UPTAKE OF REGENERATIVE AGRICULTURE TECHNOLOGIES, PRODUCTIVITY OF SELECTED CEREALS AND PULSES AND FOOD SECURITY IN THE DRYLANDS OF EMBU COUNTY, KENYA

ELVIN NYABOE OTARA

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DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree or any other award.

Signature……………………………… Date ……………………

Elvin Nyaboe Otara

Department of Agricultural Economics and Extension

A510/1351/2020

This thesis has been submitted for examination with our approval as the University Supervisors.

Signature……………………………… Date ……………………

Dr. Hezron R. Mogaka

Department of Agricultural Economics and Extension

University of Embu

Signature……………………………… Date …………………….

Dr. Samuel Ndirangu

Department of Agricultural Economics and Extension

University of Embu

Signature……………………………… Date…………………….

Prof. Jayne Njeri Mugwe

Department of Agricultural Sciences and Technology

Kenyatta University

DEDICATION

It is with genuine gratitude and warm regard that I dedicate this work to my parents Mr. James Otara and Mrs. Josephine Osero for their spiritual and financial support as well as to my siblings Judy, Eznah, Sharon, Naom and Isaac who look up to me.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
CA	Conservation Agriculture
CIDP	County Integrated Development Plan
CSA	Climate-Smart Agriculture
FAO	Food and Agriculture Organization of the United Nations
GRP	Group
HFCS	Household Food Consumption Score
HHD	Household Head
KALRO	Kenya Agricultural and Livestock Research Organization
KES	Kenya shillings
Kgs	Kilograms
KNBS	Kenya National Bureau of Statistics
LM4	Lower Midland Four
MVP	Multivariate Probit Analysis
ODK	Open Data Kit
PCA	Principal Component Analysis
PPS	Probability Proportionate to Size
RA	Regenerative Agriculture
SOM	Soil Organic Matter
SSA	Sub Saharan Africa
WFP	World Food Program

DEFINITION OF TERMS

Regenerative Agriculture This is an approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating, and supporting services. It enhances the environment and the social and economic dimensions of sustainable food production (Schreefel et al., 2020a).

Food security Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for active and healthy life (FAO, 2010).

Technology uptake Technology uptake refers to the adoption and integration of technological innovations and advancements. It involves the acceptance, deployment, and utilization of various technologies by farmers, agricultural organizations, and the wider industry to improve agricultural practices, enhance productivity, and address challenges along the agricultural products value chain (Ouédraogo et al., 2019).

Principal Component Analysis PCA is a dimensionality reduction method that is frequently used to reduce the dimensionality of large data sets by reducing a large collection of variables into a smaller set that retains the majority of the information in the large set (Hasan and Abdulazeez 2021).

Household Food Consumption Score Household Food Consumption Score (HFCS) is an index that measures food security at the household level by taking into account dietary diversity, food frequency, and the relative nutritional content of various food kinds (WFP, 2009).

Cobb-Douglas production function Cobb-Douglas production function is a function that models the relationship between production output and inputs.

Open Data Kit Open Data Kit (ODK) is an open-source tool that allows programmed questionnaires to be implemented on mobile cellphones.

Conservation Agriculture Conservation Agriculture (CA) is a sustainable agriculture production system that consists of a set of farming practices tailored to the needs of crops and local conditions in each region, with farming and soil management techniques that protect the soil from erosion and degradation, improve its quality and biodiversity, and contribute to the preservation of natural resources, water, and air, while optimizing yields (Cárceles et al., 2022).

ABSTRACT

At the global level, land degradation is on the increase thus threatening millions of livelihoods particularly in the drier ecosystems. More specifically, land degradation is a major concern in Kenya and more particularly in the drylands of Embu County. Soil fertility has been steadily declining, resulting in low agricultural output and endangering smallholder farmers who rely mostly on subsistence agriculture for a living. Selecting appropriate Regenerative Agriculture (RA) technologies in accordance with well-established policies can help construct more resilient ecosystems, increase productivity and family food security while nourishing soils and lessening the effects of climate change. Although RA has been marketed in Embu drylands, the extent of uptake has not been assessed. The potential effects of RA technologies on cereal (sorghum) and pulse (green grams) productivity and family food security have received little attention. The study aimed to characterize RA technologies and identify factors impacting adoption. The study also assessed the effects of RA technologies on the productivity of selected cereals and pulses as well as household food security in Embu County's drylands. A multistage stratified sampling procedure was used to select 400 farming households at random. Data were obtained via Open Data Kit using cross-sectional survey and a semi-structured questionnaire. The Principal Component Analysis (PCA) was used to characterize RA technologies. RA technology adoption factors were evaluated using Multivariate Probit Model (MVP). The effect of RA technologies on the productivity of selected cereal and pulse was examined using a stochastic log-linearized Cobb-Douglas Production Function. Household Food Consumption Score (HFCS) was employed to gauge household food security. According to the PCA results, the most often employed RA technologies by the respondents were cereal-legume intercrop, pasture cropping, crop rotations, mulching, cover crops, use of compost manure, and minimum tillage. The percentage of respondents employed the following RA methods, according to descriptive data, were: cereal-legume intercrop (71.3%), pasture cropping (72.0%), crop rotations (96.0%), mulching (76.3%), cover crops (14.5%), application of compost manure (24.0%), and minimal tillage (31.5%). Further, from descriptive statistics, the results showed that all adopted technologies had poor uptake. The respondents' biggest struggles with RA were a lack of education and bad weather conditions. In light of the results of the Multivariate Probit Model, socioeconomic and institutional factors, significantly impact on the uptake of various RA technologies. In addition, Cobb-Douglas Production Function revealed that cereal-legume intercropping, mulching, and the use of compost manure positively influenced green gram and sorghum productivity, minimum tillage and cover cropping positively influenced sorghum productivity, and crop rotations positively influenced green gram productivity. Furthermore, the HFCS showed that most of the households in the research region were food insecure, with those who used minimum tillage having the highest (61.1%) poor HFCS and those who practiced cover cropping having the highest acceptable score of 8.6%. The study findings suggest encouraging small-scale farmers to adopt the disseminated technologies by providing training and sensitization on the benefits of these technologies in order to boost agricultural productivity and improve food security in the drylands of Embu County, Kenya, while also regenerating ecosystems in a sustainable manner.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Rapidly increasing land degradation is a major socio-economic and agricultural production challenge globally (Hermans & McLeman, 2021). Soil infertility, in particular, poses a danger to livelihoods in Sub-Saharan African (SSA) particularly for smallholder farmers who majorly depend on subsistence agriculture (Maru et al., 2019). Smallholder agriculture is highly dependent on rainfall, thus susceptible to extreme weather conditions such as drought and prolonged dry spells as well as flooding (Borona et al., 2019). This has led to heightened food insecurity for the increasing populations in developing countries (Gunaratne et al., 2021). The world population is expected to grow to 9.1 billion people by 2050 (Brook et al., 2021), and more pressure will be put on land due to increased demand for land for settlement and farming (Pozza & Field, 2020). To meet the increasing demand, production systems have opened up new lands for cultivation and transformed land use and cultivation patterns in addition to tilling the same parcels annually (Lai et al., 2020). However, due to poor farming practices, the additional areas are still vulnerable to soil degradation thus, leading to low productivity and exposing rural smallholders to poverty (Coulibaly et al., 2021, Hermans & McLeman, 2021) .

Land degradation, diminishing soil fertility, declining productivity, and extreme climatic weather stress are all concerns in Kenya, particularly in dry and semi-arid areas (Kiboi et al., 2019; Ndeke et al., 2021). These difficulties need agricultural production system change through RA techniques (Gosnell et al., 2019). Soil fertility management technologies are needed to raise farm output, promote food security, alleviate poverty, and address climate change problems (Katengeza et al., 2019). Effective soil fertility management strategies improve soil characteristics, especially soil organic matter, maintaining the long-term survival of soil processes critical to agricultural productivity (Mairura et al.,2022).

Regenerative Agriculture (RA) comprises farming and grazing techniques that aim to increase food production and productivity (Lal, 2020) with lower negative environmental impacts (Newton et al., 2020). Regenerative Agriculture comprises of composite practices and technologies that ought to be implemented jointly for optimal results. There is no single RA practice that fits all the different soils types and agro-ecological zones (Lal, 2020). Thus, RA comprises system-based Conservation Agriculture (CA) techniques, including minimum tillage, cover cropping, mulching, intercropping and integrated nutrient and pest management (Lal, 2020) along with agroforestry and sustainably managed grazing systems. In order to mitigate the negative effects of conventional soil management techniques, which typically result in soil erosion, loss of nutrients and soil organic matter (SOM), and increased agricultural soil carbon dioxide emissions, mulch farming and low tillage or reduced tillage have gained popularity (Desta et al., 2021). Regenerative Agriculture is a comprehensive, site-specific strategy that should be implemented in line with biophysical factors and socio-economic dimensions. The system's purpose is to increase SOM content, strengthen biogeochemical cycling processes, and enhance disease resistance (Schreefel et al., 2020b). RA is focused on obtaining optimum yield for a sustainable period with minimal dependence on agrochemicals while enhancing the provision of ecosystem services (Lunn-Rockliffe et al., 2020). In light of the benefits associated with the implementation of RA technologies, in collaboration with the private sector, the Government of Kenya has put efforts to promote RA in the drylands of Embu County. Still, the uptake levels have been low, thus prompting various research studies on the use and adoption of RA technologies.

Cereals (sorghum and millet) and pulses (green grams and cowpeas) are the main crops farmed in Embu County's drylands and are the region's principal food crops (Wafula et al., 2022). The yields of these crops if boosted can increase incomes and improve household food and nutrition security. Despite their economic importance, production is still low due to declining soil fertility over time, continuous cultivation with minimal soil nutrient replenishment, poor farming techniques, and increasing spread of disease and pest incidences (Yadav et al., 2019). Regenerative Agriculture technologies seem to offer solutions to these problems and offer food productivity enhancement and food and nutrition security opportunities to resource constrained farmers (McLennon et al., 2021), thus attracting empirical research and robust evidence on the extent of uptake, and potential impacts of the technologies on productivity and household food security.

The study analyzed the adoption of various RA technologies, the factors that influence adoption, and the impact of various technologies on productivity of selected cereals and pulses. It also emphasizes on the impact of various technologies on food security at the household level. The evaluation of the factors that influence RA technology adoption will help to promote the effectiveness of services for extension and research, as well as the advancement of supportive and responsive agricultural policy and planning at the national and county levels, in order to increase adoption, scale up production, and improve farmers' household food and nutrition security. As a result, these outstanding issues formed the basis of this inquiry.

1.2 Statement of the Problem

Cereal and pulse productivity, particularly sorghum and green gram, has been dropping in Kenya over the years, particularly in Embu County's drylands. Farmers and the government are both concerned about this trend. These crops are basic foods for the vast majority of people living in semiarid settings. However, production has not kept up with rising demand for food. The County's crop yield is mostly low due to climate-related shocks and poor farming practices, which result in decreased soil fertility. To enhance production among smallholder farmers, declining soil fertility must be addressed first. To raise soil fertility and productivity, the government and private sector have provided adequate inputs and better technologies. Despite these attempts, soil fertility is declining, resulting in continued low output. Over the last five years or so, Farm Africa has disseminated Regenerative Agriculture technologies to farmers in Embu County through the Alliance for a Green Revolution in Africa (AGRA). Although RA technologies are critical for increasing soil fertility and productivity, there is a lack of understanding on the factors that influence farm-level adoption. There has been little research done to characterize RA technologies in the drylands of Embu County. The present literature lacks significant information on the impact of these technologies on sorghum and green gram productivity, as well as household food security. As a result, this study identified RA technologies commonly utilized by farmers, as well as the level to which each technology was adopted. Additionally, the study examined the socioeconomic and institutional aspects that influence the adoption of various technologies. The study also intends to publish in academic journals, adding to the body of knowledge in agricultural economics, rural development, environmental studies, and other related topics. This material can be used to lay the groundwork for future investigations and conversations. To fill the research gaps, the study used a case study of the drylands of Embu County to assess the effects of uptake on sorghum and green grams productivity as well as household food security.

1.3 Objectives

1.3.1 General Objective

To evaluate the effects of uptake of Regenerative Agriculture technologies on productivity of selected cereals and pulses and food security in the drylands of Embu County

1.3.2 Specific Objectives

1. To characterize Regenerative Agriculture technologies in the drylands of Embu County.
2. To assess socio-economic and institutional factors influencing uptake of Regenerative Agriculture technologies in the drylands of Embu County.
3. To analyze the effect of uptake of Regenerative Agriculture technologies on productivity of selected cereals and pulses in the drylands of Embu County.
4. To evaluate the influence of uptake of Regenerative Agriculture technologies on household food security in the drylands of Embu County.

1.4 Research Questions

1. What are the characteristics of Regenerative Agriculture technologies used in the drylands of Embu County?
2. What are the socio-economic and institutional factors that influence the uptake of Regenerative Agriculture technologies in the drylands Embu County?
3. How does uptake of Regenerative Agriculture technologies affect productivity of the selected cereals and pulses in the drylands of Embu County?
4. How does uptake of Regenerative Agriculture technologies influence household food security in the drylands of Embu County?

1.5 Justification of the Study

Cereals and pulses, particularly sorghum and green grams, are the most significant crops farmed in the drylands of Embu County and around the world. These crops are farmed for subsistence use, but large amounts are also sold in local markets. As a result, the produce has the potential to increase income and household food security in the County. Farmers in Embu County, on the other hand, face resource constraints such as land, labor, money, and technological know-how, as well as climatic shocks and deteriorating soil fertility, restricting production. Therefore, this research is critical for the economic development of Embu County, as most people rely on these crops for income and food security. The study has also made a contribution in the drafting of the County Integrated Development Plan (CIDP 2023-2027) particularly under the sustainable agriculture agenda. In addition, this study stands to inform County planning in respect achievement of Sustainable Development Goals 1 and 2 on poverty eradication and zero hunger respectively. Study has also made a contribution to the Government’s Bottom-Up Transformational Agenda particularly in respect to revitalizing agriculture and improvement of food security.

This study evaluated the degree of adoption and the variables influencing the adoption of regenerative agriculture technologies. The study also assessed how different RA methods affected household food security as well as sorghum and green gram productivity. This study consequently helps farmers and other stakeholders, like the county administration and the Ministry responsible for agriculture, climate change and rural development to have a greater understanding and awareness of regenerative agriculture technologies. Farmers will be able to make judgments about the best farm inputs and technology by using the information generated to understand the effects of the implemented technologies on production. With the help of information about factors influencing uptake and the potential welfare on food security, stakeholders will be able to design and implement interventions that could encourage the use and efficacy of RA technologies in smallholder production systems to increase food production and improve food security. Case studies will be released to illustrate the lessons learned from regenerative agriculture technology's characterization and degree of acceptance.

1.6 Scope of the Study

The study focuses on agricultural households in the drylands of Embu County, specifically Mbeere South Sub County. The study focused on farming households in the Sub-County's five Wards. The research used a cross-sectional survey design using a semi-structured questionnaire. The study's objectives included describing RA technologies, assessing their extent of usage, and finding and analyzing institutional and socioeconomic factors that may influence their use. Furthermore, the influence of technology adoption on family food security, as well as sorghum and green grams productivity, the region's two most widely produced grains and pulses, were assessed.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

This chapter discusses prior research on Regenerative Agriculture technologies, the need for adoption, cereal and pulse productivity, and the potential effects of uptake on household food security. Potential socioeconomic and institutional factors influencing technology adoption are also reviewed. A review of the literature showed research gaps.

2.2 Need for Regenerative Agriculture in Africa

The term "Regenerative Agriculture" (RA) refers to a group of agricultural practices that use soil conservation as a starting point for regeneration and as a way to support numerous ecosystem services such as provisioning, regulation, and maintenance. It improves not just the environmental attributes but also the social and economic aspects of sustainable food production when used (Schreefel et al., 2020b). Regenerative agriculture, among other things, focuses on the argument that achieving radical change in the agri-food system necessitates a radical renegotiation of our relationship with the environment as well as a change in our thinking and approach to transformational food politics (Seymour & Connelly (2023).

Africa faces a series of challenges in her agricultural transformation agenda which include, soil degradation, increasing scarcity of agricultural water, increasing vulnerability to climate change induced risks, declining agro-biodiversity and increasing food insecurity. Regenerative agriculture offers holistic approach that integrates ecological principles, sustainable farming practices, and the well-being of local communities (McLennon et al., 2021).

Agricultural expansion in Africa is characterized by synthetic chemical inputs, expansion of agricultural areas into non-agricultural lands and crop modifications that deplete soils and erode ecosystems. This usually leads to declining soil fertility, eroded crop genetic diversity, degraded carbon capture potential and increased emissions of greenhouse gases (Roohi et al., 2022). Declining soil fertility has led to low productivity exposing more people to food insecurity, malnutrition, chronic hunger and poverty (Mansoor et al., 2022). The declining trends in the production have also been attributed to extreme weather uncertainties and poor farming systems in Africa and the globe. Current research shows that the rate of soil degradation globally is increasing, calling for urgent actions to prevent further damage to food systems and the ecosystem (Panagos et al., 2020). With improved technologies, Africa can feed its people and contribute to global food production and livelihoods because it has a wealth of resources (Heck et al., 2020).

In the face of these challenges, RA has been advanced as a steering wheel to achieving green revolution as an alternative to enhancing future production systems. The main objectives of RA are to reduce poverty, increase food security, improve nutrition and contribute to farmer sovereignty among farming households (Lunn-Rockliffe et al., 2020). Apart from being environmentally friendly, RA also does not hurt existing soils because its techniques boost soil quality by nourishing and rejuvenating degraded soils (Giller et al., 2021). RA is thought to contribute to global prosperity through enhancing livelihoods, healthy households, and resilient ecosystems rather than by continuously boosting agricultural production and economic growth across scales (McLennon et al., 2021). The preceding literature examines Africa as a whole. The purpose of this study was to investigate and describe the extent to which RA has been implemented in Kenya, as well as its possible implications on food production and household food security, with a focus on drylands.

2.3 Factors Influencing Uptake of Regenerative Agriculture Technologies

A variety of factors influence the adoption of regenerative agriculture technologies. Age, education level, gender, farm size, farming experience, and the source and level of off-farm income are all important socioeconomic characteristics that can influence innovation uptake (Abdul-Rahaman et al., 2021). Age and technology adoption have a negative association, according to a study by (Gebru et al., 2019). Sometimes, due to illness, households can lose labor, which negatively impacts on adoption (Jew et al., 2020). Gender of household head is significant in taking up a new technology in that, male-headed households have an increased ability to adapt than female-headed households (Sanou et al., 2019). High education level is often assumed to increase the chances of one taking up an innovation as it enhances farmers' ability to understand the invention and its benefits (Pivoto et al., 2019). Engagement in off-farm activities positively impacts technology adoption (Coulibaly et al., 2021). However, Issahaku and Abdul-Rahaman,

(2019) argue that engagement in off-farm activity may impact either negatively or positively on adoption. Waaswa et al., (2022) argue that farm size affects adoption because larger acreage provides scope for experimentation and application of innovations.

Institutional factors, on the other hand, could affect how quickly new technologies are adopted. They include credit factors such as accessibility, affordability, and past experience, credit score, employment history, and viability of collateral. Types of markets, availability, accessibility, market knowledge, distance to the input and output markets, input access, land ownership, membership in operational interest group(s), and availability of extension services are all market determinants (Abdul-Rahaman et al., 2021). Access to loans and farm inputs improves a farmer's ability to adopt new technology (Coulibaly et al., 2021). Similarly, access to market information and extension services positively impact technology uptake (Xie & Huang, 2021) among small-scale farmers. Land ownership terms positively influence the uptake of innovation, similar to the input and output market (Bedeke et al., 2019). Farmer groups serve as a means through which innovations and training are disseminated to farmers, and are likely to positively impact technology uptake (Osumba et al., 2021). A study by Musafiri et al., (2022) in Western Kenya on Climate Smart Agriculture found that farmer perceptions influence technology adoption. However, information on the factors driving the adoption of specific RA technologies is scanty. As a result, the study was designed to fill the void.

2.4 Productivity of Cereals and Pulses in Eastern Kenya

Eastern Kenya is characterized by a diversity of agro-ecological zones including semi-arid and high potential areas, diversity of crops, which are grown both for subsistence and for cash and bimodal rainfall pattern. The drier parts of the region, which is the focus of this study, are associated with growing of drought resistant crops.

Cereals and pulses are the main food crops grown and consumed by most households in drier parts of Eastern Kenya. Pulses are grain legumes in the Leguminosae family that mostly include beans, cowpeas, green grams, chickpeas, pigeon peas, lentils, and chickpeas (Vanlauwe et al., 2019). Cereals are edible grain seeds in the family Gramineae grass. They include maize, sorghum, millet, rye, oats, and triticale (Perdon & Holopainen-Mantila, 2020). A vast area of Eastern Kenya is semi-arid and arid, and sorghum is a cereal that is frequently farmed there while green gram is a legume that does well in the area. Since cereals and pulses have a stabilizing influence on food security and improve the efficiency of the use of land, water, and labor, growing them together has several advantages. Intercropping also helps in risk aversion in crop failure, improving soil fertility, better weed control, and providing a balanced diet to humans (Bukovsky-Reyes et al., 2019). Other advantages of intercropping include higher total yields than sole crop yields, more excellent yield stability, and more efficient use of nutrients (Stomph et al., 2020).

Most Kenyans depend on cereals and pulses especially sorghum and green grams for food, income, soil management, and also as a source of animal feeds (Gewa et al., 2021). Despite the multiple benefits of these crops, production is still low (Otieno et al., 2020). Statistics show that domestic sorghum production has been increasing since 2010, although Kenya still imports more than one-third of overall consumption. The productivity potential ranges between 2 and 5 tons/ha, compared to the current realized productivity levels of 0.7 tons/ha, with roughly 64% of the produce used for food, 1% used for livestock feeds, one-fifth processed, and about 15% lost due to postharvest losses. With increased utilization of sorghum for biofuels, ethanol, livestock feed, and the food industry, global demand for sorghum and sorghum seeds is projected to rise by 2% each year by 2028. This emphasizes the significance of capitalizing on the crop for increased income and livelihood in the country (Kazungu et al.,2023). On the other hand, current average green gram production in the country is 0.5-0.6 tons/ha, which is well below the crop potential and compares negatively to the global average yield of 0.73 tons/ha. This production is insufficient to meet the country's need, forcing the country to absorb approximately 80% of the green grams imported from by Uganda and Tanzania (Muchomba et al., 2023).

Production of cereals and pulses has been gradually declining in Kenya as well as in the drylands of Embu County, especially Mbeere South, and the food security status of households has been reported to be worrying and declining. Despite these crops doing well in semiarid areas, their productivity is low compared to the global average. Low productivity is attributed to climate variability and poor farming practices. Eastern Kenya which includes Embu County, represents an essential cereal and pulse production zone, calling for solutions to increase productivity and household food security while regenerating soils. However, from literature the productivity of sorghum and green grams has not been evaluate in relation to RA technologies.

2.5 Regenerative Agriculture and Food Security

Food security is the condition in which all people always have physical and financial access to an adequate supply of food that is safe, nourishing, and fits their dietary needs and food choices for an active and healthy lifestyle at all time (FAO, 2010). In sub-Saharan Africa, there are currently over 230 million hungry people, and if nothing is done about it, that figure is expected to rise to 300 million in the next five years (World Bank, 2020). The majority of sub-Saharan countries, especially the East Africa region, are being negatively impacted by climate change, which raises serious concerns about the rising food demand (Ehui, 2020). The vast majority of African smallholders rely on agriculture for their livelihood, which is negatively impacted by changing rainfall patterns, flash floods, prolonged dry spells, and high temperatures (IPCC, 2014). Therefore, climate change may make the poor, who are already most susceptible, further poorer and more food insecure.

For years, Kenya has not achieved food security following several hindrances: limited investment in transformational agriculture, low access to extension services, limited access to credit facilities, climatic shocks, declining soil fertility, land degradation, limited land, population pressure and low adoption of productivity enhancement technologies (Żmija et al., 2020). Regenerative agriculture (RA), which aims to restore soil quality and biodiversity by limiting plowing, reducing bare soil, assuring plant diversity, and engaging in integrated farming, is put up as a solution for sustainable food systems.

In recent years, many countries, including Kenya, have implemented intensified agricultural production systems to solve food insecurity. Despite the realization of high yield, nutrient content has been reported to decline along with increased environmental degradation (Pozza and Field, 2020). Unlike the intensified systems, RA seeks to increase food production and improve nutrition by using farming practices that nourish ecosystems. By fostering sustainable and resilient agricultural techniques that increase production, improve soil health, conserve natural resources, and support farmer livelihoods, regenerative agriculture has the potential to greatly contribute to food security. Overall, regenerative agriculture is consistent with the principles of sustainability, resilience, and ecosystem health, all of which are critical components of achieving food security in a society confronted with problems such as climate change, population expansion, and resource restrictions. Appropriate agricultural technologies are resource-efficient and offer great potential for increasing agricultural productivity, incomes, and food security while ensuring the resilience of rural livelihoods, with little or no impacts on the environment (FAO, 2010). Reorienting the agricultural sector to using Regenerative Agriculture as one of the candidate basket of technologies with the potential of stimulating transformation needs the right policies and investments as the new approach can solve food security issues and reduce poverty in a short time while acting as a mitigation measure to climate change (Schulte et al., 2022). Even though there are guiding principles, appropriate management practices and governance still need to be implemented in order to achieve soil and food security (Schreefel et al., 2020b). Despite the foregoing assessments, the level of acute food insecurity in Embu County has not been determined. Nonetheless, the research discussed above have less to say about how RA can affect household food security. As a result, the purpose of this study was to give that knowledge.

2.6 Methodological Review

2.6.1 Principal Component Analysis

Principal Component Analysis (PCA) is a technique for reducing dimensionality that is widely used in statistics and machine learning. Its primary application is to reduce the complexity of high-dimensional data while maintaining the vital information. PCA does this by transforming the original data into a new coordinate system with dimensions (axes) aligned with the data's directions of maximum variation. PCA is not utilized to assess a model's fitness or performance. Instead, it is a dimensionality reduction technique that is applied to the input data to transform it into a new set of orthogonal variables called principal components. Principal components, then, are a collection of fresh, agnostic variables produced by linearly merging the original variables in a dataset. The first principal component accounts for the majority of variance in the data, followed by the second principal component, the third principal component, shows the third most variation, and the fourth principal component, accounts for the fourth most variation.

Thus, the purpose of PCA is to capture the maximum amount of variance in the data using fewer variables (Salih and Abdulazeez, 2021).

Eigenvalues show how much of the data's variation is accounted for by each principal component. The first principal component is the direction of maximum variance, and its eigenvalue is the largest of all the eigenvalues. The second principal component has no correlation with the first principal component, and its eigenvalue is the second largest eigenvalue. This pattern continues for all subsequent principal components. The sum of all the eigenvalues equals the total variance in the data. The association between each original variable and each principal component is reflected in factor loadings. The relationship between the original variable and the principal component is positive or negative depending on whether the factor loadings are positive or negative.

The approach is effective as it helps in drawing conclusions about a group (Hasan and Abdulazeezet, 2021). The components were then rotated under varimax rotation to increase interpretability and help in generalization about the groups. The rotation method maximizes the variance of the squared loadings of each variable for a given component, under the constraint that the squared loadings for each variable must sum to 1. This tends to produce a simpler, more interpretable solution with fewer variables contributing significantly to each component.

Image processing, data compression, feature extraction, noise reduction, and visualization are all areas where PCA can be used. PCA can assist minimize the curse of dimensionality and perhaps improve the performance of machine learning algorithms by focusing on the most essential aspects by lowering the dimensionality of the data. Remember that, while PCA is a strong technique, it is not necessarily appropriate for every dataset. It assumes that the largest variance directions are the most relevant, which may not necessarily be the case. Furthermore, in some circumstances, interpreting reduced dimensions can be difficult. The model has been successfully used in a number of studies (Andati et al., 2022, Bhat et al.,2021 and Mohd et al.,2022). The study used the PCA model for characterization.

2.6.2 Food Consumption Score

Using data from a seven-day dietary recall, the Food Consumption Score (FCS) calculates dietary diversity, frequency and source of food, and relative nutritional value (World Food Program 2008). Respondents describe the number of days in the past seven days that their respective family members consumed locally acceptable food goods. The products are divided into food groups and weighted based on their calorie content. The FCS is computed by summing the weighted values. A threshold is utilized to determine if a household's food security situation is poor if the FCS is between 0 and 21, borderline if the FCS is between 21.5 and 35, and acceptable if the FCS is greater than 35 (Tuholske et al., 2020).

2.7 Theoretical Framework

This study was anchored on diffusion and production theories. The theories are based on uptake of new innovations and guiding on optimal input combinations for maximum output. Uptake depends on perceived usefulness of the technology, and the ultimate goal being to improve farm productivity and food security.

2.7.1 Diffusion of Innovations Theory

Diffusion of innovation is the process by which people adopt new ideas, products, behaviors, or philosophies (Yi et al., 2022). Based on Rogers theory of diffusion of innovations, Al-Razgan et al., 2021 stressed that when a new concept is introduced to people, initially, a few are open to it, adopt and use it. Early adopters will then spread the idea, and more and more people will adopt, leading to a critical mass. The idea spreads over time, and saturation points are reached (Sila, 2015). Innovators, early adopters, early majority, late majority, laggards, and possibly a sixth category of non-adopters were the five types of invention adopters (Dale et al., 2021). The adoption process is affected by perceptions, personality, and social characteristics among other factors (Colussi et al., 2022). Diffusion of innovation theory is used to explain the extent of uptake of RA technologies, characterization of the technologies, and assessing factors influencing uptake of the technologies in various households.

2.7.2 Economic Theory of Production

The financial process of transforming inputs into outputs is the focus of the economic theory of production (Vasyl'yeva, 2021). This theory helps producers to determine input combinations that give optimal production. The ultimate goal of producers is profit maximization; however, the purpose of each household is to maximize utility alongside profits (Weersink & Fulton, 2020). This theory models the relationship between socio-economic and institutional factors and the level of uptake of RA technologies. A production function specifies the quantities of inputs used and the actual output (Czyżewski et al., 2019). The function shows how the output changes with different combinations of inputs over a specified period. Mathematically the function is expressed as;

$$Y=f(X_1, X_2, X_3 \ldots, X_n) \quad (1)$$

Where Y is the output which is uptake, and X_1, X_2, $X_3 \ldots X_n$ is factors that influence uptake, X_1 =land, X_2 =capital X_3 = labor, and X_n represents other factors other than land, capital and labor that influence uptake of RA technologies. This study therefore used a stochastic Cobb Douglas production function to estimate the relationship as it satisfies the most economical, statistical, and econometric criteria (Qin, 2021). The function assumes that all the parameter estimates (output elasticities) are constant and is expressed as:

$$Y = AK^{\beta}L^{\alpha} \quad (2)$$

Y is the total output, K is capital input, L is the labor input, and A is the total productivity factor. β is labour's output elasticity, and α is capital's output elasticity, respectively. The function can be converted to a linear form using the natural log (ln) and can be expressed as;

$$\ln Y = \ln A + \beta \ln K + \alpha \ln L \quad (3)$$

The Cobb-Douglas production function is a popular choice for theoretical and empirical research since it is reasonably straightforward and easy to work with mathematically. The model explains how changes in input quantities and productivity effect output. It enables economists to investigate the influence of changes in factor inputs on output.

Furthermore, the function can be used to examine the effects of different policies on production, such as changes in labor or capital taxes, technological improvements, and changes in factor costs. The model assists enterprises and policymakers in understanding how to optimally distribute inputs to optimize production or profit (Wang, 2020).

The model has the following characteristics: The Cobb-Douglas production function exhibits constant returns to scale when the sum of the exponents and is equal to one. This means that increasing inputs by a certain percentage raises output by the same percentage. The elasticity of substitution between labor and capital in the production function is one. This suggests that labor and capital can be easily and regularly substituted for one another. Labor and capital marginal products are partial derivatives of the production function in terms of labor and capital, respectively. These demonstrate how much more output is produced by increasing each input by a little unit (Vasyl'yeva, 2021).

However, the model has the following drawbacks: The model implies a linear relationship between inputs and outputs, as well as continuous returns to scale, which may not accurately characterize all industries' manufacturing processes. The approach treats labor and capital as homogeneous inputs, ignoring differences in skills, education, and capital types. Although the output elasticities and are assumed to be constant, this may not be the case for all input values. These elasticities may change in practice as inputs change. While the model can reflect increasing, constant, or decreasing returns to scale, it cannot clearly explain diminishing marginal returns to individual inputs at higher levels. In addition, fixed substitution elasticity of one may not adequately represent the substitutability of labor and capital in all industries or sectors. Finally, due to concerns with multicollinearity and data availability, predicting the values of, α, β and A from empirical data can be difficult (Wang et al., 2021). Despite these limitations, the Cobb-Douglas production function remains a fundamental tool in economics for examining production connections and gaining broad insights into how inputs contribute to output in a variety of scenarios. More complicated models are frequently used by researchers to capture unique industry characteristics or to solve the limits of the Cobb-Douglas function.

2.8 Conceptual Framework

Figure 2.1 shows the conceptual framework that demonstrates the link between the dependent and independent variables involved in the study. Socioeconomic, institutional, and regenerative agriculture technologies are independent variables, while uptake, productivity, and food security are dependent variables. Further, the framework shows the intervening variables and expected outputs, respectively.

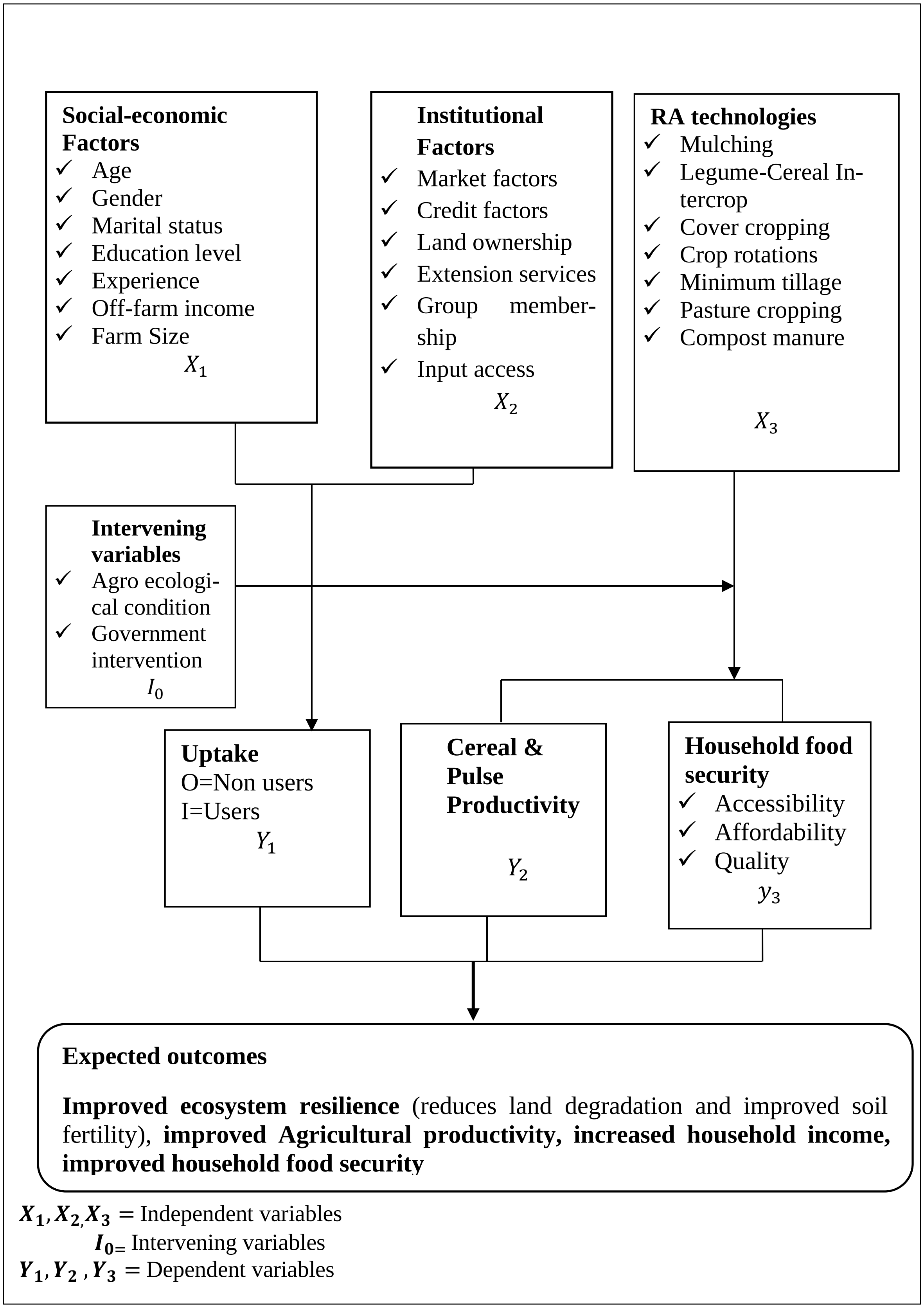

Figure 1: Conceptual framework

2.9 Research Gap

From literature, principles underpinning specific regenerative agriculture technologies (Giller et al., 2021) and their benefits have been covered adequately (Gosnell et al., 2019). Studies indicate that farmers can increase productivity through regenerative agriculture while mitigating climate change effects and increased productivity has been attributed to boosting household food security (Panagos et al., 2020). The adoption of agricultural innovations like CSA, CA, agroecology, and sustainable agriculture is influenced by socioeconomic and institutional factors, according to a number of studies (Gebru et al., 2019; Sanou et al., 2019). From literature, characterization of specific RA technologies is missing, limited attention has been given to the factors affecting the adoption of particular RA technologies. The effects of particular technologies on the production of cereals and pulses as well as household food security has also been given little concern. To bridge these gaps, the study focused on characterizing specific RA technologies used by farming households in the drylands of Embu County. The study also evaluated the potential impacts of the technologies on the productivity of cereals and pulses and household food security. The study further examined factors influencing uptake of various RA technologies

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study Area

The study was conducted in Embu County's Mbeere South Sub-County. The study location was chosen because of its arid features, potential for producing grains and pulses, and the presence of regenerative agricultural interventions to raise local residents' productivity and standard of living. The Sub-County, which comprises five wards named Mwea, Makima, Mavuria, Kiambere, and Mbeti South, the area is situated on the south-eastern slopes of Mount Kenya at an elevation of 700 meters to 900 meters. There are about 163,476 people living there in a 1,312km2 area (KNBS, 2019). It lies in between a latitude of 0°46′S and a longitude of 37°39′E, the mean annual temperatures varying from 20.70°C to 22.50°C (Ngetich et al., 2022). With an average annual rainfall ranging from 700 to 900 mm, rainfall is bimodal, with long rains occurring from mid-March to June and short rains occurring from mid-October to February. Mbeere South is in the Lower Midland (LM4) agro-ecological zone, which has hot and dry semiarid conditions that are ideal for drought-tolerant crops and cattle husbandry. The crops commonly grown in the area are pigeon peas, sorghum, millet, green grams, and cowpeas (Kiboi et al., 2019; Muthee et al., 2019). The Sub-County has experienced land degradation resulting from nutrient mining and inappropriate farming methods. This has resulted in low agricultural production, threatening household food security, which is aggravated by the fact that the majority of households rely on rain-fed small-scale agriculture.

3.2 Research Design

This study employed a cross-sectional survey research approach. This approach is best for gathering data on a population at a specific period since it enables the collection of both qualitative and quantitative information. The method was also chosen due to its low cost and capacity to employ a representative sample for the description, evaluation, and interpretation of correlations between variables (Wang & Cheng, 2020). Respondent information was gathered using semi-structured questionnaires created using the Open Data Kit (ODK)

3.3 Target Population and Sample Size

The target population for the study was approximately 27,274 rural-based farming households in Mbeere South Sub County (KNBS, 2019). Since the target population was more than 10,000, the study's sample size was 400 households based on the Cochran formula (Cochran, 1977).

$$n_{0}= \frac{Z^2PQ}{d^2} \text{ ……………………………………………………………………..…… (4)}$$

Where n_0 = required sample size, Z = t value from normal table, p = probability of success, Q= (1-p) probability of failure and d= 5% level of significance (0.049).

The standard deviation in this study is established at 1.96, which corresponds to a 95% level of confidence. Because there was no estimate of the population with the desired traits, the assumption was that at least 50% of the population possessed them. Following that, the sample size was estimated as follows:

$$\boldsymbol{n}_{0}= \frac{(1.96)^2(0.5)(0.5)}{(0.049)^2} \mathbf{= 400}$$

3.4 Sampling Procedures

Purposive, multistage stratified, and probability proportionate to size sampling procedures were used to select the respondents (Evans et al., 2021). Mbeere South Sub-County was especially chosen due to its semiarid characteristics, capacity for cereal and pulse production, and availability of RA technologies. All of the wards in the specified Sub-County were chosen. Each Ward has one sub-location chosen at random. Finally, one village from each sub-location was chosen at random. The probability proportionate to size (PPS) sampling approach was then used to calculate the number of households to be questioned in each village using a sample frame obtained from the ward agricultural offices (Samaddar et al., 2021). The proportion to size formula was used, which divided the number of people in each village by the total population in all five villages and then multiplied by the sample size, as shown below:

$$M=\frac{n}{N} x400 \text{……………………………………………………………………... (5)}$$

The proportion to size formula was used, which divided the number of farmers in the selected village by the total number of farmers in all five villages and then multiplied by the sample size, as shown below;

Table 3.1: Distribution of the respondents in the 5 wards

Ward*	**Population***	**Sub location**	**Number of households****	**Sample size**
Mwea	33,777	Karaba	2,474	87
Makima	28,722	Makima	2,902	102
Mavuria	10,270	Mavuria	1,252	45
Kiambere	6,624	Kiambere	1,336	47
Mbeti South	27,534	Gachoka	3,379	119
Total				400

*Based on KNBS (2019), **Based on the ward sample frame

3.5 Instruments for Data Collection

To obtain primary data from respondents, a semi-structured questionnaire was used in this study. Taking into consideration ethical issues, the respondents chosen were the heads of households, but in the absence of the household head, senior adult family members present were interviewed. Under careful supervision by the researcher, enumerators were trained on the subject and used the Open Data Kit (ODK) smartphone app to assist in data collection. The selected farming households were given detailed information about socioeconomic and institutional determinants, farm and farmer characteristics, pulse and cereal productivity, household food security, Regenerative Agriculture technologies adopted and their consent to participate in the survey sought.

3.6. Reliability and Validity of Instruments

Based on scientific acceptance, pretesting was done by administering about 30 questionnaires to randomly sampled households to test for the tool's accuracy. This was conducted outside the target areas (Mbeere North Sub-County specifically in Ishiara

Ward) and this sample was not included in the actual sample size to ensure the validity and reliability of the results. The split-half method was used to test for the reliability of the questionnaire. The split-half reliability technique divides the test into two equal sections, giving each exam two scores: the first score (for the first, odd-numbered questions) and the second score (for the last, even-numbered questions) (Safitri et al., 2020). The correlation coefficients (r) between halves were then calculated using Pearson Product linear correlation coefficient formula as shown below;

$r = N \sum Y - [\sum(X) (\sum Y)] / \sqrt{} [N \sum x^2 - (\sum x^2)] [N \sum y^2 - (\sum y^2)]$ ………………… (6)

Where X represents odd scores and Y represents even scores. (X) is the sum of X scores, (Y) is the sum of Y scores, (X^2) is the sum of squared X scores, $Y^2$is the sum of squared Y scores, XY is the sum of the product of paired X and Y scores, N is the number of paired scores, and r is the coefficient correlation between halves. One-half of the instruments are represented by r.

$Re = \frac{2r}{1+r}$ = 2 reliability for $\frac{1}{2}$ tests / 1 + reliability for $\frac{1}{2}$tests; the value of r lies between 0 and 1; a value approaching one shows stronger reliability while a value approaching 0 shows weak reliability. In ensuring that the tool is valid, items judged to be confusing or inadequate were reworded and re-modified to avoid respondent misinterpretation.

3.7 Data Analysis

Descriptive and inferential statistics were used to analyze the data collected. Frequencies and percentages were included in descriptive statistics. With regard to the inferential statistics, empirical models of PCA, MVP, and Cobb Douglas production function were used. The Statistical Package for Social Sciences (SPSS) version 25 and STATA version 17 software packages were used to analyze the data.

3.7.1 Characterization of Regenerative Agriculture Technologies

Regenerative Agriculture technologies used in the study area and land areas under the technologies were analyzed using factor analysis and Principal Component Analysis (PCA), respectively in SPSS version 25. PCA is appropriate for numeric data as it reduces complex data sets to lower dimensions without losing much information to reveal the hidden, simplified dynamics that often underlie it (Hasan and Abdulazeez 2021). PCA allows for both linear and nonlinear dimensionality reduction (Terol et al., 2020). Factor analysis is efficient because it shows whether several variables of interest are linearly related to a small number of unobserved factors (Alavi et al., 2020). RA technologies were grouped using factor analysis with iteration and varimax rotation to increase the interpretability of the results. The model used was specified as;

Y_j=$a_{j1}X_1$+$a_{j2}X_2$+……$a_{jn}X_n$…………………………………………………..…... (7)

Where y_j=correlated principal components a_1…… a_n=correlation coefficients and x_1…….x_n = factors influencing uptake of a particular technology.

3.7.2 Socio-economic and Institutional Factors Influencing Uptake of Regenerative Agriculture Technologies

In assessing the factors influencing uptake of RA technologies by farming households, Multivariate Probit (MVP) model was employed (Muriithi et al., 2021) in STATA version 17. Farmers in some cases use more than one technology at the same time and within the same land area. Therefore, this model is preferred because it allows for correlation in the uptake of various technologies simultaneously (Mwinkom et al., 2021). Further, the model allows for simultaneous regression of binary equations that are correlated against a single vector of predictor variables (Okello et al., 2020). MVP model has been successfully used in several studies to estimate factors influencing uptake of different agricultural technologies (Okello et al., 2020; Zakaria et al., 2020). Mathematically the model is specified as

$$Y_{i1} = X_{ij1}\,\beta_1+\varepsilon_{i1}$$

$$Y_{i2} = X_{ij2}\,\beta_2+\varepsilon_{i2}$$

$$Y_{i3} = X_{ij3}\,\beta_3+\varepsilon_{i3}$$

$$Y_{i4} = X_{ij4}\,\beta_4+\varepsilon_{i4}$$

$$Y_{i5} = X_{ij5}\,\beta_5+\varepsilon_{i5}$$

$$Y_{i6} = X_{ij6}\,\beta_6+\varepsilon_{i6}$$

$$Y_{i7} = X_{ij7}\,\beta_7+\varepsilon_{i7}$$

Where i is the household identification number, $Y_{i1} = 1$ if the household practices cereal legume intercropping system and 0 if otherwise, Y_{i2}=1 if the household practices mulching and 0 if otherwise, Y_{i3}=1 if the household practices minimum tillage and 0 if otherwise, Y_{i4}=1 if the household practices cover cropping and 0 if otherwise, Y_{i5}=1 if the household practices pasture cropping and 0 if otherwise, Y_{i6}=1 if the household practices crop rotations and 0 if otherwise, Y_{i7}=1 if the household uses compost manure and 0 if otherwise, X_i is the vector of factors influencing uptake of Regenerative Agriculture technologies, $\beta_j = \beta_1,\ \beta_{2,}\ \beta_3,\ \beta_4\ ,\ \beta_5,\ \beta_6, \beta_7$ are the vectors of unknown parameters and $\varepsilon_i$is the disturbance term. MVP model of the following form was used based on the assumption that the disturbance term may not experience stochastic independence.

$$Y_{ij} = X_{ij}\beta_j + \varepsilon_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where Y_{ij} (j =1, 2…...,7) represent Regenerative Agriculture technologies, i is the household id (i=1…400), X_{ij} is a 1 × k vector of observed variables that influence uptake decision of the farmer, β_{ij} is a k × 1 vector of unknown parameters to be estimated and ε = normally distributed error terms. To evaluate the multivariate normal distribution, the unknown parameters are estimated using simulated maximum likelihood, assuming that the disturbance terms (across j = 1..., n choices) are multivariate and normally distributed with mean vector equal to zero.

3.7.3 Effect of Uptake of Regenerative Agriculture Technologies on Productivity of Selected Cereals and Pulses

In analyzing the effect of uptake of various RA technologies on the productivity of selected cereals and pulses, a stochastic log-linearized Cobb-Douglas production function was used in SPSS version 25. Productivity was estimated in terms of output per acre. The quantity ratio of inputs used and the grain yield obtained in kilos were used to calculate output per acre. This study was best suited to a stochastic log-linearized Cobb-Douglas production function because it provides parameters that are simple to estimate and interpret (Evans et al., 2021). The general production function is expressed as:

$$\mathrm{Y} = \beta_0 X_1{}^{\beta_1} X_2\, X_3 \ldots\ldots\ldots\ldots X_n{}^{\beta_n} Z_1{}^{\alpha_1} \ldots\ldots\ldots Z_n{}^{\alpha_n} + \epsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Considering the natural logarithm, the production function is expressed as:

$$\ln Y = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \cdots + \beta_n lnX_n + \alpha_1 Z_1 + \cdots + \alpha_n Z_n + \epsilon \ldots$$

…………………………………………………………………………………… (10)

Where Y=Yield produced in Kilograms, β_0= intercept, X_1 to Xn=inputs used in production, β_1 to βn= parameter estimates of the explanatory variables, α_1 to α_n= coefficients of RA technologies, z_1 to zn= R.A. technologies, ln= natural logarithm, and ε is the disturbance term.

3.7.4 Influence of Uptake of Regenerative Agriculture Technologies on Household Food Security

The Household Food Consumption Score (HFCS) was created to assess the food security situation of households. The World Food Program (WFP) developed HFCS as a substitute for food security (WFP, 2009). Food frequency, dietary diversity, and the nutritional value of food groups consumed all contribute to the HFCS score. It categorizes food consumption as poor (0 - 21), borderline (21.5 - 35), and satisfactory (> 35). The HFCS content is calculated by multiplying the frequency of foods consumed in the previous seven days by the weighting of each food group. WFP computed the weighting of each food group based on its nutritional density. Based on the nutritional density of each food group, WFP calculated the weighting of each. Specific weights are given to the following items: main staples 2, pulse 3, vegetables 1, fruit 1, meat and/or fish 4, milk 4, sugar 0.5, oil 0.5, and condiments 0. Numerous families were consulted for information on the kind of foods eaten during the previous seven days as well as frequency. The weighting of each group according to the formula specified in the "emergency food security assessment manual" (WFP, 2009) was then multiplied by the frequency of foods consumed over the previous seven days. The formula is expressed as shown below;

HFCS=α1×f (main staples) +α2×f (pulse) +α3×f (vegetables) +α4×f (fruit) +α5×f (fish or and meat+α6×f (milk) +α7×f (sugar) +α8×f (oil) +α9×f (condiments)……… (11)

Where HFCS denotes Household Food Consumption Score, f denotes frequency (the number of days each food group was consumed in the previous seven days), and α = denotes a weighted value that represent the nutritional value of each food group.

3.8 Operationalizing the Study Variables

The study variables, descriptions, measurements, and predicted indications are shown in Table 3.2. The positive effect is shown by (+), whereas the negative effect is denoted by (-).

Table 3.2: Variable Descriptions

Variable	Description	Measurement	Sign
Dependent variables			
RA technologies	Number of RA technologies	Discrete	None
Extent of uptake	Land area under Ra technologies	Percentage (%)	None
Productivity	Crop yield (output per acre)	Kilograms	None
Household food security	Food security status in each household	HFCS	None
Independent variables			
Age	Age of respondent	In years	+
Gender	Sex of respondent	1=male,2=female	+/-
Marital status	Marital status of the respondents	1=Married 2=Not married	+/-
Education	Respondent education level	Categorical	+
Experience	Farming experience	Number in years	+
Farm size	Land under R.A. technologies	Acres	+
Off-farm activity	Off-farm occupation	1=yes, 2=no	+
Main occupation	Respondents' main occupation or engagement	1=crop farming 2=Others	
Extension services	Access to extension services	1=yes, 2=no	+/-
Land ownership	Land tenure systems	1=tittle deed 2=otherwise	+/-
Group membership	Membership to group	1=yes, 2=no	+/-
Market distance	Distance covered to the nearest market	Kilometers	+
Credit access	Access	1=yes, 2=no	+/-

CHAPTER FOUR
RESULTS AND INTERPRETATION

4.1 Overview

This chapter summarizes the descriptive and inferential analysis findings from the study. It presents the respondents' socioeconomic and institutional characteristics, characterization of various Regenerative Agriculture technologies using Principal Component Analysis, and the extent of uptake of various technologies based on land areas where the technologies are practiced. The chapter also discusses socioeconomic and institutional factors that influence the adoption of various technologies using a Multivariate Probit Model, the impact of adoption on sorghum and green gram productivity, and the influence of adoption on household food security.

4.2 Characteristics of the Respondents

Results that are descriptive of the respondents' attributes are presented in this section. The section outlines the socioeconomic and institutional features of the respondents, as well as the challenges farmers have in implementing RA technologies and the need for support to expand RA use.

4.2.1 Socioeconomic Characteristics of the Respondents

Table 4.1 displays the results of the respondents' socioeconomic characteristics. The majority of household heads ranged in age from 31 to 50 years (44.3%), with youths aged 18 to 30 years accounting for 23.3%, indicating that older individuals were more involved in farming than young people who participated in other off-farm activities. Furthermore, the majority of households (61%) were male-headed, with the remainder (39%) being female-headed, implying that males had control that give them greater leeway to make decisions on which technologies to utilize on the farm. Majority (82.8%) of the household, heads were married with only (17.2%) not married this could be useful in determining and planning on which technology to implement on the farm. Further, the results suggest that more than half (51.2%) household heads attained at most primary level of education with only (2.8%) attaining post-secondary education. This implies that a farmer, regardless of academic level, is empowered to make decisions on acceptable farming technologies to implement. Majority (38.4%) of the household heads had farming experience ranging from 10 to 20 years, meaning that the majority of the sampled farmers had extensive expertise necessary for implementing various RA methods. In addition, the findings reveal that, most (37%) of the households owned more than 5 acres of land, indicating that there was more area available for RA technology adoption. Crop farming was the principal occupation of the majority of households (89%), with 37.3% performing off-farm work in addition to farming. This emphasizes the importance of increasing the household earnings of individuals whose heads are dependent on agriculture. Off-farm activities generate extra resources that could aid in the adoption of new technology. Off-farm activities, on the other hand, may consume more time that could otherwise be committed to farming.

Table 4.1: Socioeconomic characteristics of the respondents

Variable	**Category**	**Frequency N=400**	**Percentage**
Age (Years)	18-30	93	23.3
	31-50	177	44.3
	More than 50	130	32.5
Gender	Male	244	61
	Female	156	39
Marital status	Married	331	82.8
	Not married	69	17.2
Education level	None	90	22.5
	Primary	205	51.2
	Secondary	94	23.5
	Post-secondary	11	2.8
Farming experience	Less than 10 years	129	32.3
	10-20 years	54	38.4
	More than 20 years	117	29.3
Land size (acres)	Less than 1 acre	57	14.2
	1.1-3 acres	121	30.3
	3.1-5 acres	74	18.5
	More than 5 acres	148	37
Main occupation	Crop farming	356	89
	Livestock production	26	6.4
	Salaried worker	5	1.3
	Self employed	13	3.3
Off farm activity	Yes	149	37.3
	No	251	62.7

4.2.2 Institutional Characteristics of the Respondents

Table 4.2 shows the descriptive results of the respondent's institutional characteristics hypothesized to influence uptake of various RA technologies. For this study, terms of land ownership, access to extension services, market distance, credit accessibility, and membership to group were considered. According to the results, majority of the respondents (57%) owned land with title deeds. This indicates that majority of the respondents will be free to invest the adoption of disseminated innovations. Only 24.8% of those surveyed had access to extension services. Implying that the largest segment (75.2%) of the respondents had not received any extension services and this could lead to low uptake of certain technologies. In addition, in order to reach the input and output markets, majority of the respondents (78%) travel a distance of over 10 kilometers. The long distance could hinder access to the input and output markets. Long distances to input markets, such as seed providers and machinery dealers might make adoption of a key technology difficult for farmers.

Further the findings reveal that partly 16% of the respondents accessed credit for farming with only 34% belonging to various farmer groups. Access to credit allows farmers to overcome financial constraints and acquire the necessary technologies, thereby promoting adoption (Bui and Nguyen, 2021). Group membership allows members to learn from one another about new innovations, how to produce and market new agricultural commodities (Fatch et al., 2020). Apparently, there were no respondents who accessed the agricultural markets virtually. This implies that, virtually markets are not used by small scale farmers or the farmers have no information on the dynamics and operations of digital markets.

Table 3.2: Institutional characteristics of the respondents

Variable	Category	Frequency N=400	Percentage
Main land ownership	Owned with title deed	228	57.0
	Owned without title deed	121	30.3
	Leased	27	6.7
	Communal	24	6.0
Extension services access	Yes	99	24.8
	No	301	75.2
Market distance	Less than 5 Kilometers	5	1.3
	5-10 Kilometers	57	14.2
	More than 10 Kilometers	312	78.0
	Virtual	0	0
Credit access	Yes	64	16.0
	No	336	84.0
Group membership	Yes	136	34.0
	No	264	66.0

4.2.3 Challenges Facing Uptake of Regenerative Agriculture Technologies

More than half of the surveyed farming households (56.5%) reported that they lacked sufficient knowledge about Regenerative Agriculture. This suggests that there is a need for educational and training initiatives to increase awareness and understanding of the principles and techniques of regenerative farming. Providing workshops, information sessions, and training programs could help address this knowledge gap. Almost an equal percentage of respondents (56.3%) indicated that unfavorable weather conditions were a significant challenge. This points to the vulnerability of agricultural practices to the variability of weather patterns, which can impact crop growth and yield. It highlights the need for resilient farming methods that can adapt to changing weather conditions or minimize their negative effects. 26.3% of the respondents experienced poor performance of the regenerative agricultural technologies they adopted. This could be due to factors such as improper implementation, lack of compatibility with local conditions, or unrealistic expectations about the outcomes of these technologies. About a quarter of the respondents (26.5%) mentioned that cultural factors posed hindrances to the adoption of Regenerative Agriculture practices. Cultural factors might include traditional farming practices, beliefs, or social norms that conflict with or resist the implementation of new and innovative farming approaches. Further, a significant portion of the farmers (34.3%) found labor intensity to be a challenge in adopting Regenerative Agriculture. This suggests that they perceive regenerative practices as requiring more manual labor compared to their existing methods. Addressing this concern might involve demonstrating how these practices can lead to increased efficiency and reduced labor requirements in the long run.

Table 4.3: Challenges Faced by Farming Households

Challenge	**Frequency N=400**	**Percentage (%)**
Inadequate knowledge on RA	226	56.5
Poor performance of adopted technologies	105	26.3
Cultural factors	106	26.5
Labour intensive	137	34.3
Unfavorable weather conditions	225	56.3

4.2.4 Enhancing Uptake of Regenerative Agriculture Technologies

Results on table 4.4 illustrate that significant majority (80.3%) of the surveyed respondents feel the need for training in order to effectively implement Regenerative Agriculture practices. Almost half of the respondents (48.5%) express a preference for field demonstrations. This implies that some farmers learn better through hands-on experiences rather than theoretical training. Providing practical demonstrations on how to carry out specific RA practices in real agricultural settings could be a valuable approach to help them grasp the techniques more effectively. A notable portion of the respondents (37.8%) indicate a need for credit support specifically for labor-related expenses. This suggests that while RA practices might not require significant external inputs or financing for technologies, there is still a financial aspect associated with labor costs that could be a barrier for some farmers. Offering credit options for covering labor costs could help incentivize more farmers to. The findings highlight the importance of tailored educational programs, hands-on experiences, and targeted financial support to encourage wider adoption of regenerative agricultural practices. Additionally, the recognition that RA practices often involve minimal external financing underscores the holistic and sustainable nature of these practices.

Table 4.4: Support required by farming households

Support	Frequency N=400	Percentage (%)
Training	321	80.3
Field demonstrations	194	48.5
Credit provision	151	37.8

4.3 Characterization of Regenerative Agriculture Technologies Used by Farming Households

The Principal Component Analysis (PCA) was used to characterize RA technologies typically utilized by farming households, and related technologies were divided into clusters based on acceptance. The results of the rotation reveled 4 principal components with 7 extracted technologies with eigenvalue of greater than 1. The 4 components explained 63.98% of total variation in the dataset proofing a good fit for the model. For the interpretation of the principal components, factor loadings higher than 0.6 were considered from the varimax rotation. Table 4.5 helps define each component to the associated technology.

Table 4.5: Loadings of Four components of RA Technologies

RA technology	PC1	PC2	PC3	PC4
Cereal-legume intercrop	**0.821**	-0.182	0.007	-0.005
Pasture cropping	**0.811**	-0.154	0.004	0.003
Crop rotations	**0.610**	0.408	0.180	-0.207
Mulching	-0.048	**0.748**	-0.006	0.401
Cover cropping	0.160	0.044	**0.751**	0.291
Use of compost manure	-0.106	-0.008	**0.680**	-0.387
Minimum tillage	-0.049	0.002	-0.004	**0.744**
Eigenvalues	2.021	1.417	1.229	1.101
Eigenvalues %contribution	22.346	15.745	13.659	12.230
Variance explained (63.979%)	22.021	14.834	14.099	13.026

Numbers in bold represent loadings greater than 0.6

The first principal component explained the highest variance (22.021%) and is correlated with intercropping cereal crops with leguminous crops, pasture cropping and crop rotations. The 2nd, 3rd and 4th components accounted for 14.834%, 14.099% and 13.026% variances respectively. The second component was associated with mulching, the third component was associated with cover cropping and use of compost manure, while, the fourth component contained minimum tillage. Meaning that, the preferred RA technologies were cereal-legume intercrop, pasture cropping and crop rotations in the study area. Followed by mulching then cover cropping and use of compost. Use of minimum tillage alone was preferred as a fourth option by famers.

4.3.1 Regenerative Agriculture Technologies Used by Farming Households

Table 4.6 shows descriptive statistics for each of the RA technology as used by the farming households. The results are as follows: cereal-legume intercrop (71.3%), pasture cropping (72.0%), crop rotations (96.0%), mulching (76.3%), cover cropping (14.5%), compost manure (24.0%) and minimum tillage (31.5%).

Table 4.6: Regenerative Agriculture technologies used by farming households

RA technology	Frequency N=400	Percentage
Cereal –legume intercrop	285	71.3
Pasture cropping	228	72.0
Crop rotations	384	96.0
Mulching	305	76.3
Cover cropping	58	14.5
Compost manure	96	24.0
Minimum tillage	126	31.5

4.3.2 Extent of Uptake of Various Regenerative Agriculture Technologies

The extent of uptake of various RA technologies by farming households was measured based on land area under specific technologies as a percentage of total land area. For land area of less than 30%, the extent of uptake was termed as low, land area of between 30-60% the extent of uptake was considered medium while, land area greater than 60% represented high uptake. The results on Table 4.7 reveal that all the 7 technologies taken into consideration had low uptake. Implying that majority of the households that were using these technologies on their farms, had adopted them in less than 30% of their farming land. Cover cropping and compost manure depicted the highest percentages of low uptake at 87.5% and 87.3% respectively. Crop rotations show the highest percentage of high uptake at only 21.8%, cereal-legume intercrop (17.8%), mulching (14.8%), minimum tillage (12.0%), pasture cropping (7.2%) and use of compost manure (6.0%). The low uptake was attributed to unfavorable weather, a lack of expertise with RA, high labor costs, limited access to extension services, and a lack of superior crop varieties that could withstand the harsh weather.

Table 4.7: Extent of Uptake of Regenerative Agriculture Technologies

RA technology	Uptake category (land area)	Percentage (%)	Level of uptake
Cereal-legume intercrop	Less than 30%=Low	67.3	Low
	30 to 60%=Medium	15.0	Medium
	Greater than 60%=High	17.8	High
Mulching	Less than 30 %=Low	83.0	Low
	30 to 60%=Medium	12.3	Medium
	Greater than 60%=High	14.8	High
Minimum tillage	Less than 30 %=Low	79.8	Low
	30 to 60%=Medium	8.3	Medium
	Greater than 60%=High	12.0	High
Cover cropping	Less than 30 %=Low	87.5	Low
	30 to 60%=Medium	6.5	Medium
	Greater than 60%=High	6.0	High
Pasture cropping	Less than 30 %=Low	80.3	Low
	30 to 60%=Medium	12.5	Medium
	Greater than 60%=High	7.2	High
Crop rotations	Less than 30 %=Low	30.8	Low
	30 to 60%=Medium	47.5	Medium
	Greater than 60%=High	21.8	High
Compost manure	Less than 30 %=Low	87.3	Low
	30 to 60%=Medium	6.8	Medium
	Greater than 60%=High	6.0	High

4.4 Factors Influencing Uptake of Regenerative Agriculture Technologies

Results on socioeconomic factors (age, gender, marital status, education level, farming experience, farm size, main occupation, and off-farm activity) and institutional factors (terms of land ownership, access to extension services, access to credit, membership to group, and distance to market) that affect uptake of various RA technologies are presented in this section.

4.4.1 Socioeconomic Factors Influencing Uptake of Regenerative Agriculture Technologies

To assess socioeconomic factors that influence uptake of Regenerative Agriculture technologies, the Multivariate Probit Model was employed. The beta coefficients show the direction of effect of each independent variable on the dependent variables. Results in Table 4.8 illustrate that age significantly and positively influenced uptake of minimum tillage at 5% level with a beta coefficient of 0.272 with a p value of 0.018. This means that as a farmer gets older, he or she is more likely to use minimum tillage. This was related to farming experience gained in prior years as well as perceptions of new advancements.

Gender of the household head was found to positively influenced the likelihood of using compost manure at 1% level (P=0.007) by a factor of 0.285. Majority of the households were headed by males indicating that male headed households had higher chances of using compost manure as opposed to female headed households. Marital status negatively (-0.907) and significantly (P=0.005) influenced uptake of cover cropping at 1% level. Majority (82.8%) of the household heads were married as illustrated in Table 4.1. This implies that married farmers had lower chances of practicing cover cropping as compared to farmers who are not married.

Level of education influenced uptake of mulching and intercropping cereals and legumes negatively and significantly, with coefficients of (-0.101, -0.024) and p values of (0.05, 0.026) respectively. Majority (51.2%) of the household heads achieved at most primary school level of education, 23.5% achieved at most secondary education, 2.8% attained post-secondary education and 22.5% had no formal education at all (Table 4.1). This implies that contrary to expectations, farmers with low formal education had higher chances of intercropping cereal and legume crops and doing mulching as compared to those with better formal education. This could be linked to the farmer's years of agricultural experience, comprehension of various inventions, and participation in off-farm activities

Further, the findings reveal that farming experience influenced uptake of minimum tillage negatively and significantly with coefficients of (-0.243) and a p value of (0.009) respectively. Implying that, farmers who had practiced farming for many years were less likely to us minimum tillage on their farms. In addition, the results show a positive association between farm size and uptake of minimum tillage (0.096, p=0.005), use of compost manure (0.114, p=0.001) at 1% level and crop rotations (0.213, p=0.026) at 5% level. Inferring that, households with larger farms had increased chances of taking up these innovations as compared with small farm holders. On the other hand, a negative association was observed between farm size and uptake of cereal-legume intercrop (-0.083, p=0.024) and pasture cropping (-0.120, p=0.001) at 5% and 1% level respectively. Meaning that households that had small farms were more likely to practice intercropping and pasture cropping. These technologies can be practiced simultaneously on the same piece of land at the same time thus allowing households that had small farms to practice them more easily.

The study established that main occupation significantly and negatively influenced uptake of cereal-legume intercrop, pasture cropping and crop rotations by a factor of -0.413, -0.362 and -0.516, with p values of 0.000,0.002 and 0.000 respectively (Table 4.8). Implying that, respondents who engaged in other activities had increased chances of taking up these innovations than those who practiced crop farming as the main occupation. This can be as a result of extra income generated from other activities. In addition, main occupation had a positive (0.232) relationship with use of compost manure at 5% level (p=0.050). Meaning that, farmers who practiced crop farming as the main occupation had higher chances of using compost manure to maximize production and incomes because manure is readily available.

Uptake of minimum tillage was positively and significantly influenced by engagement in off farm activity by the household heads, by a factor of 0.535 with p values of 0.000 respectively. On the other hand, engagement in off farm activity influenced use of compost manure negatively (-0.387) at 5% level (p=0.013). This implies that, respondents who participated in off-farm activities were more likely to use minimum tillage while those who did not participate in off-farm activities were more likely to use compost manure. Because engagement in off farm activity could generate more income that could be used on the farm. However, engagement in alternative activities could as well consume more time that could have been on the farm.

Table 4.8: Socioeconomic Factors Influencing Uptake of Regenerative Agriculture Technologies

Variable	Cereal-legume Intercrop	Mulching	Minimum tillage	Cover cropping	Pasture cropping	Crop rotations	Compost Manure
	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.
Age	(0.149)	(0.086)	(0.272) **	(0.098)	(0.094)	(0.198)	(-0.043)
	0.109	0.109	0.115	0.123	0.108	0.207	0.108
Gender	(-0.188)	(-0.039)	(-0.222)	(-0.038)	(-0.184)	(0.206)	0.285
	0.143	0.148	0.148	0.170	0.141	0.276	(0.150) **
Marital status	(0.022)	(0.094)	(-0.008)	-0.907	(-0.208)	(0.173)	(-0.025)
	0.189	0.195	0.200	(0.324) ***	0.183	0.327	0.199
Education level	-0.101	-0.024	(-0.064)	(0.033)	(-0.094)	(0.038)	(0.108)
	(0.094) **	(0.099) **	0.096	0.117	0.093	0.178	0.102
Farming experience	(0.145)	(0.033)	-0.243	(0.003)	(0.124)	(0.112)	(0.063)
	0.081	0.070	(0.092) ***	0.073	0.079	0.174	0.058
Farm size	-0.083	(-0.041)	0.096	(-0.054)	-0.120	0.213	0.114
	(0.037) **	0.038	(0.034) ***	0.049	(0.037) ***	(0.108) **	(0.034) ***
Main occupation	-0.413	(0.112)	(-0.088)	(0.035)	-0.362	-0.516	0.232
	(0.118) ***	0.116	0.119	0.135	(0.112) ***	(0.148) ***	(0.118) **
Off farm activity	(0.030)	(0.240)	0.535	(0.159)	(-0.046)	(0.024)	-0.387
	0.137	0.145	(0.116) ***	0.137	0.122	0.231	(0.157) **
Constant	(1.056)	(0.383)	(-0.586)	(-0.230)	(1.618)	(0.531)	-1.871
	0.550	0.566	0.541	0.669	0.539	0.970	(0.553) ***

Likelihood ratio test of Rho_{ij}=0, Chi2 (21) = 158.453, Prob > chi2 = 0.0000, Wald chi2 (63) =154.44, Log likelihood = -1214.314, ***and ** show significance at 1% and 5% level respectively, Number of observations=400.
Coeff: coefficient and Std.error: standard error.

4.4.2 Institutional Factors Influencing Uptake of Regenerative Agriculture Technologies

Results from Multivariate Probit regression in Table 4.9 showed that terms of land ownership had a negative and significant association with uptake of intercropping cereals with legumes and crop rotations with factors of (-0.172, -0.169) and p-values of (0.043,0.052) respectively. On the other hand, the association with cover cropping was positive (0.169) and significant (0.056). Implying that farmers who occupied land without title deeds were more likely to practice intercropping and crop rotations while those with title deeds were more likely to adopt cover cropping to maximize on production and land utilization.

Access to extension services was a positive and significant factor in predicting uptake of cereal-legume intercrop and crop rotations at 1% level, cover cropping and use of compost manure at 5% level. Inferring that, access to extension services by farmers increased their likelihood of taking up these RA technologies. Extension services such as farmer training and field demonstrations give more information to farmers thus farmers are likely to change their farming styles in order to maximize on production and profits as well.

Credit access had a negative significant influence on uptake of mulching, minimum tillage and crop rotations with factors of (-0.854, -0.685 and -1.159) and p-values of (0.017, 0.040 and 0.000) respectively. On the other hand, the association between access to credit and use of compost manure was positive and significant at 1% with a factor of 0. 277. This shows that households that accessed credit for farming were more likely to adopt use of compost while those that had no access to credit were more likely to adopt the technologies with negative associations. This is because most RA technologies do not require financing with significant amount of money to be implemented thus, they can easily be used by farmers. The positive association on use of compost can be a result of farmers getting money to spend on labour and other materials required for preparation of compost manure.

Membership to a group positively and significantly influenced uptake of cereal-legume intercrop, cover cropping, pasture cropping and use of compost manure at 1% level with factors of (0.828, 0.942,0.887 and 0.729) respectively. The implication could be that, farmers who belonged to various farmer groups had higher chances of taking up this RA technologies as compared to those who did not belong to any group. Those who belonged to farmer groups reported that they received training on how to undertake various technologies for better yield. It's easy to seek extension services in groups than individually. Moreover, distance to the market had a positive significant influence on uptake of mulching (0.331) and use of compost manure (0.298) at 5% level. High yield from mulching and use of compost manure may not be affected by market distance since materials used for mulching and preparation of compost manure is found within the farm. Further, farmers preferred selling their produce to brokers who would come to the farm to save on transportation costs to the output market. Thus, the long distance to the input and output markets is not a hindrance to technology adoption.

Table 4.9: Institutional Factors Influencing Uptake of Regenerative Agriculture Technologies

Variable	Cereal-legume Intercrop	Mulching	Minimum tillage	Cover cropping	Pasture cropping	Crop rotations	Use of compost Manure
	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.	Coeff. Std.error.
Terms of land ownership	-0.172	(0.170)	(-0.117)	0.169	(-0.159)	-0.169	(0.054)
	(0.085) **	0.155	0.116	(0.088) **	0.090	(0.087) **	0.081
Extension services	0.641	(0.237)	(-0.073)	0.462	(0.196)	0.580	0.363
	(0.195) ***	0.273	0.252	(0.183) **	0.201	(0.208) ***	(0.185) **
Access to credit	(-0.396)	-0.854	-0.685	(-0.095)	(-0.171)	-1.159	0.727
	0.277	(0.358) **	(0.334) **	0.255	0.298	(0.271) ***	(0.277) ***
Membership to group	0.828	(-0.139)	(-0.268)	0.942	0.887	(0.157)	0.729
	(0.157) ***	0.249	0.243	(0.154) ***	(0.172) ***	0.175	(0.154) ***
Market distance	(0.216)	0.311	(0.073)	(0.225)	(-0.260)	(-0.187)	0.298
	0.149	(0.239) **	0.237	0.148	0.167	0.157	(0.149) **
Constant	0.936	1.418	2.105	(0.278)	1.414	1.168	0.195
	(0.198) ***	(0.312) ***	(0.307) ***	0.150	(0.220) ***	(0.209) ***	0.186
Log-Likelihood value							-1059.273
Wald chi2 (42)							212.76***

Likelihood ratio test of Rho_{ij}=0, Chi2 (21) = 205.473, Prob > chi2 = 0.0000, Number of observations=400. ***and ** show significance at 1% and 5% level respectively. Coeff: coefficient and Std.error: standard error

4.5 Effects of Uptake of Regenerative Agriculture Technologies on Productivity of Selected Cereals and Pulses

The combined effect of RA technologies and inputs used in the production of sorghum and green gram was estimated using a stochastic log linearized Cobb-Douglas production function. The results of Cob-Douglas multiple regression on sorghum (Table 4.10) and green gram (Table 4.11) show that the model gave R-square values of 0.7025 and 0.6100 respectively. This implies that the explanatory variables explained 70.25% of variations in sorghum productivity and 61% of variations on green gram productivity in the study area. The F values were highly significant at 1 % (0.000). The tolerance values for each variable were computed to test the significance of regression coefficients. The results revealed t-values greater than 0.1 for significant variables suggesting increased difference between the null hypothesis and the variables. VIF values for all the explanatory variables were less than 5 implying that multicollinearity between the variables was not significant.

4.5.1 Effects of Uptake of Regenerative Agriculture Technologies on Sorghum Productivity

Four inputs namely: cost of seeds, cost of labour, farm size and quantity of manure were included in the production function. Farm size and quantity of manure were positively significant at 1% with factors of 0.606 and 0.302 respectively. This implies that, increasing land size under sorghum production by 1% will increase sorghum productivity by 0.606%. On the other hand, increasing the quantity of manure used in sorghum production by 1% will increase sorghum productivity by 0.302%. The cost of seeds and labour were not significant. RA technologies were introduced in the production function to estimate their effects on sorghum productivity. Seven technologies were considered and Table 4.10 shows the results.

The findings show that intercropping cereal and legume crops, using mulches, and engaging in low tillage were all significant at the 1% level and positive with respective factors of (0.112), (0.227), and (0.188). Using mulch would enhance sorghum yield by 0.227%, using low tillage would increase sorghum yield by 0.188%, and farmers who intercropped sorghum with legumes were expected to gain 0.112% more yield. Additionally, using compost manure and sowing sorghum with a cover crop both had favorable and significant effects at the 5% level, with coefficients of 0.158 and 0.102, respectively. It was implied that farmers who planted sorghum with cover crops would likely see an improvement in productivity of 0.158%, whereas farmers who used compost manure on their sorghum crops would see an increase in productivity of 0.102%. Crop rotations and pasture cropping, on the other hand, were shown to be statistically inconsequential. This suggests that the use of these technologies may have no effect on sorghum productivity among agricultural households.

Table 4.10: Effects of Uptake of Regenerative Agriculture Technologies on Sorghum Productivity

Variables	Parameters	Beta	S. E	t-Value	P-Value	VIF
Constant	β_0	0.028	4.217	0.250	0.507	
Inputs						
Ln seeds (sorghum)	β_1	-0.019	0.113	1.02	0.203	1.04
Ln labour	β_2	0.001	0.010	0.45	0.074	1.03
Ln farm size	β_3	0.606	1.207	20.00	0.000***	1.36
Ln manure	β_4	0.302	0.008	4.210	0.001***	1.08
RA Technologies						
Cereal-legume intercrop	α_1	0.112	2.014	3.30	0.000***	1.60
Crop rotations	α_2	0.128	3.109	1.34	0.178	1.12
Mulching	α_3	0.227	1.649	0.58	0.000***	1.04
Minimum tillage	α_4	0.188	1.615	2.74	0.004***	1.18
Pasture cropping	α_5	0.264	2.001	4.80	0.499	1.71
Cover cropping	α_6	0.158	2.020	2.05	0.040**	1.23
Use of compost	α_7	0.102	1.776	0.33	0.054**	1.20
R-squared						0.7025
Prob>F						0.000
Mean VIF						1.35

***significant at 1% and **significant at 5%.

4.5.2 Effects of Uptake of Regenerative Agriculture Technologies on Green Gram Productivity

The Cobb Douglas results on Table 4.11 show that inputs (farm size and quantity of manure), RA technologies (cereal-legume intercrop, crop rotations, mulching and use of compost manure) positively and significantly influenced the production of green grams. Farm size and quantity of manure used were significant at 1% level with factors of 0.806 and 0.252 respectively. Implicating that increasing land area under green gram production by 1% will increase yield by 0.806% while increasing the amount of manure used on green gram production by 1% will increase yield by 0.252%.

Additionally, the findings demonstrate that using compost manure and intercropping cereals and legumes were significant at the 1% level, with beta coefficients of 0.222 and 0.312, respectively. In other words, farmers who planted green grams along with other cereal crops were more likely to have a yield that was 0.222% larger than those who planted green grams as their only crop. Additionally, producers of green grams who employed compost manure saw a 0.312% boost in productivity. Mulching and crop rotation both had coefficients of 0.138 and 0.117 that were significant at the 5% level. According to this, farmers who alternated green beans with other crops on the same field produced a 0.138% better yield than those who did not. Additionally, compared to non-users, farmers who cultivated green grams and applied mulches saw a 0.117% boost in yield.

Table 4.11: Effects of Uptake of Regenerative Agriculture Technologies on Green Gram Productivity

Variables	Parameters	Beta	S. E	t-Value	P-Value	VIF
Constant	β_0	0.201	3.317	0.350	0.027	
Inputs						
Ln seed (green grams)	β_1	-0.129	0.113	1.22	0.363	1.06
Ln labour	β_2	0.021	0.100	0.55	0.754	1.15
Ln farm size	β_3	0.806	1.407	2.10	0.000***	1.38
Ln manure	β_4	0.252	0.118	5.310	0.000**	1.10
RA Technologies						
Cereal-legume intercrop	α_1	0.222	1.214	3.80	0.000***	1.71
Crop rotations	α_2	0.138	2.999	1.54	0.048**	1.12
Mulching	α_3	0.117	0.859	0.78	0.050**	1.06
Minimum tillage	α_4	0.178	0.805	2.94	0.082	1.20
Pasture cropping	α_5	0.264	1.230	4.00	0.260	1.81
Cover cropping	α_6	0.158	2.121	2.07	0.140	1.35
Use of compost	α_7	0.312	1.086	0.53	0.001***	1.32
R-squared						0.6100
Prob>F						0.000
Mean VIF						1.65

***significant at 1% and **significant at 5%.

4.6 Influence of Uptake of Regenerative Agriculture Technologies on Household Food Security

The result in Table 4.12 shows the influence of uptake of RA technologies on household food security using the HFCS. To calculate the HFCS, we first divided all dietary products into nine categories: main staples, pulses, dairy, meat/fish/eggs, vegetables, fruits, fats, sugar, and condiments. Following that, we added up the frequency with which the homes consumed different food products from the same groupings. The acquired value for each food group was then multiplied by its weight, yielding a new weighted food group score. Finally, the FCS was calculated by adding the weighted food group scores. Following the calculation, a threshold level of less than 21 was deemed to represent poor food consumption. The threshold level between 21 up to 35 was labelled as borderline food consumption while, above 35was labelled as acceptable food consumption (Sileshi et al., 2023).

The findings demonstrate that majority of the households in the area of study had a poor food consumption score. In Mbeere South Sub County households that adopted minimum tillage had the highest poor food consumption score (61.1%), majority of the households that used cover cropping had a higher borderline and acceptable food consumption scores of 39.75 and 8.6% respectively. Intercropping cereals with legumes contributed higher poor food consumption (58.9%), borderline of 33.7% with only 7.4%in the acceptable profile. Uptake of crop rotations led to majority of the households having an acceptable score of 6.5%, borderline score of 34.4% and a high poor consumption score of 59.1%. The consumption scores resulting from households using mulches on their farms are as follows poor (58.4%), borderline (36.4%) and acceptable (5.2%).

Further, households that adopted pasture cropping had a higher poor consumption (58.3%) with a borderline of 34.7% and an acceptable score of only 6.9%. Lastly households that used compost manure had an acceptable score of 7.3% a borderline of 32.3% and a poor score of 60.4%. The results reveal that majority of the households that had taken up the various RA technologies had a poor food consumption score. Meaning that majority of the households in Mbeere South Sub County were not food secure. The findings could be attributed to unfavorable weather and the agroecological conditions of the study area, that keeps production low and also the little engagement of the youth in farming. The findings are consistent with national country values, which reveal that 5.4 million Kenyans are hungry, with 4.4 million of them living in dry and semiarid areas.

Table 4.12: Influence of Uptake of RA Technologies on Household Food Security

RA technologies	**Food security indicator**	**Mbeere South Sub County (%)**
Cereal legume inter-crop	Poor	58.9
	Borderline	33.7
	Acceptable	7.4
Crop rotations	Poor	59.1
	Borderline	34.4
	Acceptable	6.5
Mulching	Poor	58.4
	Borderline	36.4
	Acceptable	5.2
Minimum tillage	Poor	61.1
	Borderline	34.9
	Acceptable	4.0
Cover cropping	Poor	51.7
	Borderline	39.7
	Acceptable	8.6
Pasture cropping	Poor	58.3
	Borderline	34.7
	Acceptable	6.9
Compost manure	Poor	60.4
	Borderline	32.3
	Acceptable	7.3

CHAPTER FIVE

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Overview

This section discusses the results outlined in chapter 4 above and summarizes the conclusions, and recommendations for future studies.

5.2 Discussion

5.2.1 Socioeconomic Factors that Influence Uptake of RA Technologies

The association between age and uptake of minimum tillage was positive. This is associated to the farmer's experience in farming which improves farming skills. Contrary, (Worku, 2019) argued that age of a farmer was negatively correlated with adoption of new technologies as older farmers were not willing to take risks and possessed little know-how on the new technologies. A study by (Gebru et al., 2019) indicated a negative relationship between age and use of new innovations. Sometimes, due to illness, households can lose labor, but older age is more likely to negatively impact on adoption (Bucci et al., 2019).

Gender was found to positively influence use of compost manure. The majority of households were headed by men, suggesting that, men stood a higher chance to make decisions on which Regenerative Agriculture technologies should be used on their farms. The findings resonate with those of (Mwaura et al., 2021). This indicates that men were responsible for making major farm/household decisions (Ndeke et al., 2021).Thus households headed by males had higher chances of using compost manure as compared to female-headed households (Oyetunde-Usman et al., 2021).This findings are corroborate to those of Ndeke et al., (2021; Sanou et al., 2019) who noted that gender positively affected adoption of new agricultural innovations. Contrary, women are most likely to take up new innovations when compared to men to avoid the overarching constraints resulting from extreme weather events that directly affect them than men (Bessah et al., 2021).

Marital status negatively and significantly influenced uptake of cover cropping. This can be related to contradicting views from couples towards a new innovation before coming to a consensus. These findings support those of (Ojo et al., 2021), who found that marital status had a negative impact on the adoption of soil water conservation methods because large families may be resource constrained. The findings contradict those by (Etim & Ndaeyo, 2020) who noted that marriage is a means of generating family labor and most women and children participate in farming. Further marriage increases concern for household welfare and food security therefore, use of new technologies was positively related to marital status.

A negative association was observed between education and uptake of mulching and intercropping cereals and legumes. This may be associated with farming experience the farmer gets over the years, as one possesses sufficient knowledge on various innovations. According to (Muriithi et al., 2021; Zakaria et al., 2020) education is believed to increase a farmer's awareness and understanding of new agricultural innovations. They argue that some technologies are knowledge intensive and require basic education to facilitate use and adoption. Therefore our findings challenge those of Muriithi et al., (2021) and other earlier empirical evidences (Tokede et al., 2020; Zakaria et al., 2020) that show a positive association between education level and farmer decisions to adopting new innovations.

Farming experience had a negative association with uptake of minimum tillage. This can be based on how a farmer perceives a new technology (Ikehi et al., 2022). Furthermore, farmers will always abandon a technique when the returns on investment begin to decline. For instance, farmers may drop use of minimum tillage following the negative marginal effect. Farming experience negatively as well as positively influence the likelihood of taking up agricultural innovations (Zakaria et al., 2020).This could be related with trade-offs that come with technological innovations. Farmers typically switch from technologies that produce lower yields to those that are likely to give higher returns as they gain more farming experience. (Ndeke et al., 2021).

The findings indicate a positive relationship between farm size and uptake of minimum tillage, use of compost manure as well as crop rotations. Land being a major resource in production, its abundance increases the chances of farmers taking up new agricultural technologies. The results are consistent with those of Teshome and Baye (2018), who found that households with larger farms are more likely to implement new land management techniques than households with smaller farms. According to Moronge and

Nyamweya, (2019) farm size influences adoption as large land gives space to experiment and practice innovations. The findings are consistent with those of (Muriithi et al., 2021), who found that farmers with larger farms were more likely to use intercropping and crop rotation than those with smaller farms. The findings further reveal a negative association between farm size and uptake of cereal-legume intercrop and pasture cropping .The findings agree to those by Llones and Suwanmaneepong, (2021) that increasing farm size will more likely increase input usage under conventional production among non-adopters thus reduced chances of adopting new innovations.

Although farming was the main occupation for majority of the respondents, it had a positive association with use of compost manure only and a negative association with cereal legume intercrop, pasture cropping and crop rotations. This meant that household that carry out crop farming as the main occupation, were more likely to take up Regenerative Agriculture especially use of compost manure and less likely to take up the technologies with negative associations. Farmers who practice agriculture in full time are more eager to increase their incomes through their produce therefore, they are ready to invest in new technologies to grasp opportunities (Mottaleb, 2018). Conversely, farmers with off farm occupations generate extra income that they can equally invest in new innovations (Zakaria et al., 2020).Further, studies by (Sarker et al., 2020) documented that, other occupation other than Agriculture had no significant effect on adoption of new Agricultural innovations.

Uptake of minimum tillage was significantly and positively influenced by engagement in off farm activity by the household heads. Implying that, farmers with off farm occupations were more likely to adopt minimum tillage on their farms. Farmers who engage in off-farm activities are likely to get an extra income that could spend on farm labor and inputs for production. This findings are similar to those by (Fikire & Emeru, 2022) whom found that, engagement in off-farm activities impacts positively on technology uptake. This is so because farmers may manage risk while simultaneously producing money from non-farm sources and overcoming their cash flow problems. It’s on this basis that new innovations will be taken up. Further, engagement in off-farm activity influenced use of compost manure negatively. This may result from farmers allocating more time to off farm occupations than agricultural activities. Preparation of compost manure takes a lot of time thus farmers may prefer use of inorganic fertilizers to compost manure. According to studies by (Kassie, 2018) off-farm activities may distract farming activities, thus impacting negatively on technology adoption.

5.2.2 Institutional Factors Influencing Uptake of RA Technologies

Results from Multivariate probit model show that, terms of land ownership had a negative association with uptake of cereal-legume intercrop and crop rotations. Moreover, the association with uptake of cover cropping was positive. RA technologies do not require much time to be implemented as they can practice season in season out. This gives opportunities to farmers who lease land or own land without title deeds to comfortably adopt these technologies to get more yield in particular seasons. In favor of the finding, (Mansaray et al., 2019) argued that land ownership does not influence adoption of Agricultural innovations especially those that can be practiced per season. However, farmers who had title deeds felt secure to plant cover crops on their farms than those without, as the cover crop can serve more than a season. Findings by (Ng'ang'a et al., 2020) showed that farmers with title deeds were more likely to devote their farms to new innovations than those without as they are more secure.

Access to extension services positively correlated with uptake of cereal-legume intercrop, cover cropping, crop rotations and use of compost manure. Extension services such as training and giving advisories give more information to farmers thus farmers are more likely to change their farming styles especially to productivity enhancing technologies. The findings support the findings of (Muriithi et al., 2021) that there is a favorable link between access to extension services and adoption of IPM practices. (Jerop et al., 2020) also found that having access to extension services influenced the adoption of conservation tillage, improved millet varieties, and group marketing. Access to extension services has a favorable impact on technology adoption since it provides as a link between farmers and researchers to boost smallholder farmers' productivity and bridge the yield gap. This is due to the fact that the extension agent aids in raising awareness of innovation and its potential (Tadesse and Ahmed, 2023).

Access to credit for farming negatively influenced uptake of mulching, minimum tillage and crop rotations. Our findings challenge those by (Feyisa, 2020) that indicate that, credit is an important factor in farming as it enables farmers to purchase inputs for production. However, most RA technologies do not require significant amount of money to be practiced as they mostly involve farm routine practices with low external input requirements thus can be easily adopted by rural smallholder farmers to enhance productivity (Giller et al., 2021). Contrary the association with use of compost manure was positive. Preparation of compost can be quite hectic and farmers may need some money to spend on labour hence the positive association. A reasonable explanation for this is that access to credit is critical in financing investments as well as acquiring inputs such as materials needed for preparation of compost manure. In order to avoid diseconomies of scale, access to credit would also support investments in capital-intensive technologies that would increase production efficiency and productivity per unit area (Ruzzante et al., 2021).

Distance to the input and output market showed a positive relationship with mulching and use of compost manure. Most rural farmers use plant remains as mulches and in preparation of compost manure. Implying that high productivity from mulching and use of compost manure may not be affected by the long distance to the market. In addition, farmers located far away from the input and output market with no other income generating activities other than farming were more likely to take up any yield enhancing innovation (Mujeyi et al., 2021).Further, famers located far away from the markets had significantly large farms where the innovations can be implemented to increase productivity. It was also found that most farmers sold their produce at the farm level to brokers to avoid transportation costs thus the positive association. Therefore, the findings challenge earlier studies by (Amare & Simane, 2017) who documented that distance to the input and output market negatively influenced adoption of Agricultural innovations as transportation costs increases production costs. The findings also contradict those of (Feyisa, 2020) who noted that, farmers located far from the input markets may face higher transportation expenses, making the entire investment in technology less financially viable.

Uptake of cereal-legume intercrop, pasture cropping, cover cropping and use of compost manure had a positive relationship with group membership. In absence of extension agents, farmers obtain knowledge by sharing ideas among themselves (Manda et al., 2020). The findings agree with those of (Fatch et al., 2020), who found that membership in farmer groups is a crucial component of an innovation diffusion model for agricultural diversification. Compared to other farmers, those who joined to agricultural groups were more diversified. Members of a group can share knowledge about how to develop and market novel agricultural commodities. Farmers that are a part of a group are therefore more likely to have access to information, some of which may be regarding agricultural diversification (Fatch et al., 2020).

5.2.3 Effects of Uptake of RA Technologies on the Productivity of Selected Cereals and Pulses

The study evaluated the effect of uptake of various RA technologies on green gram as a pulse and sorghum as a cereal. Four production inputs were used which are cost of seeds, labour, farm size and quantity of manure. Seven RA technologies were considered in the production function as dummy variables to estimate their effect on productivity of the selected crops.

From the results farm size and quantity of manure used in production of green gram and sorghum were positive and significant. Implicating that increasing these two inputs leads to farmers realizing higher yield of sorghum and green grams. The results concur with those of (Hoover et al., 2019) who found out that manure application at the recommended rates had a significant effect on agricultural productivity. Organic inputs helps increase microbial activity and water retention capacity and this leads to increased grain yield (Hammad et al., 2020). Farm size influences adoption as large land provides space for experimenting innovations that may impact positively on productivity (County et al., 2019). Further, Hu et al. (2019) also found a positive correlation between farm size and the use of new technologies and agricultural productivity.

Cereal-legume intercrop technology was positive and significant on the productivity of both sorghum and green gram. It has been demonstrated that intercropping cereal crops with legumes provides a number of benefits for planting systems, including ecological balance, greater resource efficiency, increased crop productivity, and therefore sustainability in agricultural production (Maitra and Gitari 2020). In a meta-analysis on the effects of intercrop components on yield stability, Raseduzzaman and Jensen (2017) discovered that cereal legume studies had stronger yield stability than sole crop experiments.

Uptake of mulching influenced sorghum and green gram productivity positively and significantly. Dry lands are usually water stressed and use of mulches helps in moisture conservation (El-Beltagi et al., 2022). Moisture is an important parameter in crop growth and development thus farmers using mulches are likely to have higher yield than non-users (Kader et al., 2019). Most rural small-scale farmers use plant remains as mulches which with time decompose and become a source of organic manure that has the ability to improve grain yield. The results concur with those of El-Beltagi et al, (2022) who documented that mulching has the following benefits; prevented soil erosion, buffer soil temperature, prevent water loss, minimize soil compaction, inhibit weed germination, improve water holding capacity, add organic nutrients to the soil and preserve high and sustainable yield.

The productivity of green gram and sorghum was significantly positively correlated with the use of compost manure. Compost is made up of relatively stable organic components that have undergone controlled, aerobic conditions from accelerated biological degradation (El-Beltagi et al., 2022). The findings corroborate with those of (Hammad et al., 2020) who moted that organic matter enhances the physicochemical properties of the soil by raising its cation exchange capacity, saturation percentage, porosity, and rate of nutrient turnover. Additionally, the results are in line with those of (Brust, 2019), who showed that compost retains good tilth and hence improves aeration for germination of seeds and plant root growth, which helps to increase grain productivity.

The relationship between crop rotations and green gram productivity was positive and significant. Indicating that, rotating green grams with other crops especially non legumes could increase green gram productivity. Rotating pulse crops with cereal crops increases economic returns and reduces use of nitrogen fertilizers. In a study by Liu et al. (2020) on rotating pea and lintel with wheat in semi-arid areas the results showed a positive significant effect on productivity. This was associated with the combined effects of nitrogen benefits between a cereal and a pulse. Crop rotation help in soil water conservation from branched and deep rooted legumes that allow for water and nutrient uptake during stressful conditions (Ghadirnezhad Shiade et al., 2022). In addition rotating cereals and pulses helps in pest and disease control and improving soil health thus increasing grain yield (Shah et al., 2021).

The adoption of minimum tillage, according to the findings, enhanced sorghum productivity. The results are similar to those of (Masaka et al., 2020), who discovered that limited tillage increased sorghum productivity in semi-arid regions. The brighter side of minimum tillage is labour saving. According to (Jena, 2019) there is significant labor saving from minimum tillage especially on women. According to (Liu et al., 2021), low tillage is effective at preserving nutrients, improving soil organic carbon (SOC), and reducing soil loss. Reduced tillage improves the physical characteristics of the soil and increased water availability (Das et al., 2020). However, due to potential adverse impacts on nutrient availability and crop productivity, no tillage is still debatable, particularly in dryland circumstances (Luján Soto et al., 2021).

Further, cover cropping influenced sorghum production positively. Cover crop farming is a fundamental principle of conservation agriculture in which non-cash crops are put in agricultural areas to provide soil cover between the main growth seasons. Cover cropping has been heavily advocated for as a way of preventing soil erosion and nutrient loss (Martínez-Mena et al., 2020). Our findings match other empirical studies (Deines et al., 2022) that noted an increase in yield following use of cover crops in cropping systems. In addition, ground covers have been demonstrated to boost soil nutrients, biological activity, and soil total and labile organic carbon (López-Vicente et al., 2020), hence improving soil quality and promoting crop performance. Further, it has been well established that cover crops increase aggregate stability for better soils.(Gutknecht et al., 2022) However, numerous studies show that effects vary greatly based on regional biophysical and climatic factors, the type of ground cover chosen, and other factors (Deines et al., 2022).

5.2.4 Influence of Uptake of RA Technologies on Household Food Security

Majority of the households in Mbeere South Sub County had a poor HFCS. This could be attributed to the low uptake of RA technologies, unfavorable weather conditions in the area, poor access to extension services and limited knowledge on how to undertake Regenerative Agriculture among the rural farmers. Regenerative Agriculture technologies have been suggested to be beneficial to rural households in drylands (Luján Soto et al., 2021). Despite its intriguing promise, RA is still in its infancy stage in dryland agroecosystems, and farmers are only slowly adopting it as a result of the dearth of data on both its short- and long-term effects. Thus, the influence of the disseminated technology on food security is still insignificant.

Additionally, the semi-arid settings' delayed soil response to management adjustments that hinders farmer adoption and postpone the emergence of restoration indicators. Similar to how the transition from conventional farming to RA normally takes place gradually, even with farmers who are persistently supportive, is because of socioeconomic, informational, logistical, environmental, and political limitations (Luján Soto et al., 2021). The results are consistent with a study by Mojo et al. (2017), which found that households having access to extension services were more likely to have access to food than those without. The findings are also line with those of (Kogo et al., 2021), who demonstrated that small scale farmers in semi-arid and arid areas that face recurrence drought has adversely affected household food security. Climate change compromises food access as it affects the purchasing power of vulnerable households. Moreover, extreme weather events leads to low crop productivity and this often translates to increased market prices for basic foodstuffs exposing rural households to food insecurity (Kogo et al., 2021). The increased food insecurity situation in Kenya has further been compromised by climate change and high global food prices that make it difficult for many households to afford food due to high poverty levels.

5.3 Conclusions

Objective 1: Characterization of RA Technologies

The aim of this study was to characterize Regenerative Agriculture (RA) practices by assessing the common technologies employed by farming households and gauging the level of acceptance of these technologies. The investigation revealed that among the evaluated techniques, such as cereal-legume intercropping, mulching, minimum tillage, crop rotations, cover cropping, and the use of compost manure, the majority of households in Mbeere South Sub County favored and benefited from these practices. However, despite the benefits, the extent of adoption of these technologies remained relatively low across the board. The results, which were based on the allocation of land to specific technologies, indicated that many of the evaluated technologies were not widely embraced. According to the information gathered from farmers, the primary reason for this limited adoption was attributed to insufficient knowledge regarding how to effectively implement RA practices to achieve optimal results. Moreover, some farmers expressed dissatisfaction with the performance of the technologies they had adopted, citing adverse weather conditions such as prolonged drought and inadequate rainfall as contributing factors to these subpar outcomes.

Objective 2: Socioeconomic and Institutional Factors Influencing Uptake of RA Technologies

The adoption of diverse Regenerative Agriculture (RA) technologies was significantly influenced by a range of socioeconomic and institutional factors. Factors such as age, gender, marital status, education level, farming experience, farm size, primary occupation, and engagement in off-farm activities played a pivotal role in shaping the adoption landscape. Additionally, institutional factors, including land ownership terms, access to extension services, availability of financing, group affiliations, and proximity to markets, wielded considerable influence over the adoption of various technologies. This study effectively invalidated the null hypothesis, which posited that socioeconomic and institutional factors lacked a substantive impact on the uptake of RA technologies.

Objective 3: Effect of Uptake of RA Technologies on the Productivity of Selected Cereals and Pulses

The agricultural landscape in Mbeere South Sub County is characterized by the cultivation of sorghum as the predominant cereal and green gram as the prevailing pulse crop. These crops exhibit drought tolerance and the ability to thrive with minimal nutrient inputs. Leveraging appropriate agricultural technologies holds the potential to enhance food security in arid regions. Notably, the intercropping of cereals and legumes, mulching practices, and the application of compost manure emerged as influential strategies adopted by farming households. These practices notably and positively impacted the productivity of both green grams and sorghum. Furthermore, the implementation of minimum tillage and cover cropping demonstrated positive effects on sorghum productivity, while crop rotations exhibited a positive influence on green gram yields. Surprisingly, pasture cropping exhibited no significant impact on the production of either sorghum or green gram. Additionally, a noteworthy finding was the interconnectedness of technology adoption, with the uptake of one regenerative agriculture practice often leading to the adoption of another. This suggests a sense of complementary integration in the adoption of these techniques. Optimizing the adoption of specific regenerative agriculture technologies, such as intercropping, mulching, and compost usage, can significantly enhance the productivity of sorghum and green gram crops, thereby contributing to improved food security in the drylands of Mbeere South Sub County. The interplay between various technologies underscores the potential for a holistic approach to agricultural enhancement in the region.

Objective four: Influence of Uptake of RA Technologies on Household Food Security

The prevailing crop choices in Mbeere South Sub County include sorghum as the primary cereal and green gram as the predominant pulse. With their inherent drought tolerance and minimal nutrient requirements, these crops present valuable options for bolstering food security in arid environments. The effective utilization of suitable agricultural technologies holds the promise of further enhancing household food security. Notably, among the diverse practices adopted by farming households, the intercropping of cereals and legumes, alongside mulching and the application of compost manure, emerged as influential contributors to the productivity of both green grams and sorghum. Moreover, the strategic implementation of practices such as minimum tillage and cover cropping demonstrated positive effects on sorghum yields, while crop rotation exhibited a favorable impact on green gram production. Intriguingly, the significance of pasture cropping did not materialize in enhancing either sorghum or green gram output. A notable observation was the interconnected nature of technology adoption, whereby the incorporation of one regenerative agriculture practice often facilitated the adoption of others. This interconnectedness highlights the potential for a synergistic approach to technology integration.

5.4 Recommendations

Objective 1: Characterization of RA Technologies

The government and innovators should promote regenerative agriculture by providing individualized education, farmer-to-farmer mentorship, addressing climate impacts, funding research, and engaging lawmakers. These efforts will assist agricultural households in Mbeere South Sub County in bridging knowledge gaps, ensuring effective implementation, and promoting sustainable practices.

Objective 2: Socioeconomic and Institutional Factors Influencing Uptake of RA Technologies

The study recommends that, to design targeted awareness campaigns, improve access to extension services, provide accessible financing options, prioritize inclusive capacity-building initiatives, encourage group formation, advocate for supportive policy reforms, base strategies on continuous research, and involve diverse stakeholders in decision-making to promote broader adoption of Regenerative Agriculture (RA) technologies. These measures seek to address the various socioeconomic and institutional issues that drive RA adoption, while also promoting inclusivity, sustainability, and effective implementation across various agricultural communities.

Objective 3: Effect of uptake of RA technologies on the Productivity of Selected Cereals and Pulses

We further recommend that, cereal-legume intercropping, mulching, compost manure utilization, minimum tillage, cover planting, and crop rotation be promoted to improve food security in Mbeere South Sub County's arid regions. Farmers should be taught on the advantages of these practices via hands-on training and demonstration farms. The interconnection of these disciplines should be highlighted in order to encourage a holistic approach. These measures can greatly increase sorghum and green gram yields, promoting sustainable agriculture and improving household food security in the region.

Objective four: Influence of Uptake of RA Technologies on Household Food Security

To improve food security in Mbeere South Sub County's arid environment, it is advised that drought-tolerant crops like as sorghum and green gram be promoted while agricultural technology are strategically implemented. Farmers will be educated on the benefits of cereal-legume intercropping, mulching, compost manure application, low tillage, cover cropping, and crop rotation. For optimum yield enhancement, emphasis should be made on illustrating the interdependence of these approaches. More research on the viability of pasture cropping is needed. The establishment of localized demonstration plots and extensive training programs would enable farmers to effectively use these practices, contributing to increased food security in the region.

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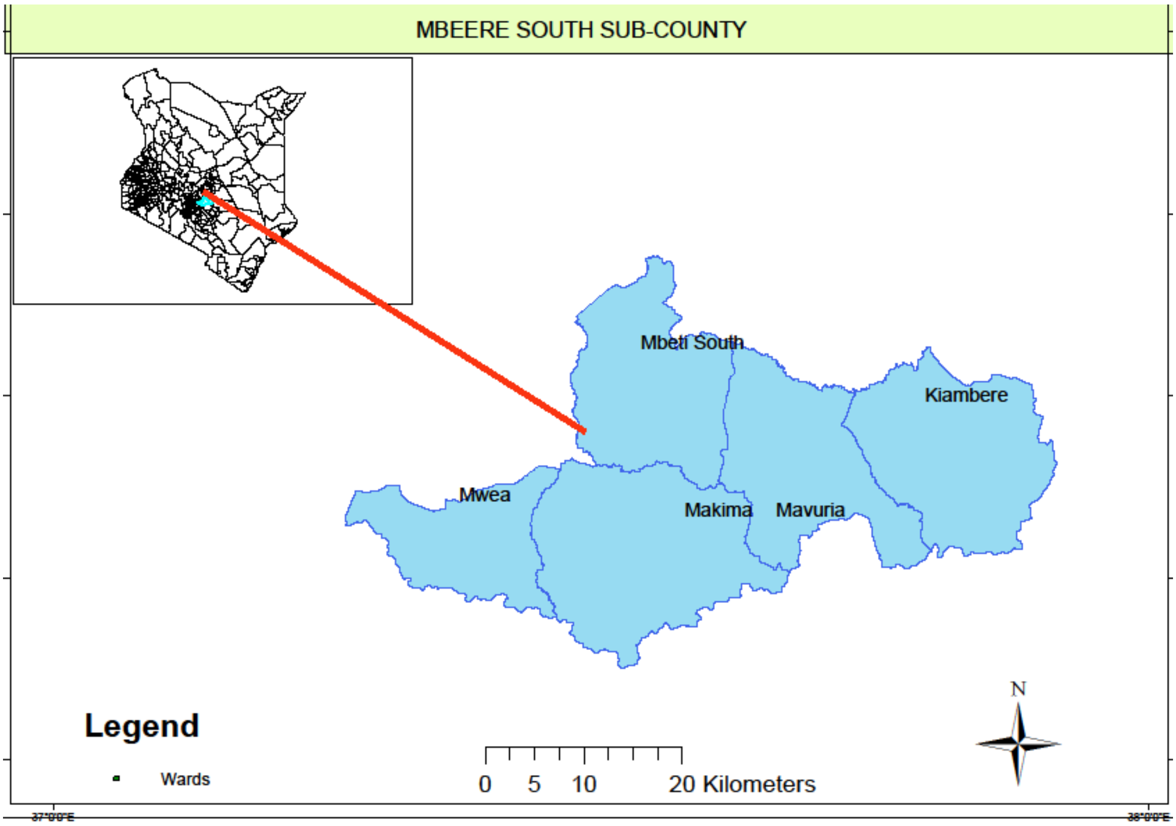
APPENDICES

APPENDIX 1: Map of the Study Area



APPENDIX 2: Survey Questionnaire

Uptake of Regenerative Agriculture Technologies, Productivity of Selected Cereals and Pulses and Food Security in the Drylands of Embu County, Kenya

Welcome to the survey. This survey questionnaire is purely for academic purposes. The aim is to collect data on the uptake of Regenerative Agriculture technologies, productivity of selected cereals and pulses and food security in the drylands of Embu County, Kenya. The information provided herein will be treated with the utmost confidentiality.

SECTION 1: GENERAL INFORMATION

Household identification no	
Name of respondent	
Date of interview	
Ward	
Sub-location	
Village	

SECTION TWO: SOCIO-ECONOMIC INFORMATION

A1 gender of household head	
A2 Marital status of household head	
A3 Age of household head	
A4 level of education of household head	
A5 Main occupation of household head	
A6 Household income per year in KES	
A7 Off-farm occupation of household head	
A8 Household off-farm income per year in KES	
A9 Experience of farming cereals and pulses in years	

SECTION 3: INFORMATION ON INSTITUTIONAL FACTORS

1. What is the total size of your land? ………………. Acres
2. What are your terms of land ownership?1=owned with tittle deed, 2=owned without tittle deed, 3=leased, 4=communal
3. Do you access extension services? 1=yes 0=No

4. If yes, from who? 1=Farmer groups 2=Non-Governmental Organizations 3=extension officers 4=Radio 5=Television

5. Which services do you get?1=Training 2=market linkages 3=Farming practices 4=Input provision

6. How often do you receive the services?1=weekly 2=Monthly 3=Frequently 4=really

7. If no, what factors hinder you from accessing extension services?1=payment for extension services 2=research centers located far 3=fewer extension officers 4=inadequate information on extension services

8. Do you sell your produce? 1=yes 0=No

9. If yes, which markets do you participate in? 1=Physical markets 2=virtual markets 3=Semi virtual markets

10. Do you access the market easily? 1=1yes 0=No

11. What is the distance covered to the input and output market in kilometers?

12. Do you access market information? 1=Yes 0=No

13. If yes, what kind of information do you access?1=pricing 2=market share 3=product information 4=market research

14. What is your perception of the markets?1=Positive 2=Negative 3=Neutral

15. Do you have access to credit?1=yes 0=No

16. If yes, from which source?1=Banks 2=Microfinance Organizations 3=Farmer cooperatives 4=Table banking

17. Was the credit affordable? 1=Yes 0=No

18. What is your past experience on credit?1=Good 2=bad

19. What is your perception on credit?

20. Do you belong to any group?1=Yes 0=No

21. If yes, which of these groups do you belong?1=producer groups 2=processing groups 3=labor groups 4=producer and marketing cooperatives 5=other (specify)

22. Which benefits do you get from the group?1=market linkages 2=credit access 3=advice on farming 4=input provision

23. Do you access farm inputs?1=Yes 0=No

24. If no, which factors hinder you from access?1=limited land 2=inadequate information 3=high-cost 4=distance to the market

SECTION 4: INFORMATION ON PERFORMANCE OF SELECTED CEREALS AND PULSES

25. Which of these crops do you grow on your farm?1=maize,2=Beans 3=sorghum, 4=millet, 5=green grams, 6=cowpeas

26. Please fill the table below on production costs

ITEM (PLANTING MATERIALS)	**AMOUNT IN KGS**	**COST/KG IN KES**
Sorghum		
Millet		
Green grams		
Cowpeas		

27. What form of labor do you employ on your farm?

1= Family labour [ ] 2=Hired labour [ ] 3=both [ ]

28. If hired labor, what is the labor requirement for planting and harvesting?

Man days………………………… cost per man-day………………………

Bags …………………………… Cost per bag …………………………

29. Please fill the table below on productivity

CROP	**FARM SIZE IN ACRES**	**YIELD/90KG BAG**	**PRICE PER KG**
Sorghum			
millet			
Green grams			
cowpeas			

30. What challenges do you face in farming these crops? 1=pests and diseases 2=weather changes 3=low productivity 4=High input costs 5=Lack of ready markets

SECTION 5: REGENERATIVE AGRICULTURE TECHNOLOGIES

31. Which of these RA technologies do you use on your farm, and what is the proportion of land under the selected technologies?

R.A. technology	**The proportion of land under the technology in %**
B1 cereal-legume intercrop	
B2 crop rotations	
B3 mulching	
B4 Minimum tillage	
B5 Agroforestry	
B6 Cover cropping	
B7 Pasture cropping	
B8 Controlled traffic	
B9 Organic Agriculture	
B10 Compost manure	

32. Why are you not practicing other technologies?1=lack of knowledge 2=high input cost 3=limited land

33. What challenges do you face in undertaking regenerative agriculture? 1=Inadequate knowledge on R.A. 2=poor performance of adopted technologies 3=inadequate labor 4=lack of inputs 5=cultural factors

34. What support do you require to address the challenges? 1=training 2=input provision 3=credit provision 4=field demonstrations

35. In your opinion, would you say that the adopted technologies have helped in improving productivity of cereals and pulses? 1=Yes 2=No

36. Give your perceptions/suggestions/comments on Regenerative agriculture based on the scale provided.

1 = totally unacceptable 2 = Unacceptable3 = slightly unacceptable 4 =Neutral 5 =slightly acceptable 6 = Acceptable 7 = Perfectly Acceptable

SECTION 6: FOOD SECURITY

37. In the last seven days, did any of your household members go to bed hungry, reduce meals taken, skip meals or substitute meals because you had no enough food? 1=Yes 2=No

38. How many days did your household eat any of the food categories in the list below in the last seven days? (Tick appropriately the type of food consumed on each particular day) leave blank on each day a specific food was not eaten.

S/N	Food item	7 days ago,	6 days ago,	5 days ago,	4 days ago,	3 days ago,	2 days ago,	1 day ago,
1	Maize meals							
2	Sorghum meal							
3	Millet meal							
4	Wheat meal							
5	Green grams							
6	Beans							
7	Cowpeas							
8	Fish/beef/pork/eggs/poultry							
9	Vegetables							
10	Tubers							
11	Sugar							
12	Oil							
13	Fruits							
14	Rice							
15	Milk and other dairy							

Thank you for the information