ASSESSMENT OF EFFECTS OF CLIMATE-SMART AGRICULTURE PRACTICES ON SMALLHOLDER FARMERS' RESILIENCE TO MAIZE YIELD LOSS IN BUNGOMA COUNTY, KENYA

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Declaration of Originality

This thesis is my original work and has not been submitted for award of a degree in any other University.

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Dedication

I dedicate this thesis to my daughter Courtney Imani Namulanda, my wife Silvia Indasi Anzimbu and my mother Roselyne Namulanda Siminyu for their love and financial support that has enabled me to get a smooth movement through my MSc studies.

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List of Abbreviations and Acronyms

AA	Agricultural Assets
ABS	Basic Services Access
AC	Adaptive Capacity
ANA	Agricultural & non-Agricultural Assets
APT	Technology in Agriculture Production
CBS	Central Bureau of Statistics
CC	Climate Change
CR	Crop Rotation
CSA	Climate Smart Agriculture
EC	Economic Activity
EIE	Enabling institutional environment
FAO	Food and Agriculture Organization of the United Nations
hh	Household
hhh	Household Head
HYMV	High Yielding Certified Maize Varieties
IFA	Access to Food and Income
IML	Intercropping Maize with Legumes
IMPS	Improved Seed
INOF	Inorganic Fertilizer
IPCC	Inter-governmental Panel on Climate Change
KACP	Kenya Agricultural Carbon Project
KNBS	Kenya National Bureau of Statistics
LEGINT	Legume Intercropping
MSD	Minimum Soil Disturbance
NAA	Non-Agricultural Assets
NGO	Non-Governmental Organization
ODK	Open Data Kit
OLS	Ordinary Least Square
PCA	Principal Component Analysis
R	Resilience
RIMA	Resilience Index Measurement and Analysis
S	Sensitivity
SALM	Sustainable Agricultural land management
SES	Social-Ecological System
SLM	Sustainable Land Management
SSA	Sub-Saharan Africa
SSN	Social Safety Nets
VIF	Variance Inflation Factors

Abstract

Shocks and stresses that are caused by low maize yields cannot be avoided. Climate-smart agriculture (CSA) mitigates against climate change by increase in crop and livestock yield and associated farm income. Efforts to address climate-related stress in agriculture recognize CSA as a promising approach. However, the effect of CSA on the resilience of farmers to maize yield loss due to climate variability is not well known. This study assessed the effect of two CSA practices (maize-legume intercropping and use of organic animal manure) on the resilience of maize farmers to maize yield loss due to climate variability in Bungoma County in western Kenya. A semi-structured questionnaire set up in open data kit (ODK) was administered to 250 randomly selected maize farmers. A multistage sampling procedure was employed to get a sample of 250 farmers. A CobbDouglas production function was used to examine how the two CSA practices affect the maize yield of smallholder farmers. While the overall model was statistically significant ($p < 0.01$), its explanatory power was weak ($R^2 = 0.19$) probably due to the maize produced per acre. A maize yield loss resilience index was generated using Principal Component Analysis (PCA). To estimate the smallholder maize farmers' resilience to yield loss an ordinary least squares regression was employed with the resilience index as a dependent variable. The overall model was statistically significant at $p < 0.01$ and $R^2 = 0.74$. Both CSA practices (maize-legume intercropping and use of organic animal manure) were statistically significant at $p < 0.01$ in the OLS model suggesting that use of the two practices assured farmers of getting a higher yield and the farmer becomes resilient to maize yield loss. Accordingly, the study recommends that awareness and capacity building of farmers who are not currently using the two CSA practices in their maize production should be enhanced. This could be achieved through extension services on the two CSA practices to smallholder farmers by the ministry of agriculture and private agriculture stakeholders.

Keywords: Climate-smart agriculture practices, maize yield loss, resilience index, shocks.

CHAPTER ONE: INTRODUCTION

1.1 Background

According to Debertin and Pagoulatos (2015), agricultural practices applied by farmers for crop production are environmentally unsustainable. This is because smallholder farmers plant without rotation, use a lot of pesticides and chemical fertilizers, apply plant hormones, and handle animal wastes inappropriately causing harm to the environment (Önder *et al*., 2011). Kurukulasuriya & Mendelsohn (2007) note that climate change is adversely affecting agricultural production and productivity because of increased temperature, the changing rainfall patterns, and increased incidence of animal and crop diseases and pests. Lobell *et al*. (2011) noted that climate change will damage crop production by reducing yield, hence smallholder farmers' lifestyle is likely to be affected in sub-Saharan Africa (SSA). This ultimately affect their food stability and income-generating activities.

For food security to be achieved and maintained, Branca *et al.* (2011), agricultural systems need to be transformed to increase the productive capacity and stability of smallholder producers. According to Neate (2013), the contribution of agriculture to climate change is being recognized. Neate (2013 notes that there are processes through which agricultural systems can be adjusted to manage the varying changes, at the same time its potential to mitigate the climate impact. Climate-smart agriculture (CSA) has a positive influence on climate change (Jamil *et al*., 2021). According to Palombi and Sessa (2013), CSA comprises three main components: agricultural productivity and income increasing, sustainability and adaption to climate change and reduction in greenhouse gas emissions.

With the application of CSA practices there is adaptation and mitigation to climate change. According to Wambugu *et al*. (2014), existing crop production activities can be transformed with a focus on CSA techniques that mitigate and cope with the factors influencing climate change. Practices that are environmentally sustainable, according to Branca *et al.* (2011), are agronomic practices that improve the environment, integrating nutrient management, managing the residues and tillage, managing water and planting of trees and shrubs, which enhance the fertility of the soil together with the crops. These practices when applied by farmers increase agricultural productivity and income and mitigate adverse effects of climate change. If a farmer uses sustainable land management practices, the farmer will be adapting and mitigating to climate change, increasing agricultural production sustainably, and increasing farm incomes. According to Branca *et al.* (2011), sustainable crop management practices include use of organic manure, maize/legume intercrop, cover cropping, crop rotation, minimum tillage, agroforestry, and soil and water management.

Smale and Jayne (2003) found that in SSA countries maize production per capita is not consistent with population growth over the last 40 years. Even with the world efforts, food insecurity has remained high in SSA from 2000 when the United Nations published its Millennium Development Goals (Herman, 2011). Meeting the food demand in SSA, which relies on rain-fed, smallholder agriculture will likely be a pipe dream if major efforts to reverse current unfavorable trends in productivity are not improved (Nata *et al.*, 2014).

According to Nyambedha *et al*. (2001), about 3.5 million smallholders in Kenya produce about 75% of the total maize output, with large-scale farming representing the remaining 25%. Nearly all agricultural households in Kenya plant maize. Some of the factors that have contributed to improved maize production in Kenya are increased use of both organic (farmyard manure) and inorganic fertilizers, soil and water conservation and management, use of high yielding seed varies, improved agronomic practices associated with extension efforts (Munialo *et al.*, 2020). For there to be increased maize production, smallholder farmers should use practices that contributed high productivity.

Reduced soil fertility is proving to be a major hindrance in maize production in Kenya. According to Morris *et al.* (2007), soil conditions in Kenya present many problems for agricultural production. Soil fertility decline and weed infestation in Western Kenya are causing a reduction in maize production (Ngome et al., 2013). These conditions have increasingly been exacerbated by historical poor land-use practices (Ngome et al., 2013). Maintaining maize production for the growing population needs the use of environmentally sustainable and friendly practices with the intensification of production and management to grow more maize on the existing cropland. Producing maize under CSA practices not only adapts and mitigates against climate change impacts but also increases yield sustainably (Choptiany *et al.*, 2015). When properly employed, CSA practices cushion farmers against maize yield losses attributable to climate shocks thereby increasing their maize productivity. According to Choptiany *et al.* (2015), CSA practices help maize farmers to mitigate and adapt to the changing climate. In maize production, CSA practices include intercropping maize with legumes, crop rotation, using animal manure, irrigation, zero tillage, and integrated nutrient, water and soil management (Anuga *et al*., 2020). In particular, intercropping maize with legumes leads to nitrogen fixation that benefits the maize plant (Karpenstein-Machan & Stuelpnagel 2000)). For example, Muoni (2019) found out that all grain legume types when intercropped with cereals increased the yield of the latter. In addition, grain legumes increased the abundance of nitrogen and phosphorus in the soil. According to Abunyewa *et al*. (2007), using animal manure as organic fertilizer increases the carbon content in the soil, hence the fertility increases and the maize crop growing in fertile soil increasing the yield.

In Bungoma County, about 80% of the residents depend on agriculture for their livelihoods (Nabusoba 2014). Despite its high rainfall and fertile soils, the prospects for expanding agriculture in Bungoma County are increasingly undermined by climate change. For example, reduced rainfall is making crop yields to reduce each season. According to the Bungoma County Integrated Development Plan [CIDP], the county government of Bungoma has adopted a value chain approach in agriculture production in order to increase yield and farm incomes (County, 2013).

Climate variability stands out as one of the major constraints to maize production in Bungoma County (Wabwoba, 2017). For example, according to Oloo *et al*. (2013), the production of maize which is a stable crop in Bungoma County is adversely affected by climate change. As maize production is an important economic activity in the county, finding a permanent solution to maize yield loss triggered by the changing climate will be highly welcomed by the communities (Wanyama, 2017).

The One Acre Fund, a non-governmental organization (NGO) in Bungoma County, has been encouraging smallholder farmers to adopt CSA practices as a way of redressing the negative impacts of climate change. Its intervention strategy is anchored on four core principles of CSA: implementing practices that mitigate climate change, building smallholder farmers' resilience to crop yield losses, adaptation to climate change impacts, and intensifying farm production sustainably. The Kenya Agricultural Carbon Project (KACP), implemented by Vi Agroforestry, trains farmers in Bungoma County in diverse Sustainable Agricultural land management (SALM) practices including agroforestry, use of crop covers, mulching, and use of green manure, to increase the organic content in the soil.

This study was undertaken in areas in Bungoma County where the One Acre Fund has built the capacity of farmers in using CSA practices. The study focused on two practices that maize farmers applied, i.e., maize-legume intercrop, and use of animal manure alongside planting of certified high-yielding maize varieties.

1.2 Statement of the Research Problem

Enhancing food security while mitigating the adverse effects of climate change and preserving the natural resource base requires the transformation of current agricultural production systems so that they can be more productive, use inputs more efficiently, have less variability and greater stability in their outputs, and are more resilient to risks, shocks and long-term climate variability (Bommarco *et al*., 2013). Efforts to address climate-related stress in maize production recognizes CSA as a promising approach which is more resilient to risks, shocks and long-term climate variability. Previous studies on maize yield have focused on the adoption of improved maize seed varieties on the effects of CSA practices on maize production. However, the effect of CSA practices on the resilience of maize farmers to yield loss due to climate variability is not well known. This study contributes knowledge to existing literature on how resilient maize farmers are to yield losses when they use CSA practices.

1.3 Purpose and Objectives of the Study

This study assessed the effect of climate-smart agriculture practices, i.e. maize-legume intercrop and use of animal manure, on smallholder maize farmers' resilience to yield loss attributable to climate variability in Bungoma County of western Kenya. The specific objectives of the study were:

1. To examine the effects of climate-smart agriculture practices on maize yield of smallholder farmers in Bungoma County.
2. To assess the effect of climate-smart agriculture practices on the resilience of smallholder maize farmers to yield loss in Bungoma County.

1.4 Hypothesis

The following hypotheses were tested;

i. CSA practices have no effect on maize yield among smallholder farmers in Bungoma County.

ii. The use of CSA practices has no effect on farmers' resilience to maize yield losses in Bungoma County.

1.5 Justification

Maize is a staple food crop in about all African countries and more so in Kenya. This implies that maize production needs to be improved in order to meet the basic food needs of Kenya's households. For a farmer to be food secure, there is need to produce sufficient amounts of maize to feed the whole year and a surplus to sale to the market and generate an income. The farmer needs to be environmentally friendly in the quest for higher maize production.

This study provides information to farmers on how they can be environmentally friendly and sustainable in the quest for high maize yield. The results of the study will help farmers produce crops using CSA practices and agriculture extension workers in building the capacity of smallholder farmers in using CSA practices. The findings of this study help policymakers, stakeholders in the agricultural sector, and development partners to come up with CSA policies. This study adds more knowledge to literature by focusing on the contribution of the CSA practices that increasing maize yield using maize-legume intercrop and animal manure.

1.6 Organization of the Thesis

The chapters of this thesis are organized as follows, Chapter One has the background information of the study, statement of the research problem, research objectives, hypothesis, and the justification of the study. Chapter Two provides a review of the literature. Chapter Three has the theoretical and empirical frameworks as well as a description of the study area data sources and sampling procedure. In Chapter Four, the results of data analysis are presented and discussed. Chapter Five covers the conclusion and policy implications.

CHAPTER TWO: LITERATURE REVIEW

2.1. Overview of Climate-smart Agriculture

The impacts of climate change in agriculture production are leading to low farm yield each season resulting to food insecurity. According to Williams *et al*. (2015), agriculture is very important to the Kenya economy and its development has implications for poverty reduction and food security. However, inequality to land access for many smallholder farmers, soil infertility and poor access to markets is a constraint in agricultural development (Williams *et al*., 2015). These constraints are increasing because of climate change which is currently a major interruption to food security and poverty reduction. Williams *et al*. (2015) notes that adaptation mechanisms in dealing with the negative impacts of climate change need to be developed for maize yield to increase and remain sustainable. According to Amin *et al*. (2015), very many strategies to the changing climate, maize-legume intercropping and animal manure.

According to Lobell *et al*. (2011), the agricultural sector needs to have new tactics to improve how the impacts of climate change on maize yield are understood. According to Palombi and Sessa (2013), CSA contributes to the attainment of sustainable development goals. It also addresses the challenges of food security and climate change by integrating the three dimensions of sustainable development goals; social, economic, and environmental. CSA has three main pillars; adapting and building resilience to climate change; greenhouse gases emission reduction where possible and sustainably increasing incomes and agriculture productivity.

Climate-smart agriculture is an approach for developing the investment, policy, and technical environments to gain sustainable development in agriculture for food security with the changing climate (Palombi & Sessa 2013).

According to Branca *et al.* (2011), CSA is a strategy aimed at helping farmers cope and mitigate the negative impacts of the changing climate by intensifying or diversifying livelihood strategies, and thereby reducing vulnerability. CSA comprises three main components: incomes and agricultural productivity increasing, climate change adaption and sustainability, and reduction of emissions of greenhouse gases (FAO 2013).

The sustainable land management (SLM) practices that were considered by Branca *et al*. (2011) were: use of agronomic practices that improve the environment, nutrient management practices that improve the environment, use of water in an efficient way, and planting of crops together with tress that add nutrients to the soil. Branca *et al.* (2011) synthesized evidence based on the yield impacts of a variety of better cropland management choices, identified with a high prospective for restoring soil carbon and thus influencing climate change mitigation.

2.2 Farmer's Awareness of Climate-smart Agriculture Practices in Maize Production

Poor agricultural practices and technology adopted by smallholder farmers lead to food insecurity (Nata *et al.*, 2014). Their study notes that adopting improved practices and technologies in agriculture will lessen food insecurity by stabilizing production systems. According to Nyang *et al.*, (2021), smallholder farmers perceive climate change to reduce maize productivity. They noted reduced precipitation, some experience poor rainfall distribution, late onset of rainfall while others an increase in temperature. Their study notes that to cope with the climate variations, smallholder farmers adopted CSA practices including; diversification of crops, change of planting time, and crop rotation. Smallholder farmers' perception of the negative impacts of the changing climate in maize production determines the CSA practice that they will adopt (Nyang *et al*., 2021).

According to Gairhe *et al*. (2018), CSA practices among smallholder farmers involve innovations and technologies like water management, the use of resilient crop varieties, zero tillage, cover cropping, maize legumes intercropping, variation in planting date, and site-specific fertilizer management. Their study on maize production found plant density, ear number, and maize grain yield substantially higher in plots with CSA practices showing that CSA was the appropriate technology to reduce potential maize loss due to climate change. Their study was on farm experiment but the current study is assessing the farmers' perception to CSA practices in maize production.

Gwambene *et al.* (2015) found that the lack of information and awareness on the changing climate, coping tactics and low adaptive ability made smallholder farmers delay to cope towards climate change. Little information and awareness on climate change contributed to low adoption of climate-smart agriculture practices. Jelagat (2019) found that CSA adoption was determined by CSA awareness, meaning that farmers who were aware of CSA practices adopted them. According to Gwambene *et al*. (2015), smallholder farmers practice climate-smart agriculture in their field however they do not know if the practices is CSA and their reason for practicing it.

According to Khatri-chhetri, *et al.* (2016), CSA practices such as managing the residues, seeding rice directly, and managing the nutrients directly on the site are not quite common among the farming community. Khatri-chhetri, *et al.* (2016) notes that government extension officers, who are mainly involved with the dissemination of information to farmers, have little information about the tools, techniques, and decision which are available to support the systems for implementation of climate-smart agriculture practices in smallholder production systems. Keeping in mind that the government under the Ministry of Agriculture is responsible for disseminating information to farmers, when they do not have information on CSA, this means that they cannot pass the information to the farmers hence the farmers will remain unaware of CSA practices. According to Abegunde *et al*. (2019), exposure to farmer groups, mass media, and frequent improved extension contacts accompanied by climate change-related education strengthen integrated farm practices that facilitate CSA adoption which mitigates on the negative impacts of climate change, building the resilience capacity of smallholder farmers and increasing their farm incomes.

According to Mutoko *et al*, (2015), the adoption behavior to CSA practices by farmers is caused by some aspects which create or bar the uptake of exact CSA practices. The hindrance to the uptake of CSA includes insufficient labor on the farm, insufficient knowledge about CSA, lack of seeds, and shortage of money to put to practice the better practices. Getting good money from the selling of tree seedlings, the farmers' monetary ability to participate in better farming would be better as found by Odendo *et al.* (2009), enabling them to adopt CSA practices. Most farmers are not aware of the CSA practices.

2.3 Maize Production and Increased Maize Yield under Climate-Smart Agriculture Practices

Maize yield in Bungoma county ~~is~~ reducing each season caused by the negative impacts of climate change (Wanyama 2017). As noted by Cairns *et al*. (2013), low crop yields are affected by droughts, low soil fertility, low input use, and use of low-yielding seeds. Output per unit of maize in SSA has remained between 1.5 tones, and 2 tones on a hectare piece of land. According to Kitsao and Zighe (2016), climate change is expected to have a negative impact on maize production in Kenya, with the addition of animal manure the soil fertility will improve suppressing weeds which are a problem in maize production. According to Smale *et al.* (2011), improved seeds are gradually being adopted which represents 44% of maize area in Eastern and Southern Africa.

Farmers are not aware whether they produce maize using CSA practices hence they can't account for maize yield under CSA practices. Berre, *et al.* (2016) focused in their study on the interaction of maize and common beans; attention was paid particularly to intercropping practices within the whole portfolio of climate-smart agriculture. The benefits of maize-legume rotations, according to Ekepu and Tirivanhu (2016), are well-known: legume production fixes nitrogen in the soil through symbiotic association with soil-dwelling bacteria so that crops can benefit from it.

Kamanga *et al.* (2010) concentrated on maize-legume arrangements since farmers indicated their intention in investigating with legumes for the soil fertility to be improved. They found out that there was an increased maize yield when maize was intercropped with legumes. Vanlauwe *et al*. (2002) found that the decline in soil fertility negatively affects food security in SSA and the FAO initiative is concerned with a better optimization of nutrient flow at crop scale. Survey results, according to Khatri-chhetri, *et al.* (2016), indicated that many farmers got higher yield in rice and wheat produces after the application of CSA practices. According to Naresh *et al*. (2014), the leveling of land for cultivation enhances water and nutrient use effectiveness, betters crop formation, and control of weeds in the cultivation area, hence leading to higher yield compared to the unleveled fields.

Sain *et al*. (2017) conducted an analysis to determine whether there was a significant difference in the costs of producing maize using CSA practices, they found out that there was a significant difference in the cost of maize produced with CSA practices. CSA practices have been documented to have an increase in crop yield. Using crop covers leads to increased yield because of the reduced on-farm erosion and leaching nutrients. Kaumbutho and Kienzle (2007) showed that maize yield improved to 2.0 t/ha from 1.2t/ha when using *mucuna* crop cover.

Pires *et al*. (2016) found that maize yield in Brazil went up by 230% when using crop covers. There is a substantial yield loss of 11% in the long run and 11.8% in the short run when maize is planted continuously compared to maize planted with different cover crops. Pretty and Hine (2000) found that farmers who embraced *mucuna* crop cover, got benefits of higher yield of maize while using less labor input when weeding. Parrott and Marsden (2002) reported that in Brazil, planting maize intercropped with legumes increased the total nitrogen content and the grain yield by 100%. According to Siminyu *et al*. (2020), use of animal manure, maize-legume intercrop, and planting certified high-yielding maize varieties increases maize yield. According to Gairhe *et al*. (2018), CSA practices increased maize yield leading to increased benefits among smallholder farmers. According to Branca *et al.* (2011), using better crop breeds boost the average produces since the seed variety of a similar crop is used. Branca *et al*. (2011) found that when farmers use farming practices that reduce soil erosion; they made their crop yield to increase.

The CSA practices which were considered by Branca *et al.* (2011) were: smallest soil commotion, planting on the same piece of land different crops each season and maize-legumes intercropping. Their study considers the effect of using inorganic fertilizers and improved maize seeds on maize yield produced. They found that there was no effect that was significant of smallest soil commotion, a constructive effect of planting of maize with legumes and a negative effect of planting different crops on the same piece of land each season on the yield of maize between the 2004-2008 span of time. These results were got through the regulation of a set of variables that had an impact on production. According to Berre *et al*. (2016), the interaction of maize varieties with common bean varieties after a long on station program, where maize was tried in mono-cropping systems, the varieties were released. After intercropping with several bean varieties, there was an intercropping potential of the maize varieties being tested. Berre *et al*. (2016) fails to consider the impact of increasing production of any maize variety with intercropping any bean variety.

2.4 Farmer Resilience to Climate Change Induced Shocks and Stresses in Crop Production

According to Parry *et al*. (2007), climate change forecasts estimate that there will be prolonged changes in rainfall and temperature trends with the occurrences and concentration of extreme weather happenings increasing, such as storms, floods, and droughts. This will reduce crop productivity. The reduction in crop productivity will mean that farmers become poorer as they will not be able to provide for their daily bread which will lead to increased food shortage. Food calamities associated with the impacts of climate change are no longer uncommon actions and an intensive determination is required towards building the resilience of farmers and pastoralists (Gubbels 2011).

According to Rioux *et al*. (2016), agricultural systems must evolve in ways that are sustainable to meet the immediate needs of smallholder farmers for them to increase food production and strengthen their resilience to crop yield loss. Productive, low-emission and climate-resilient practices should be introduced to smallholder farmers for them to be resilient to crop yield loss and be linked to policies that can provide incentives for them to adopt new CSA practices (Rioux *et al*. 2016).

According to Aylward *et al*. (2015), climate change causes a momentous negative effect on maize production directly hence providing hindrances for farmers to increase their focus on producing it. According to Harvey *et al*. (2014), farmers are exposed to pest and disease occurrences and extreme weather events interfering with their crop production times causing significant crop and income losses and worsen food insecurity. According to Kansiime *et al*. (2017), to reduce pest and disease crop losses, there should be an establishment of a sustainable pest management systems on the farm which will help in achieving food security among smallholder farmers. According to Savary *et al*. (2017), the use of CSA practices assists in addressing the functioning of food systems that would otherwise expose to plant pests and disease risks. This approach will better manage the current crop pests and diseases as well as reduce the possibility of induced shocks.

According to Choptiany *et al.* (2015), to counter the lack of ecology in vulnerability tactics, resilience has risen as a lens for understanding and investigating how a social-ecological system (SES) responds to shock, stress, or perturbations as the ones linked to climate change. According to Alliance (2010), resilience is the capacity of a structure to absorb disorders and restructure as it undergoes changes to have the same functions. Climate resilience is the capacity of a system to endure climate-related stresses and shocks. According to Choptiany *et al.* (2015), a system can change in a changing climate and thrive. Climate resilience is the capacity of a structure to endure the changing climate. According to Choptiany *et al.* (2015), climate resilience is suitable to support and improve farmers and pastoralists living in the world.

According to Boto & Pandya-lorch (2020), adapting to resilience is to identify how different areas can enhance and complement each other. They noted that a system will have low vulnerability if its resilience capacity is high. They further note that the resilience of a country, in the face of a crises, is measured by its response to react quickly and mobilize the capability after a crisis to regain and recover to a degree of normality. According to Boto and Pandya-lorch (2020), when there is a gradual decline in agricultural productivity, this may indicate a lack of resilience, but at the same time collapse may come without warning. They note that smallholder farming households lack the means to engage in livelihood activities required to build their resilience capacity. They further note that provided smallholder farmers access to the necessary related services and products is facilitated, measures that have shown to be effective can be used to build their resilience against agricultural shocks. According to Boto and Pandya-lorch (2020), building smallholder maize farmers' resilience to yield loss aims at contributing to a sustainable reduction in vulnerability in maize production and more resilient livelihoods.

According to Altieri *et al*. (2015), traditional farming systems bare measures and principles which will assist modern agricultural systems to be resilient to climatic extremes. According to Kansiime and Mastenbroek (2016), smallholder farmers need to build their resilience to crop yield loss in agriculture which is climate-induced. Their study notes that there is an urgent need to improve the resilience capacity of smallholder farmers to yield loss so that they can be food secure and improve their livelihoods enabling them to have the capacity to absorb shocks and stresses.

According to Xiong and Tarnavsky (2020), better agronomic management, like better seeds and fertilizer, regional and global market access with financing, and smallholder farmers being involved in the chain of supply, increases food security in the region will assist in building resilience through increased food productivity and income generation opportunities. Their study found that uptake of crop management strategies varies depending on the yield responses, the weather conditions, and location. A climate-smart management strategy is expected to increase maize yield and in turn increase the resilience of smallholder farmers to yield loss. According to Arslan (2016), the capacity of a living system to respond to stressors and shocks through the coping mechanisms is a crucial cause of farmer resilience. According to Ajefu *et al*. (2020), farm input enables smallholder farmers to substantially increase their food productivity and consumption hence become food secure with the climate change threats increasing each season.

According to Macholdt *et al*. (2019), smallholder farmer resilience capacity can be enhanced when their level of adaptation and management is increased on the farm practices that target the most common stressors. Li *et al*. (2019) notes that maize yield increasing practices are required in the face of the changing climate and resources variability for maize yield loss resilience to be improved.

Shocks and stresses can't be stripped. Significant effort has to be put on enhancing the resilience of those affected (Levine and Mosel, 2014). Enhanced resilience also decreases loss of life and costs linked to extreme events (Levine and Mosel, 2014). According to Berkes and Folke, (2002), past knowledge is key in order to reinforce the resilience of an individual. According to Choptiany *et al*. (2015), resilience research through different disciplines shows that in history individuals and systems bare the ability to efficiently manage and overcome encounters of hostile actions.

According to Hertel *et al*. (2021), transformation of food systems involves; equitable livelihood, access to safe and nutritious food, nature-positive production, sustainable consumption, and resilience to stress and shocks. As per their study, resilience to stress and shocks aims at ensuring food system resilience when there is increased stress from climate change, conflict over limited natural resources, and population growth. Hertel *et al*. (2021) identified five capacities that are for a resilient food system in the face of these stresses and shocks: to prevent, to anticipate, to adapt to an evolving risk, to absorb, to transform in the incidences that the food system is unsustainable. Hertel *et al*. (2021) found that resilience as a framework helps conceptualize complex issues that are related to food security and allows pointing out important challenges that need to be addressed.

Olayide *et al*. (2016) compared rain-fed agriculture and irrigated agriculture, with irrigation being a CSA practice; they found that irrigating the crops had a significant and positive effect on total agriculture produce. CSA practices have a positive impact on total agricultural production (Olayide *et al*., 2016). With the use of CSA practices in maize production, farmers mitigate and become resilient to maize yield loss (Olayide *et al*., 2016). Governments, development agencies, and institutions are putting a lot of effort to increase agricultural yield worldwide but less effort has been put into making agriculture environmentally sustainable (Dickie *et al*., 2014).

According to Cacho *et al*. (2020), improving smallholder farmers' resilience requires breeding climate-resilient seeds, accessing input subsidies, investing in seed production and distribution, and expanding extension services. According to Xiong and Tarnavsky (2020), production variability caused by weather extremes is a major risk in crop production affecting the resilience capacity of smallholder farmers. Weather extremes have caused failure in crops with a range of devastating impacts on the livelihoods of smallholder farmers (Xiong and Tarnavsky 2020). Maize faces periodic climatic stresses in Bungoma County leading to yield loss (Xiong & Tarnavsky 2020). Strategies that can enhance the resilience of smallholder maize farmers to maize yield loss caused by climate change effects are needed which will reduce the risk from food insecurity for the present generation without compromising the future generations (Lipper *et al*. 2014). According to Cacho *et al*. (2020), packaged policies in agriculture may provide incentives and infrastructure that enhance the adoption of CSA technologies and access to better markets among smallholder farmers that will develop their resilience to climate shocks. Farmers have to be trained on how they will overcome the climate stress and shocks by using systems that will make them resilient in the quest for increased maize yield (Cacho *et al*., 2020).

2.5. Theoretical review

According to McFadden (1974), the random utility theory suggests that individuals make decisions aiming at maximizing utility. According to Tesfaye *et al*. (2021), it is assumed that a rise in control measures to cushion against risks increases the level of utility at the same time while decreasing the utility from gaining access to other services and goods by the provision of existing resources within a reserved production frontier. If the gain acquired from the control measure balances the loss of value due to a reduction in resource utilization of resources, then people would be indifferent between the utilization of these two packages of gain acquired and control measure (Tesfaye *et al*., 2021). According to Tversky and Kahneman (1991), people's preferences do not rest on their current assets. There is a consideration that when people have something of significance to them, they would be willing to lose it and would like to get more reimbursement for that good than that what they would be willing to pay to acquire that good (Tversky and Kahneman 1991).

According to Hayami and Ruttan (1971), induced innovation theory involves the process by the investment of the public sector in agricultural research, agricultural development supportive institutional infrastructure, and in the agricultural technology adaptation and diffusion that is directed toward letting go of the limitations on agricultural production imposed by the factors characterized by a relatively inelastic supply. Hayami and Ruttan (1971) extend the traditional dispute by building on the mechanism of innovation inducement not only on the reaction to changes in the market prices by firms whose aim is profit-maximization but also on the reaction by administrators in public institutions and research scientists to resource endowments and economic change.

The decision to produce and consume makes smallholder farmers have a positive own price elasticity of demand for food (Taylor and Adelman, 2002). Smallholder farmers' household budget depends on the decision to produce that adds to income through the selling of the surplus produce at a profit (Taylor and Adelman, 2002). Huffman (200l) used an agricultural household model to examine smallholder farmers' off-farm labor supply, production, and consumption decisions. According to Griffin (l986), the effects depend not only on the household's economic characteristics but also on its socio-demographic characteristics.

CHAPTER THREE: METHODOLOGY

3.1. Conceptual framework

As shown in Figure 3.1, farmers' adoption of CSA practices will make them more productive and resilient to climate change shocks and stresses. This is because CSA practices, like any new technology, mitigate against climate change and increase maize yield, and therefore incomes, while removing greenhouse gases from the atmosphere (Wekesa *et al*., 2018). The CSA practices make farmers sustainable, as they produce without degrading the environment for the future generation. According to Wollenberg *et al*. (2012), farmers can mitigate the changing climate impacts by choosing agricultural practices that reduce greenhouse gas emissions. The issues that make smallholder farmers use CSA practices are soil degradation, soil erosion, and reduction in crop yield due to declining soil fertility, which collectively are caused by the negative impacts of climate change (Singh & Singh, 2012).

The adoption literature shows that farmer characteristics influence the adoption of new technologies, innovations, or practices (e.g., see Magruder (2018), Rehman *et al*., 2016, and Ogundari & Bolarinwa (2018)). For example, a farmer's awareness and knowledge about a new technology/practice could motivate him/her to want to try it out and later adopt it after confirming its utility during the trial.

Concerning this study, the theory of change of the adoption of CSA practices in maize production is as follows (see Figure 3.1): The application of CSA practices in maize production increases maize yields leading to higher farm income and food security. In addition, it reduces the adverse effects of climate change by limiting greenhouse gas emissions. These two outcomes eventually lead to higher household resilience to low yield and a sustainable production environment.

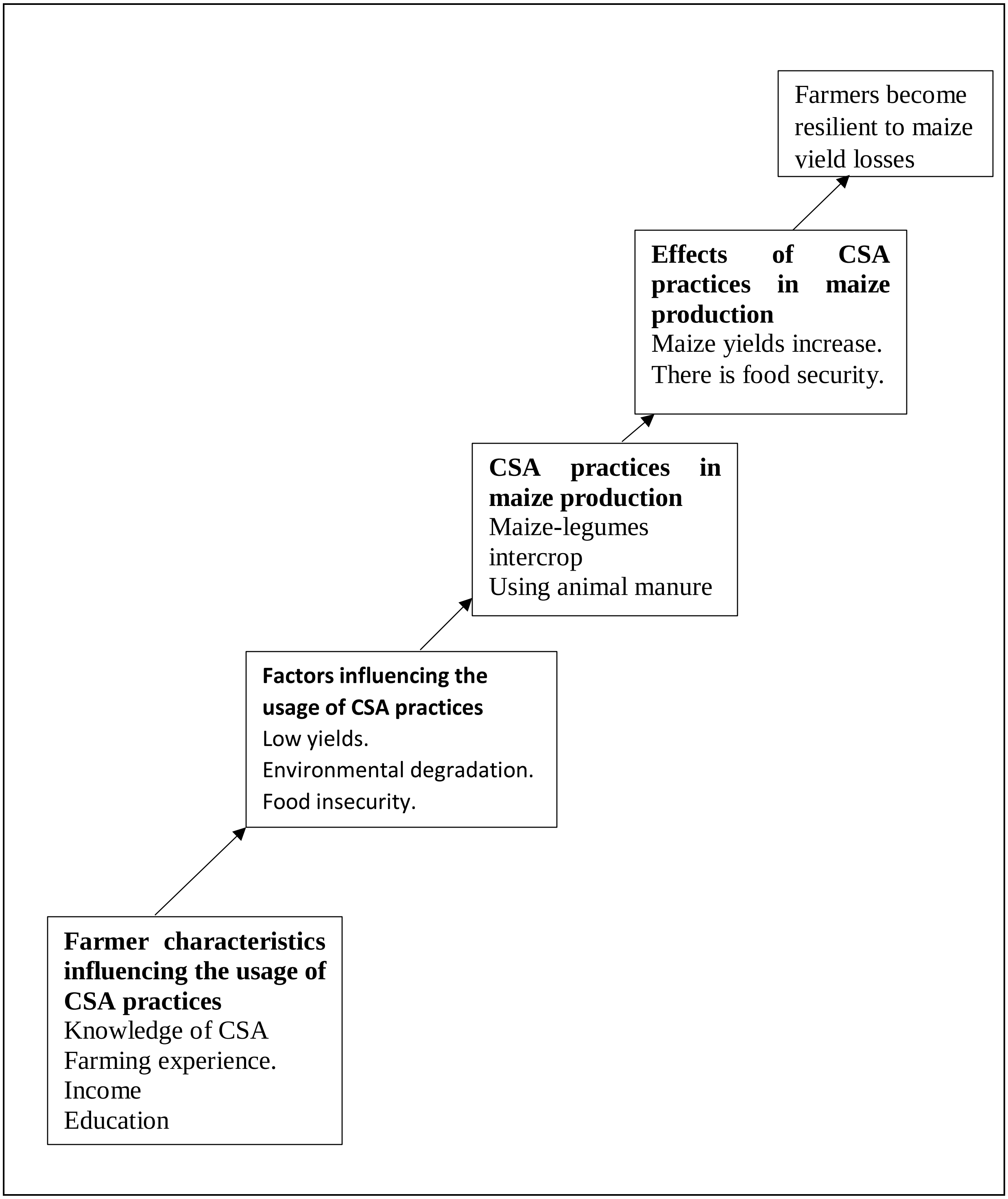

Figure 3.1: Conceptual framework

Source: Author's conceptualization

3.2. Theoretical Framework

This study is based on the theory of the firm. According to Bartlett and Ghoshal (1993), profits are at a maximum when the value of an additional product produced equals the cost of an additional unit of a variable factor. Smallholder farmers have to be aware of the marginal productivity of the factors of production over a period of time. The theory of the firm shows phases of falling and rising mean and marginal cost functions as the firm's resources that are fixed being applied more intensively. In the theory of the firm, there is a technique defined by the function production (Hart 2011), equation 3.1

$$Q = F(L), \quad \text{3.1}$$

Where L is labor and Q is output and $F' > 0$, $F'' < 0$. The selling price of the output is reasonable at price p with a fixed cost of production K, equation 3.2

$$(pF(L)-K)/L \quad \text{3.2}$$

First order conditions

$$(pF(\hat{L})-K)/\hat{L} = pF'(\hat{L}) \quad \text{3.3}$$

The mean labor product is equated to the marginal revenue product.

$$(pF(\hat{L})-K)/\hat{L} \geq w \quad \text{3.4}$$

3.3. Empirical Framework

3.3.1 Climate-smart Agriculture Practices on Maize Yield

3.3.1.1. Estimation of the Cobb-Douglas production function

The Cobb-Douglas production function was used to test the hypothesis that there is no increased maize yield when smallholder farmers use CSA practices. The Cobb-Douglas production function provides the basis for estimating a log-linear regression model, in which the parameter estimates of the explanatory variables are their partial production elasticity coefficients, holding other variables constant (Gujarati, 2011). All the continuous variables were entered into the model as logs and the CSA practices as dummies. The general Cobb-Douglas production function was expressed as (Gujarati, 2011):

$$Y = A * X_1^{\propto_1} X_2^{\propto_2} X_3^{\propto_3} \dots X_n^{\propto_n} + \mu \dots\dots\dots(3.5)$$

where Y is the output; A is the technological knowledge, and $X_{1,} X_2, \dots X_n$ are inputs and $\propto_{1,} \propto_2, \dots \propto_n$ are the model parameters to be estimated which represent the elasticities of output with respect to the inputs, μ is the error term. Taking the logarithm of equation (3.5) produces

$$lnY = lnA + \propto_1 lnX_1 + \propto_2 lnX_{2,} + \propto_3 lnX_{3,} + \cdots + \propto_n lnX_n + \mu \dots\dots\dots(3.6)$$

In the context of this study, Y is maize yield per acre of land, and the inputs considered are labour and capital. Labour is measured as the household size (i.e., the number of persons in the household). Capital is measured by the household's income per day. Other inputs considered are the CSA practices used in maize production. The CSA practices were; maize with legume intercropping and using animal manure alongside planting of certified high-yielding maize varieties. Multicollinearity was tested using the variance inflation factor (VIF) test on regressors (Gujarati & Porter, 2004) (see results in Appendix I).

Table 3.1: Description of independent variables and their hypothesized signs as used in the Cobb-Douglas production function

Variable	Description	Expected sign
Gender	Gender of the household head (1 male and 0 otherwise)	+/_
Age	Age of the household head in years	+_
Years	Household head years of schooling	+
Lr	Number of 90 kgs bags of maize produced in an acre piece of land in the long rain season of the year 2017.	+
Sizeoflandlongrains	Size of land in acres under maize in the long rains season	+/_
IML	Maize legumes intercrop (1 if maize was intercropped with legumes and 0 otherwise)	+
HYMV	Planting certified high-yielding maize (1 if certified high-yielding maize was planted and 0 otherwise).	+
M	Adding manure as organic fertilizer to the maize (1 if manure was added to the maize crop and 0 otherwise)	+
FS3	Amount spent per week on food when the farmer doesn't have any mature crops on the farm	-
S	Causes of shocks experience during the last 12 months (1 = crop pests and diseases, 2 = droughts, 3 = soil erosion)	-

This study hypothesized that a unit increase in the size of land in acres under maize in the long rains season increased maize yield. According to Graesser *et al*. (2018), the land was denoted as a productive asset with which a unit increase in land increases crop production. It was hypothesized that a unit increase in intercropping maize with legumes, adding animal manure, and using high-yielding certified maize varieties increase maize yields. According to Javanmard *et al*. (2020), intercropping with legumes is an agricultural practice that achieves a higher quantity of forage crops. Maize yields increase when animal manure is added ensuring food security among smallholder farmers (Asfaw 2022). Mwabu *et al*. (2006) found that the adoption of high-yielding maize varieties leads to significant increases in maize production if farmers adopt new ways of planting and weeding.

3.3.2 Effects of Climate-smart Agriculture Practices on Maize Farmers' Resilience to Yield Loss

3.3.2.1 Computation of resilience index

A resilience index was developed using PCA. The resilience index measurement and analysis (RIMA) method measured the maize yield loss resilience in terms of climate change (CC) factors, enabling institutional environment (EIE), technology in agriculture production (APT), and access to food and income (IFA) expressed as (d'Errico & Di Giuseppe 2018):

$\mathrm{R} = \mathrm{f}\,(\mathrm{CC}, \mathrm{EIE}, \mathrm{APT}, \mathrm{IFA})$..3.7

Table 3.2 presents the variables offered to the PCA. The suitability of PCA was tested using Bartlett's test of sphericity and Kaiser-Meyer Olkin (KMO) measure of sampling adequacy.

Table 3.2: Variables offered to PCA to compute the resilience index

Component	Indicators
Stability	• Depend on safety nets (share of transfers on all income) • Stability of the education system (ordinal; quality increased, decreased, or remained the Same.) • Ability to sustain firmness in the coming days (ordinal, 1 to 5) • The household members who have lost a job (count) • The change in expenditure (ordinal; increased, decreased, remained the same.) • Change of Income (ordinal; increased, decreased, the same)
Access to Basic Services	• Transportation and movement constraints (ordinal, 1 to 3) • The quality of educational systems (ordinal, 1 to 6) •Electricity, phone, and Water networks (count) • Physical access to health services (ordinal, 1 to 3) • What is perceived of security (ordinal, 1 to 4) • Health services quality score
Non-Agricultural assets	• Bicycles • Vehicle • Motorbike
Social Safety Nets	• Assistances of jobs (binary yes/no response) • Targeting opinion (assistance targeted to some who are not needy; to the needy; or without distinction) • The amount of cash and in-kind assistance received (local currency/person/day) • The times when the assistance was received in the last six months) • Evaluation of the quality of the assistance (ordinal, 1 to 4)
Climate change	• Late maturing of crops • Reduced rainfall • Prolonged drought
Enabling institutional environment	• Frequency of the extension advice • Extension advice
Assets	• The durability of the index (Principal Component Analysis (PCA) on the list of items: TV, Car, etc...) • Land owned (in hectares) • Tropical Livestock Unit (TLU) equivalent to 250 KG; • Housing (number of rooms owned)

Agricultural practice and technology	• Planting early maturing maize seed varieties. • Crop rotation • Use legume crops as permanent soil cover in maize fields i.e. *mucuna*, desmodium, and soya beans. • Planting certified drought-tolerant maize seed varieties. • Application of conservation Agriculture technologies in maize production. • Planting high-yielding maize varieties • Use of crop residues for soil cover as mulch. • Using animal manure
Adaptive Capacity	• The ratio of the food consumed (The share of food expenses divided by total expenditure) • The average level of education in the household. • The available strategies to cope with (Count, 0 to 18) • The employment status (ratio, the number of those employed in the household divided by the household size) • Income sources diversification (count, 0 to 6)
Income and Food Access	• Food frequency score and dietary diversity • The food insecurity access score of the Household. • The average daily expenditure per person (local currency /person/day) • The average daily income per person (local currency/person/day) • The dietary consumption energy (kcal/person/day)

Source: (Robert 2018)

The index in this study is generated by 10 variables that are linked to smallholder farmers' maize yield losses to generate the maize yield loss resilience index, Appendix II, (Ahuja *et al.,* 2003). Bartlett's score of Sphericity with a p-value of 0.000 is highly significant at 1%, hence this study rejected the null hypothesis as the variables were intercorrelated. With a 0.62 KMO

measure of sampling adequacy being above the recommended 0.6, meaning that indices constructed with the variables give unbiased inferences, Appendix II. According to Eyduran *et al.*, (2010) a KMO measure that is more than 0.60 is suitable for factor analysis.

According to Latif *et al*. (2018), the main objective of Principal Component Analysis (PCA) is to transform variables into smaller sets of linear combinations. It consists of the following steps: data matrix construction; creation of standardized variables; correlation matrix calculation and determination of eigenvectors; panel component (PC) selection; and presentation of the results (Latif *et al*., 2018). This study generated a maize farmer resilience index (MFRI), which is a weighted index of all the ten maize farmer indicators in PCA. The index provides a relatively weighted index that contains the variables used in the study. Appendix III shows the PCA analysis for the MFRI. The eigenvalue of the first component was 1.91 which was used to generate the PCA score, Appendix III. The proportional variation for the first component was 19%, Appendix III. This study generated a maize farmer resilience index (MFRI), which is a weighted index of all the eleven maize farmer indicators in PCA. The index provides a relative weighted index that contains the variables used in the study. Appendix III shows the PCA analysis for the MFRI.

The factor score coefficient of the first principal component was used to generate the resilience index following Ahuja *et al.* (2003):

$$A_{ij} = \sum_k f_k \frac{a_{ijk} - a_{jk}}{s_{jk}} \quad \ldots 3.8$$

where A_{ij} is the maize yield loss resilience score for the ith household, f_k is the factor score generated by PCA for the first component, a_{ijk} is the ith household's value for the first variable, and a_{jk} and s_{jk} are the mean and standard deviation, respectively, of each variable over all the households.

3.3.2.3 Modeling Effect of climate-smart agriculture practices on the resilience of smallholder maize farmers to yield loss

To analyze the resilience of smallholder maize farmers to maize yield loss when they use CSA practices, an OLS regression was estimated with the maize yield loss resilience index generated as the dependent variable. The presence of heteroscedasticity was addressed when a robust model was estimated (StataCorp, 2013) as shown in equation 3.5. (Arslan 2016):

$$Y_i = \alpha X_i + \delta\, IML_i + \beta HYMV_i + \kappa M_i + \infty S_i + \check{e}_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.9$$

where Y_p is the maize yield loss resilience index on household p, X is a vector of variables that includes farm and household characteristics; maize legume intercrop (IML), using animal manure(M), and planting certified high-yielding varieties (HYMV) are dummy variables which indicate the practices smallholder farmers use in the farm, (S) represents the shocks that the farmers experienced in the year to March 2018 and *e* is a normally distributed error term. Table 3.3 represents the expected signs of independent variables used in the OLS regression to assess the resilience of smallholder maize farmers to maize yield loss when they use CSA practices.

Table 3.3: Description of independent variables and their hypothesized signs as used in the OLS model

Variable	Description	Expected sign
gender	Gender of the household head (1 male and 0 otherwise)	+/_
age	Age of the household head in years	+/_
years	Household head years of schooling	+
lr	Number of 90 kgs bags of maize produced in an acre piece of land in the long rain season of the year 2017.	+
Sizeoflandlongrains	Size of land in acres under maize in the long rains season	+_
IML	Maize legumes intercrop (1 if maize was intercropped with legumes and 0 otherwise)	+
HYMV	Planting certified high-yielding maize (1 if certified high-yielding maize was planted and 0 otherwise).	+
M	Adding manure as organic fertilizer to the maize (1 if manure was added to the maize crop and 0 otherwise)	+
FS3	Amount spent per week on food when the farmer doesn't have any mature crops on the farm	-
S	Causes of shocks experience during the last 12 months (1 = crop pests and diseases, 2 = droughts, 3 = soil erosion)	-

It was hypothesized that a unit increase in the household head years of schooling causes a unit increase in farmers' resilience capacity to maize yield loss. Debebe *et al.* (2015) found that maize production is significantly and positively influenced by the education level of the household head. It was hypothesized that a unit increase in intercropping maize with legumes, adding animal manure, and using high-yielding certified maize varieties caused a unit increase in the farmers' resilience capacity to maize yield loss. According to Javanmard *et al*. (2020), intercropping with legumes is an agricultural practice that achieves a higher quantity of forage crops making the farmer resilient to yield loss. Mwabu *et al*. (2006) found that the adoption of high-yielding maize varieties leads to significant increases in maize production if farmers adopt new ways of planting and weeding. Maize yields increase when animal manure is added ensuring food security among smallholder farmers and increasing their resilience capacity to yield losses (Asfaw 2022). This study hypothesized that a unit increase in the size of land in acres under maize in the long rains season increased farmers' resilience capacity to maize yield loss. According to Graesser *et al*. (2018), land was denoted as a productive asset with which a unit increase in land increases crop production increasing the resilient capacity of the farmer to yield losses. It was hypothesized that a unit increase in the causes of shocks experienced during the last 12 months decreased the farmers' resilience capacity to maize yield loss. According to Devereux (2007), weather shocks reduce crop harvests and cause food availability to decline reducing the reliance capacity of farmers to yield losses.

3.3. Data sources and sampling procedure

3.3.1 Sample size determination

The following formula was used in determining the sample size for an unknown population for this study (Cochran, 1963):

$$n = \left(\frac{z * \text{std dev}}{\text{Margin of error}}\right)^2 \ldots\ldots 3.10$$

where:

n = the desired sample size from an unknown population

z = confidence interval of the unknown population divided by 2 and checked from the z table 2.58.

The standard deviation of the population was 3.07

The margin of error for the unknown population at a 95% confidence interval is 0.5.

$$n = \left(\frac{2.58 * 3.07}{0.5}\right)^2 \ldots\ldots 3.11$$

= 250.9

n≈ 250

3.3.2 Sampling and data collection

A multistage sampling technique was used to select a sample of 250 farmers. In the first stage, Bungoma County was purposively selected because Vi Agroforestry is training farmers in the County on using CSA practices in their farms. In the second stage, Bukembe ward was purposively selected because Vi Agroforestry is Conducting a farmers' capacity building program on the use of CSA practices in their farms. In the third stage, among 50 villages in Bukembe ward, 10 villages were randomly selected. In the last stage, 25 smallholder maize farmers were randomly selected from each village using a sampling frame of farmers obtained from the Bungoma County Ministry of Agriculture staff responsible for the 10 villages. Primary data were collected using a pretested semi-structured questionnaire setup in ODK by trained enumerators. The study used five trained enumerators to undertake personal face-to-face interviews using the ODK. The interviews were conducted in March 2018. The data was merged and cleaned in SPSS and analyzed in Excel, SPSS, and Stata.

3.4. Study Area

This study was carried out in Bukembe ward, Bungoma County. Maize in this region is produced by smallholder farmers. Bukembe ward in Bungoma County lies 1427 m above sea level in agro-ecological zone II on Latitude: 0°33′48″ N and Longitude: 34°33′37″ E. Juma and Kelonye (2016) found that the climate of Bukembe ward in Bungoma County is tropical with substantial volumes of rainfall. They further noted that Bukembe ward gets an approximate 1500 mm average annual rainfall and an average annual temperature estimated at 22.5 °C. Vi Agroforestry is a nongovernmental organization training farmers on the usage of CSA practices in their farms. Bukembe ward in Bungoma County was picked as a study area because Vi Agroforestry was carrying out farmer training on CSA practices in the region.

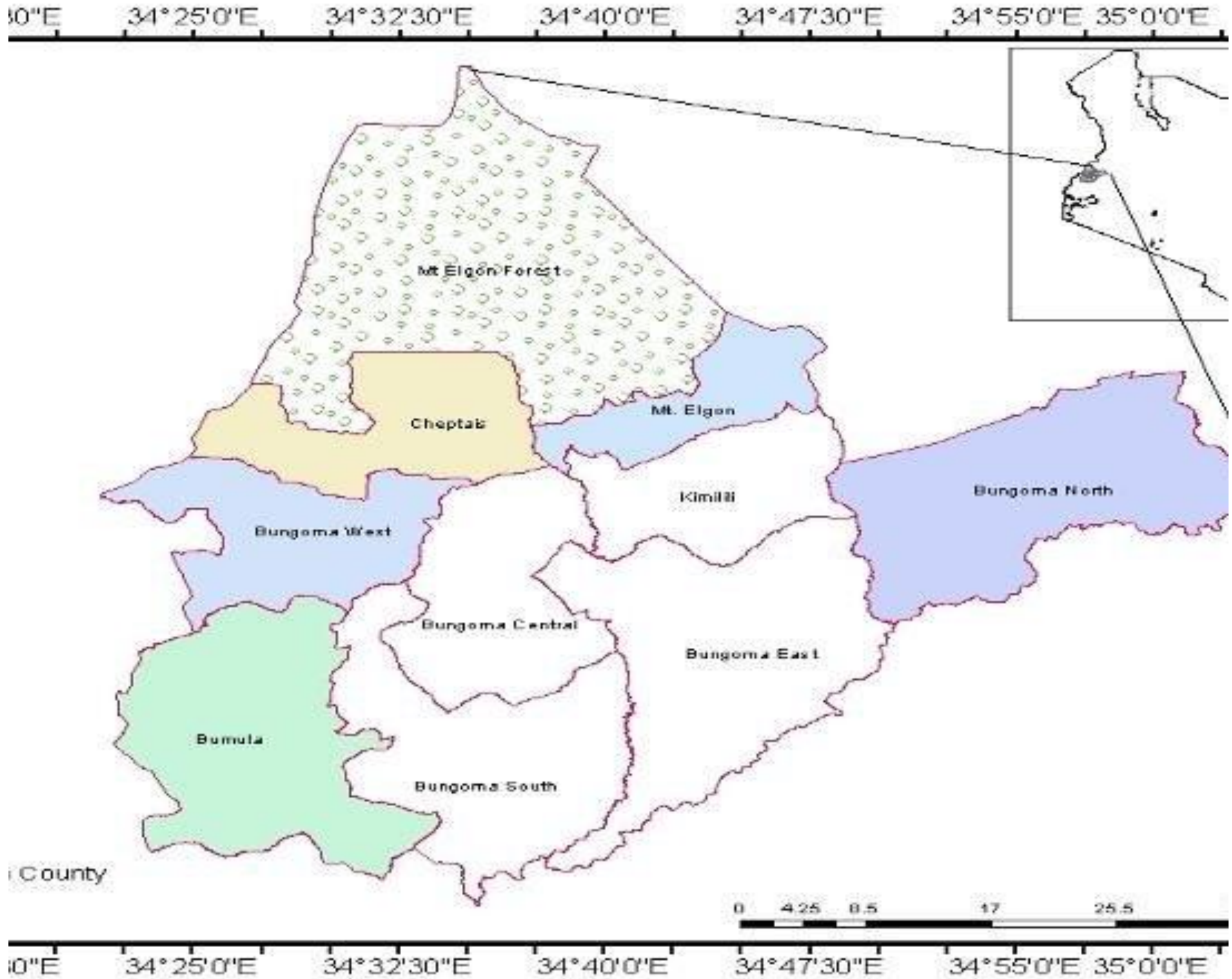

Figure 3.2: Study area
Source: online map of Bungoma County

3.5 Limitations of the Study

The current study measures the two CSA strategies as dummy variables instead of continuous variables, it never used the quantity of animal manure hence using the Cobb-Douglas production function it was not possible to discuss the causal relationship between manure use and yield in terms of values.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1. Descriptive Statistics of Farmer and Household Characteristics

Table 4.4 presents the household characteristics of maize farmers in Bukembe ward, Bungoma County.

Table 4.4: Selected farm and household characteristics of farmers in Bukembe ward

Variable	Mean (Std dev.) n= 250	Percentage (%) n =250
Male headed household		70
Number of household members	6 (2.1)	
Decision-maker household heads		79
Age (years)	50(14.3)	
Education (average years of education)	10	
Working on farm		64
The average income per day (USD)	3(2.12)	
Average daily expenditure (USD)	1.2(1.05)	
Total farm size (acres)	1.7 (0.97)	
Farm size of maize long rains (acres)	1 (0.5)	
Long rains maize production using CSA practices in an acre (90kg bags)	12 (3.6)	
Motivation of using CSA practices (I if the farmer was motivated to use CSA practices and 0 otherwise).		80
Reduction in maize yield from the year 2013 (1 if the farmer saw a reduction in maize yields from the year 2013 and 0 otherwise).		95
Increase in maize yield starting in the year 2015 (1 if maize yield started increasing in the year 2015 and 0 otherwise).		69
Farmers who associated CSA practices with the increased maize yield (1 if the maize yield was associated with using CSA practices and 0 otherwise).		93
Completed secondary education		34

Among the households interviewed 70% were male-headed households. On the decision-making regarding farming activities in the production of maize, 79% were household heads. According to Olwande *et al*. (2009), the household head is the main decision-maker concerning maize production in Kenya, which contributes to making better-informed decisions in agricultural productivity (Pernechele *et al.*, 2018). The household head had an average age of 50 years. Tadele and Gella (2012) found the average age of a farmer in Kenya to be 57 years. According to Arslan (2019), the average age of a farmer in the developing world is 49 years.

On the level of education, 34% of the farmers had completed secondary education with a mean year of schooling of 10 years. Less than half of the farmers had attained secondary education (Mburu, 2013). According to Mwungu *et al.* (2018), the literacy index influences the adoption of CSA technologies, households whose level of education is low are unlikely to examine materials and hence have lower awareness and experience about productivity increase and growing improved varieties.

The average income per day of those employed was US $ 3 with a minimum of US $ 1 and a maximum of US $ 10. The average daily expenditure was US $ 1.05, with a minimum daily expenditure of US $ 0.5 and a maximum daily expenditure of US $ 8. On average a farming household in Kenya makes an income of around US $2 527 in a year, having an average family size of five persons, being an average of US $1.4 per day per person which is below the international poverty line of US $ 1.90 per day in 2011 (Rapsomanikis, 2015). With a low-income smallholder farmers spend less money on their daily expenses (Rapsomanikis, 2015).

The average total land size in acres was 1.7 with a minimum of 0.25 acres and a maximum of 4 acres. The average total land size in acres that maize was planted in the year 2017 during the long rain season was 1 acre with a minimum of 0.25 acres and a maximum of 3 acres. The distinction between a smallholder farmer from a large-scale farmer is a farmer who is farming on less than 5 acres of land Csaki and de Haan (2003).

During the long rainy season of the year 2017 on average 12 bags of 90 kg of maize was produced per acre. Maize production in Kenya under favorable conditions is 20 bags per acre (Nyambedha *et al.*, 2001). Onono *et al*. (2013) found out that maize yield is always below the national supply in Kenya making the country continue relying on imports to come to terms with the shortage. Climate-smart agriculture practices are friendly to the environment and increase crop yield making 80% of farmers motivated to use them in their farms. Climate-smart agriculture practices provide opportunities for higher productivity through improved management technologies increasing crop and animal yield (Neufeldt *et al*., 2011).

From the year 2013, 95% of the farmers said they have noticed a reduction in maize yield on their farms. Among the farmers, 69% started noticing an increase in their maize production in the year 2015 because they started using CSA practices. Among the farmers, 93% associated the usage of CSA practices in their production for the increased maize yield. Amadu *et al*. (2020) found an increase in maize yield among farmers who adopted climate-smart agriculture practices.

4.2. Kind of Shocks that the Maize Farmers Experienced

The shocks that the farmers experienced were caused by crop pests and diseases, Droughts, and soil erosion, Figure 4.3:

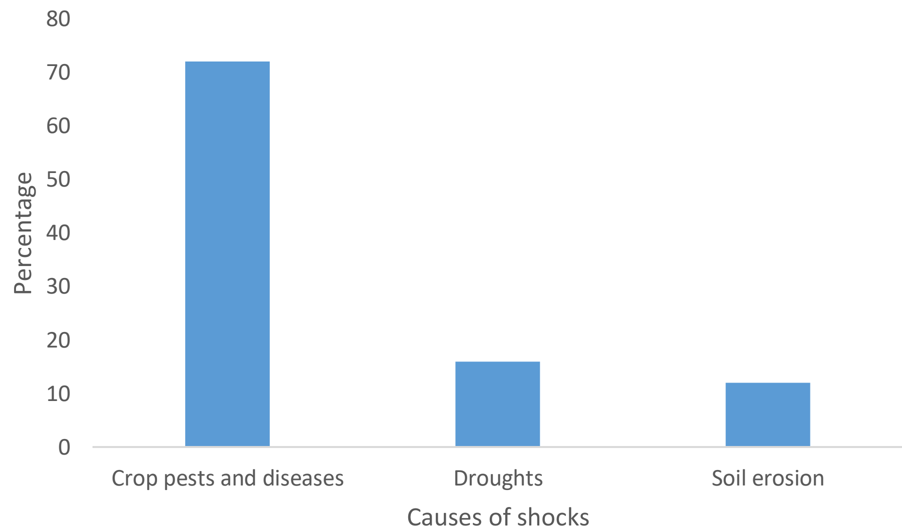

Figure 4.3: Causes of shocks experienced during the last 12 months

The major shock that the farmers experienced in the sampled population was caused by crop pests and diseases. The maize was being affected by the fall armyworm which is a new pest that attacks the maize crop, 90% of the farmers had experienced these pests attacking their maize crop. A shock will affect a farmer depending on the length of time it will stay on the crop. Among the farmers, 81% said that the fall armyworm had stayed on their maize plantation for more than 1 month, Figure 4.4. The severity of the shock depends on the length of time of the shock. For more than 1 month this may have caused a lot of damage to the maize crop, hence the reduction in maize yield.

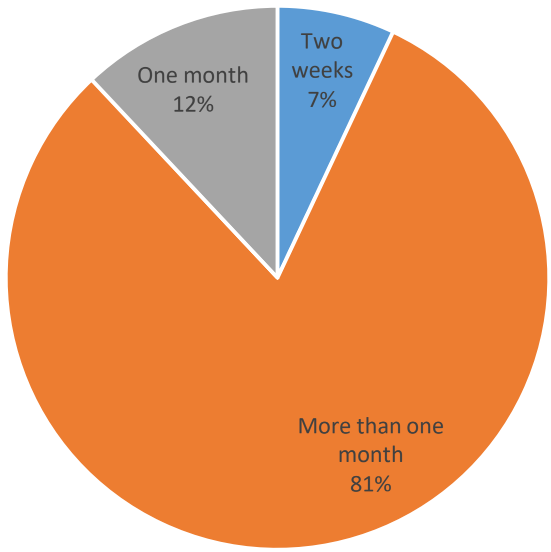

Figure 4.4: Incidence of Fall Armyworm on maize plantation

The farmers lost a lot of maize due to the fall armyworm. The mean number of 90-kilogram bags of maize that the farmers lost was 6 in the long rain season of 2017. To cover the maize yield loss caused by the fall armyworms, 52% of the farmers did off-farm and on-farm jobs so that they can supplement their incomes to cover for their expenses, Figure 4.5.

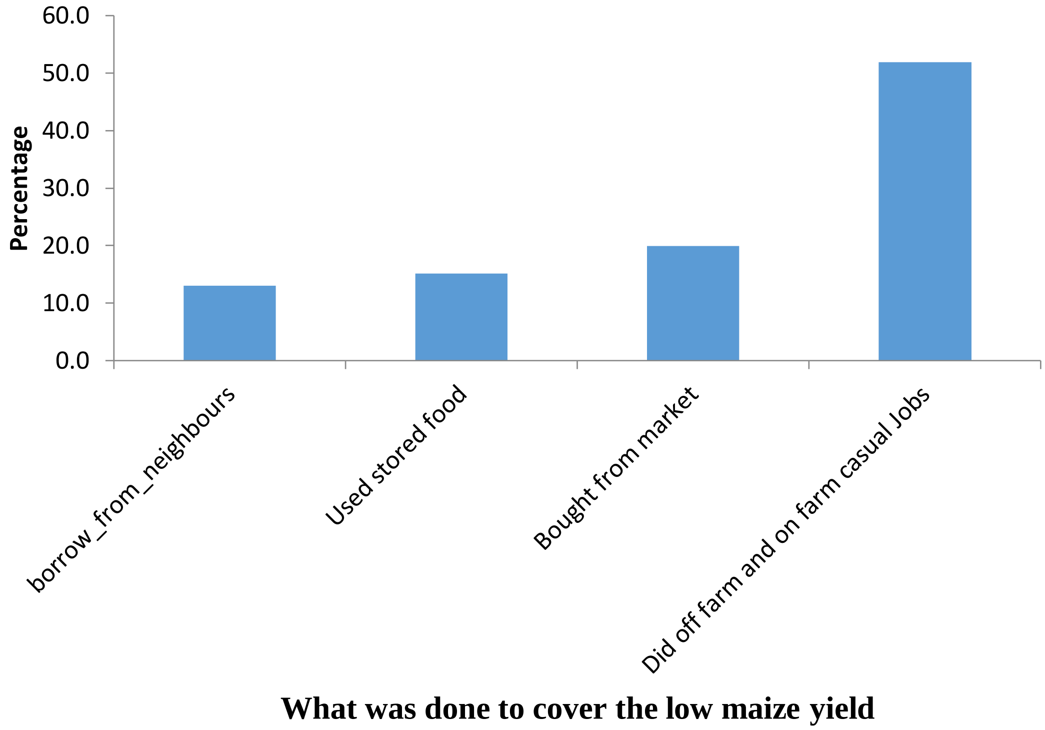

Figure 4.5: What the farmer did to cover the low maize yield

Though farmers apply a variation of risk-coping approaches they are inadequate to avoid them from remaining food insecure (Harvey *et al.* 2014). Some farmers are adjusting their farming approaches in response to climate change, owing to their limited resources and capacity. Among the farmers, 44% got support from family members and relatives during times of shock with 44% receiving farm inputs. This helped them a lot as they used these farm inputs to improve their farms. The farm input support that they received enabled 66% of the farmers to manage only 25% of the shocks.

On the initiatives that are being put in place by the farmers to manage the shocks better in the future, 60% are adopting the usage of climate-smart agriculture practices in their crop production, Figure 4.6.

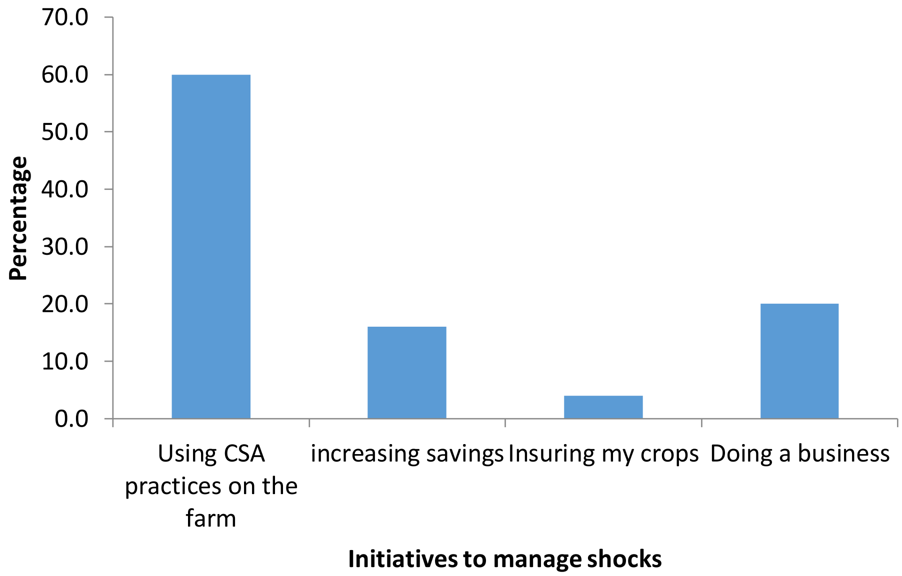

Figure 4.6: Initiatives to manage shocks better in the future

4.3 Effect of Climate-smart Agriculture Practices Used in Maize Production

4.3.1. Climate-smart Agriculture Practices Used in Maize Production.

The average number of 90 kgs bags of maize that were produced using the CSA practices from an acre piece of land in the long rain season of August 2017 was 12. The CSA practices that smallholder farmers used to produce their maize were; maize legume intercrop and adding animal manure to the maize crop with planting certified high-yielding maize varieties. Intercropping maize with legumes and using animal manure increase maize yield (Palombi and Sessa, 2013). Among the households, 84% had a maize legume intercrop, 34% planted certified high-yielding maize varieties, and 31% added animal manure to the maize crop, Figure 4.7.

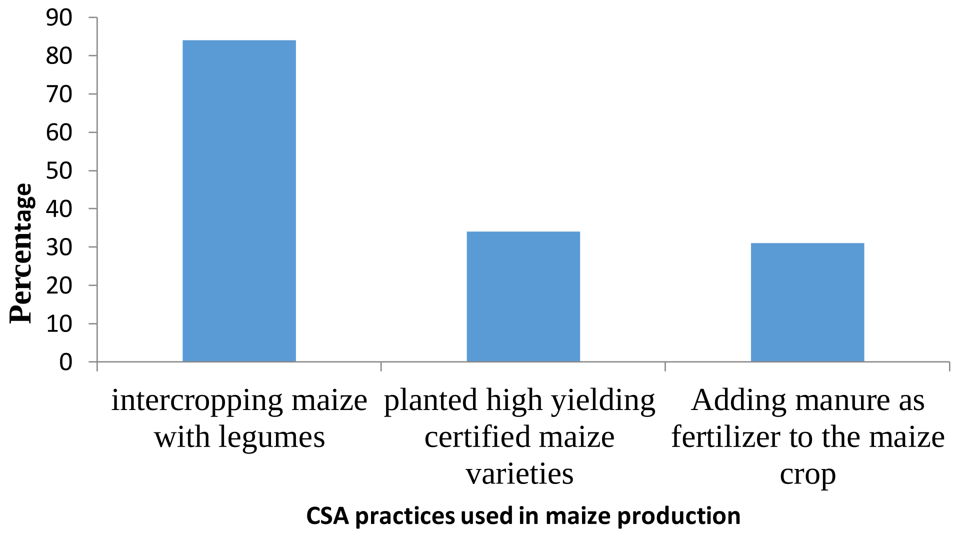

Figure 4.7: CSA practices used in maize production

Among the smallholder farmers interviewed, 81% classified the practice they used in maize production as CSA. Because of the negative impacts of climate change on agriculture productivity, smallholder farmers adopt climate-smart agriculture practices to increase crop yield and be sustainable in the changing climate (Nyang'au *et al.*, 2021).

4.3.2. Effects of Climate-smart Agriculture Practices Used on Maize Yield

Table 4.5 presents Cobb-Douglas production function regression on the effect of CSA on maize yield among smallholder farmers in Bukembe ward, Bungoma County. The overall model was significant at $P < 0.01$ with an R – squared of 19% i.e., of the variations in the dependent variable 19% of them are explained by the independent variables.

Table 4.5: Cobb-Douglas production function estimates evaluating the effects of climate-smart agriculture practices on the yield of smallholder maize farmers

Variable	Coefficient	Std. Error
Income per day of the household head	0.02285	0.035924
Number of household members	0.015276	0.059543
Land size in acres under maize in the long rains	0.208488***	0.037603
Intercropping maize with legumes	-0.16324**	0.07587
Adding manure as fertilizer to the maize	-0.22631***	0.061143
High-yielding certified maize varieties	0.097013**	0.044698
Constant	0.741878	0.256951

Statistical significance levels ***1%, **5% and *10%
Number of obs = 246
Pseudo R2 = 0.1871

Land size in acres under maize in the long rains was significant at $P < 0.01$ and positively affects maize yields by 20%, Table 4.5. This implies that a unit increase in land size in acres under maize increases maize yield by 20%. According to Epule *et al*. (2022), land under maize and maize yields have increased across Africa exhibiting a positive relationship. Farmers with bigger land sizes allocate more land to hybrid maize which leads to increased yields (Simtowe *et al*., 2009).

Intercropping maize with legumes and adding manure as fertilizer to the maize had a negative coefficient and were significant at $P < 0.05$ and $P < 0.01$ respectively, Table 4.5. This implies that a unit increase in Intercropping maize with legumes and adding manure as fertilizer will lead to a decrease in maize yield by 16% and 23% respectively. Maize-legume intercropping ensures higher yield, soil restoration, and greater utilization of available resources (Maitra et al., 2020). There are beneficial effects of adding manure as fertilizer as it releases nutrients for a good response in maize growth (Boateng *et al*., 2006). High-yielding certified maize varieties were significant at $P < 0.5$ and positively affect maize yield by 9%, Table 4.5. This implies that a unit increase in the use of high-yielding certified maize varieties increases maize yield by 9%. Using hybrid maize seeds increases maize yield making smallholder farmers' food secure (Japhether *et al*., 2006).

4.4. The effect of climate-smart agriculture practices on smallholder maize farmers' resilience to yield loss

4.4.1 Household Resilience Index

A majority (52%) of the households had moderate resilience against maize yield (Figure 4.8).

Another 28% and 21% had high and low resilience respectively, Figure 4.8.

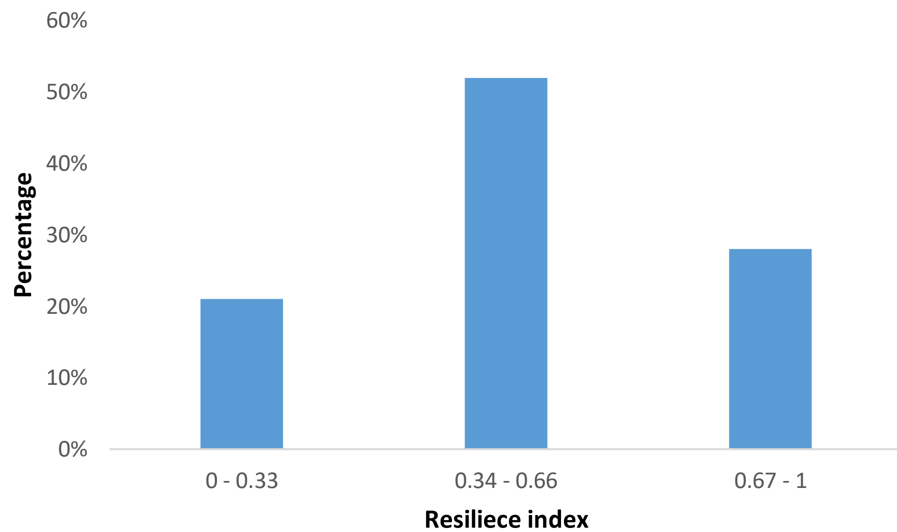

Figure 4.8: Household resilience index distribution

4.4.2. Effect of CSA Practices on the Resilience of Smallholder Maize Farmers to Yield Loss in Bungoma County

Table 4.6 presents the OLS regression analysis on the effect of CSA practices on the resilience of smallholder maize farmers to yield loss in Bungoma County. The overall model was significant at $P < 0.01$ generating an R – squared of 74%, meaning that 74% of the variations in the response variable are explained by the explanatory variables. The household head years of schooling was significant at $P < 0.05$, Table 4.6. Farmers with a higher level of schooling increase the maize produced and become resilient to yield loss.

The number of 90 kgs bags of maize produced per acre piece of land in the long rain season of the year 2017 was significant at $P < 0.1$, Table 4.6. The most effective way for smallholder farmers to cope with crop yield loss is to increase their resilience to yield losses by increasing crop yields sustainably (Gitz & Meybeck, 2012). The size of land under maize in the long rains of the year 2017 was significant at $P < 0.01$, Table 4.6. Land-use diversity is directly related to smallholder resilience to crop yield losses (Abson *et al*., 2013).

Planting certified high-yielding maize varieties was significant at $P < 0.01$, Table 4.6. Kansiime and Mastenbroek (2016) recommended the promotion of crop adaptation practices and farmer seed enterprises at the smallholder farmer level for the farmers to access and plant improved seeds for their resilience to yield loss to be enhanced. According to Dioula *et al*. (2013), smallholder farmers who can increase crop productivity on their farms are food secure and resilient to yield loss.

Adding animal manure to the maize was significant at P < 0.01, Table 4.6. According to Altieri *et al*. (2015), benefits will result from agro ecological measures such as the use of organic manure will strengthen the resilience of smallholder farmers to crop yield loss.

The amount spent per week on food when the farmer does not have any mature crops on the farm was significant at P < 0.01. Food insecure households spend a lot of money to get food from the market and are not able to buy farm inputs to use for them to be food secure (Olson *et al*., 1996). The causes of shocks experienced during the last 12 months from March 2018 were significant at P < 0.01, Table 9. Maize legume intercrop was significant at P < 0.05, Table 4.6.

Table 4.6: OLS parameter estimates evaluating the effect of climate-smart agriculture practices on smallholder farmers' resilience to maize yield loss in Bungoma County

Variable	Coefficient	Robust Std. Error
Gender of the household head	-1.1829	0.890194
Household head age	-0.0038	0.031361
Household head years of schooling	0.440669**	0.181697
Number of 90 kgs bags of maize produced	0.127774*	0.081005
Size of land under maize in the long rains	-3.71155***	1.05717
Maize legumes intercrop	-16.8782***	1.766583
Planting certified high-yielding maize	2.544375***	0.987394
Adding manure as organic fertilizer to the maize	10.77185***	0.957757
Amount spent per week on food when the farmer doesn't have any mature crops on the farm	0.001721***	0.00053
Causes of shocks experienced during the last 12 months	1.521558**	0.639368
Constant	1.192096	4.105259

n = 250
Statistical significance levels ***1%, **5% and *10%
$R^2 = 0.7392$

CHAPTER FIVE: CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Conclusion

This study presents findings from the assessment of the effects of climate-smart agriculture practices on the resilience of maize farmers to maize yield loss in Bungoma County, Kenya. Using CSA practices has a significant outcome on the maize yield in the long rains. The farmer during harvesting time gets a harvest that can be stored and sustain the household until the next harvest. Using animal manure rises the carbon content of the soil. With an increase in soil carbon content, its fertility increases which in turn increase the yield when a crop is planted. According to Abunyewa *et al. (*2007), from their animal manure and inorganic fertilizer long-term farm trials, they found a repeated improvement in maize yield with animal manure application and the application of inorganic fertilizer never increased maize yield significantly. With the Cobb-Douglas production function analysis being statistically significant with a P-value < 0.01 the null hypothesis was rejected and this study concluded that there is an increased maize yield when a farmer uses climate-smart agriculture practices.

This study generated a resilience index from the household data collected and used the index generated as a dependent variable in analyzing the effect of climate-smart agriculture practices on the resilience of smallholder maize farmers to yield loss using an OLS model. The OLS regression analysis on the effect of climate-smart agriculture practices on the resilience of smallholder maize farmers to yield loss was statistically significant with a P- value of < 0.01 hence the null hypothesis was rejected and this study concluded that the usage of CSA practice in maize production makes maize farmers resilient to yield loss.

5.2 Recommendations

Planting high-yielding certified maize varieties had a significant impact on the maize yield. This calls on the Ministry of Agriculture and all stakeholders in the agriculture industry to make sure that the seeds that are sold from agro-dealer shops to farmers are certified and high-yielding. The maize seed suppliers are to be equipped with certified and high-yielding maize seed varieties to supply to the farmers.

The findings of this study call for all stakeholders in the agriculture sector to train and encourage farmers to use CSA practices in their crop production so that the farmers can sustain themselves in the event of low crop yield and become resilient to yield loss. Awareness should be created on the importance of applying animal manure to the crops, intercropping maize with legumes, and planting high-yielding certified seeds. This is because soil carbon increases when farmers continuously use animal manure increasing its fertility and when legumes are intercropped with maize there is nitrogen fixation in the soil and a permanent soil cover.

When farmers use climate-smart agriculture practices they cushion themselves against maize yield loss because with CSA practices the farmer is assured of getting a higher yield and the farmer becomes resilient to yield loss. This makes them mitigate against climate change, adapt and be sustainable to climate change shocks and stresses and increase their crop yield and incomes.

5.3 Suggestions for Further Research

This study focused on assessing the resilience of farmers to maize yield loss when they use a combinations of the two CSA practices. There is a need for further studies to assess the resilience of farmers to yield loss when they use CSA practices in all crops produced. There is a need for further research to determine the quality of crops produced when farmers use CSA practices.

References

Abegunde, V. O., Sibanda, M., & Obi, A. (2019). Determinants of the Adoption of Climate-Smart Agricultural Practices by Small-Scale Farming Households in King Cetshwayo District Municipality, South Africa. *Sustainability*, *12*(1), 1-1.

Abson, D. J., Fraser, E. D., & Benton, T. G. (2013). Landscape diversity and the resilience of agricultural returns: a portfolio analysis of land-use patterns and economic returns from lowland agriculture. Agriculture & food security, 2(1), 1-15.

Abunyewa, A. A., Osei, C., Asiedu, E. K., & Safo, E. Y. (2007). Integrated manure and fertilizer use, maize production and sustainable soil fertility in sub humid zone of West Africa. *Journal of Agronomy*, *80*(30), 60-65.

Ahuja, V., Umali-Deininger, D., & de Haan, C. (2003). Market structure and the demand for veterinary services in India. Agricultural Economics, 29(1), 27-42.

Ajefu, J. B., Efobi, U., & Beecroft, I. (2020). Coping with negative shocks and the role of the farm input subsidy programme in rural Malawi. *Environment and Development Economics*, *26*(5-6), 561-581.

Alliance, R. (2010). Assessing resilience in social-ecological systems: workbook for practitioners (revised version 2.0). *Retrieved August*, *22*, 2021.

Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for sustainable development*, *35*(3), 869-890.

Amadu, F. O., McNamara, P. E., & Miller, D. C. (2020). Yield effects of climate-smart agriculture aid investment in southern Malawi. *Food Policy*, *92*, 101869.

Amin, A., Mubeen, M., Hammad, H. M., & Nasim, W. (2015). Climate Smart Agriculture: an approach for sustainable food security. *Agric. Res. Commun*, *2*(3), 13-21.

Anuga, S. W., Chirinda, N., Nukpezah, D., Ahenkan, A., Andrieu, N., & Gordon, C. (2020). Towards low carbon agriculture: Systematic-narratives of climate-smart agriculture mitigation potential in Africa. Current Research in Environmental Sustainability, 2, 100015.

Arslan, A. (2019). How old is the average farmer in today's developing world. *IFAD Blog.*

Amore, M. D., & Murtinu, S. (2019). Tobit models in strategy research: Critical issues and applications. Global Strategy Journal, 11(3), 331-355.

Arslan, A. (2016). Climate resilience in rural Zambia : Evaluating farmers ' response to El Niño induced drought. *Environment and Development Economics*, *26*(5-6), 582-604.

Asfaw, M. D. (2022). Effects of animal manures on growth and yield of maize (Zea mays L.). J. Plant Sci. Phytopathol, 6, 033-039.

Aylward, C., Biscaye, P., Harris, K. P., LaFayette, M., True, Z., Anderson, C. L., & Reynolds, T. (2015). Maize yield trends and agricultural policy in East Africa, macro-level literature review for six countries. *EPAR Technical Rep, 310.*

Bartlett, C. A., & Ghoshal, S. (1993). Beyond the M-form: Toward a managerial theory of the firm. Strategic Management Journal, 14(S2), 23-46.

Berre, D., Ndegwa, M., Karuiki, S., & De Groote, H. (2016). Participatory evaluation and application of climate smart agriculture practices in mixed smallholder farming systems: a case-study in the semi-arid regions of Kenya. Invited paper presented at the 5th International Conference of the African Association of Agricultural Economists, September 23-26, 2016, Addis Ababa, Ethiopia.

Berkes, F. (2002). Back to the future: ecosystem dynamics and local knowledge. Understanding Transformation in Human and Natural Systems.*Development Studies Research*, 4(1), 9–21.

Bommarco, R., Kleijn, D., & Potts, S. G. (2013). Ecological intensification: harnessing ecosystem services for food security. Trends in ecology & evolution, 28(4), 230-238.

Boateng, S. A., Zickermann, J., & Kornahrens, M. (2006). Poultry manure effect on growth and yield of maize. West African Journal of Applied Ecology, 9(1).

Bourdillon, M., Hebinck, P., Hoddinott, J., Kinsey, B., Marondo, J., Mudege, N., & Owens, T. (2003). *Assessing the impact of high-yielding varieties of maize in resettlement areas of Zimbabwe* (No. 583-2016-39536).

Branca, G., McCarthy, N., Lipper, L., & Jolejole, M. C. (2011). Climate-smart agriculture: a synthesis of empirical evidence of food security and mitigation benefits from improved cropland management. *Mitigation of climate change in agriculture series*, *3*, 1-42.

Boto, I., & Pandya-lorch, R. (2020). Agricultural resilience in the face of crisis and shocks. 30th Brussels Development Briefing on Agricultural Resilience in the Face of Crisis and Shocks.In *A Series of Meetings on ACP-EU Development Issues: Brussels Rural Development Briefings*

Cacho, O. J., Moss, J., Thornton, P. K., Herrero, M., Henderson, B., Bodirsky, B. L., ... & Lipper, L. (2020). The value of climate-resilient seeds for smallholder adaptation in sub-Saharan Africa. *Climatic Change*, *162*(3), 1213-1229.

Cairns, J. E., Hellin, J., Sonder, K., Araus, J. L., MacRobert, J. F., Thierfelder, C., & Prasanna, B. M. (2013). Adapting maize production to climate change in sub-Saharan Africa. *Food Security*, *5*(3), 345-360.

County, M. (2013). County integrated development plan. *County Government of Bungoma*, Kenya. Ecoagriculture Policy Focus; 11.

Chhetri, N., Chaudhary, P., Tiwari, P. R., & Yadaw, R. B. (2012). Institutional and technological innovation: Understanding agricultural adaptation to climate change in Nepal. Applied Geography, 33, 142-150.

Choptiany, J., Graub, B., Dixon, J., & Phillips, S. (2015). Self-evaluation and holistic assessment of climate resilience of farmers and pastoralists (SHARP). *FAO, Rome, 155.*

Cochran 2nd, W. G. Sampling techniques 2nd Edition, 1963 New York.

Debebe, S., Haji, J., Goshu, D., & Edriss, A. K. (2015). Technical, allocative, and economic efficiency among smallholder maize farmers in Southwestern Ethiopia: Parametric approach. Journal of Development and Agricultural Economics, 7(8), 282-291.

Debertin, D. L., & Pagoulatos, A. (2015). *Production Practices and Systems in Sustainable Agriculture* University of Kentucky, Department of Agricultural Economics Staff Paper 488 (No. 1639-2016-135225).

Devereux, S. (2007). The impact of droughts and floods on food security and policy options to alleviate negative effects. Agricultural Economics, 37, 47-58.

Dickie, A., Streck, C., Roe, S., Zurek, M., Haupt, F., & Dolginow, A. (2014). Strategies for mitigating climate change in agriculture. Report by Climate Focus and 544 California Environmental Associates, 545.

d'Errico, M., & Di Giuseppe, S. (2018). Resilience mobility in Uganda: A dynamic analysis. World Development, 104, 78-96.

Ekepu, D., & Tirivanhu, P. (2016). Assessing socio–economic factors influencing adoption of legume-based multiple cropping systems among smallholder Sorghum Farmers in Soroti, Uganda. *South African Journal of Agricultural Extension*, *44*(2), 195-215.

Epule, T. E., Chehbouni, A., & Dhiba, D. (2022). Recent Patterns in Maize Yield and Harvest Area across Africa. Agronomy, 12(2), 374.

Eyduran, E., Topal, M., & Sonmez, A. Y. (2010). Use of factor scores in multiple regression analysis for estimation of body weight by several body measurements in brown trouts (Salmo trutta fario).

Gairhe, J. J., & Adhikari, M. (2018). Intervention of Climate Smart Agriculture Practices in Farmers Field to Increase Production and Productivity of Winter Maize in Terai Region of Nepal. *Journal of the Institute of Agriculture and Animal Science*, *35*(1), 59-66.

Gitz, V., & Meybeck, A. (2012). Risks, vulnerabilities and resilience in a context of climate change. Building resilience for adaptation to climate change in the agriculture sector, 23, 19.

Graesser, J., Ramankutty, N., & Coomes, O. T. (2018). Increasing expansion of large-scale crop production onto deforested land in sub-Andean South America. Environmental Research Letters, 13(8), 084021.

Griffin, C. C. (1987). Methods for Estimating Value of Time with an Application to the Philippines (No. 549). Center Discussion Paper.

Gubbels, P. (2011). Escaping the Hunger Cycle: Pathways to resilience in the Sahel. *Oxfam Policy and Practice: Agriculture, Food and Land*, *11*(6), 165-288.

Gujarati, D. N. (2011). Econometrics by example (Vol. 1). New York: Palgrave Macmillan.

Gujarati, D. N., & Porter, D. C. (2004). Basic econometrics (ed.) McGraw-Hill. Irwin, a business.

Gwambene, B., Saria, J. A., Jiwaji, N. T., Pauline, N. M., Msofe, N. K., Mussa, K. R., ... & Shija, S. M. Y. (2015). Smallholder farmers' practices and understanding of climate change and climate-smart agriculture in the Southern Highlands of Tanzania. *J Resour Dev Manag*, *13*, 37-47.

Hart, O. (2011). Thinking about the firm: A review of Daniel Spulber's The Theory of the Firm. Journal of Economic Literature, 49(1), 101-113.

Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijohn, R. H., ... & MacKinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1639), 20130089.

Hayami, Y., & Ruttan, V. W. (1971). Induced innovation in agricultural development.

Herman, M. C. (2011). *Laboratory evaluation and soil test phosphorus trends in Ohio* (Doctoral dissertation, The Ohio State University).

Hertel, T. W., Elouafi, I., Ewert, F., & Tanticharoen, M. (2021). Building Resilience to Vulnerabilities, Shocks and Stresses–Action Track.*Economics and Sustainable Development*, 3(5), 91–106.

Huffman, W. E. (2001). Human capital: Education and agriculture. Handbook of agricultural economics, 1, 333-381.

Jama, B., & Pizarro, G. (2008). Agriculture in Africa: Strategies to improve and sustain smallholder production systems. *Annals of the New York Academy of Sciences*, *1136*(1), 218-232.

Jamil, I., Jun, W., Mughal, B., Raza, M. H., Imran, M. A., & Waheed, A. (2021). Does the adaptation of climate-smart agricultural practices increase farmers’ resilience to climate change?. Environmental Science and Pollution Research, 28, 27238-27249.

Javanmard, A., Machiani, M. A., Lithourgidis, A., Morshedloo, M. R., & Ostadi, A. (2020). Intercropping of maize with legumes: A cleaner strategy for improving the quantity and quality of forage. Cleaner Engineering and Technology, 1, 100003.

Jelagat, J. (2019). *Effects Of Climate-Smart Agricultural Awareness On Food Security Among Smallholder Farmers* (Doctoral dissertation, University of Nairobi).

Juma, S. G., & Kelonye, F. (2016). Projected rainfall and temperature changes over Bungoma county in western Kenya by the year 2050 based precis modeling system. *Ethiopian Journal of Environmental Studies and Management*, *9*(5), 625-640.

Kamanga, B. C. G., Waddington, S. R., Robertson, M. J., & Giller, K. E. (2010). Risk analysis of maize-legume crop combinations with smallholder farmers varying in resource endowment in central Malawi. *Experimental agriculture*, *46*(1), 1.

Kansiime, M., Mulema, J., Karanja, D., Romney, D., & Day, R. (2017). Crop pests and disease management in Uganda: Status and investment needs. Rome: PARM/IFAD.

Kansiime, M. K., & Mastenbroek, A. (2016). Enhancing resilience of farmer seed system to climate-induced stresses : Insights from a case study in West Nile region , Uganda. Journal of Rural Studies, 47, 220–230. https://doi.org/10.1016/j.jrurstud.2016.08.004

Kaumbutho, P., & Kienzle, J. (2007). *Conservation agriculture as practised in Kenya: two case studies*. Nairobi, Kenya: African Conservation Tillage Network (ACT); Centre de Coopération Internationale de Recherche Agronomique pour le Développement (CIRAD); Food and Agriculture Organization of the United Nations (FAO).

Karpenstein-Machan, M., & Stuelpnagel, R. (2000). Biomass yield and nitrogen fixation of legumes monocropped and intercropped with rye and rotation effects on a subsequent maize crop. Plant and soil, 218, 215-232.

Khatri-Chhetri, A., Aryal, J. P., Sapkota, T. B., & Khurana, R. (2016). Economic benefits of climate-smart agricultural practices to smallholder farmers in the Indo-Gangetic Plains of India. *Current Science*, 1251-1256.

Kurukulasuriya, P., & Mendelsohn, R. (2007). *A Ricardian analysis of the impact of climate change on African cropland*. The World Bank publication.

Levine, S., & Mosel, I. (2014). Supporting resilience in difficult places: A critical look at applying the 'resilience'concept in countries where crises are the norm. *OID, London.World Development*, 36(7), 1247–1260.

Li M, Peterson CA, Tautges NE, Scow KM, Gaudin ACM. Yield and resilience outcomes of organic, cover crop, and conventional practices in a Mediterranean climate. Sci Rep. 2019;9(1):1-11. doi:10.1038/s41598-019-48747-4

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., ... & Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature climate change*, *4*(12), 1068-1072.

Lobell, D. B., Bänziger, M., Magorokosho, C., & Vivek, B. (2011). Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nature climate change*, *1*(1), 42-45.

Macholdt, J., Piepho, H. P., & Honermeier, B. (2019). Does fertilization impact production risk and yield stability across an entire crop rotation? Insights from a long-term experiment. *Field Crops Research*, *238*, 82-92.

Magruder, J. R. (2018). An assessment of experimental evidence on agricultural technology adoption in developing countries. Annual Review of Resource Economics, 10, 299-316.

Maitra, S., Shankar, T., & Banerjee, P. (2020). Potential and advantages of maize-legume intercropping system. Maize-Production and Use, 1-14.

Mburu, J. M. (2013). *The relationship between government investment in infrastructure and economic growth in Kenya* (Doctoral dissertation, University of Nairobi).

McFadden, D. (1981). Econometric models of probabilistic choice. Structural analysis of discrete data with econometric applications, 198272.

Morris, M., Kelly, V. A., Kopicki, R. J., & Byerlee, D. (2007). Fertilizer use in African agriculture: Lessons learned and good practice guidelines. The World Bank publication.

Munialo, S., Dahlin, A. S., Onyango M, C., Oluoch-Kosura, W., Marstorp, H., & Öborn, I. (2020). Soil and management-related factors contributing to maize yield gaps in western Kenya. Food and Energy Security, 9(1), e189.

Muoni, T. (2019). Integrating legumes in mixed crop-livestock systems in east Africa: Farmers' perceptions, ecosystem services and support for decision making.*The Journal of Developing Areas*, 43(2), 111–124.

Mwabu, G., Mwangi, W., & Nyangito, H. (2006, August). Does adoption of improved maize varieties reduce poverty? Evidence from Kenya. In International Association of Agricultural Economists Conference, Gold Coast, Australia (pp. 12-18).

Mwungu, C. M., Mwongera, C., Shikuku, K., Acosta, M., & Läderach, P. (2018). Determinants of adoption of climate-smart agriculture technologies at farm plot level: an assessment from southern tanzania. International Journal of Climate Change Strategies and Management, 33(1), 10–21.

Mutoko, M. C., Rioux, J., & Kirui, J. (2015). Barriers, incentives and benefits in the adoption of climate-smart agriculture. Lessons from the MICCA pilot project in Kenya. *Rome: Food and Agriculture Organization of the United Nations (FAO)*.

Nabusoba, T. (2014). The impact of radio agricultural programmes on small scale farmers: The Case of "Mali Shambani" Programme on KBC Radio Taifa (Doctoral dissertation, University of Nairobi).

Naresh, R. K., Rathore, R. S., Yadav, R. B., Singh, S. P., Misra, A. K., Kumar, V., ... & Gupta, R. K. (2014). Effect of precision land levelling and permanent raised bed planting on soil properties, input use efficiency, productivity and profitability under maize (Zea mays) wheat (Triticum aestivum) cropping system. *African Journal of Agricultural Research*, *9*(36), 2781-2789.

Nata, J. T., Mjelde, J. W., & Boadu, F. O. (2014). Household adoption of soil-improving practices and food insecurity in Ghana. *Agriculture & Food Security*, *3*(1), 1-12.

Neate, P. J. (2013). Climate-smart agriculture: success stories from farming communities around the world. Journal of climate change impacts and responses, 100(6), 23-30.

Neufeldt, H., Kristjanson, P. M., Thorlakson, T., Gassner, A., Norton-Griffiths, M., Place, F., & Langford, K. (2011). Making climate-smart agriculture work for the poor.*Global Advanced Research Journal of Agricultural Science*, 1(7), 2315–5094.

Ngome, A. F., Becker, M., Mtei, M. K., & Mussgnug, F. (2013). Maize productivity and nutrient use efficiency in Western Kenya as affected by soil type and crop management. International Journal of Plant Production, 7(3), 517-536.

Nyambedha, E. O., Wandibba, S., & Aagaard-Hansen, J. (2001). Policy implications of the inadequate support systems for orphans in western Kenya. *Health policy*, *58*(1), 83-96.

Nyang'au, J. O., Mohamed, J. H., Mango, N., Makate, C., & Wangeci, A. N. (2021). Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba South Sub-county, Kisii, Kenya. *Heliyon*, *7*(4), e06789.

Odendo, M., Obare, G., & Salasya, B. (2009). Factors responsible for differences in uptake of integrated soil fertility management practices amongst smallholders in western Kenya. *African Journal of Agricultural Research*, *4*(11), 1303-1311.

Odhengo, P., Atela, J., Steele, P., Orindi, V., & Imbali, F. (2019). *Climate finance in Kenya: review and future outlook*. Discussion Paper. ADA Consortium.

Ogundari, K., & Bolarinwa, O. D. (2018). Impact of agricultural innovation adoption: a meta-analysis. Australian Journal of Agricultural and Resource Economics, 62(2), 217-236.

Olayide, O. E., Tetteh, I. K., & Popoola, L. (2016). Differential impacts of rainfall and irrigation on agricultural production in Nigeria: Any lessons for climate-smart agriculture? *Agricultural Water Management*, *178*, 30-36.

Oloo, G. I., Ngigi, M., & Mshenga, P. (2013). Evaluation of climate change adaptation strategies among smallholder farmers in bungoma county, Kenya. Journal of Science and Applied Technology, 2013, 76.

Olwande, J., Ngigi, M., & Nguyo, W. (2009). *Supply responsiveness of maize farmers in Kenya: A farm-level analysis* (No. 1005-2016-78929).

Önder, M., Ceyhan, E., & Kahraman, A. (2011). Effects of agricultural practices on environment. Biol Environ Chem, 24, 28-32.

Onono, P. A., Wawire, N. W., & Ombuki, C. (2013). The response of maize production in Kenya to economic incentives. *International Journal of development and Sustainability*, *2*(2), 530-543.

Palombi, L., & Sessa, R. (2013). Climate-smart agriculture: sourcebook. *Food and Agriculture Organization of the United Nations 2013.*

Parrott, N., & Marsden, T. (2002). *The real green revolution*. Global environmental change, 21(2), 441-452.

Parry, M., Parry, M. L., Canziani, O., Palutikof, J., Van der Linden, P., & Hanson, C. (Eds.). (2007). *Climate change 2007-impacts, adaptation and vulnerability: Working group II contribution to the fourth assessment report of the IPCC* (Vol. 4). Cambridge University Press.

Pernechele, V., Balié, J., & Ghins, L. (2018). Agricultural policy incentives in sub-Saharan Africa in the last decade (2005–2016). Monitoring and Analysing Food and Agricultural Policies (MAFAP) synthesis study (No. 2143-2019-4790).

Pires, G. F., Abrahão, G. M., Brumatti, L. M., Oliveira, L. J., Costa, M. H., Liddicoat, S., ... & Ladle, R. J. (2016). Increased climate risk in Brazilian double cropping agriculture systems: Implications for land use in Northern Brazil. *Agricultural and forest meteorology*, *228*, 286-298.

Pretty, J., & Hine, R. (2000, May). The promising spread of sustainable agriculture in Asia. In *Natural Resources Forum* (Vol. 24, No. 2, pp. 107-121). Oxford, UK: Blackwell Publishing Ltd.

Williams, T. O., Mul, M. L., Cofie, O. O., Kinyangi, J., Zougmoré, R. B., Wamukoya, G., ... & Campbell, B. M. (2015). Climate smart agriculture in the African context. Environmental science & policy 96 (2019): 37-51.

Rahman, M. H., Low, P. K. C., Almunawar, M. N., Mohiddin, F., & Ang, S. L. (2012). E-government policy implementation in Brunei: Lessons learnt from Singapore. In *Active Citizen Participation in e-government: A Global Perspective* (pp. 359-377). IGI Global.

Rapsomanikis, G. (2015). The economic lives of smallholder farmers: An analysis based on household data from nine countries. *Food and Agriculture Organization of the United Nations, Rome (2015)*.

Rehman, A., Jingdong, L., Khatoon, R., Hussain, I., & Iqbal, M. S. (2016). Modern agricultural technology adoption its importance, role and usage for the improvement of agriculture. Life Science Journal, 14(2), 70-74.

Reynolds, T. W., Waddington, S. R., Anderson, C. L., Chew, A., True, Z., & Cullen, A. (2015). Environmental impacts and constraints associated with the production of major food crops in Sub-Saharan Africa and South Asia. *Food Security*, *7*(4), 795-822.

Rioux, J., San Juan, M. G., Neely, C., Seeberg-Elverfeldt, C., Karttunen, K., Rosenstock, T., ... & Bernoux, M. (2016). Planning, implementing and evaluating climate-smart agriculture in smallholder farming systems. *Mitigation of Climate Change in Agriculture Series (MICCA)*, (11).

Robert, A. (2018). *The Role Of Camel Production In Household Resilience To Droughts: Evidence From Karamoja, Uganda* (No. 634-2020-142).

Rodima-Taylor, D., Olwig, M. F., & Chhetri, N. (2012). Adaptation as innovation, innovation as adaptation: An institutional approach to climate change. Applied Geography, 33(0), 107-111.

Sain, G., Loboguerrero, A. M., Corner-Dolloff, C., Lizarazo, M., Nowak, A., Martínez-Barón, D., & Andrieu, N. (2017). Costs and benefits of climate-smart agriculture: The case of the Dry Corridor in Guatemala. *Agricultural Systems*, *151*, 163-173.

Savary, S., Bregaglio, S., Willocquet, L., Gustafson, D., Mason D'Croz, D., Sparks, A., ... & Garrett, K. (2017). Crop health and its global impacts on the components of food security. Food Security, 9(2), 311-327.

Siminyu, P., Oluoch-Kosura, W., de Groote, H., & Mbau, J. S. (2021). Assessing the contribution of climate-smart agricultural practices to the resilience of maize farmers in Bungoma County, Kenya. African Journal of Agricultural and Resource Economics Volume, 16(2), 126-139.

Siminyu, P., Mbau, J., & Oluoch-Kosura, W. (2020). The contribution of climate smart agriculture practices in mitigating farmers against maize yield losses, a case of Bukembe Ward in Bungoma County. *Journal of Sustainability, Environment and Peace*, *3*(2), 41-45.

Simtowe, F., Zeller, M., & Diagne, A. (2009). The impact of credit constraints on the adoption of hybrid maize in Malawi. Review of Agricultural and environmental studies, 90(1), 5-22.

Singh, R., & Singh, G. S. (2017). Traditional agriculture: a climate-smart approach for sustainable food production. *Energy, Ecology and Environment*, *2*(5), 296-316.

Singh, B. R., & Singh, O. (2012). *Global trends of fossil fuel reserves and climate change in the 21st century* (Vol. 8). chapter. 2012.

Smale, M., Byerlee, D., & Jayne, T. (2013). Maize revolutions in sub-Saharan Africa. In *An African green revolution* (pp. 165-195).

Smale, M., & Jayne, T. S. (2003). *Maize in Eastern and Southern Africa:" Seeds" of success in retrospect* (No. 581-2016-39425).

StataCorp, L. P. (2013). Stata multilevel mixed-effects reference manual. *College Station, TX: StataCorp LP*, *9*(10).

Tadele, G., & Gella, A. A. (2012). 'A last resort and often not an option at all': Farming and young people in Ethiopia. *IDS Bulletin*, *43*(6), 33-43.

Taylor, J. E., & Adelman, I. (2003). Agricultural household models: genesis, evolution, and extensions. Review of Economics of the Household, 1(1), 33-58.

Tesfaye, M. Z., Balana, B. B., & Bizimana, J. C. (2021). Assessment of smallholder farmers' demand for and adoption constraints to small-scale irrigation technologies: Evidence from Ethiopia. Agricultural Water Management, 250, 106855.

Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A reference-dependent model. The quarterly journal of economics, 106(4), 1039-1061.

Vanlauwe, B., Palm, C., Murwira, H., & Merckx, R. (2002). Organic resource management in sub-Saharan Africa: validation of a residue quality-driven decision support system. *Agronomie*, *22*(7-8), 839-846.

Wabwoba, M. S. (2017). Factors Contributing to Low Productivity and Food Insecurity in Bungoma County, Kenya. *Biomedical Journal of Scientific & Technical Research*, *1*(7), 1813-1816.

Wanyama, D. (2017). A Spatial Analysis of Climate Change Effects on Maize Productivity in Kenya.*International Journal of Food and Agricultural Economics*, *2*(4), 27–48.

Wambugu, C., Franzel, S., & Rioux, J. (2014). *Options for climate-smart agriculture at Kaptumo site in Kenya*. Sustainability, 10(6), 1990.

Wekesa, B. M., Ayuya, O. I., & Lagat, J. K. (2018). Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. Agriculture & Food Security, 7(1), 1-14.

Wollenberg, E. K., Higman, S., Seeberg-Elverfeldt, C., Neely, C., Tapio-Bistrom, M. L., & Neufeldt, H. (2012). Helping smallholder farmers mitigate climate change. *Journal of Agricultural Economics*, *87*(1), 160–179.

Kitsao, P., & Zighe, E. (2016). *Adoption of climate smart agriculture (CSA) among female smallholder farmers in Malawi* (Master's thesis, Norwegian University of Life Sciences, Ås).

Csaki, C., & de Haan, C. (2003). *Reaching the rural poor: a renewed strategy for rural development*. World Bank Publications.

Xiong, W., & Tarnavsky, E. (2020). Better agronomic management increases climate resilience of maize to drought in Tanzania. *Atmosphere*, *11*(9), 982.

Appendix I: Variance Inflation Factors (VIF) for OLS regression analysis used to examine how climate-smart agriculture practices affects maize yield of smallholder farmers

Variable	VIF	1/VIF
Income per day of the household head	1.08	0.928309
Number of household members	1.14	0.881035
Land size in acres under maize in the long rains	1.12	0.893723
Intercropping maize with legumes	1.81	0.552174
Adding manure as fertilizer to the maize	1.83	0.545329
High-yielding certified maize varieties	1.02	0.982602
Mean VIF	1.33	

Appendix II: Variables used to generate the maize yield loss resilience index

Variable	Mean	Std. Deviation
Maize legumes intercrop	0.8	0.37
Planting certified high-yielding maize	0.34	0.47
Adding manure as organic fertilizer to the maize	0.3	0.46
Maize production practice that has been put in place to cushion against low maize yield	1.24	0.54
Farmer classifies the practice they use in maize production as CS	0.8	0.39
Motivation towards using CSA practices in maize production	2.2	0.4
Noticed reduction in maize yield from the year 2015	0.95	0.2
Number of 90kg bags of maize lost	5.9	3.76
A member of a savings and credit group	0.6	0.49
Information that should be included in the early warning signs of weather prediction	8.8	2.9

Number of observations = 250

Chi square = 256.915, Degrees of Freedom= 45, *P- value* =0.000

H_0 – Variables are not intercorrelated

Kaiser-Meyer Olkin, KMO measure of sampling adequacy = 0.62

Extraction Method: Principal Component Analysis.

Source: Survey data 2018

Appendix III: Results of the principal component analysis (PCA) Eigenvalues of the observed matrix

Component	Eigenvalue	Difference	Proportion
Comp1	1.91311	0.592033	0.1913
Comp2	1.32107	0.035914	0.1321
Comp3	1.28516	0.204209	0.1285
Comp4	1.08095	0.100052	0.1081

Source: Survey data 2018

Appendix IV: Questionnaire.

UNIVERSITY OF NAIROBI

ASSESSMENT OF THE EFFECTS OF CLIMATE-SMART AGRICULTURE PRACTICES ON THE RESILIENCE OF MAIZE FARMERS TO YIELD LOSS IN BUNGOMA, KENYA

Household Survey Questionnaire, March 2018

The University of Nairobi is carrying out research on assessing the contribution of climate smart agriculture practices on the resilience of maize producing farmers to yield loss in Bungoma, Kenya. The purpose of this study is to get views, experiences and suggestions of farmers on climate smart agriculture practices used in maize production, if the usage of climate smart agriculture practices in maize production makes the farmers resilient to yield loss and the maize yield those farmers get when they use climate smart agriculture practices. Respondents of this survey should be maize farmers living in a particular household and must be at least 18 years old. This study will be interested to talk to the person in the household who makes decisions in producing maize in the farm. You have been randomly selected and your participation in this survey will not be disclosed to any person. The findings of this study will be mainly used to inform policy on how farmers are resilient to yield loss when they use climate smart agriculture practices in maize production, mitigate on climate change and increasing maize yield by using climate smart agriculture practices. The interview will require about 1-hour completing.

Enumerator's name ………..Date...................................

County	
Sub County	
Village	

Household identification

Household Identification code (HHID)	
Type of Household (1= Male Headed Household, 0=Female Headed Household)	
Gender of the respondent (1=male 0= female)	
Relationship to household head? (1= household head, 2=spouse, 3=son/daughter, 4=son/daughter in-law, 5= grandson/daughter, 6= other (specify___	

2. DEMOGRAPHIC CHARACTERISTICS

Age of Household head (years)	
Marital status*(1= Single, 2= Married 3= Widowed/divorced/separated)*	
Years of schooling of Household head	
Number of males	
Number of females	

3: EMPLOYMENT AND EDUCATION

	Aged below 15 years	Aged 15-35 years	Aged 36-65 years	Above65 years
Labor disaggregation				
Working on-farm only				
Working off-farm only				
Working both off & on-farm				
Education (Quality of human capital)				
Completed Primary education; male = female =				
Completed Secondary education male = female=				
Completed Tertiary education male = female =				
Completed University education male = female =				

Dropped out at primary male = female =				
Dropped out at secondary school male = female =				
Income per day of those employed				
Daily expenditure				

4. Practices that farmers use in maize production

4.1. Who is the main decision-maker regarding the farming activities?

1=HH head; 2=Spouse; 3= Son; 4= Daughter; 5=Farm worker; 6= Other

4.2. What is the total land size for the household in acres?

4.3. What is the total land size that the household planted maize last year?

4.3.1. In the short rain season ______

4.3.2. In the long rain season ______

4.4. What are the practices that you use in maize production from land preparation up to storage of your maize?

Practice	Use (Yes 1), not use (No 2)	Do you classify this practice as climate smart agriculture? (Yes 1. No 2.)	How intensive do you use this practice on your maize production? 1. Always. 2. Sometimes. 3. not very often. 4. Never	What motived you to start using this practice in your maize production? 1. Increased yield. 2. Cheap. 3. Friendly to the environment. 4. Others (specify)
Planting of drought tolerant high yielding maize varieties				
Intercropping maize with legumes,				
Mulching				
Crop rotation,				
Organic fertilization (use of compost, animal and green manure),				
Conservation agriculture				
Agroforestry				
Irrigation,				
Zero tillage				

Integrated nutrient and soil management.				

4.5.How many 90 kg bags of maize did you produce in the last season of last year 2017?

4.5.1. In the short rain season ______

4.5.2. In the long rain season ______

4.5. How many 90 kg bags did you produce when you applied the climate smart agriculture practices you have mentioned to me?

4.5.1. In the short rain season ______

4.5.2. In the long rain season ______

4.6. Have you ever noticed reduction in maize yield from the year 2013?

Yes. 1. No. 2.

4.6.1. If yes'

Year	Area of land in acres in the short rain season	Number of 90 kg bags in the short rain season	Area of land in acres in the long rain season	Number of 90 kg bags in the long rain season
2013				
2014				
2015				
2016				
2017				

4.7. In the year ______ your maize production started increasing, please tell me why.

4.8. Would you associate the maize increase to the usage of the climate smart agriculture practices you employed in your maize production?

Yes. 1. No. 2.

SECTION 5: Exposure to Shocks and Coping Strategies

5.1. What kind of shocks did you experience during the last 12 months and how did you cope with them? 5.1.1. Please fill the table below (Tick all that apply)

Type of Shock	Did you Experience this shock in the last 5 years? 1 = Yes; 2 = No	Duration of the Shock (1. Less than a week (2. Two weeks (3. One month (4. More than one month)	Frequency in the last 12 months (number of times it occurred)	Effect on the maize yield. 1. Reduced the yield. 2. Yield stayed the same 3. Other (specify)	How many 90 kg bags did you loss?	Main effects (Rank them in order of severity) 1. Loss of crops 2. Loss of household assets 3. Loss of cash income 4. Other….	What did you do to manage this shock? (rank them in the order in which they were applied) 1. Used up Savings 2. Sold part of assets 3. Borrowed 4. Received aid 5. Received 6. Support from social groups 7. Other…… ……	What initiatives have/are you putting in place to manage this shock better in future? (rank them in the order of your preference) 1. On-farm livelihood diversification 2. Off-farm livelihood diversification 3. Adopting new farming practices e.g. drought tolerant crops; conservation agriculture. 4. Increased Savings 5. Took an Insurance policy 6. Other…………..
Droughts								
Crop pests and diseases								
Soil erosion								
Reduced soil fertility								

5.2. Are there shocks that occur concurrently? Describe…………….………………………………

………

5.3. Please fill the table below on how you relied on various social safety nets to manage the main shock:

Type of safety net	Did you receive support from this source? 1 = Yes; 0 = No	Type of support received 1 = cash 2 = inputs 3 = labor 4 = food other….	If it was a cash support, how much was it in Kenyan shillings.	What proportion of the losses did this support enable you to manage? 1) Up to 25% 2) 25% - 50% 3) 50% - 75% 4) More than 75%
Family members/relatives				
Friends				
Group members				
NGOs – including religious organizations				
National government programs				
County government programs				
Free farm support in the last 6 months				

5.4. What is the coping strategy you have applied for you to avoid these problems in future?

5.5. Which maize production practices have you put in place to cushion you against future shocks?

5.5.1. Please fill table below:

Maize production practice	Do you Practice (1 – Yes, No – 2)
Planting high yielding maize varieties	
Using animal manure	
Crop rotation	
Planting certified drought tolerant maize seed varieties.	
Planting early maturing maize seed varieties.	
Use of crop residues for soil cover as mulch.	
Use legume crops as permanent soil cover in maize fields farms i.e. *mucuna*, desmodium, soya beans.	
Application of conservation Agriculture technologies in maize production.	

SECTION 6: RESILIENCE OUTCOMES

6.1. Food Access

6.1.1. What is the average number of meals consumed in a day in your family? _____

6.1.2. How much does your household spend in buying food items per week?

6.1.2.1. When you have mature crops in the farm? Kshs………………

6.1.2.2. When you don't have any mature crop in the farm? Ksh ………

6.2. Were there any months, in the past 12 months, in which you did not have enough food to meet your family's needs?

1.Yes 2.No

6.2.1. If yes, in which months did the family experience inadequate food supplies? Please fill the table below;

	Mar 2017	April2017	May 2017	June 2017	July 2017	Aug 2017	Sept 2017	Oct 2017	Nov 2017	Dec 2017	Jan 2018	Feb 2018
Record 1=Yes 0=N0												
Extent of food insecurity 1-missed food for one day, 2-missed food for two days 3- missed food for a week												
Average number of meals your household had in a day												

6.3. What was the cause of this inadequate food supply?

1. Low supply in the market 2. High prices 3. Poor harvest 4. Others…………………………………………………………..

6.4. What coping strategies did your family undertake during months of inadequate food supply?

1. Borrow from neighbors, family and friends 2. Fed on wild fruits and tree leaves 3. Did nothing4. Other……………………..

6.5. Access to basic services

6.5.1. In the last 6 months have you been able to have access to the following:

Service	Did you get this service? 1 Yes 0 No	Distance	Expenditure in Kes	Challenges (1 Distance 2. Expensive Poor services No personnel 5 Poor quality)
Health service Mobile clinic, Dispensary, Sub county Hospital, County Hospital Private Hospital				
Water: Tap, Borehole, Stream River				
Lighting: Electricity Solar panel Solar lamp lantern lamps				

6.6. Climate change

6.6.1. Have you noticed prolonged drought in this region? 1. Yes. 2. No.

6.6.2. From which year up to which year have you noticed prolonged draught in this region. (Draughts that have occurred for more than 1 month)

6.6.3. Have you noticed reduced rainfall in this region? 1. Yes. 2. No.

6.7. Stability

6.7.1. How many members in your household have lost a job? ____

6.7.2. What is the state of your household income now compared to the last 6 months?

6.7.3. In the last 6 months how has been your expenditure?

6.7.4. According to your expenditure now compared to the last 6 months has your expenditure on food decreased or increased?

1. Decreased 2. Increased

6.7.5. What is your capacity to maintain your expenditure on food in future?

6.8. Access to Early Warning Information

6.8.1. Do you normally receive any early information regarding changes in weather conditions? Please fill the table below;

Source	Access	Terms of access	Perception;	Challenges	What other information should be included in the early warning system
	1-Yes 2-No	1-Free, 2-Paid for	1-Timely, 2-Accurate, 3-Reliable, 4-Useful	1-Costly, 2-Not Timely 3-Unreliable, 4- Other	
Radio					
Television					
Mobile phone					
Social media					
Internet					

Print media					
Other…					

6.9. Access to Savings and Credit

6.9.1. Are you a member of any Savings and Credit institution/organization group? 1. Yes2. No

If yes, which type?

SACCO2. Table banking 3. Merry go round 4. Formal bank 5. Mobile money 6. Others (Specify)…………………….

6.9.2. Have you received any credit in the last 12 months? 1. Yes 2 No.

If yes, fill the table below:

Source	Amount Received	Amount Received Vs Amount applied (1=25%, 2=50% 3=75%, 4=100%)	Use 1=Buy farm inputs, 2=Expand business, 3=Pay school fees, 4=Buy assets, 5=Buy food	Proportion of loan already repaid (1=25%, 2=50% 3=75%, 4=100%)	Challenges to credit access (1= Lack of collateral, 2=High interest, 3=Procedural 4 =Other…..)
Formal Bank					
Micro finance institution					
SACCO					
Community groups					
Relatives/friends					

Mobile Money (specify)					

6.9.3. If the household doesn't have access to credit, what is the reason why you cannot access credit facilities?

1. No need 2. Not aware 3. Lack of enough collateral to secure a facility 4. High interests 5. Too procedural. 6. Other………

6.9.4. In the last 12 months have you been able to have access to any form of extension services? 1. Yes. 2. No. If so, please fill table below:

Provider 1- Private 2- County government 3- Farmer to farmer 4-credit linked extension 5-Outgrower 6-Agro dealer Church 8-Other……….	Channel: 1. Home visits 2. Phone 3. Field school 4. Other ……… ….	Terms of provision 1. Free 2. Paid for 3. Other……	Challenges 1-Costly 2- Infrequent visits 3- Communication barrier 4- Distance 5-Farmers not willing to share information 6-Other……………	What can be done 1. Reduce costs 2. Train more contact farmers 3. Establish field schools 4. Other… ……..

6.10. Income

6.10.1. Farm Income Activities that were produced using climate smart agriculture practices (in the last 12 months)

Enterprise	Amount harvested	Amount consumed	Amount sold (units)	Price per unit
Maize (bags)				
Beans (bags)				
Onions (Kgs)				
Green grams (Kgs)				

Honey (Kgs)				

6.10.2. What are your major sources of income?

Income source	Amount Derived	Proportion of income derived from it (1=none; 2=<25%; 3 = 25-50%; 4=50-75%; 5=>75%)	Number of male adults involved	Number of female adults involved
Crops – (list 3 main ones)				
Livestock – (list 3 main ones)				
Business				
Employment				
Investment Income				
Artisan				
Remittances from family or friends				

Remittance from county government				
Gold mining				
Sand harvesting				
Charcoal Burning				
Brick Making				
Other…….				

SECTION 7: FUTURE SCENARIO

7.1.What other enterprise would you want to engage or continue in the next 5 years?

Please fill the table below:

Enterprise Livestock, -Crops, Business, Rent, etc Other……….)	Motivation (1-more profitable, 2-Less time consuming, 3-Resource availability 4-Reduced interest rates 5-Other……	Needed Support; (1-Capacity building 2- Institution framework, 3-Reduce bureaucracy 4-Infrastructure development, 5- Security 6- Reduce taxes 7-Other……