had a 34% chance of becoming (returning) non-poor. Besides, the poor households had 65% chances of remaining poor each year.

Table 9: Matrix of probabilities of poverty transitions

	Non-poor	Poor
Non-poor	47.59	52.41
Poor	34.87	65.13

The proportions of poverty spells (transitions) are presented in Table 10. The households that fell into poverty only once between 2011 and 2015 are categorized as once poor, while those that were poor two times across the panels are classified as twice-poor. Whereas the always non-poor households remained non-poor across the three panels, the always poor remained poor from 2011 to 2015. The once poor and twice poor households are the transient poor. Together with the always poor households, transient poor make the vulnerable group of households, while always non-poor are the non-vulnerable households. The results presented in Table 10 shows that 39% of the households were always non-poor across the three panels. Nearly 61% of the households were vulnerable to poverty, with about 9%, 20%, and 32% of them being once poor, twice poor, and always poor. These results provide evidence that that relatively higher proportions of households were at risk of becoming poor in the next year even if they were non-poor in 2011. Thus, relying on static poverty measures may ignore the impact of consumption volatility on household welfare over time (Imai *et al*., 2011).

Table 10: Household vulnerability to poverty

	Pooled	Western	Eastern	χ^2
Always non-poor	38.80%	34.05%	43.95%	12.15***
Once poor	8.96%	9.00%	8.92%	
Twice poor	19.86%	20.35%	19.32%	
Always poor	32.38%	36.59%	27.81%	

Note: *** p < 0.001

Further analysis at agro-ecological level reveals that 66% of the households in western region and 56% of them in eastern region were vulnerable to poverty. The difference in vulnerability levels did not significantly depend on whether the household was in western or eastern region (χ^2=12.15; *p*=0.007). This shows that vulnerability to poverty is a dynamic and spatial phenomenon. These descriptive result contrasts findings by Tsehay (2017) who indicated that besides poverty varying across agro-ecological zones, households experienced huge fluctuations of poverty status over time.

Additionally, this study focused on vulnerability driven by low consumption prospects. Ideally, vulnerability is impacted by variability in consumption expenditure over time. In other words, vulnerability to poverty is the chance of household's consumption lying below the relative poverty line as determined by consumption threshold. Households lying above set vulnerability threshold of 0.50 are said to be at risk of consumption-induced vulnerability because of the probability of consumption lying below the relative poverty line.

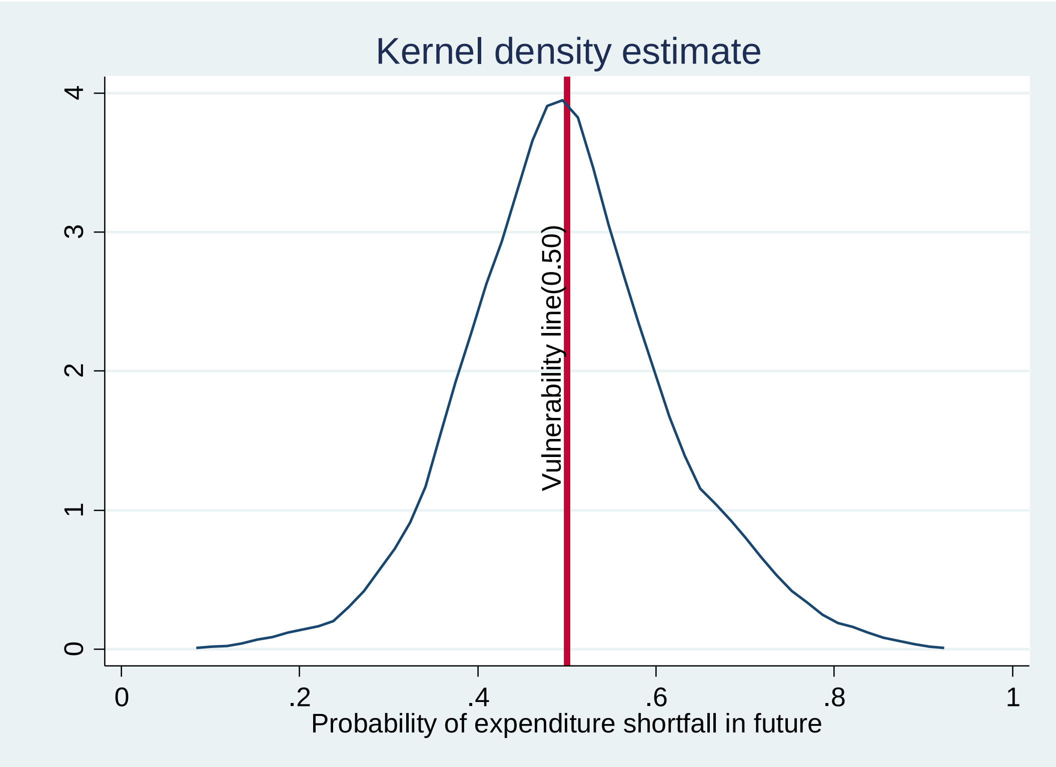

Figure 5: Vulnerability to poverty and the vulnerability threshold.

In Figure 5, the distribution of vulnerability to poverty is unimodal and almost symmetric. This implies that vulnerability to poverty is approximately normally distributed. The peak is around 0.5 probability of consumption expenditure shortfall. In Figure 6, the scatter plots show that vulnerability and the predicted vulnerability are all almost the same. Vulnerability probabilities are denser between 0.4 and 0.6. For non-vulnerable households, the probabilities of vulnerability are sparse with some falling farther below the 0.50.

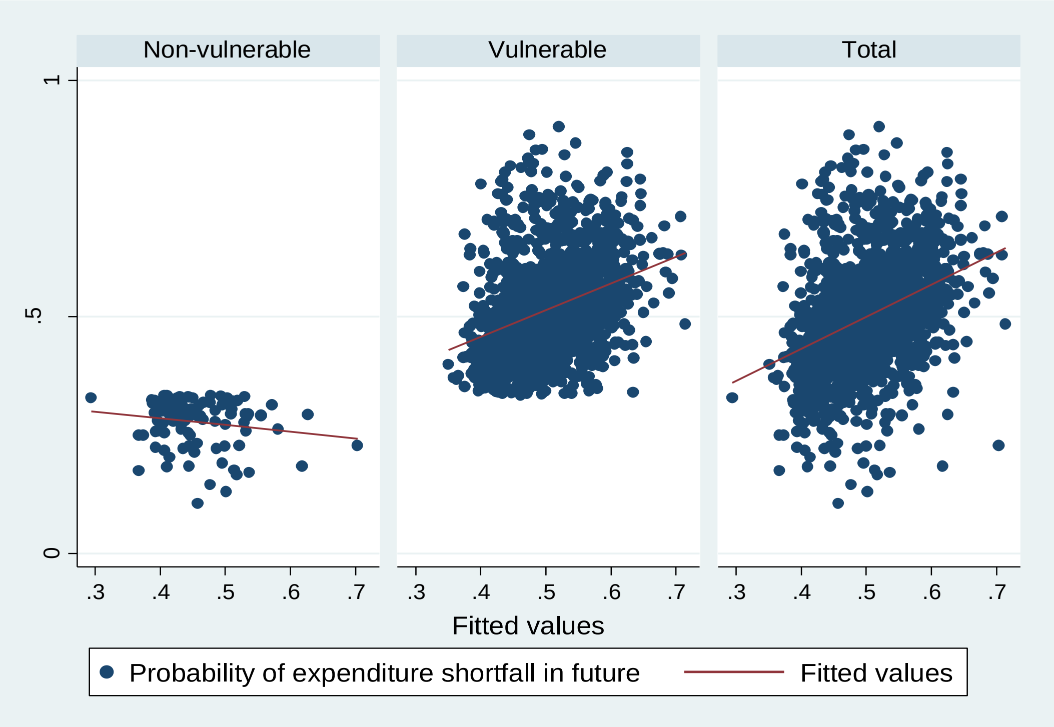

Figure 6: Scatter plots for predicted vs. observed vulnerability to poverty by vulnerability category

4.3.1.2 Idiosyncratic and covariate shocks

The surveys collected information on household exposure to 17 shocks of which 13 were panelled (Table 11). The second, third and fourth columns present occurrences of shocks per wave. The results indicate that rural households face an array of idiosyncratic and covariate shocks. This re-emphasizes theoretical and empirical works that highlight the impact of shocks on the uncertainty of rural households' welfare in developing countries (Jha & Dang, 2010; Chiwaula *et al*., 2011; Hill & Porter, 2017). Theoretical and empirical studies make a common conclusion that covariate shocks affect individual risk attitude than idiosyncratic shocks owing to their significant effect on welfare (Cassar *et al*., 2017). Consistent with this observation, the self-reported occurrence of covariate shocks was higher than the occurrence of idiosyncratic shocks. Combined, drought and a large increase in input and output prices accounted for about 42% of the reported shocks while the most reported idiosyncratic shocks; that is, crop pests and diseases, family illness and livestock diseases or death, accounted for about 26% of the reported shocks across the three panels.

Table 11: Household self-reported shocks per wave

Type of shock	Survey wave 2011	2013	2015	Total	%
Idiosyncratic shocks					
Livestock disease/death	238	202	114	554	6.85
Family illness	314	227	58	599	7.41
Death of household member	101	55	28	184	2.28
Theft of assets or crops	117	134	47	298	3.69
Reduced/failure household business income	93	54	28	175	2.16
Crop pests/diseases	354	360	226	940	11.63
Reduced/loss of employment income	60	20	5	85	1.05
Covariate shocks					
Large decrease in agricultural output prices	203	286	108	597	7.38
Large increase in input prices	382	455	132	969	11.99
Large increase in food prices	358	378	134	870	10.76
Drought	555	499	490	1544	19.10
Too much rain or floods	207	303	178	688	8.51
Hail storm	214	239	128	581	7.19
Total				8084	100

Drought was the most important shock, accounting for about 19% of the shocks across the panels. Specifically, 555 households reported to have experienced drought in the first wave which was more than any other shock. 449 and 490 households reported that they experienced drought in 2013 and 2015, respectively. Surprisingly, almost all households, 98%, reported to have experienced drought during the 2015 wave. Drought occurs frequently and is more likely to be reported by individuals and communities given that its effect is more profound than the effects of other climatic shocks (Katchele, 2017). Large increases in input and output prices were the second and third most reported shocks, accounting for almost 12% and 11% of the total self-reported shocks, respectively. A large increase in input prices may directly cause a decline in household food consumption as a result of low agricultural productivity that may be caused by low input application. A large increase in food prices may also cause low access to food as a result of low purchasing power. These possibly impacted on farmers' perceptions of the two types of shocks.

Overall, the sampled households reported crop pests or diseases as the most common type of idiosyncratic shocks across the three-panel waves. About 940 incidents (about 12% of all sampled households) of crop pests or diseases were reported across the three waves. This finding is not surprising since crop pests and diseases directly affect smallholder farmers' livelihoods. Events that negatively impacts on agricultural productivity are likely to be perceived as shocks since they cause damage to important food crops, resulting in low yields and a decline in own food consumption.

Family illness and livestock diseases were the second and third most reported idiosyncratic shocks, jointly accounting for about 14% of reported shocks. The rank of these shocks can be explained by their high frequency of occurrence or possibly due to their effect on rural livelihoods. Since most of the rural household have low access to formal health insurance, illness of household member(s) may represent an important financial burden that diverts income away from household consumption. This influences individual perceptions of sickness as a shock. This finding underscores the argument by Gloede *et al*. (2015) that individuals are more likely to perceive illness as an important shock given the magnitude of its effect on household welfare.

4.3.1.3 Sustainable agricultural intensification practices adoption patterns

Table 12 presents clusters of SAIPs that were adopted across the three panels. Nearly 44% of smallholder farmers across the three panels used cluster 5 of the SAIPs. Approximately 33% and 32% of the households applied SAIPs 3 and SAIPs 4 respectively.

The cluster SAIPs 1 combinations were the least used cluster, with only 20% of the household adopting.

Table 12: Clusters of sustainable agricultural intensification practices adopted by farmers

Clusters	Combinations	Combination description	Percent
SAIPs 1	VRM	Seed variety, crop rotation, and manure	20.34
	VRMF	Seed variety, crop rotation, manure, and fertilizer	
	VRMFI	Seed variety, crop rotation, manure, fertilizer, and intercropping	
SAIPs 2	VFI	Seed variety, fertilizer, and intercropping	26.31
	VMFI	Seed variety, manure, fertilizer, and intercropping	
	VRFI	Seed variety, rotation, fertilizer, and intercropping	
SAIPs 3	VM	Seed variety and manure	32.83
	VMT	Seed variety, manure, and minimum tillage	
SAIPs 4	VI	Seed variety and intercropping	32.16
	VIT	Seed variety, intercropping, and minimum tillage	
SAIPs 5	VF	Seed variety and fertilizer	44.21
	VMI	Seed variety, manure, and intercropping	
SAIPs 6	VR	Seed variety and crop rotation	26.00
	VRI	Seed variety, crop rotation, and intercropping	
	VRMI	Seed variety, crop rotation, manure, and intercropping	
SAIPs 7	V	Seed variety	27.22
	VMF	Seed variety, manure, and fertilizer	
	VT	Seed variety and minimum tillage	

Note: V=Seed variety, F=fertilizer, I=intercropping, M=manure, R=crop rotation, T=minimum tillage

4.3.1.4 Socioeconomic and Social Capital Characteristics

The results of socioeconomic and institutional characteristics disaggregated by vulnerability status are presented in Table 13. The per capita adult equivalent consumption expenditures for vulnerable households were significantly lower than that of non-vulnerable households (F=266.62; p=0.000). The average age of households heads of always poor, once-poor, twice poor, and always poor households were 54, 51, 54, and 53 years respectively. Nonetheless, the differences in age did not different significantly, suggesting that household vulnerability status did not depend on the age of household head. The proportions of vulnerable female-headed (63.83%) and male-headed (60.58%) households were significantly higher than the proportions of non-vulnerable male (39.42%) and female-headed (36.17%) households (χ^2=10.21; *p*=0.017). This finding underscores results reported by numerous studies in developing countries. The studies established that female-headed households were disproportionately vulnerable to poverty than male-headed households, which they attributed to most female-headed households being headed by single or widowed women or absentee spouses (Klasen *et al*. 2011; Muleta & Deressa, 2014).

Furthermore, vulnerability to poverty did not depend on educational attainment of household members (*F*= 1.99; *p*=0.113). Nevertheless, other demographic characteristics suggest that vulnerable households had significantly higher number of dependants (*F*= 6.35; *p*=0.003) and larger household sizes (*F*=9.95; *p*=0.000) than non-vulnerable households. These findings suggest that large households and a high number of dependents represent an enormous burden to the economically active members which strains household consumption over time.

Financial and physical assets play an integral role in rural livelihoods since they are important inputs in productive activities. Summary statistics in Table 6 indicate that whereas the annual off-farm incomes across the three panels did not differ significantly (*F*=0.79; *p*=0.498) by vulnerability status, and value of assets and tropical livestock units for the vulnerable and non-vulnerable households were statistically different at 1% and 5% significance level respectively. Vulnerable households owned significantly lower numbers of livestock, as well as agricultural and non-agricultural assets. This may suggest that vulnerable households are poor since assets are a store and indicator of wealth. Overall, the significant differences in financial and physical assets between vulnerable and non-vulnerable households reveal that asset ownership and livestock help households to smoothen consumption over time.

Table 13: Household socioeconomic and institutional characteristics

	Non-vulnerable	Vulnerable			
	Always non-poor	Once poor	Twice poor	Always poor	
Variable	Mean	Mean	Mean	Mean	t/ χ^2
Household per capita consumption (KES)	80,676(51087)	20,796.43(8512)	21,378.47(9504)	19,589.95(8447)	266.62***
Demographic and household characteristics					
Age of household head	53.86 (14.09)	50.66(14.36)	54.25(13.98)	53.36(13.07)	1.54
Gender of household head (%)					
Female	36.17	5.85	16.49	41.49	10.21**
Male	39.42	9.7	20.65	30.23	
Education stock	36.73(20.33)	32.76(17.68)	37.29(19.99)	34.36(17.92)	1.99
Adult Equivalent	4.49(2.16)	4.45(2.03)	5.27(2.33)	5.23(2.15)	9.95***
Dependency ratio	0.83(0.86)	1.09(1.14)	0.96(0.76)	1.13(1.02)	6.35***
Financial and physical capital					
Off-farm income (KES)	371,883(290,813)	69,080(59,272)	86,778(17,020)	47,114(41,114)	0.79
Total value of asset (KES)	1176,594(152,669)	889,250(490,180)	933,247(148,2609)	764,718(53,751)	4.5***
Tropical livestock units	1.46(3.09)	1.12(1.05)	1.09(1.71)	0.95(1.28)	3.36**
Social capital					
Number of relatives	15.02(25.37)	11.68(9.30)	11.256(14.21)	10.18(13.01)	4.24***
Level group participation	0.18(0.17)	0.18(0.12)	0.15(0.11)	0.13(0.11)	9.27***

Note: * p < 0.05; ** p < 0.01; *** p < 0 1 Standard error are presented in parenthesis

The number of relatives was statistically different at 1% significance level (*F*=4.24; *p*=0.006). Vulnerable households had a lower number of relatives living within and outside the village. These results appear to suggest that extended family and kinship ties are important in the reduction of vulnerability to poverty among rural households. Extended families offer social safety nets for households that struggle to make ends meet as a result of negative shocks. Additionally, participation in rural institutions was significantly higher for non-vulnerable households than non-vulnerable households (*F*= 4.24; *p*=0.006). The result suggests that groups could have been a powerful social network and capital that provided vital agricultural and market information, which enabled households to overcome emerging shocks that threatened consumption.

4.3.2 Empirical Results

4.3.2.1 Model Diagnostics and Fitness

First, the Wooldridge test for serial correlation in panel-data models was performed under the null hypothesis of no first order serial correlation. The results suggest the possibility of serial correlation hence the rejection of null hypothesis of autocorrelation (Appendix 10). Clustered errors were estimated to account for serial correlation. Following Green (2011), the modified Wald statistic for group-wise heteroscedasticity was applied to test heteroscedasticity. The test result (Appendix 11) indicates presence of heteroscedasticity, hence the rejection of the null hypothesis of constant variance of the residuals. Therefore, robust standard errors were estimated to control for heteroscedasticity.

Furthermore, it is important to estimate pooled ordinary least squares (POLS), random effects (RE) and fixed effects (FE) models as the first step for delineating the appropriate model for estimating the effect of SAIPs on household vulnerability to poverty. The standard errors are adjusted to account for serial correlation and heteroscedasticity in the respective models. The Langrangian multiplier (LM) test was performed to test appropriateness of RE against the POLS. The results in Appendix 12 provide evidence that there was significant differences across households ($\chi^2 = 30.09$; *p*=0.000). Thus, RE is superior to PLOS. Additionally, panel *F*-test was performed to determine the most appropriate model between POLS and FE under the null hypothesis that the observed and unobserved fixed effects are not significantly different from zero. The results showed that fixed effects were not equal to zero (*F*=1.74; *p*=0.000). Thus the null hypothesis is rejected and conclusion made that POLS results would be biased if $Cov(X_{it}, u_i) \neq 0$. Therefore, FE was more appropriate in fitting the association between adoption of SAIPs and household vulnerability to poverty.

The Hausman test was applied to discriminate between FE and RE under a null hypothesis that coefficients of the two models are equal based on the individual specific effects. The Hausman *p*-value of the test statistics, (χ^2=204.13; *p*=0.000), is lower than 5% level of significance (Appendix 13). Hence, the null hypothesis was rejected and conclusion made that there are systematic differences in coefficients of FE and RE model. Further inference is made that there is presence of correlation between observed and unobserved individual heterogeneity. Hence, based on the Hausman test, FE model is consistent and appropriate in fitting the data.

Additionally, FE fitness statistics (*F*=12.83; *p*=0.000), as well as the RE ordered probit model test statistics (χ^2=123.30; *p*=0.000), were statistically significant, meaning that both models fit the data well. The likelihood ratio test (χ^2=678.11; *p*=0.000) of RE ordered probit model indicate that the model was most appropriate in estimating the probabilities of vulnerability than univariate probit model. Furthermore, interclass correlation (rho=0.46) of the FE model suggests that 46% of the variance were due to differences across panels.

4.3.2.2 Econometric Results

Table 14 presents FE estimates of household vulnerability to poverty. The RE ordered probit results are provided alongside FE results to indicate effect of socioeconomic and institutional factors, and SAIPs adoption on vulnerability to poverty. Results show that while adult equivalent household size (β=0.066; *p*=0.000) and dependency ratio (β=0.040; *p*=0.001) were statistically significant in FE model, only adult equivalent (β=0.332; *p*=0.000) was significantly associated with household vulnerability in RE ordered probit model. Household educational stock was statistically significant in RE ordered probit regression (β= -0.025; *p*=0.000) but not significant in FE model (β=-0.001; *p*=0.281).

Table 14: FE and RE ordered probit estimates of household vulnerability to poverty

	Fixed Effects		RE Ordered Probit	
Variable	Coef.	Std. Err.	Coef.	Std. Err.
Household characteristics				
Gender of HH head	0.059	0.036	0.033	0.176
Age of HH head	-0.004	0.003	-0.004	0.008
Education stock	-0.001	0.001	-0.025***	0.006
Adult equivalent HH size	0.066***	0.011	0.332***	0.056
Dependency ratio	0.040***	0.012	0.057	0.073
Financial and physical capital				
Tropical livestock units	-0.004	0.004	-0.035	0.028
Log of asset value	-0.004	0.004	-0.024	0.022
Log of off-farm income	-0.003	0.002	-0.026**	0.012
Social capital and networking				
Number of relative	0.000	0.000	-0.005*	0.003
Group membership	0.042	0.067	-0.064	0.391
Sustainable Intensification practices				
SAIPs 3	-0.328***	0.077	-2.065***	0.512
SAIPs 4	-0.007*	0.004	-0.938***	0.209
SAIPs 5	-0.013	0.054	-0.151	0.313
Shocks				
Sickness	0.001**	0.000	0.002	0.002
Loss of employment	0.001	0.001	-0.003	0.003
High input prices	0.001**	0.000	0.003	0.003
High food prices	0.001*	0.000	0.005**	0.003
Drought	0.000*	0.000	0.002	0.002
Region	-0.031	0.071	-0.208	0.211
Constant	0.513***	0.182	5.561***	0.730
F(19,963)/Wald χ^2	12.83***		123.30***	
R^2/LR test	0.15		678.11***	
Sigma_u/ cut1	0.23		-2.68	
Sigma_e/ /cut2	0.25		-2.23	
Rho//cut3	0.46		-0.38	

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

Furthermore, while off-farm income (β=-0.026; p=0.037) and number of relatives (β=-0.005; p=0.079) were significantly associated with household vulnerability to poverty in RE ordered probit model, they had no significant influence in FE model. Two clusters of SAIPs combinations were significantly associated with household vulnerability in the two models. The cluster SAIPs 3 were improved seed variety, manure, and minimum tillage and SAIPs 4 were improved seed, intercropping, and minimum tillage. On the other hand, while sickness, high input and food prices, and drought were significant in FE model, only high food price was significant in RE ordered probit model.

Results in Table 14 indicate that cluster SAIPs 3 and SAIPs 4 combinations were statistically significant in influencing household vulnerability to poverty. Household that used different combinations of improved seed variety, manure, and minimum tillage and improved seed, intercropping, and minimum tillage had low likelihood of becoming poor across the three panels. This result is a positive indication of the potential of SAIPs in successfully yielding the desired agricultural outcomes. Adoption of SAIPs possibly reduced the element of risk in agricultural production by building resilience of maize-legume production systems against extreme climatic events which, in turn, reduced the downstream risk of low agricultural productivity.

Multiple adoption of SAIPs may have ameliorated the effect of extreme climatic events, thereby reducing crop failure. This may have enabled households to smooth production and consumption. Furthermore, SAIPs may have had productivity-enhancing effects, leading to productivity gains over time. In other words, multiple SAIPs adoption possibly exploited complementarity of SAIPs which benefited households through crop productivity increases, which translated into improved consumption and welfare (Biru *et al*., 2020). The cumulative effect of productivity gains and reduced crop failure may have translated into improved availability of food and increased incomes which allowed farmers to escape poverty or reduced the risk of falling into poverty. The finding is in agreement with previous studies by Magrini and Vagani (2016), Di Falco and Veronesi (2018) and Niles and Salerno (2018),

Household size had positive and significant "within-household" effect on vulnerability to poverty. On average, additional adult equivalent in household size over the years increased the risks of households becoming poor. This indicates that large-sized households are at a greater risk of being poor compared small-sized households. Household size possibly decelerates growth in income and poverty reduction at household level due to a higher per capita consumption. More resources are needed to meet the basic needs of larger households, thereby increasing the risk of becoming poor. The finding agrees with the results by Glauben *et al*. (2012), Ndobo and Sekhampu (2013), and Afera (2015) who found higher probabilities of large-sized households falling into poverty. Additionally, Obare and Kariuki (2014) also found a positive association between household size and vulnerability to poverty in western and eastern Kenya.

Moreover, FE model showed that dependency ratio had positive within-household effect on the probability of households being poor. The result suggests that households composed of a large proportion of children and elderly are at a greater risk of becoming poor. This can be attributed to children and elderly being less economically active and, therefore, representing an economic burden to economically active household members. A higher dependency ratio increases the demand for basic household needs which burdens the working-age household members. The wealth generated by working-age population is possibly directed to meeting increasing household demand for food and non-food consumption instead of investment in consumption-safeguarding strategies. Dartanto and Nurkholi (2013) and Lekobane and Seleka (2017) reported similar results by indicating that a high number of dependant members undermined improvement of welfare of Indonesian and Botswanan households respectively. Moreover, Demissie and Kasie (2017) indicated that dependency ratio increased Ethiopian households' vulnerability to poverty because of it negative effect on consumption.

The RE ordered probit results indicated that vulnerability to poverty was negatively and significantly associated with household educational stock. In other words, the higher the educational attainment of household members the lesser the household was at risk of becoming poor transient poor and remaining poor. The household educational stock is a reflection of human capital of households. Households with highly educated members possibly were more knowledgeable of strategies to deploy to cushion themselves against consumption shortfall both in short-term and long-run. Additionally, higher educational stock possibly influenced the innovativeness of household members, translating into improved consumption expenditure. A similar result was reported by Mina and Imai (2017) who linked reduced vulnerability to poverty to ability of highly educated household heads finding better paying jobs. In contrast, Sun *et al*. (2020) found that an increase in the number of years of education of household head increased household vulnerability to poverty in rural China, which they attributed to high economic cost of education.

The number of relatives living within and outside the village was negatively associated with household vulnerability to poverty. The finding appears to imply that relatives play an important role in reducing household vulnerability to poverty. Households may have received, relied on, or sought the support of relatives when faced with consumption shortfalls emanating from economic or non-economic hardships. In this context, relatives may have been source of resources that households used to smooth consumption. This result reemphasizes argument that extended families offer support to households during hardship times, enabling such households to sustain their consumption.

Off-farm income significantly reduced vulnerability to poverty over time. The significant within-household impact of off-farm income on vulnerability underline the integral role played by diversification of livelihood strategies. Fundamentally, off-farm income smoothed household consumption against short-term stochastic fluctuations in consumption, thereby reducing ex-ante risk of becoming poor. In addition, off-farm income could have been more rewarding than on-farm agricultural income in terms of off-setting the unanticipated household consumption disruptions. These finding corroborates results reported by Issahaku and Abdul-Rahaman (2019) who established a negative relationship between vulnerability to poverty and off-farm income among Ghanaian farmers. In another study, Kidane and Zegeye (2019) established that income diversification reduced propensity of Ethiopian households becoming poor.

Poor health of household members was an important idiosyncratic shock that impacted on household vulnerability to poverty in FE model. Specifically, sickness of household members increased the probability of households being poor between 2011 and 2015. First, sickness possibly disabled the productive capacity of household members. Second, sickness could have increased household health care costs through payment of medical bills which negated efforts to improve consumption of food and durable items. Third, health shocks could have compelled households to dispose productive agricultural and non-agricultural assets to off-set hospital and other medical expenses. These possibilities could have eroded the ability of the already poor households and previously non-poor households to improve consumption. This finding is in line with results of studies conducted in Bangladesh (Kabir *et al*., 2019) and South Africa (Morudu & Kollamparambil, 2020).

Drought was a climate change-related covariate shock that influenced household vulnerability to poverty. The probability of being poor was positively related to the loss of food crops as a result of droughts that occurred in the last decade. Droughts cause crop failure, resulting in a decline in the availability of food. Crop failure represents an important economic loss which directly causes fluctuations in household income and consumption. Additionally, drought constrained agricultural productivity, which slowed down improvement in consumption for the already poor households and reduced per capita consumption expenditure for both poor and non-poor households. Result by Hill and Porter (2011) and Sam *et al*. (2017) support this finding.

Furthermore, FE model shows that high input prices increased the probability of households becoming poor across the three panels. This result was expected because high input prices reduce consumption of yield-enhancing agricultural technologies. Additionally, high input prices reduced the optimal use of soil fertility enhancing technology which disabled farmers' ability to overcome the constraint of extensive soil mining. Low input consumption resulted in low crop yields, translating into low food availability and vulnerability to consumption shortfall. The high investment cost in acquiring farm inputs could also have reduced the returns from agricultural production which exposed households to poverty.

Additionally, large increases in food prices across the panels had positive and significant within-household effect on household vulnerability to poverty. This finding is plausible since price spikes reduce household disposable incomes, thereby increasing consumption volatility. The impact was probably more devastating for households with a high share of staple food items in food basket. A large increase in prices of staple food possibly reduced the amount of food bought and consumed by households, subsequently putting them at risk of becoming poor. Furthermore, a large increase in food prices may have reduced household purchasing power which, in turn, resulted in declining consumption. The net effect of both reduced disposable incomes and purchasing power of households is food deficits, which increase the likelihood of non-poor households becoming poor or increases the severity of poverty for the already poor households. This finding is widely acknowledged in poverty and vulnerability empirical literature (Levin & Vimefall, 2015; Avalos, 2016; Chiripanhura & Nino-Zarazua, 2016; Hill & Porter, 2017). Abdullah and Kalim (2016) contradicted the finding of this study by indicating that escalation of global food price was associated with increased per capita consumption in South Asian countries.

4.4 Conclusion

Smallholder agriculture in Kenya is rainfall dependent, exposing cropping systems to the adverse effect of climate change. For this reason, climate change and weather variability causes crop failure, resulting in reduced agricultural productivity and farm income. For instance, the study found that drought increased household vulnerability to poverty through its direct impact on food crop output. This exposes already poor household to severe poverty and puts the non-poor households at risk of becoming poor. Additionally, community-wide economic covariate shocks, including high input and food prices, also exacerbated household vulnerability to poverty. Furthermore, the rural households are exposed to idiosyncratic shock which weaken their resilience to poverty. For instance, health-related shocks such as sickness of household member increased the likelihood of households becoming poor.

Nonetheless, adoption of SAIPs ameliorates the devastating effects of climate variability on agricultural production and incomes, and indirectly impacts on food prices, which improves household welfare. The evidence generated from the study findings suggests that farmers respond to weather variability and climate change by adopting sustainable agricultural intensification practices as ex-ante risk management strategies. Furthermore, farmers do not adopt the practices in isolation. Instead, SAIPs are adopted as packages or combination to enhance the possibility of effective alleviation of undesired consequences of shocks. The study established that adoption of combinations of SAIPs reduced household vulnerability to poverty. The possible explanation for negative effect can be attributed to the productivity enhancing potential of SAIPs and the ability to improve the resilience of maize-legume production systems against adverse climate change effects. This finding affirms the potential of SAIPs in alleviating vulnerability to poverty as propounded in literature. The results justify a national agricultural policy that promotes dissemination, adoption, and continued use multiple sustainable agricultural intensification practices. Therefore, robust public-private partnerships in agricultural extension and training and strengthening rural institutions that support technology adoptions should be encouraged to improve diffusion and adoption of SAIPs.

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CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides the summary of the study. Additionally, it provides the conclusion based on the findings of the study. It also provides policy recommendations and areas of further research.

5.2 Discussion

Food insecurity and poverty are important challenges to achievement of global sustainable development goals. Notably, food insecurity and poverty are synonymous with agriculture in Kenya. A majority of poor and food insecure households in the country are rural smallholder farmers who almost entirely depend on agriculture as the main source of livelihoods. To this end, government and development agencies have tailored their interventions in agriculture to enhance the contribution of smallholder agriculture to reduction poverty and food insecurity. The common intervention is improving agricultural productivity through adoption of SAIPs. The dissemination and adoption of SAIPs are seen as critical to overcoming low consumption of improved agricultural technology and as a step to enhancing the resilience of smallholder agriculture to devastating effects of climate change.

The SIMLESA project brought together public and private agricultural stakeholders for the purpose of encouraging the uptake of SAIPs. The project played an instrumental role in the dissemination and adoption of SAIPs among maize-legume smallholder farmers in Kenya and East and Southern Africa. Besides encouraging adoption of SAIPs, the SIMLESA project aimed at overcoming socioeconomic challenges associated with smallholder agriculture. For instance, the programs aimed at enhancing the contribution of women in agriculture, which would translate into improvement in household food security and welfare outcomes. To this end, innumerable studies have focused on understanding the implication of SAIPs adoption on livelihood outcomes such as income, food security and nutrition, and poverty. In addition, there has been much focus on the climate change mitigating potential of SAIPs. This study determined effects of SAIPs and shocks on household vulnerability to poverty, which are largely missing in recent adoption literature. In addition, the study focused on determinants of the differences in gender perceptions of household food security.

First, results indicated that nearly one-quarter (24.78%) and less than one-quarter of female respondents perceived their households as food secure in 2013. However, more female (46%) than male (42%) respondents perceived households as food secure in 2015. Furthermore, about 30% and 27% of female respondents reported that their households were severely food insecure in 2013 and 2015 respectively. In contrast, nearly 27% and less than one-quarter (24%) of male respondents indicated that their households were severely food insecure in 2013 and 2015 respectively. The factors that affect food security perception differed depending on gender of the respondents. While female respondents' food security perceptions were positively influenced by household dependency ratio, educational attainment of household head and number of relatively living within and outside the village significantly reduced their perceptions of households as food insecure. In contrast, gender and age of the household head increased the likelihood of male respondents perceiving household as food insecure. While participation in rural institutions, access to credit, and off-farm income were significantly associated with female respondents' food insecurity perceptions, they did not have significant influence on male respondents' perceptions.

Second, nearly 64% of the sampled households were poor in 2011. The level of poverty increased to 73% in 2013 before reducing to 50% in 2015. Nonetheless, nearly 61% of the households were vulnerable to poverty across the three panels, which is higher than 50% poverty rate by the end of 2015. Only 39% of households were non-vulnerable to poverty across the three panels. The results show that although some households may be non-poor in one period, they may still be at risk of becoming poor in the next periods when subjected to covariate shocks. Health related shock (sickness) was an important idiosyncratic shock that increased household vulnerability to poverty. Furthermore, large increases in output and input prices, as well as drought, significantly increased household vulnerability to poverty. Besides, household characteristics, including adult equivalent household size and dependency ratio increased the risk of poverty. Additionally, education and number of relatives reduced the likelihood of household becoming poor. Nevertheless, adoption of combinations of improved seed variety, manure, and minimum tillage (SAIPs 3) and improved seed, intercropping, and minimum tillage (SAIPs 4) reduced household vulnerability to poverty.

5.3 Conclusions

i. This study established no statistical difference in gender perception of household food security. However, there were differences in number of determinants that conditioned gender perceptions of food security. While six variables were significantly associated with male respondents' perceptions of food security, females' perceptions of household food security were influenced by ten factors. The findings suggest that gender matters in household food security perceptions and that the determinants of the food security perceptions vary across gender.

ii. Besides demographic characteristics, idiosyncratic and covariate shocks represent a significant burden to already poor household preventing them from escaping from poverty. Additionally, shocks increase the likelihood of non-poor households becoming poor. Health-related shocks and covariate shocks, including drought and high input and food prices negate household progress out of poverty and reduce the resilience of non-poor households against consumption losses. Nonetheless, multiple adoption of sustainable agricultural intensification practices increases resilience of smallholder agricultural production systems, allowing productivity improvement. This results in increased food availability and farm income, which enhances household welfare and prevents households from falling into poverty.

5.4 Policy Recommendations

Based on the foregoing findings, a raft of policy implications is recommended. They are as follows:

i. In terms of gender perceptions of household food security, gender equality policy should be grounded on encouraging progressive social and economic advancement of gender roles in agriculture and rural institutions. The policies should focus on eliminating barriers to achievement of gender equality in agriculture and participation in rural institutions. This should involve redefining of gender roles in households and agriculture and enhancing gendered contribution to household food security. This can be achieved through gender mainstreaming and reinforcement of empowerment programs such as land reforms that encourage women ownership of productive agricultural resources, training in agriculture, and market participation.

ii. Ex-ante adaptation strategies should target to increase household resilience to shocks by encouraging adoption of SAIPs. Climate change adaptation discourses should encourage adoption of combinations of SAIPs instead of focusing on isolated adoption of individual practices. This would provide opportunities for smallholder farmers to exploit the complementarities of SAIPs. Agricultural policy needs to accelerate dissemination of multiple SAIPs by improving quality of public extension. Public extension should reformulate extension messages to promote knowledge of SAIPs. The extension messages, plans, and dissemination initiatives should mainstream SAIPs at local level, depending on the local agro-ecological contexts. In addition, agricultural trainings should be tailored towards enabling farmers to gain knowledge in identifying and prioritizing SAIPs that have higher investment payoff when adopted jointly.

5.5 Areas of Further Research

Although the study contributes immensely to the growing vulnerability and poverty literature in developing countries, it is not devoid of shortcoming. First, the study used highly clustered samples, that is, the households were drawn from just five out of the forty-seven counties in Kenya. Therefore, the results may not entirely be representational of the vulnerability statuses in the country which limits it generalizability. Second, the study did not capture the effect of adoption and dis-adoption of sustainable agricultural practices on multi-dimensional poverty and vulnerability. Therefore, future research should consider measuring multi-dimensional poverty and vulnerability across several counties and regions. Furthermore, future research focus on establishing dynamic impact of adopting and dis-adopting of combinations of sustainable agricultural intensification practices.

APPENDICES

Appendix 1: Questionnaire

HOUSEHOLD QUESTIONNAIRE MODULES FOR ADOPTION PATHWAYS WAVE II
(PRIMARY RESPONDENT: a person who makes most of the production decision**)**

Introductory statement:
"Dear Sir/Madam, I work for Egerton University, Njoro. We are conducting a survey in collaboration with CIMMYT to study production, marketing and livelihoods in your village. Your response to these questions would remain anonymous. Taking part in this study is voluntary. If you choose not to take part, you have the right not to participate and there will be no consequences. Thank you for your kind co-operation"

MODULE 1. HOUSEHOLD AND VILLAGE IDENTIFICATION

Household Identification	Code
1. Region:	0 1
2. County:	
3. Sub-county:	
4. Location:	
5. Sub-Location:	
6. Village:	
7. Name of household head:	
8. Sex of household head 0 = Female 1=Male	
9. Name of the respondent (include grandfather name):	
10. Sex of respondent 0 = Female 1=Male	
11. Name of respondent's spouse	

Interview details	Code
13. Date of interview (dd/mm/yyyy):	/ / 2015
14. Time started (24 HR)	
15. Name of enumerator	
16. Name of supervisor:	
17. Name of data entry clerk	

GPS reading of homestead
18. Way point number
19. Latitude (North)
20. Longitude(East)
21. Altitude (meter above sea level)

MODULE 2: HOUSEHOLD COMPOSITION AND CHARACTERISTICS

ID CODE	Name of household member [Start with respondent]	Sex 1=M 0=F	Relationship to the household head CODE 1	Age (complete years)	Marital status? CODE 2	Education (years) CODE 3	Primary occupation CODE 4
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
1							
2							
3							
4							
5							
6							
7							
8							
9							

CODE 1	**CODE 2**	**CODE 3**	**CODE 4**
1.Household head 2.Spouse 3.Son/daughter 4.Parent 5.Son/daughter-in-law 6.Grandson/granddaughter 7.Other relative 8.Hired worker 9.Other, specify……………	1.Married living with spouse 2.Married living without spouse 3.Divorced/separated 4.Widoe/widower 5.Never married	0. None/Illiterate 100. Religious education 1. Adult education or 1 year of education * Give other education in years	1.Farming (crop+ livestock) 2. Salaried employment 3.Self-employed off-farm 4.Casual labourer on-farm 5.Casual labourer off-farm 6.School/college child 7.Non-school child

MODULE 6: HOUSEHOLD EXPENDITURE FOR THE LAST 12 MONTHS
PART A: FOOD CONSUMPTION

Item	Bought in the last 12 months only for consumption							
	Qnt	**Unit**	Freq. of buying	Total number of times bought in the year	Avg. qty each time	Total qty per year	Avg. price	Total cost
A1	**A2**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11=9x10**
Staple foods								
1. Maize grain								
2. Rice								
3. Sorghum								
4. Millet								
5. Cassava								
6. Potatoes								
7. Beans								
8. Cowpea grain								
9. Groundnuts								
10. Pigeon pea								
Vegetables								
11. Tomatoes								
12. Onions								
13. Cabbage								
14. Kale								
15. Carrot								
16. Pumpkin								
17. Pepper								
18. Garlic								
Fruits								

19. Oranges								
20. Mangoes								
21. Pawpaw								
22. Pineapple								
23. Sugar cane								
24. Bananas								
25. beef/meat								
26. Pork								
27. Poultry meat								
28. Fish								
29. Milk								
30. Eggs								
31. Cheese								
32. Butter								
33. Honey								
Beverages and drinks								
34. Tea								
35. Coffee								
36. Soft drinks								
37. Beer								
38. Cooking fat								
39. Bread								
40. Sugar								
41. Salt								
42. Ginger								

MODULE 6: HOUSEHOLD EXPENDITURE FOR THE LAST 12 MONTHS (CONTINUED)
PART B: NON-FOOD EXPENDITURE IN LAST 12 MONTHS

Expense Item	Unit	Frequency of purchase	Average quantity each time	Total quantity per year	Average per unit price(KSh)	Total cost
B1	**B2**	**B3**	**B5**	**B6**	**B7**	**B8=6*7**
1. Clothing						
2. Beddings						
3. Electricity						
4. Fuel wood						
5. Charcoal						
6. Kerosene						
7. Batteries						
8. School fees						
9. School books and supplies						
10. Health care						
11. Grain milling						
12. Church contributions						
13. Contributions to associations/cooperatives						
14. House building/construction						
15. Newspapers, magazines etc						
16. Travel expenses						
17. Mobile phone air time (voucher)						
18. Kitchen utensils						
19. Household hygiene						
20. Furniture (tables, chairs, beds etc)						
21. Home repairs						
22. Purchase of bicycle, motorcycle						
23. Repairs for vehicles,						

bicycles etc						
24. Petrol and engine oils for cars						
25. House rent						
26. Utility bills (water, telephone etc)						
27. Cigarettes, tobacco etc						
28. Remittances paid						
29. Ceremony and other entertainments						

INDIVIDUAL QUESTIONNAIRE MODULES

(PRIMARY RESPONDENT AND SPOUSE INTERVIEWED CONCURENTLY BUT SEPARATELY)

Respondent sex…………………………………**CODES 0 = Female 1=-Male**

MODULE 7: SOCIAL CAPITAL, NETWORKING AND INFRASTRUCTURE

PART A: PARTICIPATION IN RURAL INSTITUTIONS

Variable Code	Institution Type	Are you currently a member of any of the following group? **0=No; 1=Yes**	Year joined **YYYY**
A1	**A2**	**A3**	**A4**
1.1	Savings and credit association		
1.2	Merry-go-round		
1.3	Input supply group, farmer cooperative union		
1.4	Crop or seed production group		
1.5	Water User's Association		
1.6	Crop marketing group		
1.7	Women's Association/group		
1.8	Youth Association		
1.9	Church/mosque association/congregation		
1.10	Development group (*nyumba kumi*)		

Codes: 1. No input 2. Input into very few decisions 3. Input into some decisions 4. Input into most decisions, 5. Input into all decisions

MODULE 7: SOCIAL CAPITAL, NETWORKING AND INFRASTRUCTURE (CONT'D)

PART C: SOCIAL NETWORKS

QUESTION			CODE	RESPONSE
C1	How many years have you been living in this village?			
C2	How many people that live WITHIN this village can you rely on in times of need?	Relatives	Number of RELATIVES	
		Non-relatives	Number of NON-RELATIVES	
C3	How many people that live OUTSIDE this village can you rely on in times of need?	Relatives	Number of RELATIVES	
		Non-relatives	Number of NON-RELATIVES	
C4	Are any of your friends or relatives in leadership positions in governmental institutions within and outside this village?		0=No 1=Yes	
C5	How many grain traders do you know WITHIN this village who could buy your grain?		Number of grain traders	
C6	How many grain traders do you know OUTSIDE of this village who could buy your grain?		Number of grain traders	

MODULE 9: HOUSEHOLD FOOD INSECURITY ACCESS SCALE (HFIAS)

No.	Question	Response options (mark where applicable)	Response code
1.	Taking into consideration ALL food sources (own food production + food purchase + help from different sources + food hunted from forest and lakes, etc.), how would you assess your family's food consumption in the past 12 months	1. Food shortage through the year, 2. Occasional food shortage, 3. No food shortage but no surplus, 4. Food surplus.	
2.	During the last 12 months, did you worry that your household would not have enough food?	0 = Never 1 = Rarely (in one or two months during the last year) 2 = Sometimes (in 3 to 10 months during the last year) 3 = Often (in more than 10 months during the last year)	
3.	Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = Never 1 = Rarely (in one or two months during the last year) 2 = Sometimes (in 3 to 10 months during the last year) 3 = Often (in more than 10 months during the last year)	
4.	Did you or any household member eat just a few kinds of food day after day due to a lack of resources?	0 = Never 1 = Rarely (in one or two months during the last year) 2 = Sometimes (in 3 to 10 months during the last year) 3 = Often (in more than 10 months during the last year)	
5.	Did you or any household member eat food that you preferred not to eat because of a lack of resources to obtain other types of food?	0 = Never 1 = Rarely (in one or two months during the last year) 2 = Sometimes (in 3 to 10 months during the last year) 3 = Often (in more than 10 months during the last year)	
6.	Did you or any household member eat a smaller meal than you felt you needed because there was not enough food?	0 = Never 1 = Rarely (in one or two months during the last year) 2 = Sometimes (in 3 to 10 months during the last year) 3 = Often (in more than 10 months during the last year)	
7.	Did you or any other household member eat fewer meals in a day because there was not enough food?	0 = Never 1 = Rarely (in one or two months during the last year) 2 = Sometimes (in 3 to 10 months during the last year) 3 = Often (in more than 10 months during the last year)	
8.	Was there ever no food at all in your household because there were no resources to get more?	0 = Never 1 = Rarely (in one or two months during the last year) 2 = Sometimes (in 3 to 10 months during the last year)	

		3 = Often (in more than 10 months during the last year)	
9.	Did you or any household member go to sleep at night hungry because there was not enough food?	0 = Never	
		1 = Rarely (in one or two months during the last year)	
		2 = Sometimes (in 3 to 10 months during the last year)	
		3 = Often (in more than 10 months during the last year)	
10.	Did you or any household member go a whole day without eating anything because there was not enough food?	0 = Never	
		1 = Rarely (in one or two months during the last year)	
		2 = Sometimes (in 3 to 10 months during the last year)	
		3 = Often (in more than 10 months during the last year)	

MODULE 10: HOUSEHOLD ASSETS, ACCESS TO CAPITAL AND INFORMATION
PART A: HOUSEHOLD CREDIT NEED AND SOURCES DURING 2014/15 CROPPING YEAR

Reason for Loan	Did your household need credit? **0=No>>A2 1=Yes>>A3**	Why did your household not need credit? **CODE 1**	Did your household receive credit? **0=No>> A4** **1=Yes >>A5-A10**	What was the amount of credit received (KES)
1	Buying seeds			
2	Buying fertilizer			
3	Buy herbicide and pesticides			
4	Buy farm equipment/implements			
5	Invest in transport (bicycle, etc.)			
6	Buy oxen for traction			
7	Buying livestock for fattening			
8	Invest in irrigation system			
9	Invest in seed drill or minimum tillage system			
10	Non-farm business or trade			
11	To pay land rent			
12	Buy food			
13	Non-food consumption needs (health/education/travel/tax,)			

MODULE 10: HOUSEHOLD ASSETS, ACCESS TO CAPITAL AND INFORMATION
PART B: HOUSEHOLD SAVINGS, *ENUMERATOR,* ***PUT 1 SOURCE OF SAVINGS PER ROW.***
B1. Did household save money in the last two years?...CODES: 0= No; 1= Yes

Savings ID	Where did you save money? **CODE 2**	Who made the decision to save money? **CODE 1**	Who made the saving? **CODE 1**	What was the total amount you saved during 2014/15? **(KSh)**
	B2	**B3**	**B4**	**B5**
1				
2				
3				
4				
5				

Code 1: 1=Household head 2=Spouse 3=Head and spouse jointly 4=Other household member 5=Head and other household member(s) jointly 6=Spouse and other household member(s) jointly
Code 2: 1=Saving at home (personal) 2=Commercial or other banks 3=Rural micro-finance 4=Saving by lending to money lender 5=Savings and loan groups 6=Other, specify…………

MODULE 10: HOUSEHOLD ASSETS, ACCESS TO CAPITAL AND INFORMATION
PART D: PRODUCTION EQUIPMENT AND MAJOR HOUSEHOLD FURNITURE

Asset Category	*Asset type*	Does the household own [...]: 1= Yes 0=No	No. owned	Current Value each **(KSh)** if they can sell [item] today	Who would you say owns most of the […]? **Code 1**	Do you singularly own **1=Yes** **0=No**
	D1	**D2**	**D3**	**D4**	**D5**	
Farm implements	Sickle					
	Hoe					
	Spade or shovel					
	Axe					
	Knapsack sprayer					
	Ox-plough					
	Water pump (manual)					
	Water pump (motorized)					
	Tractor					
Transport	Horse/mule cart					
	Donkey/oxen cart					
	Horse/mule saddle					
	Push cart					
	Bicycle					
	Motorbike					
	Car					
Household Furniture	Improved charcoal/wood stove					
	Kerosene stove					
	Water carrier					
	Fridge,					
	Table, sofas, chairs, and beds					
Communication	Radio					
	Mobile phone					
	Cassette or CD player					
	TV					

Asset Category	*Asset type*	Does the household own [...]: 1= Yes 0=No	No. owned	Current Value each **(KSh)** if they can sell [item] today	Who would you say owns most of the […]? **Code 1**	Do you singularly own **1=Yes** **0=No**
Jewelry	Gold,					
	Silver,					
	Wristwatch					
Trees	Fruit trees					
	Other trees (e.g. eucalyptus)					
Land	Land owned (ha)					
House	House					

1. Self;
2. Spouse;
3. Self and spouse jointly
4. Other household member
5.Self and other household member(s)
6=Spouse and other household member(s)
7=whole family owned
8=Someone outside the household
9=Self and other outside people
10=Spouse and other outside people
11=Self, spouse and other outside people
12. other

ODULE 11: LIVESTOCK OWNERSHIP

PART A: LIVESTOCK OWNERSHIP, MARKETING AND PRODUCTION COSTS IN THE LAST 12 MONTHS

	Animal type	Does the household own […] **0=No; 1=Yes**	No. owned	Value of each **KSh**	Marketing		
					Did the hhld sell […]? **0=No; 1=Yes**	Quantity sold (Number /kg/lit)	Average selling price **KSh**
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
1	Indigenous cows						
2	Cross bred/exotic cows						
3	Oxen						
4	Bulls						
5	Heifers						
6	Calves						
7	Goats & sheep						
8	Pig						
9	Donkeys						
10	Horse						
11	Mule						
12	Poultry						
13	Bee hives						
14	Milk						
15	Eggs						
16	Butter						
17	Cheese						
18	Skin and hides						
19	Honey						

MODULE 12: HOUSEHOLD INCOME FOR THE LAST 12 MONTHS

Income source	Did the household earn income **0=No; 1=Yes**	Total income for the past 12 months		
		Cash **(KSh)**	In-kind (cash equivalent in **(KSh)**	Total **(KSh)**
	1	**5**	**6**	**7**
1. Income from salaried employment				
2. Income from machinery services for other farms (plowing etc.)				
3. Income from casual labor (on-farm)				
4. Income from casual labor (off-farm)				
5. Income from own **non-agricultural** businesses (shops, saloons etc)				
6. Income from non-farm agribusiness (grain milling, grain trading etc)				
7. Selling charcoal, brick making, selling firewood etc				
8. Pensions				
9. Remittances from family members/friends who do not live in the household				
10. Revenues from leasing/renting out land				
11. Other sources (specify)…………				
12. Other sources (specify)…………				
13. Other sources (specify)…………				
14. Other sources (specify)…………				

CODE 1
1=Self
2=Spouse
3=Self and spouse jointly
4=Other household member
5=Self and other household member(s)
6=Spouse and other household member(s)
7=Self, spouse and other household member(s)

MODULE 13: CLIMATE CHANGE AND ADAPTATION OPTIONS: PART A: RISK, LIVELIHOOD SHOCKS, AND COPPING STRATEGIES IN THE LAST 10 YEARS

Risk factor	How many times did [RISK] occur in the past ten years?	How did [RISK] affect production of main food crop of the household **(% reduction)**	Which crops were most susceptible? Rank up to 3 crops, with most susceptible first **ANNEX 1 CODE**			As a result of [RISK] did you lose (part of) your income **(% reduction)**
	A1	**A5**	**A6a**	**A6b**	**A6c**	**A7**
1. Drought (inadequate rain)						
2. Too much rain or floods						
3. Crop pests/diseases						
4. Hail storm						

MODULE 13: CLIMATE CHANGE AND ADAPTATION OPTIONS

Risk factor	How many times did [RISK] occur in the past five years? (if zero put 0	How did [RISK] affect production of main food crop of the household **(% reduction)**	Which crops were most susceptible? Rank up to 3 crops, with most susceptible first **ANNEX 1 CODE**			As a result of [RISK] did you lose (part of) your income **% reduction**
	B10	**B14**	**B15a**	**B15b**	**B15c**	**B16**
1. Livestock diseases or death						
2. Large increase in agricultural input prices						
3. Large increase in food prices						
4. Family sickness						
5. Death of household member						
6 Reduced/loss of employment income						

Appendix 2: Possible SAIPs combinations

Combination	Variety	Fertilizer	Intercropping	Manure	Rotation	Min. Tillage
1	√					
2	√	√				
3	√	√	√			
4	√		√			
5	√			√		
6	√	√		√		
7	√	√	√	√		
8	√		√	√		
9	√				√	
10	√		√		√	
11	√			√	√	
12	√	√		√	√	
13	√					√
14	√		√			√
15	√			√		√
16	√	√	√		√	
17	√	√	√	√	√	
18	√		√	√	√	

Note: The symbol √ denotes adoption of the specified practice

Appendix 3: PCA clusters of SAIPs combinations

Rotated components (blanks are abs(loading)<.45)

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Unexplained
v							-0.4516	.5382
vf					0.5064			.622
vfi		0.4984						.4846
vi				0.6358				.3867
vm			0.6978					.3306
vmf							0.6732	.4886
vmfi		0.5484						.4132
vmi					-0.5788			.5588
vr								.4425
vri						0.7060		.4154
vrm	0.5013							.447
vrmf	0.5569							.3624
vt							0.4560	.6186
vit				0.7267				.3088
vmt			0.6839					.3554
vrfi		0.6022						.2473
vrmfi	0.5927							.3026
vrmi								.6931

Note: v=seed variety, f =fertilizer, i=intercropping, m=manure, r=crop rotation, t=minimum tillage

Appendix 4: Adult Equivalent conversion table

	Adult equivalence	
Age	**Males**	**Females**
Under 1 year	0.33	0.33
1-1.99	0.46	0.46
2-2.99	0.54	0.54
3-4.99	0.62	0.62
5-6.99	0.74	0.70
7-9.99	0.84	0.72
10-11.99	0.88	0.78
12-13.99	0.96	0.84
14-15.99	1.06	0.86
16-17.99	1.14	0.86
18-29.99	1.04	0.80
30-59.99	1.0	0.82
60 and over	0.84	0.74

Source: World Health Organization

Appendix 5: Tropical livestock units

Livestock	Conversion factor
Cattle	0.70
Donkey/Mule	0.50
Pig	0.30
Goat	0.10
Sheep	0.10
Poultry	0.02

Appendix 6: Standard random effects ordered probit model for male respondents

```
Random-effects ordered probit regression        Number of obs     =        486
Group variable: id                              Number of groups  =        370

Random effects u_i ~ Gaussian                   Obs per group:
                                                              min =          1
                                                              avg =        1.3
                                                              max =          2

Integration method: mvaghermite                 Integration pts.  =         12

                                                Wald chi2(18)     =      76.28
Log pseudolikelihood  = -602.93692              Prob > chi2       =     0.0000

                                    (Std. Err. adjusted for 370 clusters in id)
-------------------------------------------------------------------------------
              |               Robust
        HFIAS |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
--------------+----------------------------------------------------------------
          age |   .0152736   .0060856     2.51   0.012     .0033461    .0272011
         educ |  -.0001396   .0269194    -0.01   0.996    -.0529006    .0526215
    educstock |  -.0280228   .0084131    -3.33   0.001    -.0445121   -.0115334
        sumae |   .3299635    .069265     4.76   0.000     .1942066    .4657203
     depratio |  -.0357179   .0802157    -0.45   0.656    -.1929378    .1215021
       gender |   .5452644   .4314815     1.26   0.206    -.3004239    1.390953
maritalstatus |  -.1782423   .2407757    -0.74   0.459    -.6501541    .2936695
        occup |  -.0069002   .0357228    -0.19   0.847    -.0769155    .0631152
    relatives |  -.0000944   .0029817    -0.03   0.975    -.0059385    .0057496
 nonrelatives |  -.0014905   .0014176    -1.05   0.293    -.0042689    .0012878
     grpindex |  -.3348113    .635559    -0.53   0.598    -1.580484    .9108615
   lnassvalue |  -.1142359    .047578    -2.40   0.016     -.207487   -.0209848
          tlu |  -.0429443   .0464412    -0.92   0.355    -.1339674    .0480789
    lnsavings |   -.016449   .0165651    -0.99   0.321    -.0489159     .016018
     lncredit |   .0083334   .0134232     0.62   0.535    -.0179756    .0346424
  lnoffincome |  -.0221258   .0152901    -1.45   0.148    -.0520939    .0078423
       region |   -.451765   .1524465    -2.96   0.003    -.7505546   -.1529753
--------------+----------------------------------------------------------------
        /cut1 |  -1.457848   .8807853    -1.66   0.098    -3.184155    .2684597
        /cut2 |  -.9010385   .8771566    -1.03   0.304    -2.620234    .8181569
        /cut3 |   .1750842   .8765604     0.20   0.842    -1.542943    1.893111
--------------+----------------------------------------------------------------
    /sigma2_u |   .4264673   .2181686                      .1564715    1.162349
-------------------------------------------------------------------------------
```

Appendix 7: Standard random effects ordered probit model for female respondents

```
Random-effects ordered probit regression        Number of obs     =        800
Group variable: id                              Number of groups  =        490

Random effects u_i ~ Gaussian                   Obs per group:
                                                              min =          1
                                                              avg =        1.6
                                                              max =          2

Integration method: mvaghermite                 Integration pts.  =         12

                                                Wald chi2(18)     =      96.70
Log pseudolikelihood  = -984.86474              Prob > chi2       =     0.0000

                                    (Std. Err. adjusted for 490 clusters in id)
-------------------------------------------------------------------------------
              |               Robust
        HFIAS |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
--------------+----------------------------------------------------------------
          age |   .0003471   .0045574     0.08   0.939    -.0085852    .0092795
         educ |  -.0540165   .0205236    -2.63   0.008    -.0942419   -.0137911
    educstock |  -.0156021   .0056003    -2.79   0.005    -.0265785   -.0046258
        sumae |   .1800543   .0468535     3.84   0.000     .0882232    .2718854
     depratio |   .1342826   .0619706     2.17   0.030     .0128226    .2557427
       gender |  -.1573461   .2431632    -0.65   0.518    -.6339373    .3192451
maritalstatus |   .0316076   .2635137     0.12   0.905    -.4848698    .5480849
        occup |    .041394   .0296989     1.39   0.163    -.0168149    .0996028
    relatives |  -.0078474    .004538    -1.73   0.084    -.0167418    .0010469
 nonrelatives |   .0031463   .0026967     1.17   0.243    -.0021391    .0084317
     grpindex |   1.355689   .4496452     3.02   0.003     .4744009    2.236978
   lnassvalue |  -.1304809   .0418616    -3.12   0.002    -.2125282   -.0484336
          tlu |  -.0326469   .0337054    -0.97   0.333    -.0987083    .0334145
    lnsavings |  -.0099261   .0124866    -0.79   0.427    -.0343994    .0145472
     lncredit |   .0290775   .0107568     2.70   0.007     .0079945    .0501605
  lnoffincome |  -.0187728   .0121164    -1.55   0.121    -.0425205    .0049749
       region |  -.2459818   .1155684    -2.13   0.033    -.4724916    -.019472
--------------+----------------------------------------------------------------
        /cut1 |  -2.683618   .6442281    -4.17   0.000    -3.946281   -1.420954
        /cut2 |  -2.255786   .6389318    -3.53   0.000     -3.50807   -1.003503
        /cut3 |  -1.308821   .6293021    -2.08   0.038     -2.54223   -.0754114
--------------+----------------------------------------------------------------
    /sigma2_u |    .438168   .1520768                      .2219272     .865109
-------------------------------------------------------------------------------
```

Appendix 8: Constrained variables for male model

```
Testing the parallel lines assumption using the .05 level of significance...
Step  1:  Constraints for parallel lines imposed for educstock (P Value = 0.9670)
Step  2:  Constraints for parallel lines imposed for age (P Value = 0.9107)
Step  3:  Constraints for parallel lines imposed for tlu (P Value = 0.7374)
Step  4:  Constraints for parallel lines imposed for occup (P Value = 0.5270)
Step  5:  Constraints for parallel lines imposed for educ (P Value = 0.5070)
Step  6:  Constraints for parallel lines imposed for lnassvalue (P Value = 0.2946)
Step  7:  Constraints for parallel lines imposed for lnsavings (P Value = 0.2560)
Step  8:  Constraints for parallel lines imposed for traders (P Value = 0.2495)
Step  9:  Constraints for parallel lines imposed for nonrelatives (P Value = 0.2187)
Step  10: Constraints for parallel lines imposed for relatives (P Value = 0.7280)
Step  11: Constraints for parallel lines imposed for region (P Value = 0.1643)
Step  12: Constraints for parallel lines imposed for grpindex (P Value = 0.1724)
Step  13: Constraints for parallel lines imposed for lncredit (P Value = 0.1160)
Step  14: Constraints for parallel lines imposed for depratio (P Value = 0.1145)
Step  15: Constraints for parallel lines imposed for maritalstatus (P Value = 0.0760)
Step  16: Constraints for parallel lines imposed for gender (P Value = 0.1577)
Step  17: Constraints for parallel lines are not imposed for
          sumae (P Value = 0.00505)
          lnoffincome (P Value = 0.00486)
```

Global Wald test for parallel lines assumption for male model

```
Wald test of parallel lines assumption for the final model:
         ( 1)  [mleq1]educstock - [mleq2]educstock = 0
         ( 2)  [mleq1]age - [mleq2]age = 0
         ( 3)  [mleq1]tlu - [mleq2]tlu = 0
         ( 4)  [mleq1]occup - [mleq2]occup = 0
         ( 5)  [mleq1]educ - [mleq2]educ = 0
         ( 6)  [mleq1]lnassvalue - [mleq2]lnassvalue = 0
         ( 7)  [mleq1]lnsavings - [mleq2]lnsavings = 0
         ( 8)  [mleq1]traders - [mleq2]traders = 0
         ( 9)  [mleq1]nonrelatives - [mleq2]nonrelatives = 0
         (10)  [mleq1]relatives - [mleq2]relatives = 0
         (11)  [mleq1]region - [mleq2]region = 0
         (12)  [mleq1]grpindex - [mleq2]grpindex = 0
         (13)  [mleq1]lncredit - [mleq2]lncredit = 0
         (14)  [mleq1]depratio - [mleq2]depratio = 0
         (15)  [mleq1]maritalstatus - [mleq2]maritalstatus = 0
         (16)  [mleq1]gender - [mleq2]gender = 0
         (17)  [mleq1]educstock - [mleq3]educstock = 0
         (18)  [mleq1]age - [mleq3]age = 0
         (19)  [mleq1]tlu - [mleq3]tlu = 0
         (20)  [mleq1]occup - [mleq3]occup = 0
         (21)  [mleq1]educ - [mleq3]educ = 0
         (22)  [mleq1]lnassvalue - [mleq3]lnassvalue = 0
         (23)  [mleq1]lnsavings - [mleq3]lnsavings = 0
         (24)  [mleq1]traders - [mleq3]traders = 0
         (25)  [mleq1]nonrelatives - [mleq3]nonrelatives = 0
         (26)  [mleq1]relatives - [mleq3]relatives = 0
         (27)  [mleq1]region - [mleq3]region = 0
         (28)  [mleq1]grpindex - [mleq3]grpindex = 0
         (29)  [mleq1]lncredit - [mleq3]lncredit = 0
         (30)  [mleq1]depratio - [mleq3]depratio = 0
         (31)  [mleq1]maritalstatus - [mleq3]maritalstatus = 0
         (32)  [mleq1]gender - [mleq3]gender = 0

                   chi2( 32) =   36.48
                 Prob > chi2 =    0.2683

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

Appendix 9: Constrained variables for female model

```
Testing the parallel lines assumption using the .05 level of significance...
       Step  1:  Constraints for parallel lines imposed for relatives (P Value = 0.9817)
       Step  2:  Constraints for parallel lines imposed for nonrelatives (P Value = 0.9488)
       Step  3:  Constraints for parallel lines imposed for educstock (P Value = 0.8920)
       Step  4:  Constraints for parallel lines imposed for educ (P Value = 0.9401)
```

```
Step  5:  Constraints for parallel lines imposed for region (P Value = 0.8397)
Step  6:  Constraints for parallel lines imposed for occup (P Value = 0.8375)
Step  7:  Constraints for parallel lines imposed for traders (P Value = 0.6263)
Step  8:  Constraints for parallel lines imposed for lnsavings (P Value = 0.5844)
Step  9:  Constraints for parallel lines imposed for depratio (P Value = 0.5347)
Step  10: Constraints for parallel lines imposed for gender (P Value = 0.2141)
Step  11: Constraints for parallel lines imposed for maritalstatus (P Value = 0.5325)
Step  12: Constraints for parallel lines imposed for lnoffincome (P Value = 0.2803)
Step  13: Constraints for parallel lines imposed for tlu (P Value = 0.2246)
Step  14: Constraints for parallel lines imposed for age (P Value = 0.1519)
Step  15: Constraints for parallel lines imposed for lncredit (P Value = 0.0597)
Step  16: Constraints for parallel lines are not imposed for
          sumae (P Value = 0.01738)
          grpindex (P Value = 0.00765)
          lnassvalue (P Value = 0.00924)
```

Global Wald test for parallel lines assumption for female model

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

 ( 1)  [mleq1]relatives - [mleq2]relatives = 0
 ( 2)  [mleq1]nonrelatives - [mleq2]nonrelatives = 0
 ( 3)  [mleq1]educstock - [mleq2]educstock = 0
 ( 4)  [mleq1]educ - [mleq2]educ = 0
 ( 5)  [mleq1]region - [mleq2]region = 0
 ( 6)  [mleq1]occup - [mleq2]occup = 0
 ( 7)  [mleq1]traders - [mleq2]traders = 0
 ( 8)  [mleq1]lnsavings - [mleq2]lnsavings = 0
 ( 9)  [mleq1]depratio - [mleq2]depratio = 0
 (10)  [mleq1]gender - [mleq2]gender = 0
 (11)  [mleq1]maritalstatus - [mleq2]maritalstatus = 0
 (12)  [mleq1]lnoffincome - [mleq2]lnoffincome = 0
 (13)  [mleq1]tlu - [mleq2]tlu = 0
 (14)  [mleq1]age - [mleq2]age = 0
 (15)  [mleq1]lncredit - [mleq2]lncredit = 0
 (16)  [mleq1]relatives - [mleq3]relatives = 0
 (17)  [mleq1]nonrelatives - [mleq3]nonrelatives = 0
 (18)  [mleq1]educstock - [mleq3]educstock = 0
 (19)  [mleq1]educ - [mleq3]educ = 0
 (20)  [mleq1]region - [mleq3]region = 0
 (21)  [mleq1]occup - [mleq3]occup = 0
 (22)  [mleq1]traders - [mleq3]traders = 0
 (23)  [mleq1]lnsavings - [mleq3]lnsavings = 0
 (24)  [mleq1]depratio - [mleq3]depratio = 0
 (25)  [mleq1]gender - [mleq3]gender = 0
 (26)  [mleq1]maritalstatus - [mleq3]maritalstatus = 0
 (27)  [mleq1]lnoffincome - [mleq3]lnoffincome = 0
 (28)  [mleq1]tlu - [mleq3]tlu = 0
 (29)  [mleq1]age - [mleq3]age = 0
 (30)  [mleq1]lncredit - [mleq3]lncredit = 0

           chi2( 30) =   26.82
         Prob > chi2 =    0.6330
```

Appendix 10: Wooldridge test for serial correlation in panel-data models

```
Wooldridge test for autocorrelation in panel data
H0: no first order autocorrelation
    F(  1,     490) =     72.267
           Prob > F =      0.0000
```

Appendix 11*:* Modified Wald statistic for group-wise heteroscedasticity

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model
H0: sigma(i)^2 = sigma^2 for all i
chi2 (491)  =   1.2e+06
Prob>chi2 =      0.0000
```

Appendix 12: Breusch and Pagan Lagrangian multiplier test for random effects

```
v0U[id,t] = Xb + u[id] + e[id,t]
Estimated results:
                 |       Var     sd = sqrt(Var)
```

```
---------+-----------------------------
     v0U |     .106097        .3257253
       e |    .0621278        .2492544
       u |    .0089464        .0945856
Test:    Var(u) = 0
                         chibar2(01) =     30.09
                      Prob > chibar2 =    0.0000
```

Appendix 13: The Hausman test

```
Test:  Ho:  difference in coefficients not systematic
                 chi2(19) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =      204.13
                Prob>chi2 =      0.0000
```

Appendix 14: Publication abstract

CrossMark

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Determinants of gender differences in household food security perceptions in the Western and Eastern regions of Kenya

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Additional information is available at the end of the article

Abstract: In addition to Intra-household resource allocations and internal dynamics of decision-making, gendered perceptions on household food security play a critical role in households' nutritional status, especially in developing countries. However, evidence on the role of gender-based perceptions on households' food security and related implications on the households' nutritional status is limited. This study examines the determinants of gender-disaggregated household food security perceptions among smallholder farming households. We used two panels of data from households in eastern and western Kenya and employ the House hold Food Insecurity Access Scale to measure perceptions of household food insecurity, and the random effects generalized ordered probit model to evaluate the determinants of security perceptions across gender. The results reveal that the factors that influence food security perceptions vary across gender. The education level of household head and the number of relatives were negatively associated with female perceptions of household food insecurity, whereas the household dependency ratio was positively associated with female perceptions of household food insecurity. In contrast, age and gender of household head were positively

Appendix 15: Research permit

Ref No: **311069** Date of Issue: **02/July/2020**

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This is to Certify that Mr.. Cosmas Kweyu Lutomia of Egerton University, has been licensed to conduct research in Bungoma, Embu, Meru, Siaya, Tharaka-Nithi on the topic: Gender Food Insecurity Perceptions and Effect of Sustainable Agricultural Intensification Practices on Household Vulnerability to Poverty in Western and Eastern Kenya for the period ending : 02/July/2021.

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